THE R&D HISTORY OF ETRI FOR 45 YEARS

From the Era of Information to the Era of Intelligence

1976

2021

Electronics and Telecommunications
Research Institute

ETRI

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From the Era of Information to the Era of Intelligence

1976 — 2021

ETRI

From the Era of Information

A NATIONAL AI RESEARCH INSTITUTE, MAKING A BETTER TOMORROW

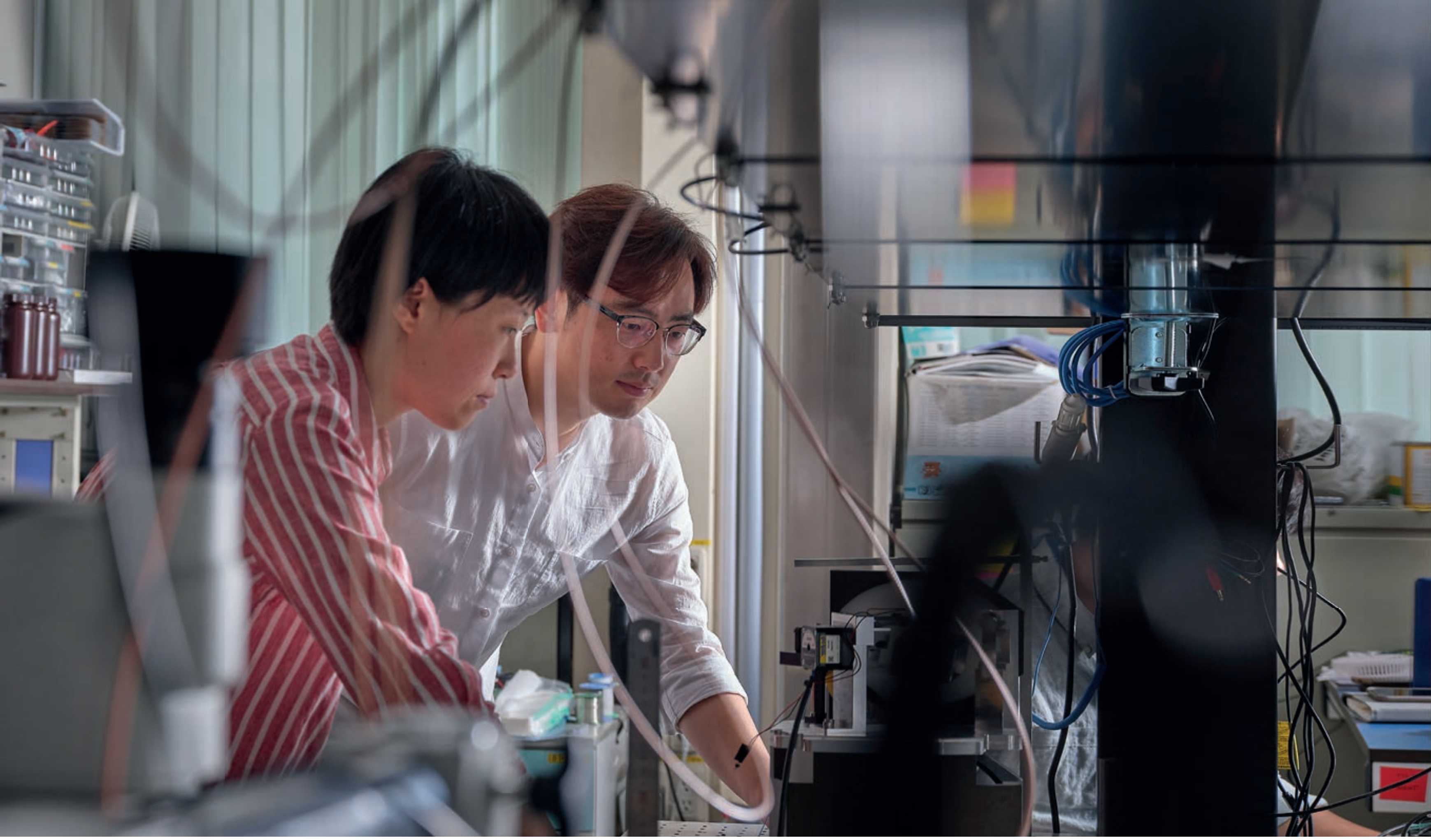
E T R I

ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE

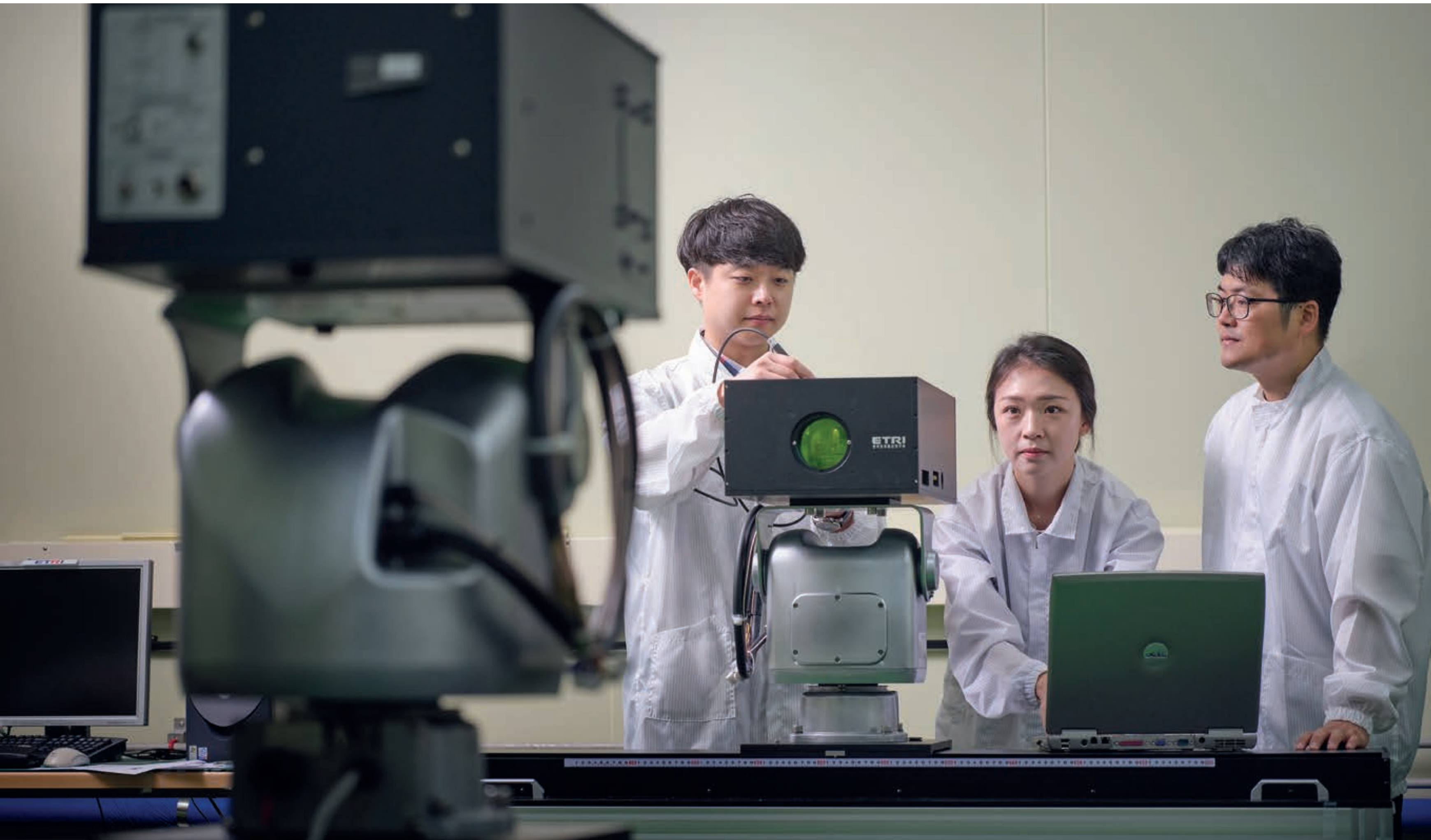
E T R I

to the Era of Intelligence


ETRI 한국전자통신연구원




[Identify Person]
심주용
선임 연구원
의료정보연구실
승인완료 !!!


ETRI


한국전자통신연구원

The era is changing slowly but ceaselessly as yesterday and today are different.
The way we live is gradually changing as the innovative technologies which we never experienced before are invented and new products are developed. The human race should have been evolved by this method for a long time. We should have been developed by challenging the impossibilities, overcoming the fear of uncertainties, doing our best to improve the world, and thinking over a better environment with thoughtful mindsets.
It is the same for trace ETRI went through.
ETRI has been leading the era with a clear insight into the times, an attitude to humbly accept failures, and above all, good intentions to understand our lives.
Even at this right moment, we are creating a new future.

From the Era of Information

To the Era of Intelligence

Single days are added together to build a life.
In the word of “a life”, countless daily lives are summed up. All the moments, whether it is good, bad, happy, or sad, are summed up densely to build a life.
ETRI's 45 years.
In that long period of time, various features which ETRI went through are contained.
Unimaginable things in the past become a reality, and the way we live and our environment has changed.
We communicate with others all over the world by exchanging information, break restrictions of time and space, and by defining the era like that, we are creating our lives. ETRI will accomplish a better future by searching latent possibilities and actualizing the impossibilities in the future.

The R&D History of ETRI for 45 Years

Electronics and Telecommunications
Research Institute

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Preface

ETRI, which was established in 1976 by the federal government, has contributed to the development of Information and Communication Technologies (ICT) and its relevant industries. The researchers of ETRI have made a considerable contribution to raising Korea to the ICT powerhouse and leading e-government and accomplishing national informatization. The history of ETRI for 45 years is the footstep we walked through and our trace. Moreover, it is the history of Korea’s ICT. First of all, I want to show my gratitude to my proud alumni and colleague who shared the history of ETRI and everyone who helped us to grow.

ETRI is not satisfied with the outcome of the researches for the last 45 years. Instead, we have established our image of the future as the “National Intelligence Comprehensive Research Institute that creates a future society”, and we are in the process of full transformation.

Now, ETRI is planning to lead the innovation and growth of the new era as the first mover based on the potential for the last 45 years. To pioneer a path nobody has stepped on, a lot of effort and dedication are required. Therefore, ETRI will keep performing the leading role of helping our country to become a powerhouse in AI through accomplishing national intelligence.

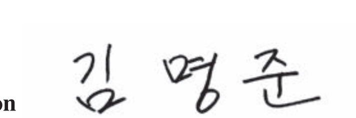
The history of ETRI for 45 years tried to include the accomplishments of the whole staff as an R&D company. The history of R&D is summarized into 6 large categories, 30 medium categories, and 242 small categories.

It is possible to see the vivid traces of Korea's ICT cultivated by ETRI's staffs.

We are planning to publish the history of R&D not only in Korean but also in English to distribute it to the countries which want to be an ICT powerhouse in the future. Based on the outcome of the researches accomplished so far, ETRI is going to work on the development and innovative research for humanity from now on. Through these efforts, we are planning to solve the livelihood problems of the citizens and create a new driving force for national growth. I want to applaud former directors, seniors, executives/staff, and the chairperson and members of the editorial committee who worked on publishing the “history of ETRI for 45 years” for their efforts.

I sincerely hope that ETRI becomes an R&D institution recognized and loved by not only Korean but also by people all over the world for the next 50 years or 100 years beyond 45 years. Thank you.

President of ETRI,
Kim, Myung-Joon



We Strengthened the Foundation for an ICT Powerhouse

ETRI is the top research institute specializing in the ICT in Korea, and it has been researching for the economic growth and improvement of citizen's lives for the last 45 years.

ETRI has developed countless top technologies including TDX, which opened the era of one phone per household, DRAM semiconductor that created the legend of a semiconductor powerhouse, CDMA that built the foundation for the advanced country in the mobile communication industry, WiBro that opened the Internet world in my hands, administrative Main computer II (TiCom) for a computer network that built the foundation for e-government, smart ship technology (SAN), immersive media that maximizes the feeling of immersiveness, Exo-Brain, a software that understands human language, Aldebaran, a process chip for autonomous driving, the world's first UHD Mobile broadcasting technology, next-generation 5G mobile communication, deep view of visual intelligence, quantum computing to lead the future ICT, and ETRI has led Korea to an unrivaled ICT powerhouse. Based on these accomplishments, Korea has secured its position as one of top 10 economies in the world and as the number 12 in terms of GDP.

To lead the 4th Industrial Revolution and the Global Intelligence Paradigm, ETRI has initiated its leaping as "National Intelligence Comprehensive Research Institute" which creates future society". It is soaring vigorously again for the future based on the unrivaled achievement accumulated for the last 45 years.

1976
- Established the ETRI, an affiliate of KIST
- Established the KIET
- Established the KERTI

1977
- Established the KTRI

1980s

1982
- Developed memory semiconductor 32K ROM first time in Korea

2000s

2004
- Developed a prototype of mobile wireless broadband internet WiBro for the first time in the world

2005
- Exported the development solution of an embedded SW for the first time
- Started Terrestrial DMB service

2006
- Developed wireless home network (UWB)
- Developed a transparent AMOLED for the first time in the world

2007
- Developed 3.6Gbps 4th generation wireless transmission system for the first time in the world

2019
- 25Gbps Tactile Internet technology 'TIC-TOC'

2020
- Visual intelligence original technology platform 'Deep View'

2021
- Intelligence robotics AI Core technology which understands roads, objects, and humans

1983

- Developed 8bit educational computer

1984

- Developed 16bit UNIX, succeeded in localizing computer

1986

- Developed Time Division Exchange (TDX) which initiated the era of one phone for one household

1988

- Developed optical communications system of 565Mbps

1989

- Starting from the development of 4M DRAM, developed 16M, 64M, 256M DRAM

1990s

1990

- Developed 32bit microprocessor

1991

- Opened TDX-10
- Developed host computer II (TiCOM)

1994

- Developed a digital satellite broadcast system

1995

- Succeeded in the commercialization of CDMA mobile communi-cations system for the first time in the world

1996

- Developed Satellite broadcasting active antenna for vehicle installation

1999

- Developed a prototype of synchronous IMT-2000(CDMA2000) STP system
- Commercially developed asynchronous IMT-2000(WCDMA)

2008

- Developed SMMD-based 4D system technology for realistic experience

2009

- Developed an eco-friendly OLED lighting technology which enlightens the world

2010s

2010

- Developed 4th generation mobile communications LTE-Advanced for the first time in the world
- Developed a smart vessel technology

2011

- Developed transparency controllable AMOLED display panel
- Developed the technology of Packet-Optical integrated Transmission Network

2012

- Developed an optical internet technology which is faster than the existing ones by 100 times
- Developed the technology of Portable Korean-English automatic interpretation, Genie Talk

2013

- DB-Call based smart study system of English (Genie Tutor)

2014

- The world's first orchestra (OCES+3.2 Tera) optical internet technology guaranteeing the speed of 10Gbps per subscriber

2015

- RoF based mobile fronthaul technology (High Five ESCoRT)

2016

- Fiber-Line-Packet integrated switching system

2017

- High-performance linguistic intelligence SW ‘Exobrain’

2018

- UHD mobile broadcast technology

History of ETRI

It Rewrote the History of ICT in Korea

1976 / 12

- Established the Korea Electrical Research and Testing Institute (KERTI)
- Established the Korea Institute of Electronics Technology (KIET)
- Launched KIST affiliate, Electronics and Korea Telecommunications Research Institute (KTRI)

1981 / 1

Launched Korea Electronics and Telecommunications Research Institute (KETRI) by consolidating KTRI and KERTI

1985 / 3

Launched the Electronics and Telecommunications Research Institute (ETRI) by consolidating KETRI-KIET

1997 / 1

Changed its name to the Electronics and Telecommunications Research Institute (ETRI)

1998 / 5

Consolidated System Engineering Research Institute (SERI) into ETRI

ETRI Built it and Makes the World Shine

1982

32K ROM

- Promoted the first domestic semiconductor R&D project led by the government.
- Developed 32K ROM without foreign technology for the first time in Korea.
- In case of 4K ROM in 1983, we showed the potential of successfully developing it in 1 month after launching.
- Based on the above accomplishment, we advanced to one of top 7 countries of semiconductor production technology.

1984

16bit UNIX

- It is a UNIX computer which ETRI developed with Samsung Electronics, and it became the foundation of domestic computer technology.
- We succeeded in designing the entire system of the microcomputer independently and localizing the main components of the computer.
- Contributed to the development of ‘SSM-16’, the first commercial computer.

1986

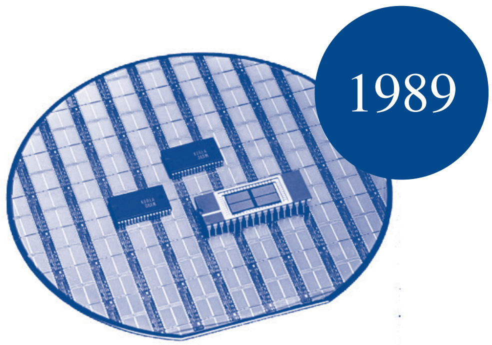
TDX

- We succeeded in developing ‘TDX-1’, Time Division Exchange, for the 11th time in the world.
- Mega R&D project where 1,300 personnel per year and KRW 24 billion in total were invested.
- Surpassed 10 million commercialized telephone network through 4 operators in Korea.
- Created the economic effect of KRW 5.3864 Trillion including the import substitution effect of KRW 4.3406 Trillion and export of 1.0458 trillion.
- Prepared a foundation for the domestic telecommunication equipment industry to leap forward by fostering relevant industries.
- A unique case of directly developing and manufacturing a digital exchanger without going through the manufacturing process of mechanical and analog exchangers.
- A full-fledged arrival of the “era of one phone for one household” in Korea thanks to the development of DX.
- The last Dr. Byoung Sung Ahn who was the executive director of DX project was selected to『the Person of Merit for National Science and Technology in 2020』held by the Korean Academy of Science and Technology (December, 2020).
- Selected to top 70 achievements of science and technology on the 70th anniversary of the National Liberation Day (2015).

1988

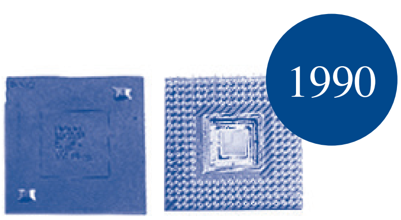
565Mbps Optical Communications System

- Compared to the existing 90Mbps system, its capacity is increased by more than 6 times, and it is possible to transmit 8,640 voices simultaneously with a pair of optical fiber.
- Used for long-distance transmission of images for the wire broadcasting.
- Built a standard and established the infra of super-high-speed information and communications network in Korea.



4M DRAM

- Centered on ETRI, Mega-scale industry-university-research joint development project where Samsung Semiconductor Communication, Goldstar Semiconductor, and Hyundai Electronics participated.
- Joined semiconductor superpowers with the development of 4M DRAM in 1988 and 16M DRAM in 1991.
- Succeeded in developing 64M DRAM in 1992 and 256M DRAM in 1994, both are the first time in the world.
- Leaped in a short time from a barren land of semiconductor technology to the number 1 exporter of semi-conductor in the world.
- Induced innovative changes to the lifestyle of the citizens and distribution structure by promoting digitalization across the country.
- The economic ripple effect of memory semiconductor developed by ETRI is about KRW 4.71383.
- Selected to one of top 70 achievements of science and technology on the 70th anniversary of the National Liberation Day.



32bit Microprocessors

- It is an essential part of CPU, and we secured the technology close to the technology level of the United States.
- It is a fruit of 9 years' efforts, and its command processing speed is 40 million cases per second.

TiCOM

- Centered on ETRI, mega-scale industry-university-research joint development project where Goldstar, Daewoo Telecom, Samsung Electronics, and Hyundai Electronics participated
- Developed a host computer II (TiCom), mid-size computer made in Korea, for the first time in Korea.
- Afterwards, we developed the main computer III (TiCom III), a high-speed medium-sized computer in 1994, and the TiCom IV, high-speed parallel computer system (SPAX) in 1998 consecutively.
- Secured the foundation of e-government with our own technology.
- Secured an opportunity of freeing from being dependent upon foreign countries' computers.
- Contributed to fast growth of domestic computer industry by training professionals related to computer.

CDMA

- Succeeded in commercialization of digital mobile communications system of CDMA type and terminal for the first time in the world.
- Invested KRW 99.6 billion of research funds and 1042 research personnel for 8 years since 1989.
- Received subscribers 10 times more compared to the existing analog method and 3 times more compared to TDMA.
- Paved the way to leap forward as a world-recognized powerhouse in the mobile communication industry.
- Generated economic ripple effect of about KRW 190.3371 trillion for 10 years since 1996.
- Selected to one of top 70 achievements of science and technology on the 70th anniversary of National Liberation Day.

1999

IMT-2000

- Developed Us-centric synchronous IMT-2000 (CDMA2000).
- Two technologies (OCQPSK, AISMA) are reflected on the international standard.
- Earned royalty of KRW tens of billion from the global companies.
- Succeeded in the commercialized service of W-CDMA centered on Europe.

2004

2005

Terrestrial DMB

- Succeeded in developing terrestrial DMB for the first time in the world.
- Started the era of ‘TV in my hand, my own broadcast’, where you can watch a seamless TV without interruption even while driving at high speed of 150 km/h or more.
- Created the economic ripple effect of about KRW 250.9 billion for 10 years since 2006.

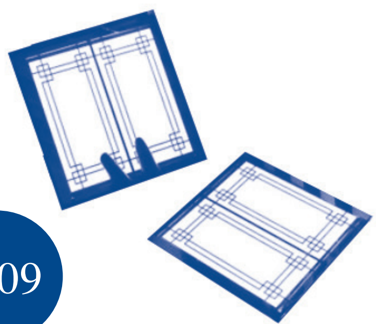
WiBro

- Commercialized 'WiBro technology', a portable Internet service based on international standards for the first time in the world.
- Demonstrated during APEC in 2005 and Torino Winter Olympics in 2006.
- The export of Technology and equipment for 5 years since 2008 amounts to KRW 30.9798 trillion.
- Production inducement effect of KRW 14.65 trillion and creation of more than 74,900 jobs.
- Afterwards, developed WiBro (2008).
- Selected to one of top 70 achievements of science and technology on the 70th anniversary of National Liberation Day.

4th Generation Wireless Transmission System (NoLA)

- Succeeded in transmitting data at 3.6Gbps which is three times faster than the minimum requirement of 4th generation mobile communication requirement of 1Gbps for the first time in the world.
- It was a trigger of accomplishing the speed of wired transmission wirelessly.

2007



2009

Transparent AMOLED Panel

- Developed Transparent AMOLED panel for the first time in the world.
- Acquired technology fees of KRW 470 million.
- The economic effect of OLED lighting and AMOLED display amounts to about KRW 7 trillion (2013~2020).

2008

SMMD (Single Media Multiple Devices) 4D System

- It is a media service that reproduces in conjunction with various devices around users to maximize media effects.
- It is a technology which transforms a living room to a theatre and a study room to an office by transcending the boundaries of places/space.

2010

SAN (Ship Area Network)

- Korea's leading shipbuilding + ICT convergence research project.
- It is a network technology which can monitor, maintain, and repair ships operating in the ocean remotely.
- Mounted SAN-based AMS to the ships of Hyundai Heavy Industries and AP Moller, the world's largest container shipping company.

2011

LTE-Advanced

- Developed LTE-A(Advanced) system, the real 4th generation mobile communications.
- Achieved performance which is faster than HSDPA by more than 40 times and faster than LTE by more than six times.
- Applied a total of 500 domestic and foreign patents and secured 24 core standard patents.
- Expect the production inducement effect of KRW 565 trillion and value-added effect of KRW 177 trillion (2015~2021).
- Estimated the economic ripple effect of LTE and LTE-A as KRW 27.7332 trillion (2011~2020).

Automatic Translation Technology

- Secured an unrivaled automatic interpretation and translation technology on various languages since 1990.
- Developed "Genie Talk", an automatic interpretation and translation app for the mobile phone.
- Provided "official automatic interpretation and translation for Olympic" for the first time in the world (2018).
- Presently, it is evolved with the neural automatic translation technology, and commercialized with "Genie Talk Go", a terminal-mounted interpreter in 2019.
- The economic ripple effect of the technology of voice recognition and interpretation/translation is estimated as KRW 1.9372 trillion (2013~2022).

2012

2013

Technology of Unmanned Valet Parking

- Developed a technology of parking and bringing back a vehicle with smartphone anytime and anywhere for the first time in Korea.
- Accomplished "fully automatic parking" by utilizing the camera sensor, ultrasonic sensor, road surface sensor, etc.
- The effect of saving social cost of KRW 18 trillion and 75 thousand of gasoline annually.

2014

Technology of Orchestra Media

- Developed an 'optical internet technology of 10Gbps' which is 100 times faster than the existing ones with the technology of mega-size NG-PON2.
- The localization rate of core parts is improved from 20% to 90%.
- Applied for 38 international patents and 1 international standard patent.

2015

High Five ESCoRT RoF Technology

- Technology of transmitting mobile signals through optical fiber after converting it directly to analog optical signals.
- Solved the problem of Energy (E), Surface Area (S), Cost (Co), Resources (R), Traffic (T) which were the urgent issues of mobile fronthaul.
- It became possible to setup the mobile communication base station based on optical transmission technology with the cost of less than one-fifteenth of the existing ones.

2016

Integrated switching system

- Developed 'Fiber-Line-Packet Integrated Switch (OCES)' where the gears for optical transmission, line transmission, and packet transmission that were used for a telephone company are integrated into one equipment.
- The effect of reducing router load by 80%, power consumption by 65%, floor area by 68% compared to the existing network equipment.
- Commercialized in various ways after relocating to a domestic institution (22 cases, starting fee of KRW 1.822 billion).

2017

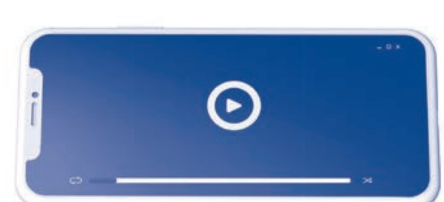
Linguistic Intelligence, Exobrain

- It is an in-depth question-and-answer technology in which the system answers human questions after understanding the content of sentences and documents.
- Won the quiz competition of the EBS Janghak Quiz against human participants by a large margin.
- Developed "KorBERT", the best language model of studying Korean which studied 700 million morphemes.
- Its performance is better than the model of Korean language distributed by Google by 4.5% on average.
- Won the first place prize at 'Machine Translation Challenge of Korean (KorQuAD V1.0)' (2019).

2018

UHD Mobile Broadcast

- Experimental broadcast of ATSC 3.0 for the first time in the world.
- Supported 'UHD mobile broadcast', a top service of ATSC 3.0 UHD broadcast.
- The effect of saving the resources of broadcast frequencies by about KRW 70 trillion.
- Economic ripple effect of K-UHD is estimated as KRW 1.4491 trillion (2013~2022).



2019

Tactile Internet TIC-TOC

- Developed the network “TIC-TOC” which is fast enough to transmit data within 1/1,000 second.
- Accomplished tactile Internet of 25Gbps with the technologies of High-speed, high-sensitivity optical transmission/reception and MAC.
- Improved laser operating speed by 10 times and minimized delay to 1/10.

Visual Intelligence Deep View

- Developed “Deep View platform” which recognizes human and objects in an image and understand its behaviors.
- Possible to detect various crimes or accidents in downtown and prevent them.
- An automatic detect technology of garbage dumping using a person's pose has improved its performance by 50% from the existing ones, and it is one of the best in the world.
- Accomplished the performance of 74.65% which is world-class based on behavioral recognition ActivityNet-1.3@100.

2020

2021

Intelligence Robotics

- Currently developing the automatic driving of Level 4 (the level where a vehicle can recognize/decide/respond to the situation accurately by itself).
- Secured driving data of accumulated 100 thousand km in various road conditions (daytime, nighttime, rainy weather, etc.), which is the largest in Korea.
- Our achievement includes 4 CI thesis papers, 3 international conference papers, and 7 cases of technology transfer, etc.

PART 1

Telecommunications

1

Telecommunications

1-1. Outline

Information and Communications Technology (ICT): This refers to a combination of information and communication technology, meaning SW, which operates and manages information devices such as computers, media and video, and all methods arising from it.

Networks

Wired communications began in May 1844 when Samuel Moss sent a full message between Washington and Baltimore in the United States. It was in August 1885, 41 years later, when wired communications were introduced in Korea. The beginning of South Korea's wired telecommunications was when the Hanseong Information Bureau sent a telegraph between Seoul and Incheon. After that, telephone services were launched in 1867 with the invention of the telephone by several inventors including Alexander Graham Bell of the United States, and the telephone was first connected in Korea between Seoul and Incheon in 1896.

As the nation's economy began to grow rapidly in the 1960s, the telephone gradually became a necessity for economic activity and foundation for the nation's economic development. In response, the government simultaneously promoted the "Five-Year Telecommunications Business Plan" along with the "Five-Year Economic Development Plan" in 1962. In the 1970s, domestic telecommunications facilities made a breakthrough. However, as telephone congestion became serious as the increase of facilities failed to keep up with the surging demand for telephones, a project to develop a time-division electronic switching system was launched under the direction of the president in 1982. At the time, with a five-year annual plan including 1,300 people and a budget totaling KRW 24 billion, this was a large-scale research and development project. Through this, Electronics and Telecommunications Research Institute (ETRI) succeeded in developing the “TDX-1,” the 10th electronic switching system in the world in 1986. In 1991, after several improvements, it developed the “TDX-10” with more than 10 times the capacity of the TDX-1. As a result, Korea became the only country to develop and produce a digital switching system without undergoing the manufacture of mechanical and analog switching system, fully ushering in the “one-household, one-telephone era.”

TDX-1B switching system

In addition, as the needs of telephone users gradually diversified, the concept of the Intelligent Network (IN) was derived, which provided a variety of new additional services through the phone, and other related technologies were then developed since 1988.

In the 1990s, Korea began developing optical network technology to prepare for multimedia services centered on future data. In particular, Korea succeeded in producing the world's seventh ATM switching system in 1995, enabling VOD services, video conferencing, two-way video call services, and multimedia search services in Korea.

Meanwhile, as the Internet quickly improved in the 21st century and broadcasting and communication convergence became a trend, ETRI pioneered the era of Gigabit Fiber To The Home (FTTH), which allows servicing of optical signals in both direct broadband and real time. It was at this time that the development of high-speed router technology, the heart of internet technology, began. In addition, orchestration technology, a distributed SDN (Software Defined Network) and NFV (Network Function Virtualization) platform, has also been developed, allowing the composition and operation of the network to be easily configured and controlled using API in the same way as computer programming.

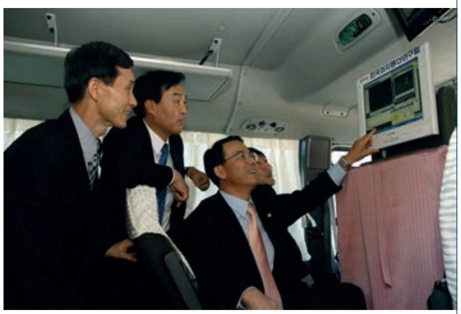
As the beginning of the 2010s predicted a lack of transmission capacity, phenomenon involving optical transmission not being able to keep up with the speed of traffic growth (10 times over 7 years) due to the explosion of internet data traffic growth. Thus, POINTS, a packet-optic integrated switch was developed in 2012, and OCES, a packet-circuit-optic integrated switch was developed in 2016.

In addition, in 2020, Korea developed Tactile Internet (TIC-TOC), which is fast enough to deliver information within 1/1,000 of a second, and began developing a "hyper-connected intelligent network," which is combined with IoT, cloud computing, 5G mobile network, data, and artificial intelligence (AI) technology.

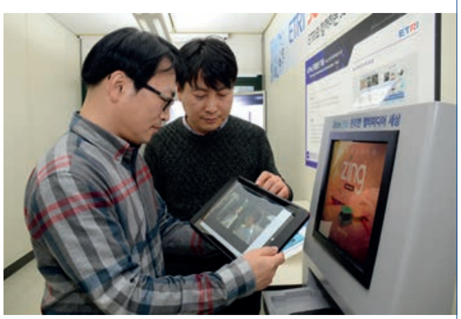
CDMA mobile communication system

Mobile Communications

In 1895, wireless communications began with Italy's Marconi, when he succeeded in operating a wireless telegraph transmission for the first time in the world in the Atlantic Ocean. Later, in 1947, Bell Lab. devised an innovative cellular concept, and in 1983, the era of mobile communications began in the US with Ameritech in Chicago, providing services for commercializing the Advanced Mobile Phone System (AMPS).



WiBro vehicle demonstration



ZING technology demonstration

In the mid-1980s, analog mobile communication services began in Korea. However, due to the nature of being a divided country, it was sensitive to national security, limiting its use. In 1988, the number of subscribers increased by more than 100% every year as restrictions were greatly lifted starting from the Seoul Olympics. Since then, there was growing awareness and demand to the extent that the second generation of mobile communication or the digital mobile communication system needed to be developed on its own to overcome the limitations of analog systems.

Thus, ETRI developed digital mobile communication since 1988 and succeeded in commercializing the world's first code-division multiple access (CDMA) mobile communication system in 1996. As a result, Korea made a quantum jump from importing mobile equipment to exporting them.

From the late-1990s, Korea began to develop third-generation mobile communications. ETRI developed the central synchronous IMT-2000 (CDMA2000) in 1999 and launched commercial services of the asynchronous W-CDMA in 2003.

In the 21st century, ETRI started to develop fourth-generation mobile communication and succeeded in implementing the first LTE mobile communications technology that meets the requirements of "3GPP LTE/SAE" for the first time in the world in 2007. In 2010, the full fourth-generation "LTE-A (Advanced)" was also developed. Meanwhile, it challenged the development of the WiBro System, a portable Internet service that allows access to the Internet anytime, anywhere, and succeeded in accessing the world's first prototype of a WiBro system that meets the international standard of IEEE802.16e on November 27, 2004, using a base station and terminal.

In the 2010s, ETRI began developing a variety of fifth-generation mobile communications technologies. In 2013, it reorganized ten 5G-related projects, which had been conducted individually through consultation with the government, into a "5G integrated project" consisting of "5G technology-oriented" and "5G market-oriented" R&D projects. ETRI has successfully developed the Mobile Xhaul Network (MXN) and Ultra-Density Network (UDN) technology through 5G technology-oriented tasks, the technology of the LTE small cell base station, MHN technology to improve the Wi-Fi environment in subways, high-speed close proximity communication (Zing), and NB-IoT (narrowband IoT) through 5G market-oriented tasks.

Chollian satellite control center

Meanwhile, ETRI began developing Wi-Fi-related technologies in 2001, judging that the importance of wireless LAN would increase as a complementary element to future mobile communications. As a result, Korea developed the world's first low-speed mobile wireless transmission system in 2007. In 2016, Korea also succeeded in developing the world's first IEEE 802.11ah SoC chipset.

In addition, from the late 2010s, terahertz wireless communication technology and three-dimensional communication technology were being developed to preemptively occupy the core source of sixth-generation mobile communications, which is expected to be commercialized around 2030.

Satellite Communications

The world's first satellite, Sputnik 1, was launched by the former Soviet Union in October 1957. The US then launched Explorer 1 in January 1958. Then, Intelsat was organized in 1964 for fixed satellite communications between countries, and Inmarsat in 1976 for maritime communications.

These enabled the international telephone services, ship communications and real-time TV broadcasting of international events such as the Olympic games. Since then, satellite communications technology has progressed rapidly, enabling not only fixed satellite services (FSS) and broadcasting satellite services (BSS) but also mobile satellite services (MSS) and personal satellite communications through low-orbit satellites.

The real history of satellite communications in Korea began with ETRI. In the early 1980s, the government planned the introduction of communications & broadcasting satellites. Additionally, Korea also planned on addressing the soaring demand for telecommunications through satellite communications services. In 1983, when ETRI began the feasibility study of communications and broadcasting satellites, Korea took its first step toward developing satellite communications. From 1985 to 1988, in collaboration with the five-leading local communications companies in Korea, ETRI had developed the nation's first satellite communications ground system, SCPC system, as a laboratory model.

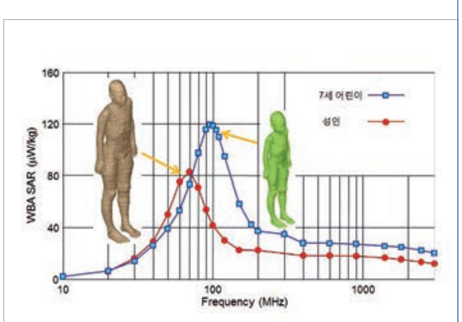
Since 1989, it has been suggested that Korea should also develop its own satellite. It could be the only means of providing communications services to cover remote mountain and island areas and it was also very important not only in terms of industry but also in terms of national security. In response, the government finalized the plan to secure its own satellite, and ETRI established the Satellite Communication Technology Center in 1990 to begin the development of satellite communications technology.

The development of satellite technologies was processed in two parts: the Earth Station and the satellite's payload systems. ETRI succeeded in developing and commercializing the Very Small Aperture Terminal (VSAT) and Demand Assigned Multiple Access and Single Channel Per Carrier (DAMA/SCPC) in 1994, which was ETRI's first international joint-development. ETRI also developed an excellent payload that meets all the considerations of satellite communications by applying an ultra-high-frequency miniaturization technology that integrates transmission between the satellite and the ground with a general semiconductor. Finally, in 2010, Chollian-1, a geostationary composite satellite equipped with a system developed around ETRI, was successfully launched. As a result, Korea is now the nation to own the world's first geostationary marine observation satellite and the world's seventh-largest meteorological observation satellite.

Meanwhile, with the digitalization of broadcasting, Korea at the second in the world began to develop the technology for digital satellite broadcasting station in the 1990s. Owing to developing a time-division multiple access (TDMA) earth station, Korea has been able to provide 24-hour nationwide HDTV satellite broadcasting since 2004, which had been the era of analog broadcasting. Since then, technology evolved with the recent successful conducting of 8K UHD trial broadcasts.

In addition, ETRI developed its own satellite control system for a multi-purpose practical satellite I launched in 1999, and continued to do so for satellites II, III, and V. In 2010, it developed the GPS/Galileo receiver technology, a satellite navigation technology. In 2019, it developed and established a ground station to continuously receive, process, analyze, and service the data from the multi-channel, high-resolution, and large-scale observations of Chollian-2A.

In the future, ETRI will take the lead in developing complex public communications satellites (Chollian-3), which is to begin in 2021.



A study on the compatibility of electromagnetic wave protection standards for children
(Comparing the average whole body electromagnetic wave absorption rate of a 7-year-old child and an adult in the frequency range of 10Mz ~ 3GHz)

Wireless charging core technology development

Radio Waves

Electromagnetic waves were theorized in 1864 by British mathematician Maxwell, based on the electron induction discovered by Faraday in 1831. Then, in 1906, the International Wireless Telegraph Treaty was signed between nations, ushering in the era of full wireless communications. Since then, wireless communications using radio waves began in Korea in September 1910, when KIS Guangjae, the government's maritime surveillance ship, introduced wireless telegrams.

The wireless and radio wave technology in Korea was still underdeveloped until the early 1980s. The use of radio waves was restricted due to the division of the peninsula, with the use of radio waves allowed only in controlled fields such as for safety communications and maritime rescue. In this situation, ETRI organized the Special Communications Office and began to develop radio wave technology to support the government's policy. In the late 1980s, it launched the Wireless Research Department.

Since then, with changes in the internal and external environment, the government began to implement policies to foster the radio wave industry in the 1990s, and various wireless services emerged (mobile phones, digital television, wireless LAN, Bluetooth, RFID, GPS, etc.). As a result, as the demand for frequencies soared, ETRI promoted the development of spectral engineering technology to efficiently manage limited radio wave resources from 1993.

ETRI's research on radio wave technology is largely classified into four categories: 1) radio wave resources (spectral engineering, frequency sharing, use of millimeter waves), to identify new frequency resources and research the efficient use of frequencies; 2) radio wave based-technology (antennas, radio wave propagation, reverberation chamber), to research radio wave materials, parts, and equipment technology as the basis for radio wave use; 3) radio wave environments (electromagnetic effects on the human body, radio wave monitoring, EMI/EMC), to secure safety of radio waves; 4) radio wave applications (medical care, drone detection/identification, wireless power transmission, magnetic field communications), to research application technologies related to electromagnetic waves.

In the early days of radio wave development, ETRI focused on the development of spectral engineering technologies that were closely related to the government's policy for radio waves. Then, when dangers of electromagnetic waves began to be discussed excitedly in the media, standards for protecting humans against electromagnetic waves were drafted by researching various effects of electromagnetic waves on the human body. Also, the EMI/EMC technology had been developed from the early 1990s, contributing to the establishment of the domestic EMC system and foundation of related industries.

In addition, by gradually promoting and localizing the development of radio wave monitoring technology for controlling an illegal radion waves from the mid-1980s, a 365-day non-stop monitoring has now been accomplished for safe radio wave transmission in Korea.

In the 2000s, Korea began to develop the technology for frequency sharing to address the shortage of frequency resources, and also the technology for frequency resource utilization in the millimeter wave band (71–95 GHz) to cope with large-scale data traffic in 5G mobile communications.

Meanwhile, ETRI is also focusing on developing various applications of radio waves, such as medical imaging technology for diagnosing cancer by using the electro-magnetic waves, radiological treatment technology for treating intractable diseases by concentrating radio waves on the desired location in the human body, wireless power transmission technology using magnetic resonance technology, and small drone identification/detection technology.

1-2. Networks - Laying the Groundwork for the Strongest Country in Information and Communications

A network is an infrastructure that supports the connection between a terminal or host and the exchange of information, which is the core technology supporting the competitiveness of a country's society. The government has been promoting the infrastructure of high-tech networks such as the telephone network of electronic exchange, which opened the era of one-household, one-telephone in the 1980s, high-speed information networks in the 1990s, and broadband integrated networks in the 2000s as the nation's core strategy. As a partner in the implementation of these national policies, ETRI has served a leading role in the development and industrialization of networks’ core technologies and has contributed to the realization of the world's strongest information society.

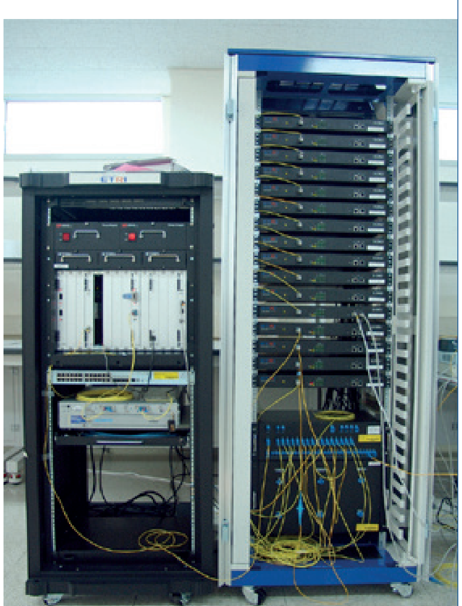
ETRI's network R&D has provided a solid foundation for the development of the nation's social, information and communications services, with constant technological evolution and phased innovation ranging from the past 40 years of switching and transmission technology to technologies on optical communication, packet communication, network control and management, and future network. Early research in the 1980s was conducted with the primary goal of urgently addressing the information and communications technology needs of the country and society that are just beginning to develop. In the 1990s, it became independently competitive in each technological areas, and by the 2000s, it was the groundwork for the realization of the world's strongest information society. Since 2010, ETRI has been taking on the challenge to develop more innovative research to lead a hyper-connected intelligent society.

The world's 10th electronic switching system TDX-1

ATM video telephone service demo

AICPS deployment ceremony workshop


FTTH service demo


10G PON system

Telephone Switching Systems

National attention was given to ETRI's network research as the first-ever ultra-large research and development project in 1982 when the TDX-1 Development Project began. With telephone congestion becoming serious as the increase of telephone facilities failed to keep up with the soaring telephone demand at the time, a project to develop a time-division electronic switching system began under the direction of the President. As a result, ETRI succeeded in developing the TDX-1, the world's 10th electronic switching system, in 1986. After several improvements, in 1991 it developed the TDX-10, which has 10 times more capacity than the TDX-1. As a result, Korea has become the only country to develop and produce a digital switching system without undergoing the production of a mechanical switching system and analog switching system. It has fully ushered in the “one-household, one-phone era.”

As the era of one telephone per household became normalized, the concept of IN (Intelligent Network) was derived, which provides a variety of new additional services through telephones, resulting in the development of SCP, SMS, STP, and SSP in 1988. Based on these technologies, a variety of IN services have been provided to Korea since the mid-1990s, including nation-wide number service (1588 and 1577), information charging agency service (060), toll-free call (080), telephone voting (1580), credit calling (161), weather forecast (131), and lifetime one number (0502), and the role of network services has switching system beyond simple communications to include the business of services.

In the late 1990s, data communications using analog telephone lines based on modems were often inaccessible or slow. In response, ETRI completed the development of the Advanced Information Communication Processing System (AICPS) in 1998, opening an era of open Internet access guaranteeing an access rate of more than 99% for over 6 million data communication users.

Optical Networks

Optical communication is a key enabling technology for information society. The optical communication transmits and exchanges information from one place to another by sending pulses of light through an optical fiber.

The 2nd internet workshop

The world's 1st QOS guaranteed access router (S-20)

Following the development and commercialization of SDH based 155M bps synchronous transmission system in 1992, ETRI had been continued to develop an optical transmission system for 2.5 Gbps and 10 Gbps. Since 2000, it has led the development of high-speed broadband technology, including the development of 160 Gbps and 1.6 terabit systems using WDM methods. Since then, it has continued to accelerate the transmission speed of optical receiver units to 10 Gbps, 40 Gbps, 100 Gbps, 200 Gbps, and 400 Gbps to meet the needs of new services and markets, and has focused on modularizing the system's key functions.

Meanwhile, with the rapid penetration of the Internet and the convergence of broadcasting and communications, ETRI has pioneered the era of broadband series to residential area. With the replacement of traditional copper wires with optical fibers since the 2000s, optical access network continuously evolved into higher speed system providing broadband services to residential users (FTTH: Fiber-to-the-Home). In 2015, ETRI developed the 100-times-faster 10 Gbps optical Internet through the development of large-capacity NG-PON2 technology. Recently, optical access has been expanding its applications to mobile communication network to accommodate 5G and beyond. In 2019, it was developed RoF based indoor distributed system to allow anyone to fully access 5G services in indoor environments without the shadow of radio waves. Since 2019, ETRI is developing high capacity and low latency optical Tactile internet (TIC-TOC technology) that is fast enough to deliver information within 1/1,000 of a second.

As the development of optical transmission technology could not keep up with the growth of explosive data traffic (10 times over 7 years), ETRI developed a packet-optical integrated switch (POINTS) system in 2012 that automatically sets the optimal route by integrating optical and packet transmission equipment. Furthermore, in 2016, the development of the optical carrier ethernet switch (OCES), which integrates optical transmission equipment, circuit delivery equipment, and packet delivery equipment, served a role in bringing new vitality to the sluggish domestic network industry.

Packet and Internet Communications

In the 1990s, the environment of communication rapidly shifted from voice-centric to data-centric multimedia services. As a result, the technology of exchange and transmission

Network equipments test center opening ceremony

also shifted the paradigm from the exchange of lines to the packet base, and in accordance with this, ETRI prepared for the entry of the Internet era by developing ATM switching system and MPLS technology.

ETRI began research on ATM switching system in 1992 as part of the Highly Advanced National (HAN) R&D project, to lead the 21st century's technological development. In 1995, it succeeded in producing the world's seventh ATM switching system. As a result, VOD services, video conferencing, interactive video phone services, and multimedia search services became available in Korea, but ATM technology failed in the market.

Meanwhile, since the early 2000s, ETRI has pushed ahead with the development of high-speed router technology, the core of Internet technology. In 2001, ETRI developed a router system (HSR-80) that could process 20 Gbps to 80 Gbps for the first time in Korea, and soon developed a router with guaranteed quality that provides services with enhanced data flow. In 2008, it developed a differentiated quality-guaranteed access router (S-20) for the first time in the world. This resulted in the securing of routers of almost all models needed for the next generation network.

Future Network Technologies

Since the 2010s, networks have rapidly evolved beyond the traditional role of connectivity and simple exchange of information into platforms that have to support various types of services with different requirements as quickly as possible.

ETRI first developed the innovative core technologies for open programmable networks that can transform the existing hardware-oriented closed network equipment industry into a SW-oriented open ecosystem. The Network Operating System (NOS) can be mounted on various open network equipments, which helped solve the dependency issues that we had with overseas network equipment manufacturers.

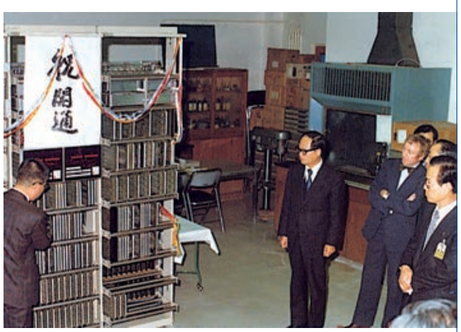
ETRI then developed standards and technologies on Software-Defined Networking (SDN) and Network Function Virtualization (NFN). The SDN controller reached commercial level. The distributed SDN/NFV orchestrator provided the capabilities to configure network infrastructure on the fly considering the computing and network resources collaboratively. The technology played an important role in enabling the flexible and immediate provisioning of services in virtualized infrastructure, which contributed to reduce the time required for operators to develop new services to 1/10, significantly reduce costs.

ETRI is also working on the research of innovative future networks to support hyper-connected intelligence society, focusing on securing related core technologies. Networks will become more important as the essential infrastructure at the core of a hyper-connected data-centric society, together with IoT, cloud, 5G/6G mobile networks, data, and AI technologies. ETRI will continue to take on the challenge continuously so that Korea can maintain its position as the strongest country in networking technologies as well as network-based industries and services.

1-2-1. TDX swtich / Intelligent Network Services

1-2-1-1. TDX Switching System

As the nation's economy grew rapidly after the 1960s, telephones began to be recognized as a necessity for economic activity and foundation for the nation's economic development. The number of backlog cases, which was just over 10,000 in 1972, increased by nearly 600,000 in 1978, subscriber had to wait more than one year for telephone installation. In response, the government began discussing the localization of switching systems, and in 1976, at the economic ministers' meeting under the direction of the president, the development for localizing electronic switching system was decided in a surprise move.



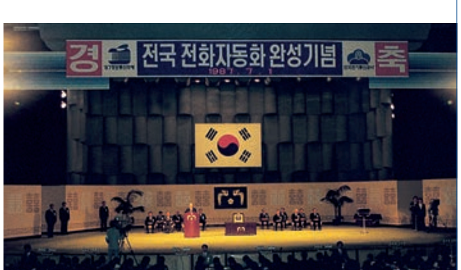
Private switching system KIST-500

TDX: A Mega National Project with KRW 24 Billion in Research

In 1981, interest in the development of the Time Division Exchange (TDX) grew as the government pushed for a plan to install an electronic switching system in rural areas.The government has determined the basic direction for developing TDX in the form of joint development of businesses centered on ETRI. Finally, the development project for TDX-1 began as an unprecedented mega research development project with a five-year research period in 1982 (1982-1986), KRW 24 billion in research funds, and 1,300 research participants. The development of the technology was led by ETRI and manufacturers (who participated as joint researchers). Korea Telecom, a state-run company, provided development costs as business operators and users of switching systems.

TDX-1 switching system

In addition to the development of military equipment, research projects worth KRW one billion were also rare at that time. In this situation, investing as much as KRW 24 billion in research was a huge venture, but the government pushed ahead with the development of the TDX-1 in consideration of both the electronics industry's development and long-term national development.



The ceremony of nation-wide telephone deployment completed

In the beginning, however, the opposition was considerable. First, there was a widespread opinion in the academic society and National Assembly that it was impossible for Korea, which has no base technology, to develop an electronic switching system on its own with lower research funding than in foreign countries. Some social organizations said that it would be better to build another bridge on the Hangang River at that cost.

The opening ceremony of TDX test center

At that time, the electronic switching system technology was strategic and owned by only five advanced countries, so this opposition was somewhat reasonable.To overcome this distrust, ETRI's researchers worked hard on their studies, day and night. It was from this time that ETRI was nicknamed the "Laboratory Where the Lights Don't Go Out."

Successful Development and Commercialization of TDX-1, the World's Tenth Electronic Switching System

In 1986, the researchers of ETRI finally succeeded in developing the TDX-1, the world's 10th electronic switching system. The TDX-1 is designed to handle 9,600 lines of capacity with a fully distributed structure in which hundreds of microprocessors share functions. It has also achieved technical achievements such as real-time operating systems, securing reliability by redundancy of processors and major equipment, processing of stable signals that enable easy increase in capacity, user-friendly operation and maintenance, and verification of system integration and testing. ETRI developed all the HW and SW needed for the system on its own. At that time, there was no specific information on the technologies and functions contained in the foreign switching system, so developers gathered various requirements of Korea Telecom’s operator and combined their creative imaginations to develop new technologies.

TDX-1/TDX-10

TDX-10 Opened the "One-Household, One-Phone Era"

The TDX-10 development project’s purpose is developing large-capacity electronic switching system, which began in 1987, shortly after the development of the TDX-1.

In 1991, the researchers succeeded in developing an electronic switching system capable of processing 110,000 subscribers, more than 10 times the capacity of the TDX-1. The TDX-10 is excellent in all areas, including system size, performance, and availability of services by applying the latest technologies in each field, including computers, semiconductors, telecommunications, and SW, and was designed as an open structure based on the flexibility and modularization of the structure to facilitate function expansion or maintenance.

The Development Effect of the TDX

ETRI opened a new chapter in the history of communications in Korea with the development of the TDX that took over a decade. With the successful development and commercialization of the TDX, Korea became the only country to immediately develop and produce a digital switching system without undergoing the process of manufacturing mechanical and analog switching system, becoming both the world's tenth electronic switching system and the sixth exporter. Also, the development of the TDX has produced tremendous economic and industrial benefits, such as the inducement of domestic production, replacement of exports and imports, reduction in technology costs, and inducement of employment. It also reduced additional costs from upgrading new functions, costs of network management and maintenance for Y2K issues, development costs for research in other areas through the use of technology of development, and creation of new industries. The inducement effect of domestic production reached KRW 4 trillion (1985-1997), the effect of replacing imports totaled USD 4.1 billion (1987-1997), and the effect of reducing royalty cost was estimated to be about USD 400 million. Also, from 1991 to 1997, exports to 15 countries including Russia, China, and Vietnam amounted to USD 570 million from 3.92 million lines.

The significance in succeeding the TDX development does not stop here. This has instilled a spirit of confidence and ambition to domestic researchers in all fields as well as those who participated in the development of TDX. It is also significant in that ETRI has secured its own technology system beyond the subjugation of advanced countries in the field of information and communications.

Korea's success in commercializing the world's first CDMA-type mobile communications in 1996 was also made possible thanks to the development of TDX technology.

1-2-1-2. Intelligent Network Services

As the distribution rate of telephones increased, users began to demand various services other than the existing ones, such as changes in reception location by time zone, flexible pricing, and speech dialing. To cope with this paradigm shift, communication service providers combined existing PSTN and computer networks with ITU-T signaling system

The opening ceremony of Intelligent Network Services in field network(December 14, 1993, KT)

No.7 to create a new concept called the intelligent network (IN) that can create and manage new services quickly and conveniently.

Korea began to develop intelligent network services relatively quickly around the same time as advanced countries. ETRI and Korea Telecom (KT) began developing SCP/SMS and the signal transfer point (STP) in 1988, and SSP and SIGNOS in 1990. In 1991, it completed the development of SMX-1 (Signaling Message eXchange-1), and in March 1992, it developed and tested a prototype of the Network Information Control/Management System (NICS), a management and control system for billing and credit call services. Incoming billing and credit call services using NICS were first commercialized on March 1, 1995 for subscribers in Seoul and Busan.

The advanced intelligent network (AIN) services can be applied to all networks, including PSTN, ISDN, and PLMN, providing the capability of networks to provide services independent from the services and networks in multi-vendor environments. Together with KT, ETRI continued to push for the development of the AIN services such as service creation environment (SCE), SCP/SMS, SSP, and intelligent peripheral (IP; an intelligent information provision system). As a result, KT opened the AIN services at the Gayang Telephone Office on November 2, 1999.

1-2-1-3. Open Internet Access Technology

ETRI began developing the Advanced Information Communication Processing System (AICPS) in the late 1990s. AICPS is an information and communication platform that allows high-speed access to the information of service providers connected to the packet network, frame relay network, and the Internet, as well as a telephone network providing a nationwide 014XY-based number system. Previously, one had to subscribe to a specific ISP separately when using the Internet and had to enter the ID and password for each access. But just by using AICPS, calling 014XY took over all the procedures.

ETRI completed the development of AICPS in 1998 and conducted a development confirmation test successfully with KT. This opened firstly in the world the era of open Internet access services, guaranteeing access to more than 99% of services for more than 6 million data users. With fast connection speeds, most of regular telephone subscribers were able to reach up to 56 Kbps and up to 64 Kbps with ISDN, the highest level at the time. Around 60,000 lines were equipped in 1999 and around 40,000 more in 2000. If the representative of the domestic voice communications network was TDX, AICPS was the representative technology of the domestic data communications network.

AICPS

1-2-2. Optical Networks

1-2-2-1. Optical Transmission Technology

ETRI developed a 6.3 Mbps optical transmitter that transmits 96 coded voice channels from the pulse code modulation (PCM) in 1978 and tested it at the President's new year inspection tour in February 1979. This was the first optical transmission testing demo in Korea.

In the 1980s, as the paradigm of optical communications changed to long wavelength (1.3 μm), ETRI continued to develop asynchronous long wavelength optical transmission systems of 45 Mbps, 90 Mbps, and 565 Mbps starting in 1984.

The first optical transmission testing demo in korea (February 6, 1979)

Development of a Giga-level Optical Transmission System

The 2.5 Gbps optical transmission system, which could be used for long distance trunk, was developed from 1989 to 1994, and applied to the commercial network in 1996. The system provided a starting point for giga-level optical transmission using ultra-high-frequency technology, which had almost no base in Korea.

ETRI developed a 10 Gbps SDH optical transmission system from 1993 to 1998 and completed a commercial test in 1999. ETRI developed key components such as GaAs ASIC and limiting amplifiers (limiting AMPs), which were not commercialized due to the lack of technology in advanced countries, and contributed to blocking the introduction of competitors' products in Korea by completing the 10 Gbps optical transmission system. It also helped reduce the cost per channel by 35% to 40% compared to the existing 2.5 Gbps optical transmission system, enabling cost effective transmission.

The ceremony of 2.5G transmission equipment commercialization (January 30, 1996)

As part of the HAN/B-ISDN project, a 160 Gbps optical transmission WDM system was also developed since 1993. The system was developed to the level of commercialization in 2000 after KT's development confirmation test which was then used to develop technologies for the 800Gbps and 1.6Tbps WDM optical transmission.

Terabit-level Pioneer of the Optical Fiber Transmission Era

ETRI began research on terabit-level WDM optical transmission systems in 2000. As a result, in 2002 it developed optical transmission systems for 800Gbps and 1.6Tbps WDM based on 10Gbps channels, and in 2003 it secured core technology for the implementation of the optical transmission network for tera-level WDM based on 10G and 40G channels. ETRI secured the development of 100G Ethernet and optical transmission technology from 2008 to 2011, and in 2017 secured the core technology for space division multiplexing optical transmission capable of 10km transmission based on multimode.

In 2018, through the research of packet switching based on the Photonic Frame, it succeeded in simplifying the multi-stage data center network based on the electrical switch into a first-tier structure based on the optical switch. Through this, it has secured optical switch-based networking technology that can reduce energy consumption to 1/3 and reduce network delay time to 1/10.

ETRI secured technologies for high-speed, high-capacity transmission, such as a 200Gbps optical transceiver, 400G Ethernet optical transceiver, optical transmitter and optical receiver for metro-access networks in 2019.

The 6G Era, a Challenge in Developing Core Technology for Peta-level Optical Transmission

Based on the technology secured so far, ETRI is developing a silicon-based optical transmission chip technology, Terabit-level Ethernet optical transceiver technology, Terabit-level Ethernet optical transmission and signal processing technology, silicon-based terabit-based optical connection and optical switch-based networking technology. ETRI plans to develop terabit-based optical core technology to lead the era of tera-level optical communications and take on the challenge in developing a peta-level optical communications technology for 6G in the future.

1-2-2-2. Optical Access Technology

Development of FTTH(Fiber to the home, Fiber to the premises), a Combined Network Services for Broadcasting and Communication

The innovation by optical communication in access network was also started since the 2000s. In 2002, ETRI began a full-scale study of optical subscriber access, starting with the task of developing technology for high-speed broadband networks with nine companies including Samsung Electronics and KT, participating as joint research institutions. Meanwhile, ETRI agreed to promote the FTTH service development experimental project with Gwangju Metropolitan City. In 2005, ETRI established an optical subscriber network with KT and Hanaro Telecom. At that time, the construction of the FTTH infrastructure is based on E-PON, WDM-PON, and G-PON equipment developed by ETRI.

Opening ceremony of FTTH infrastructure and service
(July 27, 2006, ETRI)

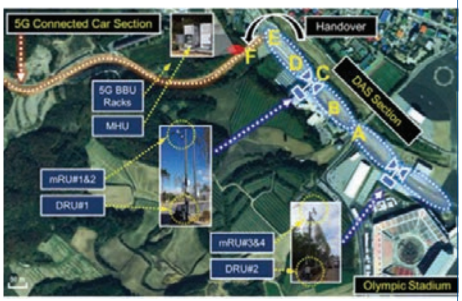
Starting with the opening of the first FTTH subscribers in February of 2006, 6,220 lines (1,759 real subscribers) of FTTH were opened for 10 apartment complexes in Gwangju Metropolitan City by June, with a total of 16,000 lines and 6,000 households by 2008.

The Development of 100-times-faster Optical Internet Technology

ETRI developed the 100-times-faster fiber-optic Internet technology from 2010 to 2015 with the agenda of developing key technologies of high-capacity NG-PON2 platforms. Large-capacity NG-PON2 technology was an innovative technology that could deliver 10 Gbps per subscriber using dedicated optical wavelengths, which is 100 times faster than the speed of 100 Mbps for Internet subscribers at the time.

The Development of Indoor DAS Technology Based on RoF for 5G Mobile Communications

As mobile telecommunications technologies evolve to LTE to 5G, cell capacity is going up to 20 Gbps and traffic in indoor environments is expected to jump more than 100 times compared to that of 4G LTE. To preemptively respond to such problems, ETRI conducted a project that developed analog radio over fiber (RoF)-based indoor distributed antenna system (DAS) technology for mobile communication from 2016 to 2019.



The world's 1st 5G trial services using IFoF-DAS technology (the Pyeong Chang Winter Olympics, 2018)

The goal of the project was to overcome the capacity issues in indoors area such as buildings, tunnels, and stadiums due to the nature of the high carrier frequency of 5G systems. The RoF technology for 5G mobile communications was the first the firt time in the world by ETRI in 2014. At the PyeongChang Winter Olympics in February 2018, ETRI demonstrated the world's first 5G (V2X) pilot service using IFoF-based DAS technology, and in April it successfully demonstrated the giga-level 5G mobile service by linking the DAS developed by the project with the millimeter wave-based 5G mobile communication system developed by ETRI as part of the Giga Korea project. As a follow-up study, the development of the core technology of near-range transmission (up to 10 m) of Terahertz, which can provide high-speed wireless data services (approx. 100Gb/s), has been underway since 2019. This technology is likely to be adopted as the basis for future 6G services.

Tactile Internet a step closer to reality: Time Controlled Tactile Optical Access (TIC-TOC)

Since the 2010s, optical access network continuously evolved into higher speed system providing broadband services to residential users (FTTH: Fiber-to-the-Home), and has been expanding its applications to mobile communication network to accommodate explosive mobile data traffics. From 2015 to 2020, ETRI carried out a project which was mainly focused on the development of 25 Gb/s per wavelength based optical access technology to accommodate bandwidth intensive as well as mission-critical low-latency services such as AR/VR, meta-verse, 4K/8K UHD, drone, and remotely controlled robot, etc. The researchers developed key enabling technology such as MAC/PHY chips, channel bonding, low latency dynamic bandwidth allocation, high-sensitivity optical receiving modules, optical transmission and receiving technology. This technology, named TIC-TOC (Time Controlled Tactile Optical Access) is a critical component of the optical access network, in which information is sent and received at speeds on par with human perception. The 25G tactile internet was applied to KOREN (Korea advanced research network), and demonstrated by field trials combining the access network with long haul transmission link.

Future optical access networks have various challenges including high capacity, low latency, flexibility, and so on. The long journey to explore enabling technology for future optical access network still continues.

1-2-2-3. Packet Optic Transport Network System

ETRI developed the POINTS(Packet-Optic Integrated Network Transport System) in 2011.

POINTS is a transport network equipment that provides packet switching and wavelength switching capabilities. It supports connection oriented ethernet protocols (both of PBB-TE and MPLS-TP) and ROADM functions.

The POINTS resolve traffic big-bang issues and accelerates low-delay & high-reliability service deployments. It also reduces network construction and operation costs (CAPEX/OPEX)

As a follow-up to POINTS, ETRI worked on the development of the OCES(Optical Carrier Ethernet System), which provides packet-circuit-optic converged switching capabilities for 5 years from 2012. It is equipped with processing capacity for 3.2 terabit packet(1G, 10G, 100G line interface), processing capacity of 1.6 terabit circuit(10G, 100G line interface), and wavelength switching of 100Gbps-80 channels. It is also possible to automatically set and control the optimal route.

The OCES passed successfully the field trial test of KOREN(Korea Advanced Research Network) in January 2016.

ETRI transferred the OCES technologies to domestic industries and has been commercialized in various ways. These products include the UTRANS Series PTN and ROADM of Coweaver, OPN Series POTN and APS Series PTN of WooriNet, and M Series PTN/POTN of Telefield.

1-2-2-4. Application and Industrialization of Optical Technology (Honam Research Center)

Honam Research Center, R&BD of ICT Convergence Technology

In May 2001, ETRI established its regional branch, the Honam Research Center (HRC). Since then, the HRC has focused on fostering optical communication components, international accreditation tests, and optical subscriber networks.

ETRI launched the Research on Optical Communications Test-bed System project in 2001. It was the only institute in Korea to qualify as an international accreditation center designated by A2LA (American Association for Laboratory Accreditation) and was selected as one of the "Top 100 Achievements in National Research and Development" in 2007.

HRC also conducted Experimental Project for FTTH Service Development since 2005. As a result, 21,912-line FTTH was deployed, being the first in Korea to succeed in providing convergence of two-way 1 Gbps communication and broadcasting services per subscriber.

Since 2010, HRC carried out Experimental Project for Green-IT City Model Based on Optical Convergence Technology and developed the core technology for broadband low-power network technology and system solutions based on the XG-PON standard of ITU-T.

From 2014, it also conducted a project on Building Optical-based Manufacturing Innovation Platform for Industry Support and established the Optical Packaging Assist Center (OPAC). As a result, it succeeded in the commercialization of 25 Gbps optical transceiver consisting of DFB-LD and PIN-PD, as well as low-cost optical multiplexers and demultiplexers (AWG MUX/DeMUX).

HRC has completed the commercialization of 100 Gbps TOSA/ROSA technology in 2015 through a project on Development of commercialization technology for 100 Gbps small form-factor optical communication modules. This technology was selected as one of the "Top 100 Achievements in National Research and Development" in 2019.

Since 2018, as part of the development of optical applications including intelligent edge gateway, wireless optical communications, and hyperspectral imaging systems,

The ceremony of FTTH field trial service deployment

Development of ICT Convergence Technology for Honam Regional Industry, a multi-disciplined project, is on its way up.

Fostering Gwangju as the Largest Complex of Optical Industry in Korea

The Honam Research Center has reduced the development costs of domestic optical components by KRW 12.5 billion and increased the sales by KRW 775.9 billion through its support of A2LA International Accreditation Test. It also posted direct sales performance of KRW 70 billion, reduced the costs of development by KRW 11.3 billion, and increased sales by KRW 310.5 billion through the operation of the OPAC. In addition, its commitment toward the Development of commercialization technology for 100 Gbps small form-factor optical communication modules has been accompanied by the successful achievements of 13 cases of commercialization, direct sales of KRW 23.7 billion, and indirect sales of KRW 43 billion by the end of 2019.
ETRI has played a key role in fostering Gwangju as the nation's largest optical industry complex. As of 2019, the number of optical-related companies has reached up to 284, which increased 6 times than the 47 in 2000.

Telecom'91 exhibit ATM switch

1-2-3. Packet and Internet Communication Technology

1-2-3-1. ATM Switching System

In the early 1990s, as the paradigm in the field of information and communications was expected to shift from a voice-oriented telephone network to a data-based comprehensive information network (B-ISDN), advanced countries began to contend for the research and development of the B-ISDN. The International Telecommunication Union (ITU), an international standardization organization, has also begun the standardization for B-ISDN.

The ATM Switching System's Ten-Year Journey

As part of the HAN/B-ISDN project, ETRI organized the development of the ATM switching system over ten years from 1992 to 2001. Joint research institutes included telecommunications operators KT, Samsung Electronics, LG Electronics, Hanwha Information and Communication, Mercury, and Dong-A Electronics. This was a large-scale national research and development project by the government and companies.

The ATM switching system transmits data and information asynchronously, thus allowing the system to respond directly to other networks. This is considered a key technology for high-speed information and communications as it can accommodate services of various transmission speeds and can be used as a switch for voice, video, and Internet. As a result, the competition for securing such technology worldwide was very fierce.

In consideration of the proliferation and dissemination of information networks and advances in technology, ETRI began developing its implementation target systems in three stages: ACE64, ACE256, and ACE 2000.

The ACE64 switching system began commercial services by supplying 16 systems to KT and five to Dacom during the second phase of the government's high-speed national network in 1999. The high-speed national network was launched simultaneously in 144 areas across the country in July 2000, launching a nationwide commercial service for the ATM exchange network. Since then, with the increase in subscriber lines and traffic capacity, ETRI has developed and supplied new exchange systems such as the ACE256 and ACE2000. ACE256 is a 40 Gbps ATM switching system developed to accommodate the rapid increase in subscribers to the Internet and to increase economic efficiency of the network. It has been installed in high-speed national networks since 2000.

Also, ACE2000 is a large-capacity ATM switch that improves performance and price competitiveness of the system for integrating networks such as voice, data, and IMT-2000, as well as processing large-scale traffic. It was developed in 2000 with the aim of fully supporting multimedia services including the functions of Multi-Protocol Label Switching (MPLS). With the development of ACE2000, Korea has secured the base technology for large-scale 160 Gbps relay and subscriber access. In 2001, it launched a two-stage commercial service for a high-speed national network as an ATM switch for ACE2000.

HANbit ACE256 system

The Key to Success is Solid Technical Skills

There are several reasons that enabled ETRI to successfully pursue the business development for ATM switching system over the course of ten years. However, the most valid factor lies in ETRI's accumulated technology. Since the late 1980s, ETRI has been researching and developing technologies underlying the ATM switch, by analyzing of the structure and performance of switch networks, studying subscriber-accessing technology and technology that motivates high-speed digital signals. In 1991, an ATM prototype switch was developed, and the possibility of developing an ATM switching system by submitting it to Telecom '91, was also confirmed. It was also a major factor in the success that participating researchers for the study on TDX switch were involved in developing the ATM switch, linking the technology and know-how between TDX and ATM switching system.

QSS12, an early product of service quality guaranteed routers

The ceremony of National Broadband High Speed Network Deployment

1-2-3-2. Router Technology with Guaranteed Quality

Challenge to Router Technology, the Core of Internet Technology

In the 21st century, the proliferation of the Internet has led to a gradual increase in the amount of traffic that needs to be processed on the network. As a result, the need for router localization has increased, as they are a key technology of the Internet that smoothly processes multimedia traffic in real time.

ETRI thus conducted a two-year project in 2000 that developed a high-speed router. The goal of the project was to secure the technology of edge routers capable of Internet Protocol (IP) routing from 20 Gbps to 80 Gbps. However, the IP router technology was completely different from that of the previous circuit switching, and ETRI's initial technology level was very low. The researchers made strenuous efforts with joint research institutes to overcome technical limitations, and succeeded in developing the High Speed Router System (HSR-80) in 2001.

Development of the World's First Router with Guaranteed Six Million Flow

ETRI succeeded in developing the world's first access router with guaranteed quality (S-20) in 2008, providing differentiated service quality of six million flows. By developing access routers along with existing flow-based backbone routers (S-240) and metro routers (S-80), ETRI has secured almost all types of routers needed for next-generation networks. As a result, Korea has been able to achieve technological independence by the necessary equipment for the convergence of Internet networks such as IPTV.

Based on the access router technology with guaranteed quality, the technology for distributed denial-of-service (DDoS) attack detection and response router was also developed in 2010 to protect the network from attacks by DDoS. 80 Gbps flow routers equipped with technology to detect and respond to DDoS have also succeeded in commercialization, including two routers for the preemptive response to DDoS in Seoul City Hall (July 2011) and four routers for the establishment of a DDoS response system in the cities and districts of the government's integrated computer centers (November 2011).

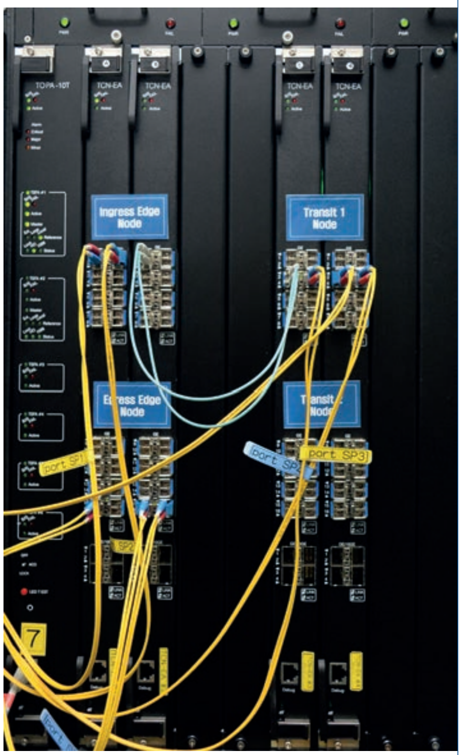
1-2-4. Future Network Technologies

1-2-4-1. Software-Oriented Open Networking Technologies

In the late 2000s, the network infrastructure industry suffered a severe slump due to limitations in investment in infrastructure facilities and delays in business innovation. To address these problems, there was a strong demand for a paradigm shift to turn the existing HW-focused closed infrastructure equipment industry into an open ecosystem centered on SW.

Development of MONCP/N2OS to Solve the Technological Dependency Problem

From 2008 to 2011, ETRI developed MONCP, a technology for a multi-tier optical network control platform. MONCP is an SW technology that streamlines the network’s



Ultra low delay & no-loss TCN technology
(TCN-Time Controlled Network)

control and operation by integrating the transmission of optical and packet layers, as well as managing and controlling the composition, topology, resources, and performance of multi-layer networks in an integrated manner.

Meanwhile, it promoted the development of the Network Operating System (NOS) from 2013 to 2017, which can be mounted on various performance networks while also guaranteeing 99.999% availability, securing the technology of its primary neutralized network operating system (N2OS).

Immediate Introduction of New Services Through Virtualized Network Infrastructure

As the industrialization of open switches and SDN technologies progressed rapidly, ETRI conducted a project on developing core technologies for smart networking in 2014. The goal of the project was to convert the infrastructure of the network from hardware (HW)-oriented equipment to a software (SW)-oriented open platform, allowing the composition and operation of the network to be easily configured and controlled centrally using API in the same way as a computer program. This drastically reduces time and cost for the development of new services.

ETRI secured the core technology for open programmable networking, such as the orchestration technology for network virtualization and commercial-level SDN controllers and strongly integrated computing and networking resources. ETRI also developed standardization for such technologies both domestically and internationally.

Setting the Stage for Innovating the Network Infrastructure

Software-oriented open networking technologies developed by ETRI provided an opportunity for the domestic network infrastructure industry to shift from a closed market HW-oriented equipment, such as transmission, exchange, routers, and operation management, to an open industry centered on general-purpose, server-based SW. As a result, various new services after 5G were quickly introduced and operated optimally on a single physical infrastructure. The realization of various ICT convergence services based on future networks is expected to accelerate.

1-2-4-2. Future Internet Technologies

Laying the foundation for Future Internet Technologies

ETRI has started the research on Future Internet technologies from 2010. The current TCP/IP-based Internet architecture was regarded as too ossified to bring new innovation. Clean-slate approach, therefore, was adopted in the design of future Internet architecture without considering compatibility issues with the current TCP/IP. Through this research, ETRI has come to secure the knowhow to design a new network from scratch and technologies on the future Internet architecture. However, even after putting a lot of efforts, it failed in the commercialization of the new network architecture since the barrier was still too high to jump over in the compatibility with the existing TCP/IP-based network architecture.

Development of Hyper-Connected Intelligent Network and Edge Network

Learning lessons from the past failures, ETRI has once again challenged the research on the future of networks. In order to best cope with the extreme diversity, increased complexity, and more openness expected in a hyper-connected intelligent society, a new research project has been pursued for five years from 2017 to 2021.

The project is targeting to achieve a challenging goal to transform a network into an intelligence creation platform. The researchers are designing a new network architecture which is called hyper-connected intelligence network. The innovative network architecture is expected to work as a basic infrastructure for various new industries and services to emerge in the future. They first performed a thorough analysis to estimate characteristics of the future hyper-connected intelligent society. In the design of the new network architecture, the knowhow and insights on the Future Internet, which they have learnt from previous experience, are added onto the analysis.

Data is the most important element in order to make intelligence emerge freely in a network. Therefore, the new network architecture is focusing on the best way to deliver, share, process, and store the data that can be generated anywhere in the network. The researchers in this project did not opt to reinvent the wheel. Instead, they chose the most promising future Internet architecture which has survived the cold winter season in the research on this area. Information-centric networking (ICN), more specifically named data networking (NDN), was selected as the base of the project. NDN is one of the embodiments of ICN that is still being actively studied as a collaboration of academia and industries. NDN can even run on the existing Internet, which greatly lessens the burden to support compatibility with other networks and enables a gradual migration.

The development of intelligent edge networking technologies is also being pushed based on artificial intelligence in preparation for the future society where AI-based intelligent services are expected to increase rapidly. The project will be carried out for three and a half years from July 2018 to December 2021. The network-wide AI platform, as a result of the project, is expected to provide optimal AI processing for application services through the collaboration of terminal, edge, and cloud. The best location and timing for AI processing will be dynamically decided considering the computing resources, processing speed, and data location required by AI application services.

ETRI has also been working on the Time-Controlled Network (TCN) technologies from 2017 to 2021 to support the increasing demands for ultra-low-latency services and high-precision vertical services. A follow-up research project is being planned to commercialize the core technologies to domestic network system industries. In addition, ETRI started a new project on end-to-end ultra-precise network technologies for 6G which is expected to be commercialized in 2028. The main goal of the project is to extend the scope of ultra-low delay and no-loss coverage to the end-to-end wide-area network for ultra-immersive and high-precision 6G services. The previous generation of mobile networks including 5G have focused on mobile access and core networks. not only of the Internet’s magnitude for ultra-immersive and high-precision 6G service.

1-3. Mobile Communications - Making the Way for Mobile Communications in Korea

Mobile communication is a type of communication that connects moving objects such as people, cars, trains, ships, and aircraft, or between a specific fixed point of a moving object. It refers to mobile phone, radio paging, telecommunications relay service (TRS), satellite mobile phone, and wireless data.

Mobile communication began with analog mobile communication, which started around 1980. Since then, an increase in subscribers has led to problems in the quality of calls, such as a lack of frequency resources, poor access, or calls being dropped, which has led to the introduction of digital mobile communication.

In the mid-1980s, analog mobile communication services began in Korea. However, due to the nature of being a divided country, it was sensitive to national security, limiting its use. In 1988, the number of subscribers increased by more than 100% every year as restrictions were greatly lifted starting from the Seoul Olympics. Since then, there was growing awareness and demand to the extent that the second generation of mobile communication or the digital mobile communication system needed to be developed on its own to overcome the limitations of the analog systems.

In response, ETRI led the development of digital mobile communications, contributing to the commercialization of the world's first CDMA in 1996, the commercialization of WiBro as the world's first mobile Internet in 2006, the development of the world's first LTE system’s core technology in 2007, the development of LTE Advanced as the fourth-generation mobile communication system in 2010, and the development of fifth-generation mobile communication technology in 2018.

Demonstration related to mobile communication R&D

CDMA mobile communication test system (RTS) installation (1992)

Second Generation (2G) Mobile Communications Technology

The most important thing in developing digital mobile communication systems was the access method to efficiently use the given frequencies. At that time, there were different access methods, with the US using TDMA and Europe using GSM methods, each had substantial pros and cons, making it difficult to determine the most suitable method for Korea. Meanwhile, ETRI decided to adopt the CDMA method developed by Qualcomm, a US corporate venture capital, in 1991. CDMA was a new technology with ten times the subscriber capacity of analog and more than three times that of TDMA.

In April 1996, ETRI succeeded in commercializing CDMA-type digital mobile communication systems and terminals for the first time in the world. As a result, Korea has made a quantum jump from importing all mobile devices and systems to becoming an exporting country. The development of CDMA technology not only raised Korea to the strongest country recognized worldwide in the mobile telecommunications industry, but also served as a catalyst for Korea to become an ICT powerhouse.

IMT-2000 system test

Third Generation (3G) Mobile Communications Technology

At the same time as the success of commercialization of CDMA, ETRI jumped into the development of the third generation mobile communications technology. At that time, the research and development for third generation mobile communication had been proceeded by two competitive groups, namely the asynchronous W-CDMA camp centered in Europe and the synchronous IMT-2000 (CDMA2000) centered in the United States. ETRI began developing a US-centric CDMA2000 system targeting the mobile telecommunications market in North America. In 1999, it succeeded in developing the synchronous 5 MHz broadband IMT-2000 system test plant (STP).

However, as Japan joined the W-CDMA camp, 70-80% of the global IMT-2000 market came to use the W-CDMA technology. In response, ETRI rushed to develop the W-CDMA system even before the development of CDMA2000 was completed. Eventually in December 2003, it was able to succeed in launching the W-CDMA commercial service in Korea.

Demonstration of 3GPP LTE/SAE system development (January 30, 2008, ETRI)

Meanwhile, ETRI developed the world's first "SDR-based multimode base station" in 2007. This allows users to freely switch functions of base stations to WiMAX mode or HSDPA mode by downloading multiple SW to one HW.

Fourth Generation (4G) Mobile Communications Technology

As the third-generation system revealed limitations in transmission speed and capacity, 3GPP has worked on a 3GPP Long-Term Evolution (LTE) standard since late 2004 that satisfies high transmission speed and low latency through evolved wireless transmission technology and the structure of a simplified IP-based mobile communication system network.

In response, ETRI began developing a mobile communication system at the commercial level of LTE, and in 2007 succeeded in realizing LTE mobile communication that meets the requirements of 3GPP LTE/SAE for the first time in the world. Also, in 2010 ETRI developed LTE-A (Advanced) for full fourth-generation mobile communications. With the development of LTE and LTE-A systems, Korea has entered the era of fourth-generation mobile communications. Since then, users of domestic mobile communications services have been able to enjoy high-speed internet service, full-HD/UHD video and broadcasting service, and three-dimensional image services indoors and outdoors, at any time, without interruption.

Meanwhile, ETRI took on the challenge of developing the WiBro System, a portable Internet service that allows users to access the Internet anytime, anywhere. ETRI succeeded in connecting the world's first prototype of the WiBro system, which meets the international standards of IEEE802.16e, on November 27, 2004, using a base station and terminal. This was subsequently finally approved as the sixth standard for ITU-R 3G (IMT-2000) in 2007, a year after its official commercialization. With the adoption of international standards, following the CDMA technology development, Korea once again had the occasion to lead the global mobile telecommunications market. In 2008, the fourth-generation WiBro-A technology was completed, achieving peak transmission speeds of 400 Mbps, and in 2012, WiBro-A was adopted as the international standard for ITU-R.

Fifth Generation (5G) Mobile Communications Technology

In 2013, ETRI reorganized ten 5G-related projects, which had been conducted individually through consultation with the government, into a "5G Integrated Project" consisting of 5G technology-oriented and 5G market-oriented R&D projects.

5G technology-oriented project is focusing on creative and challenging R&D items that could change the paradigm of mobile networks in the long term, beyond technological commercialization in the short-term. Representative achievements include the new Mobile Xhaul Network (MXN) technologies designed to get the full network employment flexibility by providing the mobility for base stations and mobile stations alike, and ultra-dense network (UDN)'s core technologies, which are essential to increasingly demanding mobile-centric network in the long term, rather than existing base-centric network.

The 5G market-oriented project is focusing on the competitiveness of small and medium enterprises through the commercialization of technology, including technologies for small cell base stations, MHN, high-speed close proximity communication, and narrowband IoT. The development of LTE small cell base station technology was promoted to efficiently implement various services by sharing the roles of macro base stations, and in 2018 it succeeded in developing core technologies such as LTE-FDD, LTE-TDD, CA, and MBMS. A small cell software that was developed was named "SORAN."

ETRI also developed the mobile hotspot network (MHN) technology to improve the Wi-Fi environment of domestic subways where connection is frequently grayed out and transmission data rate is low. In 2016, it conducted a test run in Seoul Subway Line 8 (Seokchon-Jamsil-Songpa Station).

It then developed a system for 2.5 Gbps and 10 Gbps MHN in 2017.

It also succeeded in developing the world's first high-speed close proximity communication technology (Zing). Compared to existing NFC, Zing technology implements instantaneous transmission of 3.5 Gbps for 8,000 times the speed and 30 pJ/bit for 4,000 times the energy efficiency of NFC. It is evaluated to have a very high potential for commercialization by applying low complexity and low power technology of 60 GHz.

In addition, in 2018 it developed the NB-IoT (Narrowband IoT) technology as an IoT technology based on mobile communications. This technology will be actively used for remote reading services applied to various electric, water, and gas meters in the future, and environmental monitoring services applied to air, temperature, and humidity sensors. Meanwhile, it developed the core technology of mobile communications using millimeter wave bands (10 to 40 GHz) in 2018. ETRI's central research team developed a mobile communications base station of 20Gbps 5G, 5G modem technology with average support of 1 Gbps up to 5 Gbps, 20 Gbps 5G Xhaul hub, 10 Gbps Xhaul terminal, 5G mobile communication standards, and promoted international standardization.

Wi-Fi

Judging that the importance of wireless LAN would increase as a complement to future mobile communications, ETRI began to develop Wi-Fi-related technologies in 2001. As a result, Korea developed the world's first low-speed mobile wireless transmission system in 2007. In 2016, it also succeeded in developing the world's first IEEE 802.11ah SoC chipset. In 2014, 28 researchers from the Wireless LAN Access Control Research Team and Wireless LAN Transmission Research Team, which were working on Wi-Fi, founded a research institution called Newratek. Newratek was the first case in Korea where an entire research team in a particular field participated in a startup, rather than a single or a small number of joint startups.

Over the past three decades, ETRI has paved the way for South Korea's mobile telecommunications to move forward from the second generation to the fifth generation. ETRI's efforts served a major role in Korea's emergence as the world's top mobile telecommunications powerhouse in the barren land of mobile telecommunications technology.

Recently being intensively developed is an on-time-on-rate (OTOR) technology that guarantees the speed of transmission at the desired time in order to prepare the sixth-generation mobile communication’s key source technology that is expected to be commercialized around 2030. Also, other technologies are terahertz wireless communication technology that provides 50 times the data transmission speed of 5G, Three-dimensional communication technology is expanded from the center of the existing two-dimensional communications to air and satellite. In the future, ETRI will continue to strive in becoming the driving force for mobile communications that will lead Korea's mobile communications technology.

1-3-1. Second Generation (2G) Mobile Communications

CDMA commercialization ceremony (April 1, 1996, ETRI)

CDMA commercialization certification plaque for "70 Science and Technology Achievements for the 70th Anniversary of the Independence of Korea"

1-3-1-1. CDMA

ETRI studied the concept of mobile telecommunications and service specifications in 1989 and began to develop with Qualcomm in 1991. From 1992, ETRI promoted the development of CDMA terminals, base stations, and personal communication systems, and succeeded in commercializing the CDMA mobile communication system in 1996.

In January 1996, SK Telecom (formerly KMT) launched CDMA services in Seoul and Incheon, and on April, an official opening ceremony for the CDMA commercial service was held at ETRI. Sinsegi Telecom (later acquired by SK Telecom) also launched CDMA services in Seoul and Daejeon.

ETRI thus achieved the world's first CDMA commercial service at a national level.

In April 1996, ETRI succeeded in commercializing the world's first CDMA mobile communication system and terminal. As a result, Korea was able to make a quantum jump from importing all mobile devices and systems to exporting them. The technology was also selected as one of the "70 S&T Achievements for the 70th Anniversary of the Independence of Korea" by the government in 2016.

The battle between David and Goliath: A royalty dispute with Qualcomm

When ETRI and Qualcomm began their joint research, a separate contract was signed between the two to prepare for the success of CDMA commercialization. This was a contract saying that Qualcomm pays 20% of the technology fees collected from domestic mobile carriers to ETRI every year. Qualcomm paid this part under the terms of the contract in the first year of 1996, but as the size of the technical fees grew, from 1997, it began paying only 11% of the total amount of technical fees collected without providing evidence, except for PCS, within the scope of distribution.

Initial CDMA phone

코리아헤럴드 (8면) 2000년 12월 13일 수요일

Court rules Qualcomm share CDMA royalties with ETRI

By Hwang Jang-jin
Staff reporter

An international arbitration court has sided with a domestic institute in its ongoing royalty dispute with Qualcomm Inc.

The International Court of Arbitration (ICA) ruled last Friday that the U.S. firm share additional royalties for sales on its wireless technology in Korea with the Korean Electronics and Telecommunications Research Institute (ETRI).

ETRI and Qualcomm cooperated in 1992 to commercialize the U.S. firm's mobile service technology called code division multiple access (CDMA) in Korea.

The arbitrary panel, an arm of the International Chamber of Commerce, ordered that Qualcomm pay a one-time charge that has now reached $80 million this quarter, and continue to share part of royalties it will collect from Korean equipment makers. The payment is expected to reach $4 million per quarter, depending on the sales of phones and networking gear in Korea.

The ruling wrapped up a two-year dispute between the former partners whose collaboration resulted in the world's first launch in Korea of commercial CDMA-based digital cellular services in 1996.

ETRI and Qualcomm signed an agreement in 1992 under which The San Diego-based firm is supposed to allot 20 percent of the running royalties from domestic companies to ETRI. The two disagreed on some points in the deal.

The most controversial was the issue of which the agreement should covered both the digital cellular system and personal communications services (PCS), both based on the same CDMA technology.

Qualcomm argued that the agreement is applicable only to cellular system, and not included PCS. On the ground, the company has paid only 11 percent of the total royalties it received from domestic makers of PCS and cellular handset and equipment, excluding the PCS portion.

ETRI has argued that the royalty sharing agreement is valid for all applications based on CDMA technology, including PCS phones and equipment like private area branch exchanges (PABX). Digital cellular and PCS services in Korea represent different applications of the same CDMA technology they developed, ETRI has maintained.

ETRI has repeatedly demanded Qualcomm make due payment. After being rejected, it took the case to the ICA in October in 1998.

The panel's ruling, though not compulsive, has increased the chances that the state-funded institute to win the dispute and receive huge amounts of royalties.

"Qualcomm may not accept the decision and bring the case to U.S. court. We hope to settle the dispute out of court," said an ETRI official.

Qualcomm has garnered a total of $650 million in royalties from Korean companies.

Under the ruling the company is to give $80 million to ETRI for back payment of additional royalties as well as interest and other costs for the period from 1992 to September 2000, and about $4 million in every future quarter.

However, the company insists the ICA ruling will not impact its future ability to collect royalties on CDMA.

"While we are disappointed by the ICA's decision, we continue to look forward to receiving strong royalty revenue from sales of CDMA equipment in Korea," Louis Lupin, senior vice president and general counsel of Qualcomm, said in a statement. "The ICA's decision does not in any way affect Qualcomm's ability to collect royalties on CDMA, WCDMA or other CDMA-based standards, and has no impact on the ability of Qualcomm to collect royalties from sales of CDMA equipment in Korea."

Korea Herald (December 13, 2000)

ETRI immediately formed a "Qualcomm Special Task Force" and took a rapid response to the extent that then President Chung Seon Jong served as the head of the task force. The dispute was even called “the battle between David and Goliath" because Korean companies and institutions rarely win against companies from advanced countries in royalty disputes, and Qualcomm was known as a mastermind in managing intellectual property rights.

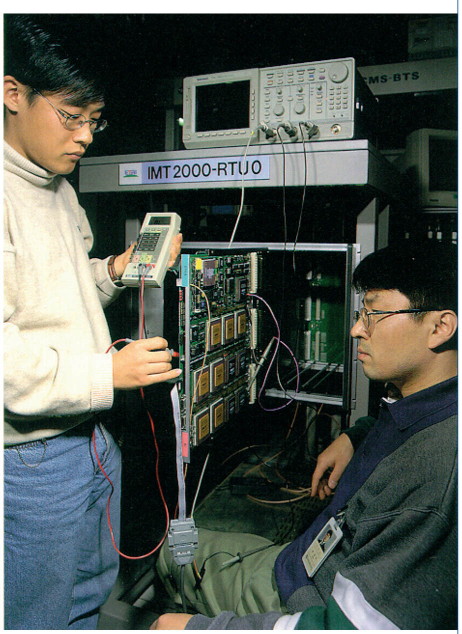
The special task force visited Qualcomm's headquarters in San Diego, US, and continued to protest in writing. In October 1998 it filed a petition with the International Chamber of Commerce's International Court of Arbitration for arbitration on Qualcomm's "violation of the CDMA joint development agreement.”

Qualcomm then set up a strong response team with global legal firms and took an even tougher stance. They even demanded that ETRI return the distribution of technology fees already paid. In the end, the dispute led to a long trial over a year and a half without reaching an agreement.

At a hearing in San Diego, US in July 2000, ETRI claimed victory by presenting what amounted to 18,000 pages of evidence on the extent to which the technology was distributed, how the distribution was calculated, and the timing of the end of the technology distribution. In December 2000, the International Court of Arbitration ruled that Qualcomm should pay ETRI 20% of technical fees, not only for cellular, but also PCS and wireless PABX until the end date for receiving technical fees from domestic companies. It was additionally ruled that they were to allocate not only four technical fees for domestic designated producers, but also 20% of technical fees for domestic sales by non-designated manufacturers. With ETRI's strong will and thorough response, the long dispute finally ended in ETRI's victory.

- Korea Herald, December 13, 2000 -

As the number of mobile subscribers increased explosively, the era of one phone per person began to open, and development speed of domestic mobile phone manufacturers, including Samsung Electronics and LG Electronics, accelerated. Also, installation of radio repeaters to improve the quality of mobile communication services created a new market. According to the ETRI Technology and Economy Research Department report, the ripple effect of the CDMA economy for six years from 1996 to 2001 amounted to KRW 190.5 trillion.



Synchronous IMT-2000 system

1-3-2. Third Generation (3G) Mobile Communications

1-3-2-1. Synchronous IMT-2000 (CDMA2000)

At the same time as the success of commercialization of CDMA, ETRI also jumped into the developing the third generation of mobile communications.

Through this, it succeeded in developing the 5 MHz broadband synchronous IMT-2000 (CDMA2000) system test plant (STP) system in 1999. In October 2000, SKT launched the world's first CDMA2000 commercial service.

During the development of third-generation mobile communications, ETRI focused on designing, implementing, and commercializing the independent mobile communications modems for the CDMA2000 system. As a result, intellectual property rights were secured by developing technologies such as OCQPSK[1] and AISMA[2].

The independently developed OCQPSK and AISMA technologies were reflected in the IMT-2000 international standards in 1998 and 1999, respectively, and have collected tens of billions in KRW in technical fees from the world's leading mobile phone makers including Apple and Nokia.

1-3-2-2. Asynchronous IMT-2000 (W-CDMA)

ETRI developed a US-based synchronous CDMA2000 system aimed at the telecom-

1) Offset Quadrature Phase Shift Keying (OCQPSK): This is a method and device for cross-channel proliferation. This can extend the life of the device's power in a modulation method that consumes low power in the reverse direction.

2) Acquisition Indication Sense Multiple Access (AISMA): This is a random access device and method of the upper common channel in the code-sharing multiple access method. This limits the load of packets and improves throughput by informing them of the acquisition of packets.

munications market in North America, but at that time 70-80% of the world's IMT-2000 market used the W-CDMA method. This meant that W-CDMA had become the general trend for third-generation mobile communications. The nation's economy was structured to grow centered on exports, making it impossible to give up the W-CDMA approach.

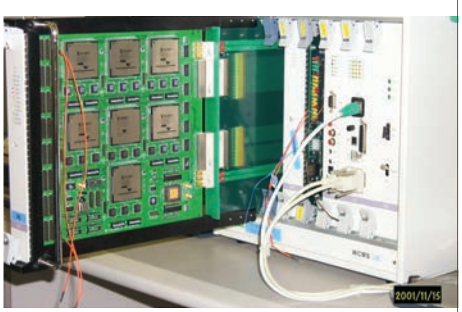
The development of the W-CDMA was a considerable adventure for ETRI. This is because there was already confidence in the implementation of the CDMA modem through the development of CDMA2000, but the GSM-based wireless protocol in Europe was a completely unfamiliar technology. Moreover, the start of development was later than that of advanced countries. However, Korea was able to succeed in the W-CDMA commercial service in December 2003.

W-CDMA development

1-3-2-3. Multi-mode Base Station

ETRI succeeded in developing the world's first multi-mode base station based on SDR in 2007. This allows users to freely switch functions of base stations to WiMAX mode or HSDPA mode by downloading multiple SW to one HW.

The co-developer, PicoChip, developed the Picocell base station commercial product, an early model of the current small cell, and marketed it to the international market, enabling ETRI to earn USD 4.5 million in international royalties.



W-CDMA test terminal

Cooperative research building completion ceremony

1-3-3. Fourth Generation (4G) Mobile Communications

1-3-3-1. WiBro/WiBro-A

ETRI started research and development on WiBro mobile communications system in 2003. Wireless Broadband Internet (WiBro) is a portable Internet service that allows users to access the Internet at anytime, anywhere, just as its name suggests.

The connection method introduced a new method of OFDMA[3] based on ETRI's own specifications. ETRI proved that OFDMA technology is a key wireless transmission with

3) Orthogonal Frequency Division Access (OFDMA): This is a multi-access approach that allows multiple users to receive service from both wireless and mobile communications at the same time.

WiBro-A research results presentation
(December 21, 2007, ETRI)

WiBro certification plaque for "70 Science and Technology Achievements for the 70th Anniversary of the Independence of Korea"

WiBro demonstration of technological development
(March 31, 2005, ETRI)

easy broadband and can satisfy the transmission capacity required by next-generation mobile communication systems through application of capacity-enhancing technologies such as MIMO, and achieved international standardization, demonstration, and early commercialization.

On November 27, 2004, the research team succeeded in accessing the world's first WiBro system prototype using a base station and terminal, developed by applying the IEEE 802.16e international standard.

In recognition of its technological progress and contribution to national development, WiBro technology was selected as the "70 S&T Achievements for the 70th Anniversary of the Independence of Korea" in 2016.

Through the development of the WiBro system, ETRI submitted more than 120 contributions to IEEE802 and secured more than 380 intellectual property rights. In 2007, it was only a year after the commercialization of the formula that the WiBro technology was finally approved as the sixth standard for ITU-R[4] 3G (IMT-2000).

As a follow-up to WiBro, the development project for WiBro’s advanced mobile communication system was promoted from 2006 to 2008. Through this project, the research team applied 4x4 MIMO technology in the bands of 10, 20, and 40 MHz, completing a full fourth-generation WiBro-A technology that achieves the highest transmission speed of 400 Mbps. WiBro-A was adopted as the international standard for ITU-R in 2012.

1-3-3-2. LTE/LTE-A

ETRI performed the research task for LTE mobile communications system from 2005 to 2007.

ETRI simultaneously undertook the development for 3GPP Long Term Evolution (LTE) / System Architecture Evolution (SAE) system and standard specifications. As a result, ETRI succeeded in implementing the world's first 3GE technology that meet the requirements of 3GPP LTE/SAE in 2007. 3GE technology requires data rate of over 100 Mbps at low speeds (3 km/h) and over 30 Mbps at high speeds (120 km/h). ETRI secured over 300 intellectual property rights for the technology they developed and

4) ITU-R (ITU Radiocommunication Sector): This is one of the three segments that make up the ITU, the protocol of the band of radio frequencies.

Demonstration of LTE-A technology development
(January 25, 2011, ETRI)

verified through this project, and submitted 170 contributions to 3GPP. The developed technologies were also selected as part of the "Top 100 Achievements in National Research and Development" in 2008.

ETRI pursued the research task for LTE-A mobile communications system from 2006 to 2010 to develop LTE-A technology as a full-fledged fourth-generation mobile communication.

Through this, ETRI applied more than 500 international and domestic patents, submitted more than 400 contributions to 3GPP, reflected more than 200 contributions, and secured 24 core standard essential patents and reflecting them on the LTE-A standard of ITU-R.

The LTE-A mobile communication system development was also selected in 2011 as one of the "Top 100 Achievements in National Research and Development."

The prototype of LTE-A produced at the time achieved data rate of 600 Mbps. In addition, the downlink data rate measured while moving outdoors was also implemented at 120 Mbps. This meant that high-speed multimedia services were possible without interruption even while moving at a high-speed.

1-3-3-3. LTE Terminal Modem Chipset Technology

At that time, there was no precedent for commercializing mobile communication terminal modem chips in Korea. However, ETRI finally succeeded in developing the country's first LTE terminal modem chipset in 2011. The developed modem IP showed superior performance of more than 1dB on average compared to the minimum required performance presented by the 3GPP conformance test standard for all modes including 1x2 SIMO, 2x2 and 4x2 open loop/closed loop MIMO, and diversity. It also adequately satisfied the Rel. 9 version (March 2009), an LTE standard specification of 3GPP, including support for intra/inter frequency handover. In recognition of its excellence, this technology was awarded the "Ministry of Knowledge Economy's Best Technology Award" in 2010. In 2011, This technology was transferred to GCT semiconductor which is global wireless modem chipset vender.

1-3-4. Fifth Generation (5G) Mobile Communications

1-3-4-1. The source and core technologies of 5G (5G technology-oriented project)

The 5G technology-oriented project is aimed at leading global 5G technology by developing source and core technologies and securing intellectual property rights by focusing on creative and ambitious research that changes the paradigm of mobile communication networks rather than a mere short-term performance. The slogan of the project was "Quadruple x 1000," showing the willingness to achieve more than 1,000 times the four performance categories of capacity, delay, number of devices, and power efficiency.

Through the 5G technology-oriented project, researchers studied the source and standard technologies of 5G, including the technology for increasing transmission capacity using high-capacity antenna systems, the technology for low-latency wireless access to satisfy tactile delay sensitivity, the technology of providing large-scale connectivity for access to hyper-connected devices, and the technology of the broadband Xhaul network in the provision of mobility.

The Mobile Xhaul Network (MXN), which completed development in 2018, is a representative achievement of this project. This is the world's first wireless network where not only terminals, but also base stations move, and it is a technology that can reliably convert all stages of the network to wireless, from terminals to base stations and relays, while maintaining a high speed transmission. As a result, even in fast-moving places like subways, there were no slowing or interruption in the network.

This is one of the representative achievements of the ultra-dense network (UDN) technology. This technology is essential for transforming the structure of the existing network, which provides wireless links to multiple terminals at the center of the base station, as the structure of the network that forms wireless links among multiple base stations at the center of one terminal.

1-3-4-2. MHN Technology

ETRI began developing the giga-level MHN technology in 2012 to improve the quality of Wi-Fi services in subways. ETRI succeeded in implementing services of giga-level data by providing the world's first mobile wireless backhaul using millimeter waves[5).]

ETRI developed a prototype of a 500 Mbps system in 2013, followed by a demonstration of the technology in Seoul Subway Line 8 (Seokchon-Jamsil-Songpa Station) in 2016. This was the first in the world that MHN technology which utilizes millimeter waves for the wireless backhaul link for train was demonstrated directly inside a subway.

It succeeded in developing a system of 2.5 Gbps in 2016, and 10 Gbps in 2017. The technology was also selected in 2017 as one of the "Top 100 Achievements in National Research and Development."

Demonstration of 5G technology development (December 18, 2015, ETRI)

MHN development prototype

1-3-4-3. NB-IoT Technology

As part of the 5G market-oriented project from 2016 to 2018, ETRI promoted the task of developing the NB-IoT technology suitable for IoT construction. NB-IoT technology is a representative example that meets all the requirements of a low capacity, wide-area coverage, low unit price, and low power based on mobile communications.

The convergence terminal was developed to integrate telecommunications' functions and sensors into one chip to allow small and medium-sized enterprises(SMEs) to target niche markets among larger companies by optimizing performance and lowering the unit price of chips. As a result, researchers succeeded in producing the world's first low-power integrated chip combining the NB-IoT communications functions and sensors. Also, general-purpose terminals were developed to implement various services that SMEs demanded.

1-3-4-4. Zing Technology

Since April 2013, ETRI has been working on the near-field instantaneous radio data transmission technology as part of the 5G market-oriented task. It implements 3.5 Gbps-class instantaneous transmission, which is 8,000 times the speed of existing near-field

5) Millimeter Wave: This includes electromagnetic waves with wavelengths of 1 to 10 mm and frequencies of 30,000 to 300,000 MHz. It is capable of broadband transmission and is used in satellite communications, mobile communications, wireless navigation, earth exploration, and radio astronomy.

Zing technology development

communications (NFC), and high energy efficiency of 30pJ/bit, which is 4,000 times that of NFC, and is considered highly likely to be commercialized by applying low-complexity and low-power technology at 60GHz frequency band. The Zing technology was finally reflected on the international standard (IEEE 802.11.3e: High Rate Close Proximity) published in February 2017.

It won the Minister of Science, ICT and Future Planning Award at the "Future Growth Engine Challenge Demo Day" in 2017. Also, in the same year, the technology of realistic internet communications for high-speed public transportation users was submitted as a result of the integration of 5G by combining Zing, MHN, and small cells. This was then selected as one of the "Top 10 Outstanding Research Results" by the National Institute of Science and Technology Research.

LTE-A Pro TDD/FDD small cell base station software development

1-3-4-5. Small Cell Base Station Technology

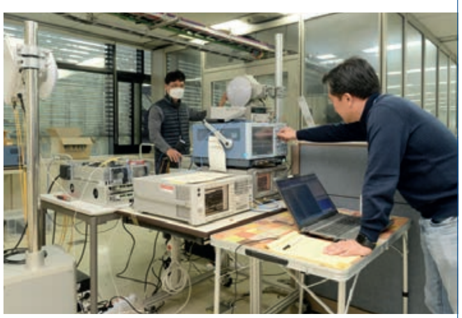
From March 2014 to February 2018, ETRI promoted the task of developing technology in small cells as part of the 5G market-oriented project. Small cells are small base stations that serve smaller areas, compared to existing base stations. This can then be efficiently implemented on various services through several small cells sharing the role of macro base stations.

As a result of the study, it succeeded in developing LTE-FDD, LTE-TDD (all seven configurations), CA, MBMS, and the technology of dual connectivity underlying 5G. Under the name of "Small Cell Key Technology, Anytime, Anywhere High-Speed Mobile Communication", these technologies were selected as one of the "Top 100 Achievements in National Research and Development" in 2019.

1-3-4-6. Millimeter Wave 5G Mobile Communication System

From September 2013 to April 2018, ETRI promoted the millimeter wave 5G mobile communication system development (GK-5G) as a part of Giga KOREA Project.

Track-1 has developed core technologies and the specification for Xhaul wireless communication network that gives mobility to the network based on millimeter waves. With a HUB of 20 Gbps capacity and TERMINALs of up to 10 Gbps peak data rate, the Xhaul enables maximum 10 Gbps throughput to the moving network. It applied the developed HUB and TERMINALs as a mobile backhaul for small cells of commercial LTE to provide commercial services in the real field environment where LTE small cells in a vehicle with a Xhaul terminal are traveling at maximum speed of 60 km/h. This technology was chosen as one of the "Top 10 Research Achievements" in 2016 under the name of "My Own Ultra-realistic Service, Millimeter Wave 5G Mobile Communications Technology."



25Gbps class wireless backhaul technology development

To apply the pilot 5G service at the 2018 PyeongChang Winter Olympics, Track-2 developed a 5G mobile communication base station system of up to 20 Gbps per cell and a UE modem chipset that supports average of 1 Gbps and up to 5 Gbps. The pilot 5G mobile communication service using the developed base station and UE modem chipset was successfully given during the event.

These technologies were selected as one of the "Top 100 Achievements in National Research and Development" in 2018 under the name of "Development of Access and Xhaul System for mmWave-based Mobile Communications."

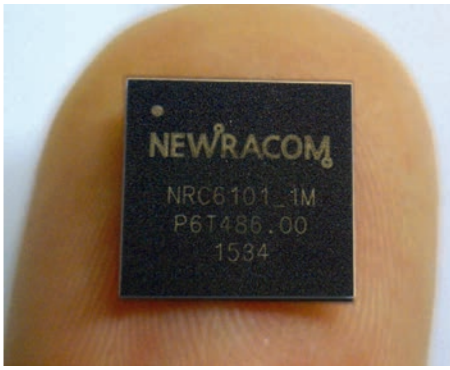
1-3-5. Wi-Fi

1-3-5-1. Wi-Fi Technology

ETRI began the development of technology related to wireless LAN in 2001 through a project that developed a device for matching 5 GHz broadband wireless access networks and technology based on 60 GHz broadband wireless LAN. This led to the development of IEEE802.11n modem chipsets in 2006.

Demonstration of 3.6Gbps low-speed mobile wireless transmission system development (2007, ETRI)

In 2007, it developed the world's first low-speed mobile wireless transmission system, providing a transmission speed of 3.6 Gbps, which is more than three times the minimum standard of 1 Gbps for static and low-speed (3 km/h) movement of fourth-generation mobile communications (IMT-Advanced).



Low-power, long-distance Wi-Fi chip for terminals based on international standards

ITU-R exhibition of 3.6 Gbps low-speed mobile wireless transmission system (October, 2008, Seoul)

From 2009 to 2011, it conducted a study on IEEE 802.11 VHT high-speed wireless LAN wireless transmission.

As a type of development of chipsets for modems, the project for developing 200 Mbps class IEEE 802.11n modems and RF chipsets began in 2006. It succeeded in developing a 270 Mbps high-speed wireless LAN chip.

For three years from 2013, it has undertaken the task of developing high-speed wide-range Wi-Fi technology for the service of future intelligent communication of things. It also succeeded in developing the world's first IEEE802.11ah[6] SoC chipset and earned major royalty income by securing numerous standard patents related to IEEE802.11ac and IEE802.11ah.

Thus, in 2014, Newratek (CEO Sok Kyu Lee) was founded as a research institute of 28 researchers at the Wireless LAN Access Control Research Team and Wireless LAN Transmission Research Team, which were doing research related to Wi-Fi. This was the first time in Korea that an entire research team in a particular field participated in a startup, rather than merely a single or small number of co-founders.

6) IEEE802.11ah: This is a wireless LAN standard that uses unlicensed frequencies of less than 1 GHz.

1-4. Satellite Communication - Expanding the Field of Communications to Space

The history of satellite communications in Korea began with ETRI. In the early 1980s, the government planned the introduction of communications & broadcasting satellites, and satellite communications services were to meet the soaring demand for telecommunications. In 1983, when ETRI began studying the feasibility of communication and broadcasting satellites, Korea took its first step toward the development of satellite communications. Then, from 1985 to 1988, ETRI was the first in Korea to develop the satellite communications earth station, a model of the laboratory, in collaboration with the nation's five leading industries (Gold Star, Daewoo Telecom, Dongyang E&C (OTELCO), Samsung Electronics, and Hyundai Electronics).

Around 1989, it has been suggested that Korea should develop satellites on its own. Communication satellites were the only means of providing services to cover the remote mountain and island areas, which were very important not only in terms of industry but also in terms of national security. In response, the government decided to secure a single satellite, and ETRI launched the "Satellite Business Group" in 1990 and began to develop the technology for satellite communications in earnest.

A briefing for demonstraton of mobile active antenna system for satellite broadcasting reception on the sea

Satellite Earth Station/ Weather Ground Station

The development of the the satellite communications earth station was conducted by five domestic electronics and information and communications giants, together with MPR Teltech of Canada and Thales Alenia Space of Italy as joint research institutes, which was ETRI's first international joint-development. As a result, ETRI succeeded in developing and commercializing both VSAT system for only low speed data transmission and DAMA·SCPC system for administrative communication of remote mountains and islands in 1994.

Meanwhile, with the digitalization of broadcasting, it began to develop the technology of the digital satellite broadcasting transmission. ETRI introduced the time-division multiplexing (TDM) method and developed a technology that accommodates more than 10 HD-class channels with one repeater. More than 20 years later, this method is still regarded as the optimal technology. Based on this, Korea was able to provide 24-hour HDTV satellite broadcasting services nationwide since 2004, when it was still the era of analog broadcasting. Since then, ETRI continued to develop and standardize second-generation standards such as the core technology of satellite transmissions based on DVB-S2, the technology of satellite broadcasting transmissions in the 21GHz band, and the technology of channel-adaptable realistic satellite broadcasting transmissions. In 2018 and 2019, it successfully broadcasted the 8K UHD test signals through the Chollian satellite with KT Skylife.

As the frequency and severity of natural disasters caused by climate change ncreases, the damage to humans and nature is becoming more serious. Accordingly, the meteorological satellites that observe global weather conditions and utilize them for weather forecasting became more important. In response, ETRI developed and built a meteorological satellite ground station for geostationary orbit to continuously receive, process, analyze, manage and service data from multi-channel, high-resolution and large-scale observations of Chollian-2A from 2014 to 2019, which greatly improved the accuracy of weather forecasts.

In addition, as some countries began to build their own satellite navigation system in the late 1990s, in order to respond to the movement of charging for the US satellite navigation system, Global Positioning System (GPS), ETRI developed the technology of GPS/Galileo composite receiver that can handle both the US's GPS and the EU's Galileo satellite navigation signal, and a satellite navigation environment simulator that generates, receives, and processes signals from SW-based GPS/Galileo. In 2011, it developed a GPS radio wave disturbance monitoring system and HW-based satellite navigation signal generator based on these technologies, laying the groundwork for a satellite navigation system tailored to Korea in response to GPS-based attacks.

SG meeting of Asia-Pacific Satellite Communications Committee

Satellite Payload and RF

Developing the technology of satellite communication payloads, which correspond to the brain of satellites, began in 1996. ETRI completed the accumulation of technology on the system of the analog type satellite by 2002. Based on this, it began research on localizing the communication system that is planned to be mounted on its own satellite. At that time, ETRI was a latecomer in the field of satellite communication, but it succeeded in developing an excellent payload that satisfies all the considerations of satellite communications by applying ultra-high frequency semiconductor technology that integrates the transmission and receiving devices between the satellite and ground as with a general semiconductor. Finally, in 2010, Chollian-1, a geostationary composite satellite equipped with a system developed by ETRI, was successfully launched. As a result, South Korea is now a nation to own the world's first geostationary marine observation satellite and the world's seventh meteorological observation satellite. Meanwhile, ETRI has also succeeded in localization of radio frequency (RF; ultra-high frequency) and ground terminal RF components for various satellite communications in the high frequency bands required for satellite communications.

In addition, from 1996, it began to develop the active antenna system for satellite broadcasting receiver. In 2003, it applied active phase array technology to civilian products for the first time in the world, which was applied only to military radar in some advanced countries at the time. As a result, it developed MSIA, antennas for accessing mobile satellite Internet for vehicles and MoBiSAT for ships.

Demonstration of multi-purpose practical satellite control system (March, 1999)

Satellite Control and Payload System

In 1995, the government launched the Multi-Purpose Practical Satellite Development Project as a pan-ministerial project. Multi-purpose practical satellites are low-orbit observation satellites that travel over the Korean peninsula three to four times a day in orbit around Earth, following the sun's synchronized orbit at an altitude of 685 km. For this project, the US TRW and the Aerospace Research Institute jointly manufactured the satellite, and the control system was developed by ETRI in the form of its own technology. At the time, the only area of controllable area throughout the project was its localization, so researchers at ETRI had to take on a considerable sense of burden and responsibility at the same time.

As a result of constant efforts, on December 21, 1999, the multi-purpose practical satellite 1 was successfully launched, which was operated using ETRI's control system. Since then, ETRI continued to develop control systems for multi-purpose practical satellites 2, 3, and 5, which achieved the grafting of new technologies such as lightweight systems and object-oriented techniques.

Meanwhile, from 2003 to 2010, the government carried out the Chollian Satellite Development Project, a geostationary complex satellite, in cooperation with various ministries. Of the entire project, ETRI was responsible for Ka-band communication payloads, test ground station, and geostationary satellite control systems. ETRI already had a core source of technology for these areas at the beginning of the technology's development. Based on these technologies, it smoothly conducted the test process as well as design for the development of payload with various specialized companies in Korea. As a result, it was able to successfully launch and operate the Chollian satellite in 2010.

The satellite earth station technology, satellite broadcasting technology, satellite control technology, satellite navigation and antenna technology, and satellite components developed by ETRI contributed greatly to the development of the nation's satellite communication technology and related industries. Recently, with the reuse of satellite launch vehicle, the cost of launches and communications were reduced due to the development of high-throughput satellite (HTS).

In the future, based on the technologies of accumulated satellite communications, ETRI will continue to take on challenges in the development of new technologies such as transmission technology based on low-orbit satellites communication and planar antennas technology in preparation for the New Space era. ETRI will lead the development of a complex public communications satellite (Chollian-3), which will begin in 2021.

VSAT system and its pilot service operation scene

Mobile broadband satellite VSAT system and its terminal

2002 Korea-Japan World Cup 3DTV satellite broadcast

1-4-1. Satellite Earth Station/Weather Ground Station

1-4-1-1. Satellite Communications Earth Station Technology

Starting with the feasibility study on telecommunications and broadcasting satellite in 1983, ETRI developed a digital satellite communications earth station system of PAMA-SCPC method using the Ku-band (12-14 GHz) in cooperation with five companies including Gold Star, Daewoo Telecom, DongYang E&C (OTELCO), Samsung Electronics, and Hyundai Electronics from 1985 to 1988. And then from 1990, it also developed VSAT systems with Gold Star, Samsung Electronics and Hyundai Electronics Industry in cooperation with Canada, and DAMA-SCPC systems with Daewoo Telecommunications and DongYang E&C in cooperation with Italy. These are ETRI’s first international joint-development.

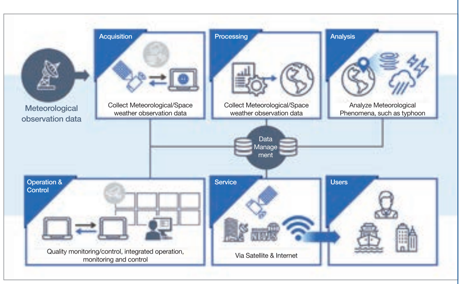
In addition, it developed the pagng earth station system, PAGES, in 1994. In 2003, it developed the DVB-RCS-based VSAT Earth Station, which is now being used by the Coast Guard.

It developed the mobile VSAT system from 2003, developed the second-generation VSAT system in 2015, verified it by using the Chollian satellite. It developed the DVBRCS2+ M standard, which was installed and demonstrated by the Coast Guard in 2017.

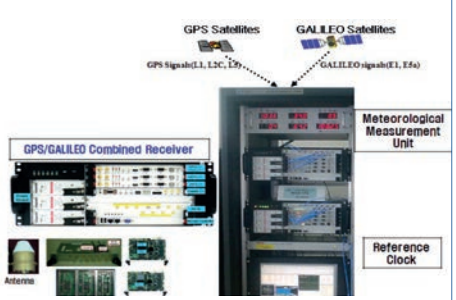
1-4-1-2. Satellite Broadcasting Earth Station Technology

Korea’ digital satellite broadcasting system was introduced as the second in the world through the TDM digital transmission method in 2002, and was demonstrated with real-time 3DTV broadcasting service for the 2002 Korea-Japan World Cup. Since 2004, it developed an ASIC chip for DVB-S2 core technology and modem, and also developed the Ka band satellite broadcasting technology by 2009. 4K UHD satellite broadcasting service became available in 2014.

Geostationary orbit meteorological satellite ground station scene



Schematic diagram of the weather satellite ground segment system



GPS/Galileo combined receive

1-4-1-3. Geostationary Weather Satellite Ground Station Technology

From 2014 to 2019, ETRI had jointly developed the ground station technology for geostationary weather satellite for Chollian-2A with the Korea Aerospace Research Institute (KARI), the Korea Astronomy and Space Science Institute (KASI), 18 universities, and 8 small and medium-sized enterprises. In addition, it established the weather satellites broadcasting system that provides the raw resolution of observations for countries in Southeast Asia, such as Thailand and the Philippines, which do not have weather satellites.

1-4-1-4. Satellite Navigation Technology

In September 2006, ETRI signed the Korea-EU Galileo Agreement to participate in EU's Galileo project, which developed a complex receiver technology that can handle both GPS and Galileo satellite navigation signals, and transferred its technology to domestic companies. In 2011, it developed the GPS radio disturbance monitoring system. In 2016, North Korea's GPS radio wave disturbances were identified by the system and reflected in the ICAO[7] chairman's statement.

1-4-2. Satellite Payload and RF

1-4-2-1. Payload System Technology

Since 1996, ETRI developed satellite communication payloads in earnest, and Satrec Initiative, Korean Air, and Cospace participated as joint research institutes. In 2010, Chollian-1, a geostationary orbit complex satellite equipped with a developed system, was successfully launched. In 2017, ETRI developed a technology to selectively adjust the strength of the signal only in areas requiring high output through the development of core technologies for the next generation satellite, flexible communication and broadcasting satellite. Through these technologies, it made it possible to selectively adjust satellite signals.

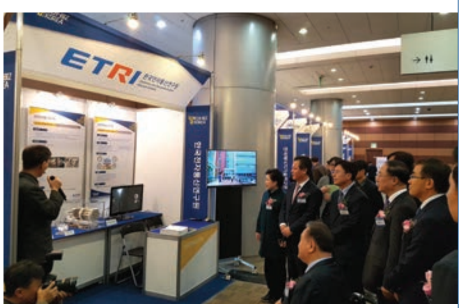
7) International Civil Aviation Organization (ICAO): This is a specialized organization under the UN which studies the principles, technology, and safety needed for international air transportation.

Exhibition of satellite payload technologies
(April 27, 2009, National Assembly)

1-4-2-2. Technology for Satellite RF and Its Components

In 1995, ETRI began developing RF parts for the Ka-band, and in 2004, it succeeded in developing RF and components for various satellites communications, including active and passive components. The RF components were then applied to Chollian-1 in 2010 and have been transferred to domestic industries and exported to the world.

Currently, flexible RF and digital RF technologies are to be developed and applied to the development of satellite and image radar of complex public satellite communications and ground terminal of the satellite system, which will begin development in 2021.



Demonstration of satellite payload components
(Tech Biz Korea 2016, December 13, 2016, COEX)

1-4-2-3. Satellite Antenna Technology

By 1998, ETRI worked with Russia's Apex in collaboration with domestic companies of High Gain Antenna and Ace Technologies to develop an active antenna for the reception of satellite broadcasting signals for mobile vehicles. Also, in 2002, it developed satellite communications antennas for ship mounting. Meanwhile, in 2003, it developed MSIA, a mobile antenna for satellite Internet access on vehicles, and MoBiSAT for vessel mounting. MSIA was demonstrated in Japan in 2003, and MoBiSAT was demonstrated on board a deep-sea training ship.

X band satellite communications electronic
antenna system for vessels

1-4-3. Satellite Control and Payload System

1-4-3-1. Satellite Control and Payload System

From 1990, ETRI developed a laboratory model of the satellite control system by 1994, which began to be developed in cooperation with Hyundai Aerospace and Daewoo Heavy Industries in 1995. As a result, on December 21, 1999, a multi-purpose practical satellite equipped with ETRI's control system was successfully launched. Later, it developed a control system for multi-purpose practical satellites 2, 3, and 5, and a control system for Mugunghwa satellites 7 and 5A from 2003.

Meanwhile, it participated in the development of the Chollian satellite in cooperation

Arirang 2 satellite control system developed with domestic technology

Chollian satellite
(satellite body, Ka band payload, repeater / antenna)

with KARI, the Ministry of Land, Transport and Maritime Affairs, and the Korea Meteorological Agency. In 2010, it developed a Ka-band payload, a test ground station, and a control system for geostationary satellite, and secured national status for its own development of the world's 10th communication satellite.

1-5. Radio Waves–Laying the Foundation for the Domestic Wireless Industry

The wireless and radio wave technology in Korea was still underdeveloped until the early 1980s. The use of radio waves had been restricted due to the situation of the divided peninsula. The use of radio waves were allowed only in controlled fields such as for safety communications and maritime rescue. In this situation, ETRI organized the Special Communications Office and began to develop radio wave technology to support government's policy, and in the late 1980s, it was expanded and reorganized to the Wireless Research Department.

Since then, as the internal and external environment changed, the government began to pursue policies to foster the wireless industry in the 1990s, and various wireless services (mobile phones, digital television, wireless LAN, Bluetooth, RFID, GPS, etc.) were emerged. As a result, the demand for frequencies soared. ETRI promoted the technological development for the use of radio waves (development of spectral engineering technology) in 1993 to efficiently use and manage the resources of limited radio waves. In addition, ETRI has been researching about various types of radio wave technologies.

The research areas for radio wave technology in ETRI is largely classified into four categories: 1) Radio wave resources (spectral engineering, frequency sharing, millimeter wave utilization) to identify new frequency resources and research the efficient use of frequencies; 2) Radio wave-based technologies (antenna, radio wave propagation, reverberation chamber) to research radio wave materials, parts, and equipment technology that form the basis for radio wave use; 3) Radio wave environments (electromagnetic effects on the human body, radio wave monitoring, EMI/EMC) to secure the safety of radio waves; 4) Radio wave applications (medical care, drone detection/identification, wireless power transmission, magnetic field communications) to research applied technologies related to electromagnetic wave.

20 km radius radio wave direction detection technology

Radio Wave Resources

Early radio wave resource research was conducted in close connection with the government's radio wave policy. Spectral engineering technology, which began development in 1995, has been technically supported to implement the government's policies on various frequencies and to ensure the proper supply of mobile communication frequencies. Since 2010, with the change in the government's frequency allocation policy, mobile operators are paying for allocated frequencies. Part of the cost of frequency allocation secured by the support of ETRI spectral engineering technology is again being reinvested for the development of research, contributing greatly to bringing Korea's ICT to the highest level in the world.

In addition, it has developed frequency sharing technology to resolve the shortage of frequency resources since 2005, which is CR (cognitive radio communication) technology that utilizes unused and idle frequencies and had leaded domestic and international standardization. As a result, Korea has been able to promote the distribution of frequencies in idle bands for TV, and domestic services are in progress, albeit limited.

In addition, since 2008 it has begun developing advanced technologies to utilize the resources of frequencies in millimeter waves (frequencies over 30 GHz). In particular, this paved the way for the era of millimeter waves by developing technologies for MMIC and new concepts of antennas that run up to the 100 GHz band. And in 2012, it became the first in Korea to form a study group of SHF/EHF mobile communications to apply millimeter waves to mobile communications, paving the way for Korea to take a global lead in the technology of millimeter wave for 5G mobile communications.

Radio Wave Environments

Since the 1990s, the human risks of electromagnetic waves became topic of discussion in mass media. In particular, when it was reported in 1996 that mobile phones raised the temperature of the scalp, fear spread regarding electromagnetic waves emitted by power transmission towers, mobile base stations, and mobile phones. Consequently, the government came up with measures to protect the human body from electromagnetic waves. In 1998, the government promoted research on the effects of electromagnetic waves on the human body. ETRI established the protective standards for human body against electromagnetic, and developed guidelines for the use of mobile phones for children. ETRI is steadily researching the effects of electromagnetic waves on cell division, protein expression, active oxygen production, fetal development and sperm production. ETRI is also actively participated in global joint research such as Mobi-Kids and GERONIMO.

Also, EMI/EMC was developed in the early 1990s, contributing to the establishment of the domestic EMC system and the foundation of related industries. In particular, technologies in the field of electromagnetic wave measurement and evaluation are recognized worldwide by being reflected on international standards.

In addition, it started researching radio wave detection technologies for the first time in Korea since the mid-1980s and has secured the entire technology of radio wave monitoring, ranging from key HW such as antennas, RF receivers, and digital signal processors to radio wave directional detection algorithms, thereby realizing the safe environment for radio waves in Korea that can be monitored constantly for 365 days a year. According to an analysis by the Central Radio Management Service (CRMS) in 2019, the effect of reducing the cost of radio monitoring system built by ETRI after 2005 amounted to KRW 112.9 billion (does not include the R&D cost).

Radio Wave-Based Technologies

ETRI began research on technology of radio wave propagation in the 1990s to optimally allocate and distribute spectrum and frequency resources limited for global common or national services. It developed a technology that can measure and predict the propagation characteristics of the ultra-high frequency (UHF) band, the microwave band, and the millimeter wave band below 6 GHz and above 20 GHz, which are mainly used in the domestic environment.

In addition, it successfully implemented the multi-band/multi-mode reconstructed antenna technology by developing an intelligent antenna using radio waves from the mid-2000s. In 2018, the structure's technological design for reverberation chamber of electromagnetic waves was developed by using the SW of 3D numerical interpretation (including the structure and location of the base). The technology was then transferred to several small and medium enterprises and is being sold as commercial products such as EMF meters and monitors.

Radio Wave Applications

In the late 2000s, along with the rapid development of radio waves including mobile telecommunications, concerns began to rise over the adverse effects of electromagnetic waves such as the human effects of radio waves. In response, the government has developed technologies for the application of radio waves with beneficial functions such as convenience and utility so that people can overcome excessive concerns and use radio waves with confidence.

Typical examples are medical imaging technology for diagnosing cancer using microwave that are safer than conventional X-rays, and radio wave treatment technology that treats intractable diseases in a non-invasive method by concentrating radio waves on the desired location of the human body.It also promoted the development of wireless power transmission technology using magnetic resonance technology. In 2016 developed the E-Cup, which allows a smartphone to charge efficiently in a cylindrical 3D space, and succeeded in commercializing wireless chargers for cars for the first time in Korea.

In addition, from 2019, ETRI attempted to apply radio wave technology to identify and detect drones to prevent privacy and security threats by using small drones. ETRI is also challenging research on magnetic field communication technology that can transmit wireless data even in extreme environments.

Test scene for electromagnetic wave breast cancer diagnosis system

Over the past three decades, ETRI fostered the nation's wireless industry through the development of radio wave-based and applied technologies. In the future, it aims to promote the health and safety of people and lead the development of related industries by continuously researching new applications and developing technologies based on accumulated radio wave technologies.

1-5-1. Radio Wave Resources

1-5-1-1. Spectral Engineering Technology

From 1993, ETRI began research on the utilization of radio wave resources. Since then, it has conducted spectral engineering research, millimeter band research, and the development of core technologies for improving the frequency efficiency. This resulted in securing 800 MHz, 900 MHz, 1.8 MHz, 2.1 GHz, and 2.6 GHz band mobile communications at 3.4 GHz, and 5G mobile communication frequency resources at 26 GHz.

It also developed a technology for interference analysis between mobile communication services in Japan and domestic TRS, between mobile communications in W-CDMA, LTE, and 5G, and between devices in unlicensed bands. The developed technology was reflected in the government's establishment of frequency policies in cooperation with the National Radio Research Agency, the Korea Communications Agency, and the Korea Radio Promotion Association. The government utilized its results for frequency auction of mobile communications since the 2010s.

1-5-1-2. Frequency Sharing Technology

Since 2005, ETRI has developed the core technology for cognitive radio (CR) in collaboration with universities and companies. Samsung Electro-Mechanics, the Philips US research institute, CRC in Canada, and I2R in Singapore participated in developing relevant guidelines and standards. In 2009, seven cases were reflected in the ECMA-392 standard, and in 2011, five cases were adopted for the IEEE 802.22 international standard. With the development and standardization of CR technology, this could drive the assignment of frequencies on TV’s idle band. Additionally, limited domestic services are currently underway.

90 GHz wireless backhaul testbed

1-5-1-3. Millimeter Wave Technology

Since 2008, ETRI developed 10 Gbps transmission technologies using 70/80/90 GHz millimeter waves, and has succeeded in developing technologies for most module units, including MMIC and antennas for millimeter wave band. In addition, it technically verified the concept of new radio wave orbital angular momentum (OAM) and the line of sight MIMO (LOS-MIMO) in 2017. The results were published in the SCI journal. It also implemented and demonstrated the LOS-MIMO system by applying MIMO.

1-5-2. Radio Wave Environments

1-5-2-1. Technology for the Effects of Electromagnetic Waves on the Human Body

ETRI's standard for the electromagnetic wave protection guideline was developed in 1998 and became the government's standard in 2002. It developed a model for children's exposure to electromagnetic waves in 2006. ETRI in the first in the world studied the effects of electromagnetic waves on the human body under the simultaneous exposure of multiple frequencies in 2007. ETRI also led the evaluation for exposure rate in Asia with Mobi-Kids' international research in central Europe since 2009, which served as a key institution in the follow-up GERONIMO project.

1-5-2-2. EMI/EMC Technology

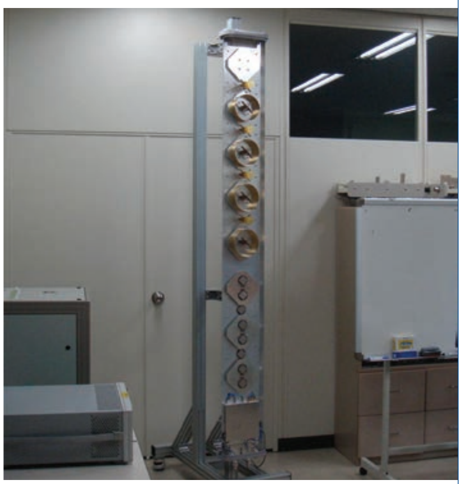
ETRI began developing technologies for EMI and EMC in early 1990. Since 1991, it developed new measuring equipment such as the 4-port TEM Cell and GTEM Cell, which are also reflected in international standards. In 2000, it developed PEMAS for EMI interpretation, materials and parts for EMI/EMC in 2004, and the technology for EM wave absorber in 2006. ETRI later then transferred these to companies.

It also developed the EMC standard from 2001 to 2007. After that, research on EMC in radio wave-intensive space such as major infrastructures like ICT facilities were conducted in 2015.

Scene of Radio Monitoring System exported in Laos
(2011, Laos Post Office)

1-5-2-3. Radio Monitoring

Based on the technology that detect the direction of radio waves from the mid-1980s, the radio wave monitoring system was developed in 2008. In 2016, the semi-fixed type system was developed and installed in the Central Radio Management Service (CRMS). Parts of these technologies were supported to the developing countries. Meanwhile, in 2017, ETRI developed a radio disturbance monitoring system.



Intelligent antenna system for base station

Measurement scene of propogation characteristics on radio channel (Receiver Channel Sounder)

1-5-3. Radio Wave-Based Technologies

1-5-3-1. Antenna / Radio Wave Propagation Characteristics / Reverberation Chamber Technologies

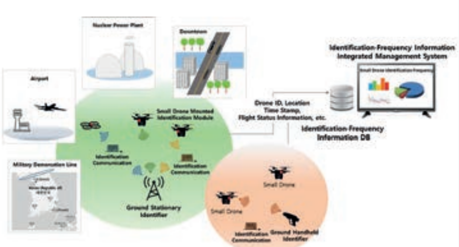
In 2010, ETRI jointly promoted intelligent base station antennas for mobile communications with SKT, Gamma Nu, Ace Technology, HGA, and KMW, which implemented the multi-band/multi-mode reconstruction antenna technology for beam forming.

Meanwhile, it began researching radio wave propogation characteristics in the 1990s and developed propagation models for UHF band and microwave band. In 2017 it developed broadband channel sound and 28 GHz/38 GHz band propagation models. In addition, it developed a route loss model of 0.8 GHz to 73 GHz and standardized it internationally, which contributed to the adoption of the ITU-R chairman's report and standardization.

For reverberation chamber technology, it developed technologies for interpreting, designing, manufacturing, and evaluating the electromagnetic wave chamber since 2015, and has secured technologies for evaluating the EM performance of wireless devices such as WiFi, which has been transferred to small and medium companies and sold as commercial products such as EMF measurements and monitors.

ETRI reverberation chamber (December, 2017)

Microwave breast cancer diagnosis test system installed at Seoul National University Hospital



Concepts of the integrated system managing both identification and frequency for the low-altitude small drone

1-5-4. Radio Wave Applications

1-5-4-1. Radio Wave Medical Technology

Started in 2010, ETRI developed a breast cancer diagnosis microwave tomography (MT) system in 2015 and completed clinical trials with Seoul National University Hospital. This system passed the medical device certification test for clinical research trials by the Korea Testing Laboratory. Since 2016, ETRI researched technology for concentrated radio wave heat therapy and developed therapeutic guidance technology to monitor heat changes in the body by 2020.

1-5-4-2. Wireless Energy Transmission Technology

From the late 2000s, ETRI began developing technology for wireless energy transmission. In 2010, it developed a 60W wireless charging system for robot and secured its three-dimensional wireless charging technology. In 2015, it was commercialized as the first wireless automotive charger in Korea and was supplied to Hyundai Motor and Kia Corporation.

1-5-4-3. Drone Identification Technology / Magnetic Field Communications Technology

Since 2019, ETRI has been developing low-altitude small drone identification technology and is also participating in its standardization activities. It focuses on the development of a communication system that finds frequencies suitable for drone identification purposes and transmits and receives information on identification. On the other hand, from 2019, it began developing a medium- and long-distance magnetic field communication technology based on the 10pT micrometers, which is scheduled to end in 2028.

1-6. Conclusion

Networks

ETRI's network sector has evolved over the past 40 years and has constantly innovated technologies on transmission and exchange, control and management, wired and wireless access, and Internet-based multimedia service. As a result, Korea has secured the infrastructure of hundreds of gigabytes for optical access, tera-level optical networks, and flexible networks based on SDN/NFV.

In the future, ETRI plans to develop the source technology for Terabit Ethernet optical transmission to lead the era of tera-level optical telecommunications and take on the development of peta-level optical telecommunications technology for 6G. Also, in the field of optical access, it will develop various technologies to quickly enter the era of tactile Internet, which can transmit information within 1/1,000th of a second and focus on developing technology for near-field transmission of terahertz (up to 10 m) that can provide high-speed (approx. 100 Gb/s) wireless data services.

In addition, it will push for the development of a hyper-connected intelligence network that is closely combined with IoT, cloud computing, 5G mobile networks, data, and artificial intelligence technologies so that various new industries and services can emerge.

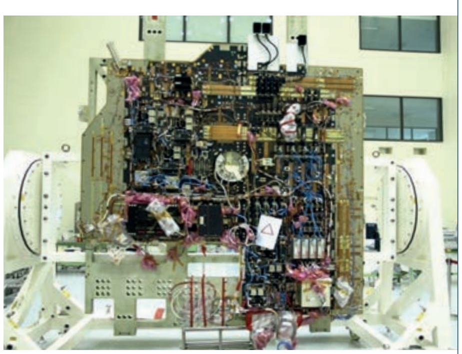
Mobile Communications

ETRI has led the development of digital mobile communications by commercializing the world's first CDMA in 1996, commercializing the WiBro, developing the world's first mobile Internet in 2006 and core technology of the world's first LTE system in 2007, and developing LTE-Advanced, the fourth-generation mobile communications system in 2010, as well as fifth-generation mobile communications technology in 2018.

Building on this success, ETRI continues to take on the challenge for creating new technologies. ETRI is developing technologies such as 5G New Radio (NR) small cell software for early commercialization of 5G small cells used by small and medium enterprises in Korea, industrial IoT to overcome the limitations of the performance of 5G, and moving network (MN) to provide high-speed Wi-Fi services to passengers on buses.

It also focuses on on-time-on-rate (OTOR) technology, which guarantees transmission speed at the desired time to preoccupy the core source’s technology for sixth-generation mobile communications, which is expected to be commercialized by around 2030. Moreover, ETRI will work on the terahertz wireless communication technology, which provides 50 times the data transmission speed of 5G, and the three-dimensional stereoscopic communication technology that expands from the center of existing two-dimensional communication into air and satellite. In the future, ETRI will continue to strive becoming the driving force for mobile communications to lead the technology for Korea's mobile communications.

Satellite Communications



The core components for satellite payload

The history of Korea's full application of satellite communications began with ETRI. Since the early 1980s, ETRI has led the development of domestic satellite communications by developing technologies such as the satellite communications earth station, satellite broadcasting, satellite control systems, satellite navigation and antenna, and satellite payload component. Recently, the cost of launches has been lowered with the reuse of satellite launch vehicle enabled and the cost of communications has been reduced due to the development of high-throughput satellite communication (HTS).

In the future, based on accumulated technologies for satellite communications, ETRI will continue to take on challenges in the development of new technologies such as transmission based on low-orbit communication satellites and planar antennas in preparation for the New Space era. Additionally, ETRI will lead the development of a complex public communications satellite, Chollian-3, which will begin in 2021.

Radio Waves

Radio wave research is one of the oldest research areas in the history of ETRI, and over the past 45 years, it has served as a cradle of radio technology that develop various wireless services in mobile communication, broadcasting, RFID, and UWB.

In the meantime, ETRI has developed innovative technologies in four areas: radio wave resource research, radio wave-based research, radio wave environment research, and radio wave application research. By supporting the technical foundation for the government's policy on radio waves, it helped secure the resources of insufficient frequencies, accurately analyze the effects of electromagnetic waves on the human body, and prepare countermeasures for such health problems. In addition, it materialized the safe environment for radio waves in Korea, which can be monitored constantly for 365 days a year. It focused on developing radio wave application technologies that use radio waves in various fields such as medicine, drones, and wireless power transmission.

In the future, ETRI will continue to promote people’s health and safety and lead the development of related industries by continuously searching and developing new technologies and new industries such as 6G mobile communication RF antennas and radio wave image radar sensors based on the accumulated radio wave technologies.

PART 2

Broadcast Media /Contents

* CNPD : Content-Platform-Network-Device.

2

Broadcast Media/Contents

2-1. Overview

Broadcast Media

In February 1927, broadcasting started in Korea with the opening of Gyeongseong Broadcasting Corporation (radio station). TV broadcasting then began in 1956 in black-and-white based on the National Television System Committee (NTSC)'s standard. In December 1980, this developed into color TV, that is also viewable on a black-and-white. In the 1990s, the era of multimedia and multi-channel began with the advent of new media broadcasting. In March 1995, cable TV entered the main broadcast, and Korea Broadcasting System (KBS) began satellite test broadcasting using the Mugunghwa satellite in July 1996, opening an era of diversified broadcasting system, in which cable TV and satellite TV coexist along with the previously existing terrestrial broadcasting. At this time, Korea began to develop and standardize technologies for digitalizing broadcasting with ETRI as the institute in charge.

ETRI began the development of digital broadcasting media technology in 1993, starting with the development of digital satellite broadcasting systems. In 2001, terrestrial digital broadcasting transmission technology, relay technology, and signal processing technology were quickly developed and laid the technical foundation for Korea to successfully switch to digital broadcasting.

Meanwhile, since 1993, ETRI focused on the development and standardization of codec for high-efficiency compression of video signals in digital high-definition TV broadcasting systems, video coding technology for minimizing the loss of image quality of digital video signals, audio coding technology to reduce the amount of data while minimizing the loss of sound quality of digital audio signals, and MPEG-21-based multimedia framework for multimedia services in broadcasting and communication convergence environments. As a result, it secured several international patents and generated hundreds of billions in expected profits.

In 2002, the government announced the DAB-based Terrestrial DMB Basic Plan, which adopted the US's Advanced Television System Committee (ATSC) standards for fixed DTV broadcasting service and European DAB for mobile DTV broadcasting service.

The world's first demonstration of terrestrial DMB data broadcasting technology

Successfully developed the world's first real-time 3DTV broadcasting technology during the 2002 World Cup soccer match

Under the plan, ETRI also began developing terrestrial DMB technologies. ETRI speeded up the development of DMB as it had accumulated DAB transmission and reception technologies since 2001 and succeeded in developing the world's first terrestrial DMB in October 2003. In December 2005, DMB broadcasting began in the Seoul metropolitan area. As a result, it started the so-called "TV in My Hand, My Own Broadcasting," where you can watch TV constantly while driving at speeds of more than 150 km/hour.

In the mid-2000s, when there was a growing demand for data broadcasting services that use additional multimedia services while watching TV and customized broadcasting services that can be converted according to the users' intention in a multi-channel environment, ETRI also jumped into data broadcasting and customized broadcasting service technology development. Also, with the birth of IPTV, which is capable of two-way and broadcasting communication convergence services, ultra-high-definition broadcasting using quality assurance IPTV network was implemented, focusing on the development of related technologies. As a result, Korea became a world-recognized IPTV powerhouse.

Meanwhile, the development of 3DTV broadcasting technology began in the late 1990s. ETRI developed the stereoscopic 3DTV broadcasting technology, 3D AV-based technology, and Ultra-High-Definition Television (UHDTV) broadcasting technology that supports 3D without glasses. Based on this, Korea provided the world's first 3DTV terrestrial broadcast (SBS) in November 2013.

As stereoscopic films became widespread under the influence of stereoscopic 3DTV broadcasting, ETRI continued to challenge multi-view 3D compatible with UHDTV broadcasting technology, full mobile three-dimensional content technology, and AV coding and LF media technology for hyper-realistic media. In addition, since 2011, it has promoted three national representative tasks in the field of digital holography and developed core technologies for the generation, compression, and reproduction of holographic acquisition.

In the 2010s, broadcasting media technology was rapidly converging with various fields, and was in need of numerous functions that were not previously available. In response, ETRI began developing the technology for Smart TV 2.0, which surpasses the existing smart TV from 2011, providing an opportunity to transform the traditional TV industry into a new eco-system centered on SW. In addition, ETRI developed the 12Kx2K ultra wide vision (UWV) live broadcasting technology by challenging the large-screen panorama image (UWV), also known as the world's widest and clearest TV.

Furthermore, it has led the standard technology development of ATSC 3.0, the next-generation version of ATSC, and the standard for digital broadcasting, securing more than one-third of all core patents in the area of ATSC 3.0 channel coding technology and successfully promoting the spread and commercialization of said technology. In 2018, it also developed the UHD mobile broadcasting technology, a representative service of ATSC 3.0 UHD broadcasting.

Meanwhile, with the growth of over-the-top (OTT) media service based on IP and the emergence of realistic content such as VR/AR, there have been growing calls for cable broadcasting to meet this paradigm. In response, ETRI developed the RF-signal over IP (RoIP) technology and same-band full duplex transmission technology, which has enabled domestic cable broadcasting parts and equipment technology to be independent from overseas exports.

Content

"Content" refers to data or information including symbols, letters, shapes, colors, voices, sounds, images, videos, etc. Since the 1990s, the spread of computers has led to a surge in digital content produced and processed in digital form. Various contents have attracted attention as an area of great value in the industry because it is easy to copy and process, not to mention its advantage of reusability (one source, multi-use). Moreover, Korea has the world's best infrastructure for wired and wireless communication and the foundation of content industry, with the likely potential for growth. However, the problem was that there was an absolute lack of quality content to utilize the infrastructure.

As a result, ETRI started to focus on developing digital content since the late 1990s and has been leading the domestic digital content sector by developing digital actors, 3D game engine, hologram reproduction technology, and interactive VR technology over the past 20 years.

E-learning system

ETRI has developed its own computer graphic (CG) technologies to further enhance the level of video content in Korea when CG was considered exclusive for Hollywood movies. As the fruits of ETRI's efforts, it has successfully created its own digital actors, fluid simulation, digital creature animation, and interactive real 3D technology. In particular, digital actors developed in 2005 were used in various films, and ETRI became the first Korean research institute to receive technical awards at the Grand Bell Awards and the Blue Dragon Film Awards.

In the 21st century, as game trends changed rapidly from offline to online and from 2D to 3D, ETRI began to focus on developing online 3D game engines to promote the domestic game industry. Because game engines require comprehensive IT such as servers, networks, terminals, and CGs due their nature, researchers tried to develop various core technologies in an integrated manner. After developing game engines such as Dream 3D and cross-platform since 2003, it succeeded in developing “Venus Blue,” which is the world's first game server performance and stability test solution in 2008.

Since the launch of EBS's Internet CSAT broadcasting service in 2004, e-learning has become the new paradigm for education, and the convergence of IT and education has progressed rapidly.

Therefore, ETRI started to focus on developing educational content, and in the late 2000s, it developed various 3D learning content such as 3D interactive learning content for customized learning and experience-type fairy tale storytelling service using 3D virtual space. Also, in the mid-2010s, it developed and spread participatory e-learning technology using AR, VR, deep learning, and VR sports system for students' indoor sports activities.

As network technology advanced in the 2010s, there has been a growing demand for realistic experience content that give people a sense of reality and immersion as if seeing and experiencing it in real life. Based on its long research experience in AR and VR technology, ETRI developed an urban-type VR theme park technology since the early 2010s and various content that can assemble and restore digital cultural assets virtually, as well as in reality. In addition, from the mid-2010s, high-speed video generation and processing technology, high-speed hologram generation technology, interactive technology for the realization of holograms, and hyper-point video production tools have been secured so anyone can enjoy a hyper-connected real-life experience in a giga-level wired and wireless network environment in the upcoming 5G era.

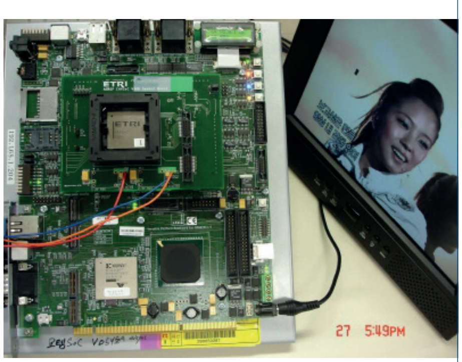
Along with the explosive growth of smartphones and video sharing services, ETRI also led the development of various types of search and recognition technologies, such as image search and motion recognition. ETRI will continue to strive to materialize a positive digital life centered on humans and culture with the development of advanced content technology.

2-2. Broadcast Media – Implementation of Hyper-Realistic CPND

Broadcast media technology is a technology that provides users with new values and knowledge through the acquisition, storage, compression, transmission, reenactment, and reproduction of content that includes the following four value chains: content, platform, network, and device. ETRI has led domestic and overseas standardization by developing necessary technologies at the world's highest level whenever Korea challenged new services such as HDTV broadcasting, DMB broadcasting, 3DTV broadcasting, IPTV broadcasting, and UHDTV broadcasting for nearly 30 years.

Content

First, by looking at the aspects of content in the value chain, it is visible that they are evolving towards the direction of high capacity, high quality, and realism. This is because people want content that feels just like real life in terms of hearing and seeing. In fact, the service was developed into analog TV broadcasting even before HDTV broadcasting in the early 2000s, 3DTV broadcasting in the early 2010s, and 4K UHDTV broadcasting from the mid-2010s to the present. ETRI's technologies that contributed to this development include MPEG-2-based HDTV broadcasting codec technology, MPEG video coding technology, MPEG audio coding technology, 3D realistic audio technology, ultra wide vision video technology, 3DTV broadcasting technology, light field video technology, and digital holographic technology.



MPEG

Platform

Broadcasting media platforms are rapidly shifting from supplier-driven to user-driven platforms. Before the production and distribution of media through the Internet started to take off, the supplier-led media environment was established in which content were produced and delivered to the terminal, which was then managed by individual operators such as terrestrial, cable, and satellite broadcasting operators. However, as IPTV and OTT services have become popular and the number of individual creators using online video platforms such as YouTube has explosively increased, the user-led media environment that allows consumers to freely choose the content they want became more common. In the future, this system is expected to evolve rapidly into a media-driven environment in which media will make the first move to suit the user’s tastes. ETRI's technologies that have contributed to this development include IPTV broadcasting, Smart TV broadcasting, limited reception for charged broadcasting subscribers, broadcast content protection, management, and management technology, and the MPEG-21 multimedia framework technology.

Network

Networks for delivering broadcast media are evolving due to media’s high-quality trend in wanting to enhance mobility by increasing the transmission efficiency of the internet, satellite, cable, and terrestrial networks. In particular, ATSC 3.0, which can be combined with large-scale media transmission and communication network, has been adopted as a standard for domestic UHD terrestrial networks broadcasting since May 2017. This led to innovations in the media market. ETRI's contributions to this development include digital terrestrial broadcasting, ATSC 3.0 broadcasting, digital cable broadcasting, digital DMB technology, digital radio broadcasting, digital satellite broadcasting, and broadcasting of disasters in order to protect people's lives and property.

Device

Broadcast media devices are spreading from traditional media consumption devices such as TV and STB to various smart devices such as smartphones, tablets, and head-mounted displays (HMD). As a result, the presentation tailored to the characteristics of each device became important, and competition among media devices also went beyond technical function and performance, shifting the focus on satisfying user convenience and usability. In addition, as TVs became larger and higher in quality, and virtual reality/augmented reality (VR/AR) devices are increasingly used, user interfaces are evolving into various multi-modal interfaces such as voice, gesture, and eye tracking. ETRI's technology that contributed to this development included data and customized broadcasting technology, IPTV, Smart TV, and welfare broadcasting technology for people with disability.

Broadcast media technologies and services continue to evolve in line with trends such as content digitization, widening of networks, convergence of broadcasting and communications, mobilization of devices, and advancement of smart devices. With 3D video technology and transition to a hyper-realistic tera media supported by 6DoF, it is evolving into a hologram video camera technology that can be easily captured by broadcasting media's 2D camera. On the other hand, UWV is developing into an immersive media that provides an overwhelming on-site sense of large displays. Through the development of these technologies, ETRI will continue to innovate and lead the technology of broadcasting media.

2-2-1. Digital Broadcasting

2-2-1-1. Digital Satellite Broadcasting Technology

Digital satellite broadcasting head-end

When Korea decided to go digital in July 1993 for its transmission method of satellite broadcasting, ETRI's research on digital satellite broadcasting standards, which began in early 1993, became a reorganization of the expansion of developing a digital satellite broadcasting system, which led to the development of digital broadcasting technology. The three-year research period of the project was conducted with a research budget of KRW 161.5 billion (KRW 15.9 billion for KT, KRW 2.5 billion for LG Information & Communications), and 114 researchers per year (60 for ETRI, 40 for MPRs, and 14 for LG Information & Communications). Considering the short acquisition period of imported materials, ETRI decided on a joint development with MPR of Canada and LG Information & Communication as the local participant.

Simultaneously with ETRI’s development, its domestic standardization contributed to the standardization of broadcasting systems, devices, and home appliances and prevented foreign technology from taking over the domestic satellite broadcasting transceiver market. In addition, ETRI supported the establishment of long-term broadcasting policies in the country to induce industrialization of related technologies in Korea.

2-2-1-2. Digital Terrestrial Broadcasting Technology

Digital satellite broadcast receiver

Due to the noise of ATSC method’s multi-pass being relatively weak and impossibility of SFN configuration, these disadvantages led to having to use other frequencies at the relay station. In order to overcome this, an amendment in relation to ATSC's standard was proposed to enable the SFN on the existing ATSC transmitter. In particular, the equalization digital on-channel repeater (EDOCR) developed by ETRI was adopted as the Design of Synchronized Multiple Transmitter Network of ATSC SFN in the US TV, in September 2004.

One of the difficulties of digital transitioning period was installing the repeater in order to resolve grayed out areas due to the lack of broadcasting frequency. The development

Started digital TV broadcasting in Gangjin area
(June 17, 2010, ETRI)

DTxR(Distributed Translator)(Left) and
EDOCR(Equalization Digital On-Channel Repeater)
(right)

of distributed translators (DTxR), which are used by the same frequency between ETRI's repeaters, solved this problem.

It coincided with the launch of digital TV broadcasting in Gangjin, Jeollanam-do in 2010, creating a successful establishment and utilization of a DTxR.

ETRI provided the technical foundation for Korea's successful conversion of digital broadcasting, and such technologies were actively presented to other domestic companies. In particular, DTV's signal processor, Master Antenna Television System (MATV), was developed to improve the reception environment in common housing, which led to the successful transfer and commercialization of 14 broadcasting equipment companies from 2004 to 2011. With these efforts, the nationwide expansion of digital broadcasting using domestic terrestrial broadcasters, and active production of HD content by broadcasting companies followed. Resultingly, Samsung Electronics and LG Electronics became the world's best household electronics companies beyond the domestic market of HDTV.

2-2-1-3. ATSC 3.0: Broadcasting Technology

As the need for new broadcasting services while developing high-definition coding (including 4K-UHD), the discussion for ATSC 3.0 as ATSC's next-generation digital broadcasting became a topic of interest in 2012. ETRI developed high-performance and high-efficient channel coding and multiplexing technologies, LDPC11 and LDM12, that provide 4K UHD and mobile HD broadcasting simultaneously. These technologies were adopted as the mandatory standards for ATSC 3.0. Specifically, ETRI secured one-third of the 24 core patents in the area of channel coding and included non-uniform constellation (NUC), signaling coding, framing, and Transmitter Identification (TxID) for the final physical layer standardization of ATSC 3.0. In this process, ETRI was recognized and won many awards, including the Journal Award in IEEE's Field of Broadcasting (2018) and several best papers from IEEE's Broadcasting Technology Society.

ETRI started to support UHD mobile broadcasting, a representative service of ATSC 3.0 UHD, by combining its patent-owned Scalable HEVC (SHVC) and LDM in 2018. With these technology, ATSC 3.0 can be efficiently connected with Wi-Fi, LTE, and Internet-based broadband network. Furthermore, UHD mobile broadcasting technology was selected as the 100 Best Achievements of National Research Development in 2019. Various types of receivers and measurement equipment, subject to ETRI's ATSC 3.0 standards have been proactively developed and transferred to domestic small and medium-sized companies to be used in the global market. A total 15 cases of technology transfers were successfully conducted. In addition, the commercialization of ATSC 3.0 technology has led to massive collaboration among domestic companies with various infrastructure technologies. ETRI technology-based UHD signal processors have been installed in seven public apartments for pilot service and are currently under commercial service. Also, related technologies have been transferred to small and medium-sized Korean companies and resulted in sales of more than 1,500 units (as of June 2020).

2-2-1-4. Digital Cable Broadcasting Technology

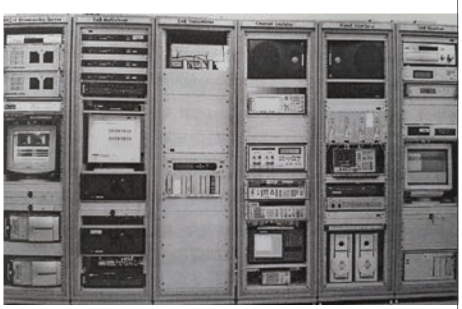
The development of RF-signal over IP (RoIP) technology for two-way linkage of light IP network-based smart media project was carried out for three years from 2016, and the development of technology for simultaneous transmission of the same-band and downward signal for multiple giga-level services of cable networks project was carried out for three years starting in 2017.

RoIP digitalizes the analog RF's signal, and turns it back to analogue RF's signal after the digitalized signal is transmitted to the IP network. RoIP was verified by CJ Hello North Incheon Broadcasting Co., Ltd. at the end of 2018, and was approved for three ITU-T's13 standards. With the development of full duplex transmission in the same band, there is no distinction between upward transmission within full duplex transmission's resources in the same band and the simultaneous transmission in the same band, which doubles the efficiency when using the same band. In South Korea's first case of 192 MHz transmission, full duplex transmission in the same band and verification of the performance and function of the test conducted by the Digital Cable Laboratories at the end of 2019 was completed, leading to the approval of a single standard for ITU-T.

RoIP head-end/terminal prototype (top), Same-band full-duplex transmission head-end/terminal prototype (bottom)

2-2-1-5. Digital Radio Broadcasting Technology

ETRI researched multimedia transmission using DAB in 2001 through the development project for terrestrial digital radio broadcasting technology in order to digitalize FM radio as part of the development project for intelligent integrated information broadcasting (Smart TV) technology. In 2009, ETRI carried out an experimental broadcasting project of digital radio comparison to identify the appropriate digital radio solution in Korea. ETRI successfully secured technologies for transmitting improved sound quality at the bit rate of 48 kbps by using USAC, the latest audio codec, through the development project for USAC-based digital radio transmission system. Despite ETRI's continued R&D and efforts, digital radio technology has not led to commercialization without overcoming differences between related agencies and operators on the stakeholders' interests in the existing radio broadcasting market. But these challenges faced by ETRI researchers became fruitful. Through this research and development, those in the field of broadcasting and communications can grasp the performance and pros and cons of core digital radio technologies that could be applied in Korea, such as DAB, HD-Radio, and DRM. ETRI's experiences with data analysis on performance will serve as the basis for the future commercialization of digital radio in Korea.



Digital radio transmission system resulted from 'Development of terrestrial digital radio broadcasting technology' project

2-2-1-6. DMB Broadcasting Technology

ETRI planned a multimedia mobile broadcasting service using the European DAB (Eureka-147) technology in 2001 and started the development of terrestrial DMB system technology as part of the Smart project in January 2002. To provide VCD-like quality video and stereo audio, it adopted MPEG-4 AVC video and MPEG-4 BSAC, known as the latest codecs, as well as Reed-Solomon FEC and MPEG-2 TS.

In addition, ETRI actively participated in the government's DMB-related policies through activities such as terrestrial DMB frequency research team, terrestrial DMB experimental broadcasting task force, and terrestrial DMB policy research team. As a result, ETRI was first in the world to develop the terrestrial DMB system, which led to the opening of the so-called "TV in My Hands, My Own Broadcasting" era.

Cooperation agreement with German IRT for DMB globalization

DMB system exhibition at 'Korea Construction & IT Exhibition' (March, 2007, Qatar)

Received the Technology Innovation Award at '2010 NAB Show' (April, 2010, Las Vegas, USA)

People could enjoy clear TVs with DMB receivers while driving at speeds of more than 150 km per hour, while DMB broadcasting began in Seoul metropolitan in December 2005.

The terrestrial DMB broadcasting system was selected as one of the 100 Outstanding Achievements of National Research and Development in 2006 and the 40 Representative Achievements of 40 Years of History of ETRI.

With these achievements, Korea became a leading country on par with the world from the periphery of broadcasting technology and standards. Terrestrial DMB broadcasting equipment is still being used by terrestrial DMB broadcasting systems.

Until then, the domestic broadcasting market had introduced broadcasting methods, standards, and broadcasting systems developed abroad. However, terrestrial DMB broadcasting technologies developed by broadcasters and manufacturers under the leadership of ETRI were adopted as ETSI standards, ITU-R recommendations, and domestic standards.

2-2-2. MPEG

2-2-2-1. MPEG-2-based HDTV's Broadcasting Codec Technology

The development of high-definition television (HDTV) technology was first carried out in analog by Japan and Europe in the mid and late 1980s. However, America's adoption of HDTV via digital method in 1992 led to a digital shift in the global flow of HDTV. Korea also decided to adopt the digital method at the end of 1993 and the development of related technologies was initiated.

ETRI has contributed to the development of HDTV transmission since 1993, contributing to the establishment of HDTV's broadcasting method, and the development of MPEG-2 based HDTV's broadcasting codec technology. With the standard MPEG-2 as the basis, the HDTV's encoding module was designed, which led to the development of a chipset for encoding MPEG-2 video and the development of a HDTV encoder system using a

MPEG-2 based high-definition TV encoder

HEVC decoder demonstration

chipset. The digital broadcasting system and equipment that HDTV developed were used for the joint experiment broadcasting with four terrestrial broadcasters in 1999. Through this, experiments were conducted based on the performance of HDTV's codec, as well as whether it interfered with signals of existing analog broadcasts.

ETRI's MPEG-2-based HDTV broadcasting codec technology provided the technical bridgehead for domestic digital broadcasting and served as the basis for securing several international standards related to MPEG.

2-2-2-2. MPEG Video Encoding Technology

Digital broadcasting services require video coding technology that reduces the amount of data while minimizing the loss of image quality of digital video signals. From 2008 to 2016, ETRI went through several challenges when developing the core technology of the next-generation DTV, the technology for UHDTV broadcasting with glasses-free multiview 3D support, convergence service for UHD immersive broadcasting of ultra high-quality content, digital cinema, and signage. These led to the development of HEVC algorithms and participation in international standardization, securing 43 (family basis) essential patents for HEVC's pool of patents. Among those, the UHD immersive broadcasting technology of ultra high-quality content was selected as one of the 100 Best Achievements in the national R&D category in 2017.

In addition, the challenge of the next phase of HEVC coding was carried out from 2016 to 2019, and the development and standardization of technologies at the core of fifth-generation video standards, which provides twice as much compression as HEVC, was carried out to secure many patents for international standards. Furthermore, based on the video coding technology it has accumulated over the years, ETRI is challenging new ultra-high-compression video coding technologies such as AI-based post-VVC technology and volumetric video coding technology.

2-2-2-3. MPEG Audio Coding Technology


MPEG-H 3D audio playback environment

The standard technology for audio coding, which is designed to reduce the amount of data while minimizing the loss of the digital audio's signal and sound quality, has been developed with MPEG since the late 1980s. The standardization when developing various audio coding technologies, ranging from MPEG-1 of the first generation to the fifth generation MPEG-H 3D audio, is underway. After the beginning of ETRI's research on the source of digital audio coding in the early 2000s, through the development project on rich media broadcasting technology by advancing the codec of AV in 2007 and development project for next generation DTV's core technology in 2008, the development of audio coding began to take off. ETRI was recognized internationally for the MPEG-D USAC (unified speech and audio coding) standardization in the late 2000s and MPEG-H 3D audio standardization in the late 2010s.

2-2-2-4. MPEG-21-based Multimedia Framework Technology

Multimedia expert workshop

High-performance chip for ubiquitous networks

ETRI carried out the development of framework of convergence for broadcasting and communication services based on MPEG-21 project with the aim of developing and establishing international standardization of multimedia services in the environment of convergence between broadcasting and communications, which took three years starting from 2002. The project involved four universities and three SMEs as joint research institutes. In particular, the technology for color adaptation was developed so that information on multimedia content's colors provided through TVs, monitors, mobile, or phones, can be delivered to people with visual or color impairment. The technology was also transferred to joint research institutes. Samsung Electronics successfully commercialized this technology with their launching of the PAVV TV in 2004. This project was selected as the field of the revolution in content service and was chosen as one of the 100 Outstanding Achievements among national R&D, selected by the Ministry of Science and Technology from 2003 to 2005. ETRI took the initiative to participate in the enactment of international standardization for MPEG-21-based multimedia framework, which resulted in the adoption of a total of 10 international standards in the field of MPEG-21's digital item adaptation (ISO/IEC 21000-7). This is equivalent to 25% of the total international standard technology of MPEG-21. In addition, ETRI secured intellectual property rights, including six applications for standard patents.

2-2-3. Immersive 3D Broadcast Media

2-2-3-1. 3DTV Broadcasting Technology

As Korea and Japan's joint hosting of the 2002 FIFA World Cup was confirmed, the two countries agreed to send high-definition broadcasts of cultural events and live soccer matches. As a result, an agreement on technical cooperation between telecommunications ministers in South Korea and Japan was reached in 1999, marking the start of ETRI's experimental service of 3DTV broadcasting relay, raising the anchor of research on 3DTV broadcasting technology. The project succeeded in providing a pilot service for 3DTV broadcasting of the 2002 FIFA World Cup Korea-Japan.

3DTV

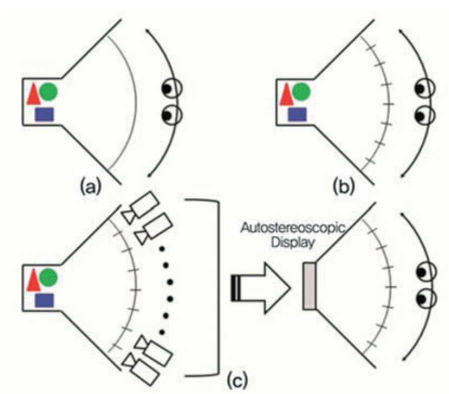
With the success of the three-dimensional film Avatar in 2009, 3D glasses gained great attention and ETRI carried out a pilot broadcasting of high-definition 3DTV in 2010. This pilot service of high-definition 3DTV showcased the 2011 World Athletics Championships in Daegu.

'World's first high-definition 3DTV experimental broadcast Opening Event' by KCC (October 29, 2010, Korea Science and Technology Center)

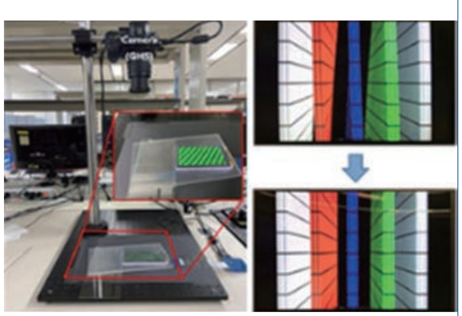
With the establishment of 3DTV PG under the Broadcasting Technical Committee of Telecommunications Technology Association (TTA) in 2010, the standardization for 3DTV broadcasting, which secures the backward compatibility with existing HDTV broadcasting, was beginning to be officially promoted. The national standard was completed in 2011, and the ATSC standard of 3DTV broadcasting was adopted in early 2013. With this, SBS carried out the world's first 3DTV broadcast as a terrestrial broadcaster in November 2013.

2-2-3-2. Multiview and LF Video Technology

As three-dimensional films became widespread after the demonstration of the world's first cross-strait 3DTV broadcasting in 2013, the demand for technology to allow more natural viewing of three-dimensional images without glasses continued. In 2011, ETRI started developing a multi-view TV technology based on binocular video as a detailed technology for the development project on multiview 3D-compatible UHDTV broadcasting technology. From 2014, in their development projects for UHD realistic broadcasting, digital cinema, and digital signage convergence technology (that support ultra-high quality content), ETRI started to develop the glasses-free multi-view 3DTV technology that can provide a three-dimensional effect without glasses. With the beginning of Giga Korea project in 2013, as there was a demand for technology to acquire, transmit and reproduce fully three-dimensional realistic media on the mobile platform, the development of complete three-dimensional terminal and mobile content, led by Samsung Display was initiated in 2015. ETRI took part in this project to develop technology for the deployment of adaptive sub pixels mapping, which enables real-time playback of LF videos through the mobile terminal of 5-inch, 10K with the basis of viewer's location tracked with cameras. Meanwhile, ETRI conducted the development of audio/video coding and light field media's fundamental technologies for hyper-realistic tera-media since 2017. As part of the project, ETRI is developing an LF image-based spatial information acquisition technology, HMD-based omnidirectional LF image reproduction technology, and HMD-based omnidirectional LF image transmission/reception element technology, based on its experience that has been achieved in the process of developing core technologies for the multi-view and LF image reconstruction on the terminal. Finally, the developed LF media core technology will be verified through a 6DoF (Degree of Freedom) support HMD-based LF video service platform after advancing and integrating element technologies.



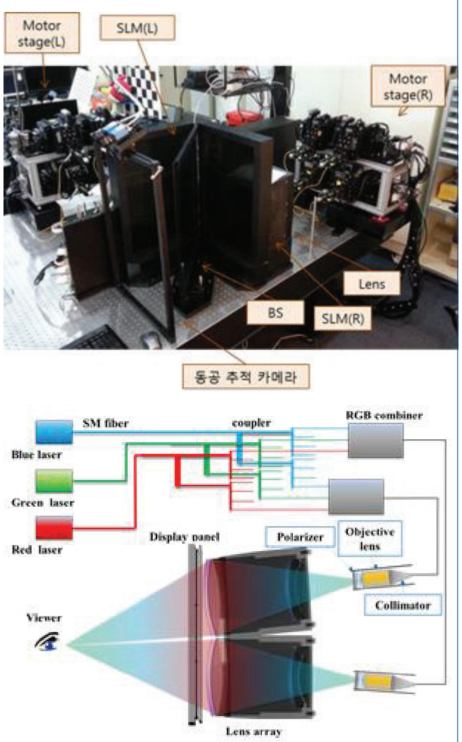
Glasses-free multi-view 3DTV principle



LF display matching error correction system

2-2-3-3. Digital Holography Technology

Holography is a technology that uses light interference and diffraction to record the information of three-dimensional images and display those recorded images in space. It has been getting attention as the best technology to observe natural images without



Large screen holographic display system - full color 10fps hologram video using 4K LCD large area SLM (July, 2014)

tiring the eyes or any physiological inconveniences. However, the commercialization of holography has been difficult due to the wide usage of flat displays with a very narrow viewing angle. In order to overcome such limitations, ETRI is carrying out the national project in the field of digital holographic.

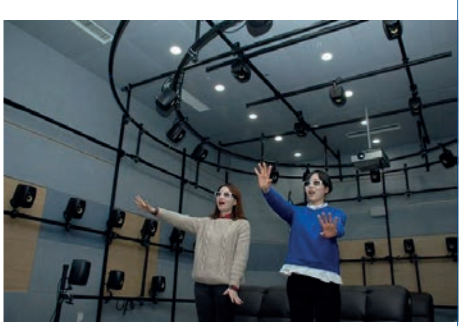
The project is the development of table-type terminal technology for digital holography, which is being promoted by Giga Korea from 2014 to 2021. Through this project, researchers introduced a display that allows users to view the world's first 5-inch color video hologram to multiple users from any angle. It was selected as one of the 100 National R&D Excellence in 2017 and received the 2020 Award of Excellence from Society for Information Display (SID) in August.

The developmental project of core technology for holo-TV’s holographic video service was carried out from 2019 and will continue through 2028. The holographic video camera is the only technology in the world to acquire a hologram of color videos that are directly used in reality like the existing 2D camera without using LED or lasers.

2-2-3-4. 3D Immersive Audio Technology

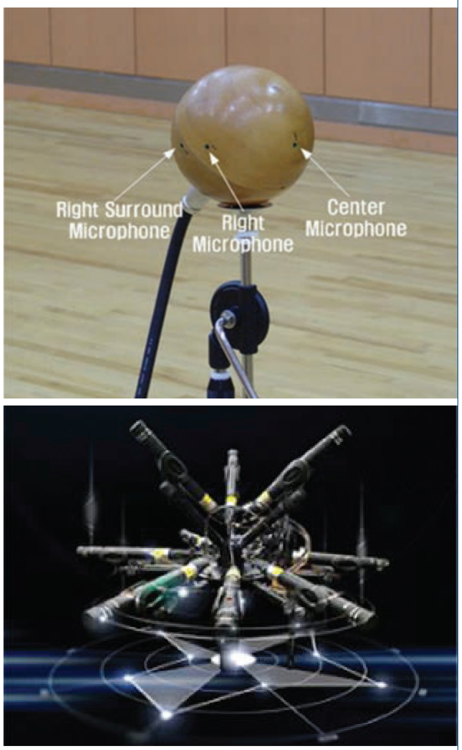
3D immersive audio technology presents listeners a realistic sound that resembles the original sound source. In order to develop such technology, ETRI developed the Smart TV in 2002, DTV’s core technology in 2008, creative music technology in 2009, broadcasting technology of UHDTV in support of multiview glasses-free 3D in 2011, UHD’s convergence service of signage in support of ultra high-quality content in 2014, and spatial audio source technology in 2017.

In 2020, ETRI initiated the development project and standardization of acoustic coding technology for high-quality simultaneous support space to reproduce special audio of full freedom with the experience of developing the 3D immersive audio technology in the previous 20 years.



3D immersive audio

2-2-4. Broadcasting Media of Next Generation



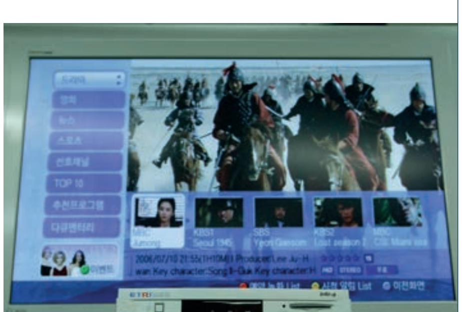
5.1-channel microphone (2005) and 10.2-channel microphone (2016)

2-2-4-1. Data and Personalized Broadcasting Technology

In order to introduce data broadcasting services along with digital TV, ETRI carried out two development projects for integrated data broadcasting technology and super-intelligent multimedia anytime-anywhere realistic TV (Smart TV) from 2000 to 2006. Through these two projects, ETRI developed the nation's first terrestrial interactive broadcasting system compliant with the ATSC data broadcasting standards of the United States in May 2003, and a data broadcasting system based on ATSC-ACAP that is compatible with terrestrial and cable broadcasting media in 2006.

In addition, from 2001 to 2003, ETRI worked on development projects for MPEG-7-based metadata broadcasting technology and super-intelligent multimedia anytime-anywhere realistic TV (Smart TV) to introduce customized broadcasting services. ETRI developed an MPEG-7-based metadata editing tool, transmission server, and terminal platform that allows viewers to access content and services at any time and in any way on the user terminal platform, regardless of the broadcast time. These technologies have become the basis for customized and intelligent broadcasting services. In addition, it secured a number of standard intellectual property rights by actively participating in MPEG-7 international standardization.

The technologies accumulated through the development of data broadcasting and customized broadcasting technology, broadcasting experience for new services, and the manpower with technological know-how became the core foundations for the next-generation media industry.



Personalized broadcasting platform

2-2-4-2. IPTV Broadcasting Technology

In the mid-2000s, the government set out the goal of developing next-generation IPTV technologies that can access content anytime, anywhere, at any device. This is set to achieve the vision of providing world-class user-centered IPTV services, constructing a virtuous ecosystem of IPTV, and winning the title as a global powerhouse with IPTV's three technologies.

The world's first ATSC DASE-based terrestrial data broadcasting experiment during the 2002 Korea-Japan World Cup(June, 2002, ETRI)

IPTV 2.0 Concept Diagram

Demonstration service applying next-generation IPTV technology to the system(2010. 12. 22. KT)

ETRI selected core technologies of different fields based around the CPND ecosystem14 and set the focus on developing required technology and its standardization. They placed focused on head-end equipment for transmission and utilization of content's adaptive security technology, and regardless of the device for adaptive compression of super high-quality media of IPTV, it can freely adjust the quality of services by environment for service consumption. It became easier to create new broadcasting, telecommunications, and convergence services in the wired and wireless integrated network environment for content-sharing platform and standardization, which led to the establishment of a platform for broadcasting, communication, and testing of convergence services. In terms of network, ETRI as one of Korea's greatest strength, worked to gain quality of service (QoS) and quality of experience (QoE) in all sections of the integrated wired and wireless networks. In terms of device, ETRI is working on the standardization and upgrade of middlewares and set-top boxes' functions for interactions between devices for domestic enterprises to lead the field.

ETRI's was able to build a world class status in technology involving IPTV 2.015 by successfully developing the core technologies for the next-generation IPTV and its corrective technology. It also got a hold of the prosumer-based next-generation open IPTV platform, offering convergence of broadcasting and communication service to various content creators and producers of third-party services.

Securing such technologies became the foundation for diversifying the bi-directional business and application services, leading to the growth of the domestic IPTV industry in terms of quality and size. The technological achievements through international standardization include six ITU-T stands, nine international standard patents, and six TTA standardization.

2-2-4-3. Beyond Smart TV Broadcasting Technology

ETRI introduced the concept of next generation smart TV (smart TV 2.0), which is different from the existing smart TV (smart TV 1.0). Smart TV 2.0 is a next-generation smart TV that is controllable by user-friendly multimodal human interface and provides services such as multi-screen-based broadcasting type, communication type, broadcasting convergence, communication convergence, and computer type.

ETRI's development of a beyond smart TV technology in 2011 led to the development of smart TV 2.0. The goal of the project was to ensure user's diverse and beneficial customized content and while allowing for convenient control of the TV. ETRI developed Korea's smart TV 2.0 devices and platform to the highest level through the development of beyond smart TV technology.

Various HW, SW and application services that were not in the older smart TV were provided for ETRI's smart TV 2.0, which changed the traditional TV industry to be centered on SW and content central in a new ecosystem in terms of commercialization. In addition, it moved away from older TV viewing culture in terms of sociocultural aspect, by providing various new information, culture, and experience opportunities such as infotainment, video conferencing, social media, and games through TV.

2-2-4-4. Ultra Wide Vision Technology

Ultra wide vision (UWV), a panoramic video of a large screen, is an ultra-high-definition video with a wide viewing angle of 120° or more, like a human’s field of view. It is a realistic video technology that provides live performance of sports events or cultural performances without having to go to the event site. The viewers can immerse into the atmosphere that fills their entire range of vision. ETRI's start of securing the source of UWV from 2011 led to the investment of about KRW 7 billion in research funds until 2018, and the development of live broadcasting technology at 12Kx2K level in UWV-based 4K-class ultra-high-definition video.

Ultra Wide Vision System

ETRI not only developed technology, but also produced content of various genres, including sports events, K-Pop concerts, tourism, musicals, and movies, and these contents verified for the technologies’ various applications. In cooperation with the Ministry of Science and ICT at the 2018 PyeongChang Winter Olympics, the production of various UWV content, including major sports games, K-pop concerts, and Korea's natural scenery, were presented to the public. On February 19, 2018, a UWV video was broadcasted live at the ICT lounge at the Incheon International Airport, which was hosted by the Gangneung Art Center. In addition, in cooperation with the Korea Institute

Netherlands-Peru national soccer match intercontinental relay experiment (2018. 9.)

of Science and Technology Information, TNO and Johan Cruyff Arena on September 6, 2018, such technology was applied to present a live broadcast of a friendly match between the Netherlands and Peru at Johan Cruyff Arena's soccer field in Amsterdam and in 2019, SK Telecom's 5GX wide view service, broadcasted a professional baseball game in a 5G environment.

2-2-5. Protection of Broadcast Content

2-2-5-1. DCAS Technology

Since the transition from analog to digital method for cable broadcasting, DCAS16 technology that can be equipped with security modules of the U.S. multi system operator (MSO), National Cable Television Association (NCTA) and the U.S. Cable TV Broadcasting and Telecommunications Association has been reviewed and standardized. The domestic cable broadcasting industry also begun to call for the introduction of the technology to reduce subscribers' inconvenience and costs.

ETRI carried out the development of the downloadable limit reception system by investing a total of KRW 10.4 billion (KRW 7.3 billion in government contributions and KRW 3.1 billion in private contributions) for three years from March 2007 to February 2010. ETRI led the research, and domestic enterprises were involved in the early commercialization of the developed equipment. CoreTrust oversaw the server development for certification of DCAS's head end for cable broadcasting. DigitalStream oversaw developing DCAS's device platform for cable broadcasting and finally, CoreCross was in charge of developing DCAS's device security module and descrambler chip for cable broadcasting. Meanwhile, KLabs participated to verify the technology of broadcasting and commercialization of the pilot program. This effort led to the world's first success in implementing DCAS's system.

DRM Standard

UCI-Watermark Experimental Broadcasting by Taejeon Broadcasting Corporation (TJB) (January 21, 2010, ETRI/TJB)

2-2-5-2. Protection and Management Technology of Broadcasting Content

As analog broadcasting was converted to digital broadcasting and the functions of TV's multimedia could be provided, the possibility of unauthorized copying and illegal distribution of high-quality broadcasting content increased as side effects. Especially since K-dramas, pop songs, and the growing value of domestic broadcasting programs such as movies has led to a surge in cases of infringement of intellectual property rights due to unauthorized copying and illegal distribution in some parts of East Asia.

Also, early personal Internet TV broadcasting services were in conflict between existing broadcasting media and copyright infringement due to lack of laws and systems. As a result, DRM technology that protects the copyright of content and prevent piracy became in-demand.

Since 2001, ETRI steadily developed DRM technology to protect broadcasting content through development projects for digital content technology in 2001, framework for broadcasting and communication convergence based on MPEG-21 in 2002, smart TV in 2002, technology for protecting terrestrial DTV broadcasting programs in 2007, and framework for distribution of broadcasting content via universal content identifier (UCI), and the national standard identification system in 2009. These challenges focused on solving the problem of lack of mutual compatibility, a drawback to ETRI's existing DRM technology. As a result, the concept of ToolPack, which is provided in the form of a package for copyright management tools of broadcast content, is defined for the first time in the world. ETRI also developed a core DRM solution that provides mutual compatibility that is applicable to various media such as digital cable broadcasting, satellite broadcasting, and IPTV.

In 2009, the experiment on HD's broadcast, which was applied for program protection for terrestrial broadcasting along with the four broadcasters (KBS, MBC, SBS, and EBS), verified ETRI's level of protection, management, and technology. In addition, the SBS and TJB's broadcasting content were secretly inserted in the form of UCI's digital watermark at the end of 2010, and the experiment was conducted in the capital area and Chungnam.

2-2-6. Disaster/Welfare Broadcasting

2-2-6-1. Disaster Broadcasting Technology

The purpose of disaster broadcasting is to quickly deliver the situation of a national disaster to the citizens to minimize damage by notifying them of the estimated level of danger and countermeasures for such situations. ETRI laid down the technical foundation for disaster broadcasting to fully achieve this purpose.

ETRI developed a technology for broadcasting disaster alerts based on terrestrial DMB in 2005 and a new disaster alert transmission system, where urgent disaster information was provided to the vehicle's built-in DMB devices and the individual's portable DMB device was prepared. In addition, the development of terrestrial DMB disaster broadcasting technology for tunnels, a technology that can provide local disaster warning broadcasts in certain areas such as tunnels and underground spaces in the event of disasters, took place in 2009.

Since then, in 2016 and 2017, a series of earthquakes of magnitude 5.0 or higher in Gyeongju and Pohang areas have revealed the problems of the existing disaster alert delivery system. Discussions have been made for installing new UHD technology for disaster broadcasting by terrestrial broadcasters.

As a result, the development of the disaster broadcasting technology based on terrestrial UHD for reducing disaster damage began in 2018, followed by the development of the customized technology for each region, group and device. ETRI also expanded technology for disaster broadcasting services into indoor and outdoor environment, rich media service technology to provide multimedia information on disasters, and handover technology of disaster broadcasting services to expand the coverage of services in the mobile environment.

Declaration Ceremony of Terrestrial UHD Disaster Alert Service (September 23, 2019).

With such foundation, it marked the beginning of the world's first disaster alert service of terrestrial UHD based on the ATSC 3.0 standard in 2019, while related technologies are currently implemented in some domestic terrestrial broadcasting channels. In addition, a joint pilot service with U.S. broadcasters took place to promote the excellence of Korea's disaster alert service technology and many domestic broadcasting equipment companies prepared to enter the US market also participated in it.

Avatar sign video showing personal guidelines for COVID-19 quarantine (2020.)

2-2-6-2. Welfare Broadcasting Technology for PWD

ETRI's development of broadcasting technology for people with disability (PWD) began in 2013. The development of broadcasting technology for PWD, which includes the development of emotional speech synthesis technology using deep learning technology from 2019, emotional expression subtitle service technology, which includes moving emoticons, and Avatar sign language technology, which is connected and provided by converting Korean into Korean sign language, is under way. Taking in consideration complaints and improvement by organizations of people with audio and visual impairment who are direct consumers, promotion of quantitative and qualitative improvement of technology and rapid change in the broadcasting environment (such as the convergence and digitalization of broadcasting and telecommunications), the gap between alienation and information of PWD is becoming more serious, and measures to overcome these problems are being made.

2-3. Content - Realizing a Human-centered Digital Life

ETRI began to lead the development of digital content technologies in the late 1990s, with the development of digital actors, 3D game engines, hologram representation technology, and interactive VR/AR over the past 20 years.

Computer Graphics

ETRI's representative achievement in the field of technology in computer graphics (CG) is digital actors developed in 2005. Digital actors were acclaimed for acting dangerous scenes or difficult actions in films such as For Horowitz, Hanbando, and Joong-cheon on behalf of human actors, and a technology award was awarded at the Korean research institute's first Daejong Film Festival and the Blue Dragon Film Festival. ETRI then developed fluid simulation technology, which realistically reproduces the movement of water and fire in 2007, and digital creature technology, which naturally expresses the movement of fish and birds in 2009. In addition, the interactive real 3D technology developed in 2010 enhanced the experience of 3D images, which had been viewed unilaterally, that are now viewable in the viewer's desired form and point of view and can be watched freely as if they were playing a game.

Digital actor

Game Content

Researchers tried to develop various core technologies in an integrated manner because game engines require comprehensive IT such as servers, networks, terminals, and CGs due their nature. In 2003, Dream 3D, a game engine that combines these technologies, was developed. While in 2005, a cross-platform game engine was developed, creating an environment where PC games can be connected to other devices such as consoles and mobile devices. Also, in 2008, the world's first solution to test the performance and stability of a game server named Venus Blue was developed, while in 2010, the improved EasyQA was developed.

Establishment of Digital Animation Research Society

Immersive Experience Content

ETRI also led the development of realistic experience content that gives people a sense of reality and immersion as if they were seeing or experiencing real situations. First, based on long research experience in AR and VR technology, urban VR theme park technology (such as air glider simulator, virtual safari system, lightning punch system, virtual roller coaster, etc.) was developed from the early 2010s and was actually applied to domestic and foreign theme parks. It was followed by the development of 3D avatar, a system that can be used for makeup and makeup simulation. Also, content such as Touchbeam, Hetris, X-top, etc. where users can experience assembling and restoring digital cultural assets, were developed. In addition, the high-speed generation and processing of ultra-high-point images, the high-speed generation technology of holograms, the realistic interactive technology of holograms, and tools to produce hyper-point images have been secured so that hyper-connected experiences can be enjoyed by anyone in the giga-level even in wired and wireless network environment in the 5G era.

Education Content

In the mid-2000s, as e-learning became a new paradigm for education, ETRI also started the development of the technology for educational content. In 2008, ETRI developed 3D interactive learning content that allows customized learning anytime and anywhere with terminals and mobile phones dedicated to learning. In 2009, ETRI developed a variety of 3D content, including an experience-type fairy tale research service that can be felt directly by making the background of various fairy tales into a virtual 3D space.

Also, the development of participatory interactive content was focused on after 2014, securing participatory e-learning technology used by AR, VR, and deep learning such as interactive learning system of space, experience-type learning system, and the tutoring system of customized creative learning. In addition, the VR Sports System for students' indoor physical education activities has been developed and distributed to elementary, middle, and high schools across the country.


3D interactive learning contents

Content Search/Recognition

ETRI began developing the technology of image search in the late 2000s and secured the technology to search for world-class images, ranking first in the International Low Power Image Recognition Contest (LPIRC) in 2018. In addition, the development of three-dimensional motion recognition technology has secured technology that can recognize movements without a separate equipment. Golf and home training are a few examples. Motion-based music recommendation technology that recommends music according to the user's mood was also developed.

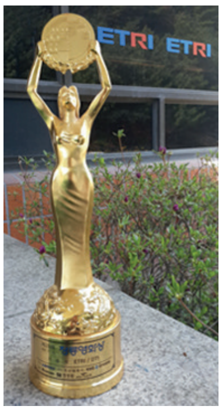
Copyright Protection Technology

From 2001, the development of digital rights management (DRM) technology for content copyright protection began for ETRI. ETRI developed digital forensic marking technology that monitors and tracks the first distributor of illegal content, illegal work filtering technology that prevents illegal distribution of content in P2P, web hard drives, and portals, and digital fingerprinting technology that protects copyright by extracting unique characteristics of content such as human fingerprints. Also, within the scope of use of DRM's technology, distribution in the form of downloading and streaming was limited, but it gradually developed to a different environment beyond smartphones and multicast. ETRI's DRM interlocking technology was adopted as the standard for ITU-T in 2011. After 2015, it upgraded the technology of copyright by introducing artificial intelligence technology to DRM.

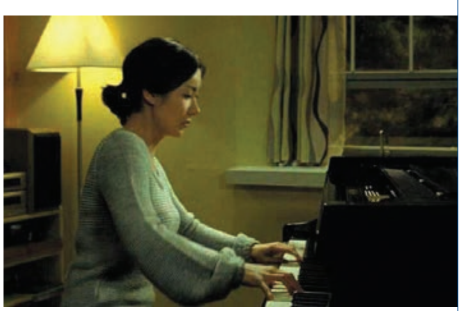
Over the past 20 years, ETRI has led the field of domestic digital content by securing technology for CG, VR, games, DRM, and e-learning. In the 2020s, it is challenging the development of core technologies of next-generation content such as creation and recognition of content based on artificial intelligence, and immersive sensual technology that includes touch and smell. Through this, ETRI will always provide people with a new and amazing experience and pleasure, and create a happy digital life centered on humans and culture.

2-3-1. Computer Graphics

2-3-1-1. Digital Actor Technology



Blue Dragon Film Festival Award



Body digital double in the movie 'For Horowitz'

Until the early 2000s, technology for computer graphics (CG) was led by mainstream Hollywood studios in the United States, which was rarely made public. Due to the small size of CG companies in Korea, the development of such technology was not even possible.

ETRI promoted the project of life-level digital video content and development of SW from 2003 to 2007 to overcome this situation and secured the source technology for CG. Through this task, ETRI developed the core technology that produces high-quality CG special effects, including digital actors.

A digital actor is a digital character that can replace a real, human actor when producing a film by applying almost the same level of modeling, animation, and rendering technology as the actual film.

The technology for digital actor has greatly raised the level of domestic video content by acting out dangerous or difficult actions scenes on behalf of actors in movies such as For Horowitz, Hanbando, and Joong-cheon. In 2007, it won the Daejong Film Festival's Film Technology Award (June) and the Blue Dragon Film Festival's CG Technology Award (December) for the first time among domestic research institutes.

2-3-1-2. Fluid Simulation Technology

Simulation of bubble generation by gas

Fluid simulation is to compute and visualize the random behavior of fluid that moves on the surface. such as water, fire and smoke. ETRI carried out the task of development of fluid simulation technology dedicated to visual effects in collaboration with Australia's CSIRO from 2004 to 2008.

While precisely analyzing existing technologies, researchers secured various resolution simulation techonology to optimize the presentation of steam, dust, fire, soap membrane and the source of fluid control.

RealFit: Virtual try on technology

2-3-1-3. Interactive Real 3D Technology

ETRI developed Interactive Real 3D Technology for six years from 2008 through the project for development of full 3D reconstruction in broadcasting communication fusion environment.

Through the development of the first stage of research, ETRI promoted the development of technologies based on the restoration of full 3D and the definition full 3D transmission's format. Through this, it developed technologies on basics and elements, such as the appearance of dynamic objects, motion restoration technology, static landscape, background separation technology, and multi-camera correction technology. In the second phase of the study, the development of the source for full 3D restoration and the standardization of codecs for full 3D transmission were promoted, including the technology of restoring 3D appearance and motion for a large number of moving people, and the core technology of visualization for extremely realistic expressions. In addition, in the development of the three-stage research, the technological development for restoration of full 3D and the standardization of the Lego-type codec framework were carried out.

AVAGEN: 3D photo booth

2-3-1-4. 3D Avagen

The movie "Avatar", which was released in 2009, has raised standards for 3D three-dimensional images, and naturally, attention of the population shifted to the technology and process of 3D video production. Against this backdrop, ETRI developed a technology and system for reconstructing 3D face based on stereo image, called 'Avagen' that is abbreviation for Avatar Generation. This analyzes information on the contour of a face from two photos of a face taken at a different angle and turns it into a three-dimensional data, which makes it easy to obtain 3D face data without 3D modeling.

Digital content technology demonstration

2-3-2. Game Content

2-3-2-1. Dream 3D

ETRI began developing game engines in 2001 by developing online 3D game engines. Its business goal was to secure an integrated solution for content on online and 3D games. ETRI involved Korean game producers in the business for commercialization and promoted the establishment of the Game Technology Support Center at the same time, actively supporting game engines and authoring tools to domestic online game companies.

At the beginning of the project, ETRI already had core technologies related to CG, including more than a decade of accumulated knowledge on rendering, sound, and animation. They also had network and server technology for the development of MMORPG[17] content. In 2003, ETRI succeeded in developing Dream 3D, a game engine optimized for MMORPG. Dream 3D produces the effects for animation, audio and sound field, and integrates content editors and server engines separated into indoor and outdoor environments, making it an unprecedented breakthrough solution at the time.

2-3-2-2. Game Server Load Test Solution

Game developers and service companies are supposed to fully verify the performance and stability of the game's server before releasing a new online game, but until the early 2000s, they had mainly humans to verify them and it took a lot of time and money, which was inefficient.

Demo contents like MMORPG

To address this problem, ETRI began developing technologies in which performance and stability can be tested by non-human SW through creating virtual users and generating artificial load on servers, challenging the development of cross-platform game technology based on multi-core CPU and MPU from 2006 to 2008. As a result, Virtual Environment Network User Simulation (“Venus Blue,” Blue Edition), a test solution for verifying the performance and stability of servers before the release of online games in 2007, was developed for the first time in the world.

Venus Blue has left a unique example of technology transfer abroad in the stage of a noncommercial prototype. In the first year of development, the technology was transferred to Testronic Labs, a global company responsible for multimedia testing of global companies such as Sony, BBC, Disney, and Universal Studios. As technological transfer became known, many domestic game companies also introduced Venus Blue, and the time and cost of game server testing was greatly reduced.

2-3-3. Immersive Experience Content

2-3-3-1. VR Theme Park Technology

Since the early 2010s, ETRI started to develop the core technology of the urban VR theme park. In 2011, it promoted the development for the Live 4D content platform with the expansion of hands-on experience space to develop some of the key elements necessary for the realistic visualization and interaction of VR content. ETRI conducted a follow-up development project for immersive join & joy content based on Instant 3D objects that enables remote users' simultaneous participation and experience, which costed around KRW 18 billion from 2014 to 2018 as a follow-up project to build a pilot model of the indoor VR theme park.

Opening ceremony of 'Lightning Man(*Bungaeman*) Space Center' (December 10, 2017)

Through the performance of these projects, researchers succeeded in developing interactive VR content systems for a variety of hands-on experiences such as air glider simulator, which allows a virtual experience like flying on a real paragliding, Virtual Safari System, which allows users to interact with objects of various animals appearing in the content, Lightning Punch System, which allows users to stretch their hands forward and interact with a large projection content system, and virtual roller coaster, which allows users to experience theme content related to China by riding on a double-track rail installed in a small indoor space.

Realistic makeup simulation

2-3-3-2. Realistic Makeup Simulation Technology

In 2011, ETRI carried out the task of developing simulation of realistic makeup based on 3D facial avatars. The goal of the project was to create a 3D facial avatar that resembles the appearance of the user, then develop a system to enable makeup simulation as a virtual tool and apply it to actual performances, plays, and regular university classes.

ETRI accurately detected the skin color of the face restored in three dimensions by using realistic color reproduction technology previously had, then developed a technology that accurately detects the color of actual cosmetics based on the spectroscopy information. In addition, based on those acquired information, it succeeded in developing a simulation technology that reproduces the same effect as actual makeup on a three-dimensional face, considering the relationship between skin color and cosmetics. The technology for expressing accurate colors on a computer using spectral information was adopted as an international standard for MPEG-V in 2016.

TouchBIM

X-Top

2-3-3-3. Content Technology for Digital Heritage Experience

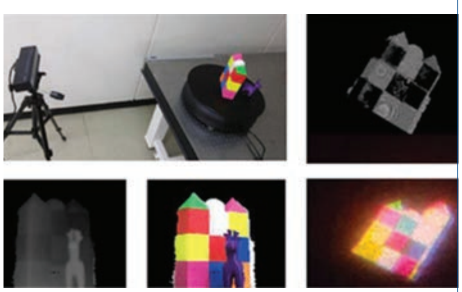
For three years starting in 2013, ETRI carried out the development of technology for virtual restoration and interactive simulation of digital cultural heritage for the purpose of experiencing and learning about cultural properties of traditional structures. The goal of the project was to produce pilot content by developing content for digital cultural assets that enable the realistic reproduction of building cultural assets and the simulation of interactive restoration to experience digital cultural assets.

ETRI used actual CAD drawings and three-dimensional scanned data provided by the Cultural Heritage Administration to model Korean traditional architectural materials, developed the BIM construction technology, and established a pipeline of works on digital cultural heritage by linking them with tools that are widely used in industrial sites. This pipeline laid the foundation for producing digital cultural heritages in various forms and purposes, using accurate information on the characteristics of Korean cultural heritages.

2-3-3-4. Glasses-Free 3D and Hologram Processing Technology

Realistic VR fire training technology

As part of Giga Korea's project, ETRI conducted the project of developing technologies for high-capacity and two-way immersive content since 2013. The goal of this task was to develop a system of large-volume, interactive multimedia technology at the core of holographic content and a system with realistic content that can be used in areas of education, medicine, broadcasting and communications, to realize the service of Tele-experience[19] in the environment of giga-level wired and wireless networks.



Hologram acquisition device and high-speed CGH result

Through the project, researchers developed high-speed generation and processing of point cloud images, high-speed generation of holograms, and tools to produce super multi-view images.

In the field of high-speed generation and processing of super multi-view images, a technology to generate images from the final point of view of 180 to 350 in real time using 18 cameras was developed. In addition, ETRI developed a GPU-based real-time multiplexing technology that works with a commercial game engine, which has successfully achieved performance of more than 70 fps at the point of view of 108 and more than 30 fps at the point of view of 300, making it the world's first and best technology. This technology enabled realistic remote conferencing using glasses-free stereoscopic images, realistic telemedicine, realistic broadcasting, realistic sports broadcasting, and remote.

2-3-4. Educational Content

3D virtual experience fairy tale contents (December, 2009, Seoul National Library for Children and Young Adults)

2-3-4-1. Interactive 3D Learning Content Technology

Since the launch of EBS's Internet CSAT broadcasting service in 2004, e-learning has become the new paradigm for education, and the convergence of IT and education has progressed rapidly. Thus, ETRI piloted the support for 3D learning content and development of u-learning-based technology in 2008. The goal of the project was to develop source technologies for VR-based virtual-world experiences and apply them to public libraries and elementary, middle, and high schools.

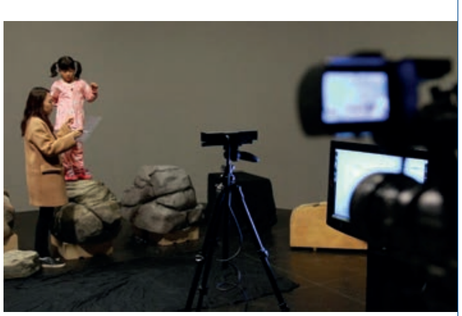
As a result of the study, ETRI developed 3D interactive learning content that allows customized learning anytime or anywhere with learning-only terminals and mobile phones in 2008. In 2009, ETRI secured a variety of 3D content such as developing an experience-type story-telling service that allows users to touch them directly by turning the background of various fairy tales into a 3D virtual space.

This service provides 23 contents to about 70 institutions, including libraries and schools, and is significant in that it contributed to the promotion of books and revitalization of libraries by expanding book-oriented book services in the form of a three-dimensional experience.

2-3-4-2. Participatory E-learning Technology

ETRI conducted the development of tutoring technology with customized interaction for learners based on the environment of participatory, interactive content, along with collaborative learning since 2014, to establish an environment for mutual interaction and participatory education based on advanced ICTs. In particular, through services of future advanced education in the e-learning environment, it intended to realize national policy goals, such as the revitalization of public education, elimination of financial burden for private education, equal distribution of educational opportunities, resolution for incompatibility between regions and classes, and training for future human resources. The techniques developed through the task were applied to various fields in education. The virtual augmented reality education system was applied in kindergarten, and for the first time in Korea, augmented reality technology was used for educational broadcasting such as EBS's Ding Dong Dang Kindergarten (TV program) and English education radio program, while applying customized learning technology to English education in cooperation with Jeju National University of Education. In addition, it applied the developed virtual augmented reality technology not only in education but also in areas such as exhibition halls and museums, and even exported it to China.

Spatial AR interactive learning system



EBS's ‘Ding Dong Dang Kindergarten’ filming using spatial AR system (December, 2015, EBS)

VR sports system

VR sports room
(2017, Seoul Oksu Elementary School)

2-3-4-3. Virtual Reality Sports Technology

From 2015 to 2019, ETRI began the Ministry of Culture, Sports and Tourism (MCST)'s project for the integrated platform of realistic sports for youths. Researchers focused on the development of an algorithm that allows the system to accurately analyze human body movements such as soccer steps, taekwondo posture and the three-dimensional motion of sports equipment without having to wear additional devices.

To apply the VR sports system to the actual school site, researchers built a VR sports room at Seoul Oksu Elementary School (for general students) in 2016, Seoul Sinjeong Elementary School (for elite players) in 2017, and Seoul Samyang Elementary School (by applying double screen techniques) in 2018.

Convinced of the outstanding utility of the VR sports system, the MCST launched a project to distribute virtual reality sports rooms jointly with local governments in 2017 and plans to distribute VR sports rooms to more than 600 elementary schools across the country by 2023. VR sports rooms are also being exported abroad. It was exported to Beijing, Yanan, and Shenzhen in China and Jakarta, Indonesia. Its commercialization is also underway in Vietnam and the Middle East.

2-3-5. Content Search/Recognition

2-3-5-1. Image Searching Technology

As the demand for image search increased with the explosive growth of smartphone and video sharing services, ETRI began developing the technology for image searching in 2008. It upgraded its image search technology by carrying out the rich UCC technology development to develop an identifier for video search for two years in 2011, a UVD-based smart mobile search in 2012, and content visual browsing online and offline in 2018.

ETRI focused on the technology for extracting and analyzing features of an image and the design of a structure of an efficient search system to develop the technology for image search. Since the mid-2010s, it focused on developing technologies for classifying and detecting images using deep learning.

Visual Place Recognition Service
Using Street-View Images

ETRI is actively engaged in international standardization of MPEG-7, while increasing its technology through continuous participation in international image search competitions. As a result, it ranked fifth in ImageNet Large Scale Visual Recognition Challenge (ILSVRC) in 2016 with image classification and third in image detection. In addition, it ranked first in the Low-Power Image Recognition Challenge (LPIRC) in 2018 in the field of lightweight deep-learning-based technology. LPIRC is a competition that measures the performance and power of detecting objects in a video, which is significant in that it evaluates the possibility of applying the actual technology. In addition, ETRI ranked eighth in the Google Landmark Retrieval competition in 2018.

2-3-5-2. Motion Recognition Technology

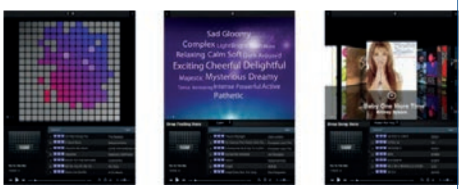
ETRI developed a three-dimensional depth-sensing technology with structural light through a three-year project starting in 2010, which secured the technology that extracts a user's skeleton and recognizes motion.

Over the next three years since 2013, an advanced depth-sensing technology that can measure in all directions in 360 degrees and has a user-motion recognition technology based on the extraction of multiple user skeleton was developed and applied to the field of sports (golf). This technology was then transferred and commercialized to Maum Golf Co., Ltd., a developer of screen golf systems. This allows users to automatically analyze their swing poses just by using screen golf courses.

Through the task of status of non-contact users interaction technology based on recognition of intention, the recognition of user behavior from tow-dimensional color images was developed and recognizes user behavior from two-dimensional color images was developed and applied to home workout which was conducted for four years starting 2016. It also developed a technology for skeleton extraction and motion recognition based on color images that can be mounted on smartphones and can recognize motion without additional equipment. The technology was transferred to Kakao VX Corp., a developer of the home workout system. Its commercialization as a home workout system that intelligently analyzes the recovery of movement and the user's pose by notifying errors is still under process.

Golf swing poses analysis service based on
motion recognition technology

2-3-5-3. Emotion-based Music Recommendation Technology



Emotion-based music recommendation technology

In 2010, ETRI began the development of an emotion-based music recommendation technology to create an emotional classification model for music beyond simple algorithmic approaches through a digital rights management (DRM) R&D project supported by the MCST.

The developed technology was first unveiled to the public in 2011 through Olleh Music's emotion-based recommendation service that automatically selects music according to feelings and emotions. Since then, emotion-based music recommendation technology has been used in Korea's top music services such as Bugs Music and SKT Music Mate, following KT Music. It was also installed in all Keumyoung karaoke machines, which was released after 2014.

2-4. Shortcoming

Broadcast Media

ETRI led the domestic and overseas standardization by developing necessary technologies at the world's highest level whenever Korea challenged new services such as HDTV broadcasting, DMB broadcasting, 3DTV broadcasting, IPTV broadcasting, and UHDTV broadcasting for nearly 30 years.

Recent social trends, such as hyper-connected society based on ICT (where everything is connected to the network), the environment of technology based on artificial intelligence, the importance of personalized sensibility, and the routinization of media consumption and creation, are gradually diversifying and intellectualizing the technology and services of broadcasting media. Accordingly, digitization of content, realization, convergence of broadcasting and communication, and mobilization and smartization of devices are rapidly progressing.

In the future, the technology for broadcasting media is expected to develop from gigamedia, such as UHD and all-round VR, to terramedia that enables hyper-realistic services, such as fully three-dimensional holograms, LF images, and spatial media. Teramedia will digitize the real world and reproduce it into real life level. In addition, the structural space composition of the media will provide a surreal experience that goes beyond the constraints of time and space, and humans will face a new era of media that maximizes the depth of communication and experience.

In the terramedia era, ETRI will include UWV service, which provides more than 100 degrees of optical vision to provide a field sense that exceeds UHD; emotion-based broadcasting service that enhances human senses and emotions using the five human senses, emotions and biological information; LF and broadcasting service, which gives users the same three-dimensional effect as reality; and VR and AR beyond 3D UHDTV. It also seeks to focus its capabilities on the development of related technologies as traditional single and discontinued media services are expected to evolve into a form of new media combined with multiple AVs and graphics.

On the other hand, advances in media and telecommunications will make it very easy for ordinary individuals to produce or distribute videos, and the field of personal broadcasting and media will be greatly expanded. Accordingly, ETRI plans to quickly develop technologies that analyze and predict the propensity of individual media consumption and provide personalized services by using artificial intelligence and big data analysis.

ETRI will continue to strive in providing people with a more new and enjoyable experience through the development of hyper-realistic broadcasting media technology that breaks the boundary between virtual and reality.

Content

Since the late 1990s, ETRI has been providing new experiences that have never existed before by studying virtual reality, computer graphics, intelligent interaction, and computer games. In the future, ETRI will promote the development of innovative technologies that will lead the global content technology and industry by utilizing its long accumulated technologies, commercialization experience, and Korean Wave content.

ETRI's advanced content technology will enable a variety of things that have only been imagined.

This means that sophisticated digital actors that are not distinguishable from real actors will become the center of the film industry, and with the development of 3D avatar modeling, they will be able to fit clothes in stores or compare before and after effects of plastic surgery. Also, game engines will be converged with artificial intelligence to become more realistic. Moreover, using the cloud environment, people will be able to play high-end games anytime, anywhere, regardless of the capacity of the user's device.

In addition, super multi-view and hologram images will make it possible to enjoy a remote working environment at home as if actually working in the workplace, or watching a sports game as if you are in a stadium. For motion recognition technology, it will evolve into a technology that recognizes emotions, conditions, and intentions by detecting the movement in that moment and the biological signal that changes according to the user's emotion.

Golf swing analysis service based on motion recognition technology

ETRI will continue to realize a cutting-edge digital life centered on humans and culture through the development of hyper-realistic, immersive content that combines artificial intelligence, VR, AR, and content technology of the five senses.

PART 3

Software/ Computing

3

Software/Computing

3-1. Outline

Software

Artificial intelligence (AI) is one of the most important topics in the scientific technology industry in 2020. AI is now becoming a commodity, a product that is easily provided by simply opening a valve, like water, electricity, and gas, and is securing itself as a whole paradigm beyond technology. The foundation of AI is based on software such as operating systems.

ETRI started operating system development since 1987, starting with the development project for mid-sized computers (TiCom series). Through this, an operating system for multiprocessors was implemented with independent os technology. Parallel operating system technology based on microkernels was also developed for the first time in the world. Then, from the late 1990s, when “embedded” became a new term, development was conducted for embedded operating systems, and through continuous development of QPlus-T, QPlus-P, and QPlus operating system platform and QPlus/Esto, QPlus Web, etc., ETRI established itself as an independent “software leader.” Meanwhile, from 1994 to the mid-2000s, foreign development methodology were completely replaced through the MaRMI series, a Korean software development methodology.

Starting from the 2000s, there was a boom for people seeking Linux. Accordingly, ETRI developed Booyo, a domestically distributed standard software platform, up to V3.0 and passed it on to public institutions and corporations. Starting then, various Linux servers based on this standard were released within Korea. Also, through the development of "WIPI", a Korean standard wireless Internet platform, it provided the foundations for domestic mobile communication businesses to develop independent from foreign technology.

In the 2010s, through the SW innovation plan, backed up largely by the government while beginning the development of many core operating systems, development of cyber-physical system (CPS), a next-generation software core technology, was also kickstarted. The development team at the time immersed themselves in development by persuading the academic and research fields, where even the term CPS was yet to be established.

MaRMI manual

Software research department workshop

From 2014 onwards, CPS has been continuously applied to smart factories, IoT, digital twins, etc.

After the 2010s, ETRI put even greater efforts into software development for the safety of the nation and its citizens. In the case of embedded software, the main task of the CE sector was given to the private sector while ETRI focused on important system fields (SCS) such as national defense, flight, or driving. It then developed SCS software such as QPlus-Air, QPlus-Hyper, and QPlus-Earth, which are being actively applied to new industries such as drones.

Artificial Intelligence

AI technology is an innovative technology which brings large-scale changes in the structure of the industry and society, playing an important role in the quality of life and national competitiveness. Since the 1990s and the beginnings of AI technology, with the goal of securing long-term AI technology where AI can independently listen and learn just like humans, ETRI conducted a research with a focus on the fields of linguistic intelligence, voice intelligence, visual intelligence, and smart data.

GenieTalk: Multilingual speech translation service

Automatic translation technologies for various languages have been developed starting from development of an automatic translation system for Japanese-Korean in 1996 and Korean-Japanese in 1997. By structuring the global consortium C-STARII in 1996, a collective dialogic verbal language translation system was secured that combines voice recognition, language translation, and voice synthesis technology.

Later, ETRI continued with smaller scale projects, but dived into related research with the rapid rise in global interest in AIs since the 2010s. In particular, the development of GenieTalk, an automatic interpretation and translation app for mobile devices, began in 2012. GenieTalk could automatically interpret and translate between three languages in 2014, which was used at the Asian Games in Incheon, and in 2016 achieved automatic interpretation for five languages (English, Japanese, Chinese, Spanish, and French). Also, during the PyeongChang Winter Olympics, it achieved the feat of the world's first official automatic interpretation and translation service for the Olympics. In addition, with the development of neural network automatic translation technology since 2016, the quality of automatic translation has been greatly improved. The neural network automatic translation technology developed by ETRI for the first time in Korea was forwarded to Hancom Interfree to be commercialized as a mobile interpreter called GenieTalk Go in 2019.

Meanwhile, with the suggestion of the need to conduct AI technology development on the national level for securing future national competitiveness, the development of Exobrain, a sophisticated question-and-answer technology, began from 2013 together with multiple companies. Exobrain displayed surprising results, winning the Kings of Kings' Challenge by a large margin against competitors who had achieved perfect scores on the National Entrance Exam in November 2016. Also, in 2019, a language model KorBERT, which even considers morphemes, the smallest unit of meaning in the Korean language, was developed and distributed to academic and industrial fields.

From 2010, with the goal of achieving digital native instructors, computers that will replace or supplement the role of native teachers for listening (speech recognition and understanding), speaking (speech processing), and teaching (evaluation, tutoring) of foreign language learning are under development. The developed conversational English education system was transferred to various companies and contributed to the development of the public and private language education industry.

Since the mid-2010s, the focus shifted to visual recognition technology development, and the DeepView platform was developed, which recognizes and understands people and objects in a video. DeepView achieved second rank for object type recognition in ImageNet Large Scale Visual Recognition Challenge (ILSVRC), the world's greatest international video recognition competition with skilled teams competing from across the globe, and is currently being applied to an empirical study on illegal waste disposal in Seoul and Sejong.

Analysis of future population-welfare simulation using Population Dynamics Micro Simulation

DBMS/Big data

ETRI led the evolution of the domestic data sector over the last 30 years from database management system (DBMS) to big data analysis. ETRI first began to research DBMS in 1988. At the time, DBMS research was conducted by only a handful of universities in Korea, and they were in the early stages. In this situation, ETRI independently conducted the BADA project for 15 years until 2002, which performs all processes required for DBMS development such as defining requirements, design, implementation, testing, etc.

As a result, the relational DBMS BADAI (1991) and BADAII (1993), multimedia DBMS BADAIII (1997), BADAIV (2000), and cluster DBMS BADA-V (2002) were successfully developed. Additionally, the development of memory-based DMBS began from 1991, and Mr.RT, a main memory data storage system, was developed by 2000 over three consecutive steps, and lastly, UbiCore, a DSMS that focuses on RFID data processing, was developed in 2006. These DBMS were transferred to small and medium companies (SMEs) and were actively used in the field. Accordingly, the domestic DBMS market, which was originally filled with foreign-made DBMS in the 1980s, was gradually replaced with DBMS made using purely domestic technology.

Meanwhile, as the need for heterogeneous DBMSs integration technology is suggested for efficient data management, DataBlender (2003), VISION (2006), and unified transaction/analysis DBMS (2019) were developed.

With the rise of big data platform technology since the mid-2000s, ETRI performed platform and analysis technology research using big data based on the database-related technology acquired over the years. First, analytics technology for big data edge was developed, which created an opportunity for domestic big data analysis to make groundbreaking progress in terms of quality and quantity. Also, from the mid-2010s, by starting development on big data analysis system, which supports public decision-making such as traffic policies, population policies, city and social policies, etc., the future population change analysis system (ABCD) was developed in 2016. The world's first cloud-based traffic prediction simulator, SALT, was also developed in 2019. In 2018, technology for a digital twin (virtual Sejong) for city administration is being developed for Sejong's science policy decisions.

National administration network main computer II (TiCom) Development Report held at Korea Electronics and Telecommunications Research Institute

Server Computing

ETRI began developing computer technology starting from the time when the word "computer" was not yet familiar to people. It has recently been expanding the scope of research to memory-based computing systems, which is an all-new computing technology. ETRI started developing computer technologies in 1987 when they developed the national administration network main computer II (TiCom). Subsequently, the national administration network high-speed mid-sized computer III (TiCom III) was developed in 1994, supplementing the drawbacks of the TiCom II, and in 1998, TiCom IV was developed as a high-speed parallel computer system (SPAX). Through the development of the TiCom series, not only was Korea able to secure the foundations of an electronic government, but was also able to raise domestic computer system technology to a global level and break free from the dominance of foreign computers. Also, many computer-related professionals were trained, accelerating the development of the domestic computer industry.

Even after that, by developing a high-speed multimedia server SANtopia based on SAN, the next-generation Internet server SMART, the massive global Internet general solution (GLORY), supercomputer (MAHA) for analyzing genomes, the low-power micro server (KOSMOS), ETRI led Korea as a globally acknowledged leader in computing technologies.

Cloud Computing

Although the concept of sharing computing resources emerged in the 1960s, it was not widely used due to the immature technology. Then in 2006, as the term "cloud" appeared, "cloud computing" became a de facto standard for smart computing services. A cloud refers to computing where the user borrows IT resources with flexible expandability through the network.

The cloud is an innovative paradigm that changed the concept of IT resources from ownership to lending. In Korea, technology related to cloud computing slowly appeared beginning in the late 2000s, and cloud infrastructure service technologies started to appear in the market that allowed access to computing resources quickly and easily from remote areas. Meanwhile, the government established a comprehensive plan for cloud computing vitalization in 2009, a full stack cloud research plan across cloud infrastructures, platforms, and applications to deviate from overseas dependency.

ETRI started cloud computing technology development from the late 2000s based on its acquired technology on server computing, operating systems, system SW, platform SW, computer application services, etc. Starting from developing the standard-based system virtualization management SW VINE in 2009, ETRI contributed to the development of cloud computing with a series of research. It consecutively developed the cloud virtual desktop (DaaS) technology to increase cloud processing power and reduce establishment fees and in-memory based modular virtual desktop system technology to strengthen performance for large-scale user environments.

After the mid-2010s, the institution has been focusing on high-speed deep learning cloud technology, which greatly reduces the required study time for AI deep learning, and multi-cloud service common framework technology, which maximizes the usage and expansion of various multi-clouds.

Through these efforts, ETRI is striving to disseminate domestic technology to overseas companies, dominate domestic cloud market, and promote national competitiveness in the global cloud computing sector.

Terminal

Korea's computer devices reached full scale starting from the specialty research development project in 1982 led by the national government, and peripherals such as terminals, floppy disks, and printers were developed through a joint effort between the government and private sector. Starting from developing and distributing 8-bit educational computers in 1982, ETRI led the development of domestic device technology and industry for nearly 40 years.

In the 1980s when computers were first being introduced in Korea, ETRI developed PCs and mid-sized computers to lead the public use of computers. In the 1990s when owning computers became more common, ETRI went straight into multimedia computer development and created the "ComBiStation I", a multimedia workstation, and "HandyComBi II", a mobile device for multimedia input and output.

Also, as the distribution of personal data devices (PDA) expanded in the mid to late 1990s, ETRI led the development of intelligent personal clients (IPC), following the government's designation of next-generation PCs as one of the "9 New Growth Engines", and focused on conducting related businesses with a watch-type PC, cloth-type wearable device, wearable gesture-sensing technology. ETRI consecutively developed to expand the horizons of the domestic device industry.

Wearable gesture technology demonstration

In addition, starting from the smart haptic interface in 2004, human interface technology development began, creating the opportunity for haptic interface technology and transparent interface systems to spread in Korea. Starting from 2017, development for physical ability enhancing technology is being conducted to reinforce physical abilities and rehabilitation of the elderly and people with physical disabilities using high-tech ITC.

3-2. Software - Forming the Foundations of the Fourth Industrial Revolution

Innovative technologies, which can drastically change the lives of humankind, such as AI, robots, quantum computing, and IoT, along with the Fourth Industrial Revolution, have begun to evolve quickly. The foundation of these technologies is software (SW) such as operating systems (OS). ETRI started software development from the late 1980s and led the development of UNIX, Linux Server OS, Manycore OS, embedded OS, SCS SW, CPS technology, and SW platforms, in Korea.

Server Operating Systems (OS)

ETRI TiCom

Conference of RealiTime OS for information appliance

ETRI began development for SW operating system with the development for the national administration's main computer (TiCom). Even the AT&T Bell Lab, which boasted the world's best technology at the time, was only able to secure OS technology for a single processor. However, ETRI took on the challenge of OS development for multiprocessors. With the success in developing parallel operating system technology based on microkernels through the development of the TiCom series for the first time in the world, a new structure and features were developed for the expandability of UNIX. These features are used even today in Linux OS.

With the Linux boom in the early 2000s, the government established a plan for public SW vitalization in 2004. Since then, ETRI jumped into the domestic public SW standard platform development with major corporations and strong SMEs in Korea. In 2005 ETRI succeeded in developing Booyo Linux 1.0, a standard server OS for public distribution. Afterward, V2.0 was released in 2006 and V3.0 in 2007, which were all transferred to public institutions and companies. Then, various Linux servers based on this standard began to be released within Korea.

Meanwhile, as the Ministry of Science, ICT, and Future Planning went forward with the SW innovation plan in 2014. ETRI dived into Manycore OS development with various universities inside and outside of Korea by launching the Next-Generation OS Research Center. The research achievement was released as “Public SW Project 1” and produced 260 academic papers.

Web acceleration technology for embedded system (Qplus-Web)

Demonstration for Qplus Esto

Embedded Operating Systems

ETRI began embedded OS development starting from the late 1990s when the word "embedded" was new in the field. Starting with developing a real-time OS, Qplus-T, for I-TV and D-TV setup boxes in 2000, the expansion of QPlus-P was released in 2001. Then the embedded OS-based home server was released in 2002, which is a key device for digital appliance services. From 2003, the QPlus operating system platform was developed, which supports various functions and sizes of embedded systems and optimizes into 3 parts (standard type, micro, nano). Additionally, by developing the QPlus/Esto, a system development tool, it succeeded in localizing embedded development tools which were originally dependent on foreign technology. QPlus Web was also developed as a web-based development environment, with image processing speeds enhanced by more than 20 times. Korea was able to establish itself as an independent and prominent figure in SW development through the evolution of QPlus OS over the last 20 years.

The lightweight OS, Nano-QPlus, was slowly developed into integrated development solution for IoT devices and was transferred to Nuri Telecoms Co., Ltd. In 2015, the company succeeded in signing the contract for Norway’s SORIA Project, a massive overseas project worth KRW 121 billion.

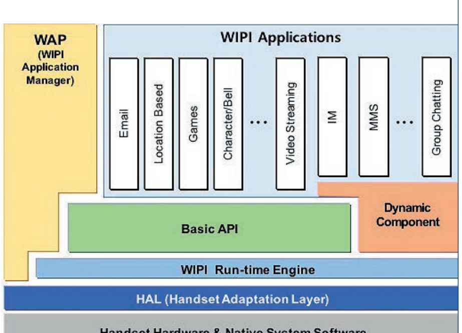
In the 2010s, Consumer Electronics (CE) sector was left to private companies, and ETRI focused on developing embedded system SW for safety-critical systems (SCS) such as national defense, avionic, driving, etc. Through this, in 2015 the RTOS QPlus-Air for unmanned aircraft, and the QPlus Hyper, which can run more than two OS in one hardware, were developed. In 2017, EARTH, an upgraded version of QPlus Hyper, was developed and applied to drone systems.

Embedded Middleware

With the rapid growth of the computer application sector after the 2000s, there was a need for technology that can safely control various objects in the real world. From 2010, ETRI began developing the cyber physical system (CPS), a key next-generation SW technology. As it was only the beginning for CPS, the research team focused on its development by persuading the academic and research fields, where there was no definition of the term “CPS.” From 2014, CPS is constantly being applied to smart factories, IoT, digital twins, etc.

In addition, in order to respond to network-based future weapons systems, a communication middleware with national defense standard data distribution service (DDS) was developed in 2012, and domestically produced 100% of communication middleware for national defense. Moreover, an LVC gateway to link LVC battle training systems was developed in 2017. This is a key technology for Build-I, whose development is to be completed by 2020 and was planned to be used for practical system development for five years starting from 2021.

Meanwhile, ETRI has been focusing on increasing R&D capacity for future industries (smart city, smart mobility, smart medicare, smart farms, etc.) connected with regional strategic industries through the advancement of AI-based ICT fusion technology since its establishment in 2006. Based on the research institute, research corporations were also established, where erae Automative used ADAS for driving environment detection technology 2014, Confirst used the vehicle driving environment detection and traffic subject high-speed detection system in 2015, and Ndos Co., Ltd. used radar application technology in 2018. The number of patents that the research institute applied during the past five years (2015–2019) is 232, and the number of support cases for difficulties and technological support reached 223.



WIPI design philosophies

SW Quality and Platform

Due to the difficulties caused by the lack of SW development methodology fit for the domestic development environment, ETRI began development of MaRMI from 1994, which is a Korean SW development method theory, with MaRMI-I (1997); supporting structural methods and information engineering methods, MaRMI-II (1998); supporting object-oriented methods, MaRMI-III (2003); supporting SW component-based development, and MaRMI-IV (2006); supporting product-based development. These were then transferred to about 180 institutions in Korea. Currently, the MaRMI series completely replaced foreign development method theories, and has been established as the domestic development standard.

Meanwhile, the Korean Wireless Internet Standardization Forum (KWISF) centered around ETRI marked the beginning of the development of the Korean wireless Internet platform standard called Wireless Internet Platform for Interoperability (WIPI). WIPI V1.0 developed in 2001 was selected as a TTA group standard in 2002, and additional development continued on to V1.1, V1.2, and up to V2.0. The Ministry of Science and ICT made it mandatory to include WIPI in all mobile devices released in Korea from 2005, which continued up to April 2009. Through this, the time and money spent by device manufacturers on implementing platforms on new devices were greatly reduced, and for content developers, content could now be serviced across all three mobile providers at minimal change.

This case remains as a key example of leading governmental policies to success through technological support.

ETRI led the domestic software technology development throughout the past 30 years and laid the foundations for the nation as an SW technological power. ETRI will continue developing various new software for Korea to lead an AI technology.

3-2-1. Server Operating Systems (OS)

3-2-1-1. Booyo Linux Operating System

Linux-based data search system

Booyo Linux logo

Starting from the 2000s, there was a boom in people seeking Linux. As a part of this, the public SW key technology development project was conducted. The research team produced a standard for Linux servers and desktops. Accordingly, in 2005, the standard for public distribution servers was established and Booyo Linux 1.0 was put on the market. In 2006, the standard for server expansion was developed and Booyo Linux 2.0 was developed. In 2007, a desktop standard fit for mobile devices and a server standard version that improved the Xen feature was developed, leading to the release of Booyo Linux 3.0. The greatest achievement from the project was that a Linux-based desktop and server platform using domestic standards were commercialized, giving rise to related industries. 3510 devices, comprising 2206 desktops and 1304 servers were supplied to Daejeon City Hall and the Ministry of National Defense, which accelerated public SW usage. As a technological achievement, the two public SW that Korea proposed to Open Software Development Laboratory, (OSDL; now Linux Foundation) were registered as a proof of concept (PoC) appropriate for international OSDL-DCL. Booyo Linux gained global popularity as well. In 2008, Uzbekistan used Booyo standard technology to develop Uz-Booyo. Uz-Booyo was used in Tashkent University of Information Technologies (TUIT), a key IT university in Uzbekistan, and local vocational high schools.

3-2-1-2. Manycore Operating Systems

In the mid-2000s, HW community steered its direction toward leveraging parallelism. This triggered the change from multicore OS to Manycore[8] OS. Accordingly, ETRI launched the Manycore-based ultra-high-spec scalable OS research project. ETRI set an ambitious goal of researching Manycore OS to increase the OS performance according to the increase in cores, which even Google struggled. ETRI solved the OS expandability problem in the cloud environment. It also proved that the multikernel structure is superior to Linux in terms of expandability and can provide better performance through multikernel operating system research.

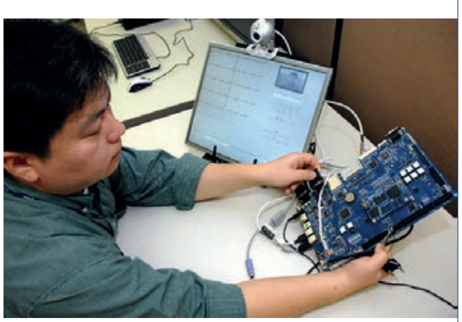
8) Manycore: A technology which creates performance by combining hundreds to thousands of cores with simple functionality into a single CPU.

The development achievements were designated as “Public SW project No. 1” where research is released to the public. Accordingly, ETRI released around 30 software results in a free SW hub called GitHub (https://github.com/oslab-swrc). The “Manycore SW technology” developed was also selected for the “100 Future Tech” list by NAEK in 2017.

3-2-2. Embedded Operating Systems

3-2-2-1. Embedded Operating Systems for Smart Devices (Qplus)

Qplus on the gas safety monitoring system



Qplus performance evaluation on the health device

Qplus-WEB

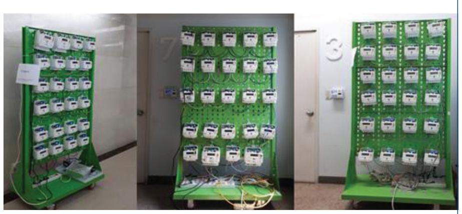
ETRI began embedded OS development from the late 1990s when the word “embedded” was still new in the field. The real-time OS, Qplus-T, was developed by conducting a modular real-time OS for three years from 1998. Subsequently, an embedded operating system Qplus-P was developed, and ETRI succeeded in developing the embedded OS-based home server in 2002. From 2003, research began on the embedded SW standard OS platform. The commercialized system was exported to an electronic payment system company in the United States in 2005, expanding into the global market.

ETRI developed Qplus Web in 2014 as a web-based development platform that does not depend on native operating system platforms. Qplus Web boasts ten times faster 2D and 3D graphics execution speeds and more than 20 times faster image processing speeds compared to conventional platforms to provide faster and stable app execution in various mobile devices. This technology obtained the WebCL certification from the standardization organization Khronos Group for the first time in the world, certifying its excellence.

3-2-2-2. Nano-Qplus Lightweight Operating System

The Nano-Qplus OS technology development began as an international joint research project from 2006 alongside six institutions in Europe. Nano-Qplus was developed as an operating system which developed into an integrated development solution for IoT devices. Based on Nano-Qplus, a routing protocol that conforms to the ZigBee[9] standard was developed in 2008 and was applied to various IoT demo businesses. Also, various international standard protocols such as CoAP, 6LoWPAN, IPv6, etc. were created and obtained the IPv6 Ready[10] international certification in 2014. In the early 2010s, a highly reliable routing protocol which conforms to the Time-Slotted Channel Hopping (TSCH) international standard was developed for commercialization of large-scale high-reliability IoT services. NuriFLex Co., Ltd., which received the Nano-Qplus OS and TSCH wireless communication technology, contracted the large-scale overseas SORIA Project in Norway in 2015, worth KRW 121 billion, and reported KRW 5.6 billion in sales through device delivery. ETRI's industrial IoT wireless platform key technology development and success in domestic and foreign commercialization was selected for the list of "Top 100 Achievements in National Research and Development" in 2019.

Nano Qplus



Installation of remote meter reader in the field in Norway

ETRI developed the real-time OS Reliable OSEK (ROSEK) for automotive, and obtained the OSEK/VDX standard from Mercedes-Benz Technology in 2009 for the first time in Korea. Hyundai AutoEver then conducted safety evaluation tests on ROSEK for four years. As a result, ROSEK was determined to display similar or greater safety performance compared to their German counterparts. Hyundai Motors Inc. included ROSEK in the ECU of the accent lineup beginning in 2013, and currently, ROSEK is installed in the engine-control ECU of Hyundai's Avante line and Kia's Morning line.

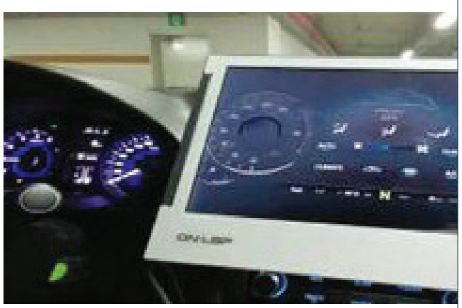
3-2-2-3. Safety Critical System SW Technology

ETRI then focused on developing embedded system SW for the safety critical system sector for national defense, avionic, and motor vehicles, where safety is important. Through the standard SW solution for unmanned aircraft and test-bed development project conducted for three years since 2010, ETRI made the jump into development of SW for avionic, which is considered one of the most difficult sectors for safety system

9) ZigBee: A standard technology for communicating by establishing a personal communication network using small and low-power digital radios. It was created based on the IEEE 802.15.4 standard.

10) IPv6 READY: IPv6 is a protocol in the network layer, and is a next-generation protocol equivalent to version 6. IPv6 READY is an international certification certifying that IPv6 can be used and its tests for the appropriateness of IPv6 devices and their interrelation.

Aircraft flying equipped with Qplus-AIR



Qplus-Hyper evalution on the Smart Car IVI

Qplus-AIR certified ARINC-653

CPS research staff

SW development. As a result, by succeeding in developing an RTOS called, Qplus-AIR, for unmanned aircraft, the domestication of avionic OS that originally relied on foreign technology was finally made possible. Qplus-AIR is the first domestic OS that conforms to the international avionic technology standard ARINC-653, and it obtained DO-178B Level A from the US avionic SW certification, which is the highest level achievable.

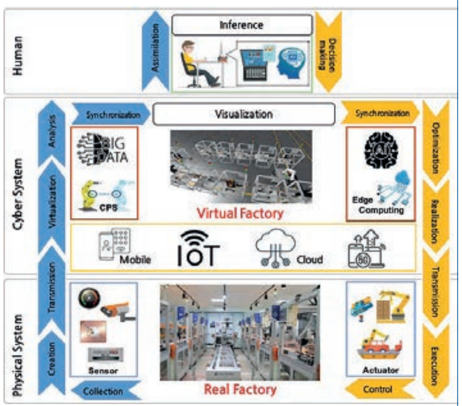
In 2015, through the development of primary technology for ultra-small/high-reliability (99.999%) dual OS that can run multiple high-performance multicore OS project, Qplus-Hyper was developed as an OS that can run multiple operating systems on a single HW unit. From 2017, through the ICT-based technology development for safe unmanned mobility project, Qplus-Hyper was upgraded to ETRI Advanced Real-Time Hypervisor (EARTH), and obtained DO-178C Level-A certification from the US FAA supervisors (DER) in 2020.

3-2-3. Embedded Middleware

3-2-3-1. CPS Technology

ETRI conducted the development of CPS core technologies for highly confidential autonomic control software project from the birth of CPS technology for five years in 2010 and began full CPS research. The result of their effort was success in developing real-world modeling for digital twins and hybrid simulation technology, communication middleware technology for large-scale system support, highly confidential autonomic control technology, etc. The technology developed from this project was selected for the list of "Top 100 Achievements in National Research and Development" in 2014 under the category for Cyber-Physical Systems (CPS) for high confidential autonomic control SW.

The CPS-based smart factory infrastructure technology research for Industry 4.0, initiated in 2014, was a project for applying CPS in the field of smart factories. Through technological cooperation with Germany, which had suggested the Industry 4.0 project, research was conducted with KIST-EU, Korea's only overseas research institute, establishing the ETRI-KIST Europe Smart Factory Joint Research Lab in



Digital twin concept diagram for smart factory

Germany's Saarland University campus. Also, from 2017, the 5G-based Multi-Access Edge Computing (MEC) technology development, which allows real-time control over complicated industrial environments where large devices exist, is being developed to create a real-world example of CPS establishment. Currently, in 2021, ETRI is conducting various tasks to apply CPS technology to smart factories, 5G, smart cities, shipbuilding, auto-driving cars, etc.

3-2-3-2. EDDS and LVC Gateway Technology

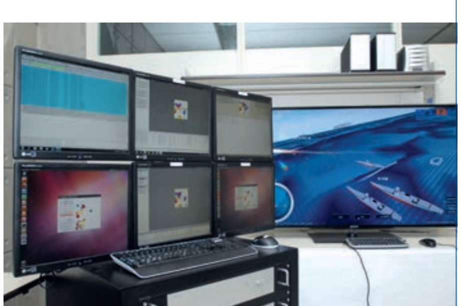
Through the development of CPS core technologies for highly confidential autonomic control software starting from 2010, real-time data distribution service (DDS) and modeling, simulation key technologies were developed, which led to the successful development of EDDS (ETRI-DDS), a standard national defense DDS communication middleware in 2012. Through the development of EDDS, Korea was able to domestically produce 100% of national defense communication middleware.

ETRI conducted LVC connection gateway development for four years from 2014. LVC gateway consists of close coupling of data processors for DDS data types, minimizing the data processing time when moving to higher protocol layers and thus improving performance. With the government actively conducting LVC-based Build-I since 2019, it may be possible to not only collectively conduct LVC simulation training for the entire army, but also collective training for small scale bases below division class.


Distributed SW seminar

3-2-3-3. SW Convergence Technology Based on Regional Industries (ETRI)

According to the region-specific IT cluster support plan by the Ministry of Science and ICT in September 2006, ETRI established a support center for ETRI embedded SW technology in the Daegu/Gyeongbuk region, where embedded SW is a strategic industrial sector. The center is focusing on fostering future industry R&D capacity by the sophistication of combined ICT based on AI connected to regional strategic industries. The key fields of study include smart cities, smart mobility, smart medicare, smart farms, etc.


Demonstration for communication middleware

Opening ceremony of Daegu Embedded SW Technical Support Center

In 2018, on the topic of vehicle recognition for smart traffic control, ETRI’s technology was recognized by taking the no. 1 rank in the high-tech traffic monitoring system sector in the "AVSS 2018 Challenge," the world's largest video security society. Meanwhile, Advanced Driver Assistance Systems (ADAS) is being developed as a technology to advance the car parts industry, an infrastructure industry in Daegu/Gyeongbuk region. In particular, a key sensor, and antenna manufacturing technology, which is the key to radar communication, as well as advanced technologies such as system technology, signal processing technology are the main focus. The technologies for mapping and location-tracking, obstacle recognition, and movement trajectory and follow-up, which are all crucial for operating logistical robots, are being developed. In particular, logistics robots which can work alongside human workers are currently being prioritized for development.

The center developed an automatic hair transplanter for the first time in the world with the Kyungpook National University Hospital Hair Transplantation Center and Ohdae Metal Co., Ltd. located in Daegu, halving surgery time and reducing motions by 90%. Accordingly, a rapid hair transplanter which improved the drawbacks of the single hair transplanter completed development and obtained US FDA approval in 2019. From 2013 onwards, research was focused on smart farm technology. The smart farm multipurpose environment control solution technology was advanced to be currently applied in 60 farms within Korea. In the future, key technologies of the Fourth Industrial Revolution such as IoT, robots, bit data, and AI, will be applied to this solution to develop an even wider variety of agricultural service technologies to eventually complete the AI-based automated greenhouse technology where machines grow crops without human interference.


Overall view of ETRI Daegu-Gyeongbuk Research Center

3-2-4. SW Quality

3-2-4-1. MaRMI, a SW Development Methodology

ETRI developed a Korean SW development methodology called Magic and Robust Methodology Integrated (MaRMI), based on structural methods and engineering methods from 1994 to 1997. MaRMI defines even the specific processes in the project management and support field aside from the development field, which made it easy to learn using only a manual. Following the development of SW development technology, ETRI continued to conduct development and distribution of development method theory by releasing MaRMI-II in October 1998, which supported object-oriented methods. MaRMI-III was released in 2003, which supported SW component-based development, and MaRMI-IV in 2006, supporting product-oriented development.

MaRMI explanatory meeting

In October 2010, the MaRMI distribution plan for securing competitiveness in the national SW industry, together with efforts to improve its credibility, was conducted through an agreement with the Ministry of Science and ICT. The MaRMI development methodology is currently successfully transferred to around 180 institutions in Korea and is being used in various SW development projects. Through the supply of quality domestic development methodology which reflects the development environment of Korea, it completely replaced foreign development methodology and secured its position as the domestic development standard.

3-2-5. SW Platform

3-2-5-1. Wireless Internet Platform for Interoperability (WIPI), a Korean Standard

As we entered the 2000s, the utilization and services of domestic mobile communication experienced an explosive increase. In 2001, the development of the Wireless Internet Platform for Interoperability (WIPI), a Korean wireless Internet platform standard, began under ETRI's leadership. After discussions began on the need for WIPI in July 2001,

Inaugural meeting for 'Korea Wireless Internet Standardization Forum'

Signing ceremony for joint development of wireless internet platform standard specifications

WIPI V1.0 was developed and selected as the group standard for the TTA in May 2002. Three years later, in 2005, the Ministry of Science and ICT made WIPI mandatory for domestically released mobile devices starting from April 1 according to the announcement on interconnection of electronic communications devices. Until the mandatory usage of WIPI was lifted in April 2009, new versions V1.1, 1.2, and up to 2.0 were developed to provide a standardized utilization and service development interface. Devices equipped with WIPI were first released by LG Electronics in June 2003, and by March 2005, 64 models (SKT 48, KTF 14, LGT 2) were equipped with WIPI V1.x.

ETRI noticed the expandability of mobile phones through the development process of WIPI, and created a Linux platform for mobiles phones, the Linux mobile platform. Researchers provided technical support based on the previously developed Linux mobile platform when Samsung Electronics was actively conducting development of mobile devices based on Linux.

3-3. AI - Leading the Conversion to the AI Era

AI (artificial intelligence) is a field of computer science and information technology which researches ways that a computer can conduct actions that is typically performed by human intelligence, such as thinking, learning, self-development, etc. AI technology is an innovative technology which brings out large-scale changes in the structure of the industry and society and plays an important role in the quality of life and national competitiveness.

ETRI has been researching mixed AI that integrates language, voice, and visual intelligence since the early 1990s. In 2003, the developments teams for language processing and the sound recognition were combined to create the Sound Data Research Center to nurture synergies. ETRI's AI research is generally divided into language processing, visual recognition, and sound recognition sectors.

Signboard hanging ceremony of Speech Information Technology Research Center

International demonstration of Korean-Japanese speech translation

Language Processing Technology

"Language processing technology" is a technology which handles analysis, understanding, creation, and intellectualization of human language, and it is used in key areas such as information search, question and answer, conversation processing, and automatic translation.

In the automatic translation sector, automatic translation systems for Japanese-Korean language pair was completed in 1996 and Korean-Japanese in 1997. Full research for English-Korean, Korean-English, and Korean-Chinese was conducted from 1998. Also, along with the Korean Intellectual Property Office, an automatic translation system for patent documents was developed and put into commercial use in 2005. From 2008, spoken language processing technology and TV series automatic translation technology was developed. In addition, with the development of neural network automatic translation technology since 2016, the quality of automatic translation greatly improved. The neural network automatic translation technology developed by ETRI for the first time in Korea was forwarded to Hancom Interfree to be commercialized as a mobile interpreter called GenieTalk Go in 2019.

In the question and answer sector, through the Exobrain project from 2013, an in-depth question-and-answer technology is under development in which the system can understand the content of the phrase or document and provide an answer according to the question asked by a human. This system displayed surprising results by winning the Kings of Kings' Challenge by a significant margin in November 2016 against competitors who had achieved perfect scores on the National Entrance Exam. From 2019 onwards, an educated Korean deep learning language model, KoBERT, is being distributed to the academic and industrial fields.

Visual Recognition Technology

"Visual recognition technology" is a technology where the system processes an image or a video and understands the subject, providing an appropriate response according to the purpose. ETRI has been developing the DeepView platform since 2014, which recognizes people and objects and understands actions from videos. DeepView achieved second rank for object recognition in ILSVRC, the world's greatest international video recognition competition with skilled teams competing from across the globe, and is currently being applied to an empirical study of illegal waste disposal in Seoul and Sejong.

Collection of multilingual speech database

Demonstration of Korean-English-Chinese-Japanese smartphone embedding speech translation

Voice Recognition Technology

"Voice recognition technology" is generally divided into automatic interpretation technology and language education technology. Among these, technological development for automatic interpretation technology began after development for interpreting software was included in the five-year plan for complex future technology development for a new economy. ETRI launched the C-STAR II consortium with Carnegie Mellon University, ATR, and Siemens to conduct cooperative research for automatic interpretation technology.

Later, Italy and China also joined the consortium. Through this research, ETRI developed a verbal language voice language translation system which combines voice recognition, language translation, and voice synthesis technology to automatically translate around

5000 Korean words into English, Japanese, and French, and gave a demonstration in July 1999 along with the US, Japan, and France. By asking a question to a native speaker in a foreign country via the screen, the demonstration showed the language being immediately interpreted through the speaker in the other person's language.

In 2009, an IPTV system was developed that allowed users to search for the desired content just by speaking. The inconveniences of typing on remote control keypads were finally solved thanks to this development. Also, in 2010, a device-embedded voice recognition technology, which can understand tens of thousands of location names by voice, was developed for the first time in the world.

Starting from 2012, the development of the automatic interpretation app for mobile devices, GenieTalk, began, contributing to the successful hosting of the 2014 Asian Games and the 2018 PyeongChang Winter Olympics. In particular, the zero UI simultaneous interpretation concept, which can interpret without any actions, was suggested and designated as an international standard for the first time in the world. Also, official Olympics automatic interpretation service was provided for the first time in the world during the PyeongChang Winter Olympics.

International demonstration of Korean-English-Japanese-French speech translation

In the language education sector, with the goal of achieving digital native teachers, technological development for English conversational speaking education began from 2010. Through this, computers were developed to replace or supplement the role of native teachers for listening (speech recognition and understanding), speaking (speech processing), and teaching (evaluation, tutoring) for spontaneous speech foreign language learning.

With the introduction of the Fourth Industrial Revolution in the mid-2010s, AI technology began to evolve at a very fast pace across the world. AI is now going beyond individual technologies to take its place as a single paradigm. In order to lead this change, ETRI is striving to enhance neural automatic translation technology into the next level to copy the human brain; evolve and disseminate Exobrain, an AI question and answer technology; and DeepView, a visual AI.

3-3-1. Artificial Intelligence (AI)

3-3-1-1. Automatic Interpretation Technology (GenieTalk)

GenieTalk-Zero UI

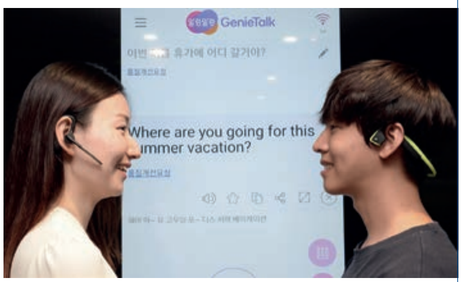
Development of the Automatic Interpretation App, "GenieTalk"

Automatic interpretation technology is a complex technology that allows communication with foreign language speakers in their own language, and consists of voice recognition of various languages, automatic translation and voice combination technology. It is a field with a lot of competition for market dominance between world-class IT companies such as Google, Microsoft, and IBM.

ETRI developed the core technology for automatic translation from the early 1990s, developing the automatic interpretation app GenieTalk, in 2008 for mobile devices, and conducted a pilot service for Korean-English automatic interpretation in 2012. Later, GenieTalk expanded its target languages and provided services to the 2014 Asian Games in Incheon, thus providing the experience needed to successfully provide automatic interpretation services for the 2018 PyeongChang Winter Olympics.

After the Olympics, ETRI created the zero UI simultaneous interpretation concept, where interpretation can be conducted without touch actions, for the first time in the world. Until now, when using an automatic interpretation app, there was always the inconvenience of needing to touch the screen of a smartphone. Researchers proposed and achieved the concept of zero UI simultaneous interpretation, eliminating these inconveniences. Thus, Users can now use automatic interpretation services as they would by naturally speaking without the need to reach for their smartphone.

This technology received the Chungmugong Award in December 2017, and was selected as the international standard under the name of "Face-to-Face Speech Translation" among the ISO/IEC JTC 1/SC35 international standardization group in February 2018.



Neural automatic translation technology

GenieTalk Go: Smartphone embedding speech translation service provided by Hancom Interfree Co.

3-3-1-2. Neural Automatic Translation Technology

Automatic Translation Technology is Directly Related to Global Competitiveness

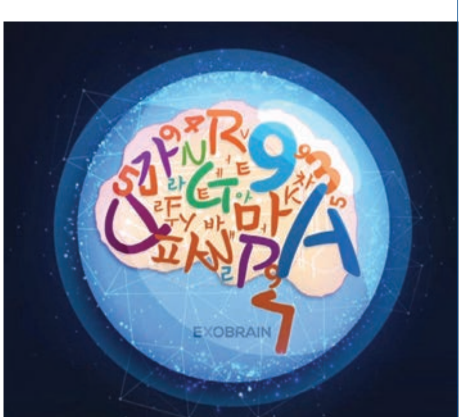
Automatic translation technology is a technology designed to translate one language into another to solve global communication problems that occur due to language barriers. Through the development project for real-time expansion-type core technology for interpretation knowledge that started in 2016, development began for a neural automatic translation technology as well. The initial goal for technological development is to demonstrate automatic interpretation services for eight languages during the PyeongChang Winter Olympics in February 2018. In this project, Systran Translate, Hancom Interfree, Saltlux, Evertran, and others participated as joint research institutes.

3-3-1-3. Exobrain

Issue on the Need for an AI Project at the National Level

In 2011, IBM’s supercomputer, Watson, appeared in the "Jeopardy Quiz Show" and won the competition against its human counterparts. From this point onwards, AI technology that can process information like humans experienced rapid evolution based on global companies such as Google.

In Korea, there was an issue regarding the need for an AI technological development project at the national level to secure international competitiveness. The Ministry of Science, ICT and Future Planning thus launched the Exobrain project from 2013, which is planned to run for ten years. The project had the goal of creating a language SW that can understand human language, study knowledge, and service information at the professional level. In the initial phase was the Exobrain SW core technology analysis on normal areas, the second phase targeted applied Exobrain technology for professional fields, and the third phase was the development of Exobrain SW technology for commercial use that can receive questions and provide answers. ETRI supervised the entire Exobrain project and took part in the first sub-project



Exobrain: Korean AI brain

on technology that can understand human language, enabling question-and answer sessions with professionals in a given field.

Expansion of the Exobrain Through Technology Release, Standardization, and Commercialization

ETRI has been releasing language analysis, question-and-answer, and deep learning technologies through an Open API site since October 2017. As of October 2020, there were more than 24 million API accesses from around 1300 institutions (around 28,000 per day). Also, seven items within the Exobrain are of the TTA standard in Korea, and four were designated as the ISO and ITU-T[11] international standard. Additionally, from 2017 to 2019, a total of 22 cases of technology transfer were completed, with earnings of KRW 1.81 billion worth of payments, and commercialization performances hit 17 cases, earning KRW 3.8 billion.

In particular, Mindslab released the emotional AI service based on the transferred technology and received the "Korea ITC Award" in 2017 for the intelligent information category. Meanwhile, Datasolution received the "SW Technology Award" (Ministry of Science and ICT Award) in 2018.

Exobrain wins the EBS Janghak Quiz (November, 2016)

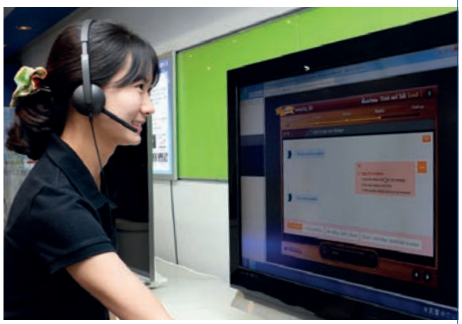
3-3-1-4. Voice Recognition Technology (Genie Tutor)

Creating a Digital Native Teacher

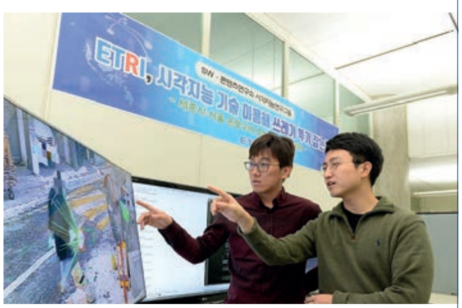
With the goal of creating digital native teachers, technological development for English conversational speaking education began from 2010. Through this, computers were developed to replace or supplement the role of native teachers for listening (speech recognition and understanding), speaking (speech processing), and teaching (evaluation, tutoring) for spontaneous speaking skills in a foreign language. In order to develop technology suitable to language education, the industrial, academic, and research sectors conducted joint research from the initial stages.

The developed conversational English education system was transferred to various companies and contributed to the development of the public and private language

11) ITU-Telecommunication (ITU-T): An electronic communication standardization sector of the ITU.



GenieTutor: Conversational English learning system



Deep View: Visual AI

Field trial of trash surveillance system (Eunpyeong-gu, Seoul and Sejong City)

education industry. Key examples of the application of technology include HodooEnglish, a conversational English game service based on MMORPG developed by NCSoft, EBS's Chomokdal speaking service, the Naver/Snow cake education app, LGU+'s AI Speaker YMB English, Samsung English's Miss Selena, i-Scream Edu's Homerun English, etc.

3-3-1-5. Visual Intelligence DeepView

Developing the DeepView Platform

ETRI began developing the DeepView platform in 2014, where humans and objects can be recognized and understood, through the development of a visual discovery platform for real-time large scale video data understanding and prediction project. This national large-scale project is to be conducted from 2014 to 2023 over the course of ten years with KRW 45 billion in research funding and 1,000 researchers working on the project. It will proceed in the form of collaboration between the industrial, academic, and research sectors. ETRI develops the core technology for the DeepView platform, and a university consortium consisting of Seoul National University, KAIST, and Chungbuk University will conduct research related to big data processing, while Conan Technology, Innodep, Wisenut are participating for its early commercialization.

3-4. DBMS/Big Data - The Challenge to Become a Data Powerhouse

As a data economy where data and its analytical technology determines value becomes the new paradigm for technology and society, the importance of data is abruptly expanding across private and public sectors. In particular, as the training data for AI technology development, the value of big data is becoming even more important.

ETRI began database-related technological development from the mid-1980s, which is the previous step to big data technology, and today ETRI is developing a big data analysis system that supports public decision-making for traffic, population, and city planning.

Showcase for 'Ubicore'

Workshop for 'Vision'

Workshop for transaction/analysis unified DBMS

DBMS

The database management system (DBMS) is a system SW that allows multiple people to access, search, and save shared data through their own application SW.

ETRI led the domestic DBMS technological development through the BADA project, which was conducted for 15 years from 1988 to 2002. During that time, Korea was an undeveloped nation for DBMS, so ETRI independently conducted all processes required in developing DBMS including defining of the requirements, design, implementation, and testing, and succeeded in developing the relational DBMS BADA-I (1991) and BADA-II (1993).

As Internet usage increased in the early 1990s, so did the need for DBMS technology that could efficiently manage HTML-based online documents, so development of a new multimedia DBMS began in 1994. As a result, the multimedia DBMS BADA-III was released in 1997, and BADA-IV, which supports storing/management of XML and image data, was developed. BADA-V was successfully developed as a DBMS cluster.

Meanwhile, a DBMS was needed in areas where real-time processing is required. Thus, ETRI began developing a memory-based DBMS and consecutively developed the main

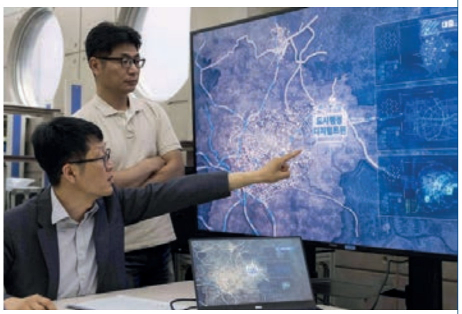
Showcase for 'Big Data Analysis Technology'

memory data storage system Mr. RT (Real-Time Main-memory Resident) through three stages until 2000. Also, as the demand increased for data stream management system (DSMS), where streaming data can be used at appropriate times, UbiCore, a DSMS that focused on RFID data processing, was developed in 2006.

In the 2000s, establishing combined DB-utilizing systems such as relational, multimedia, and main memory DBMS came into the spotlight. ETRI thus developed the XML-based integrated database middleware, DataBlender, in 2003, and the VISION system, which collectively provides detailed information on smart objects, in 2006. Meanwhile, a unified DBMS for transaction/analysis was developed in 2019 that can analyze large amounts of transaction data in real-time and provide immediate responses accordingly for various business situations.

— Summary of the development of "BADA" series

Product Name	Development Period	Research Cost/Workforce	Characteristics	Current Usage
BADA-I	July 1988~ June 1991	KRW 18 billion/60 people	• Relational DBMS • SQL support	• Part of the main computer project • Technology transfer to 4 participating companies • Commercialization of Daewoo Communications “Hanbada”
BADA-II, FLASH	July 1991~ Decembrer 1993	KRW 12.5 billion/28 people	• BADA-I improved • SQL2 support	• Part of the TiCom III project • Commercialization of Hanbada 2.0
BADA-III, Mr.RT1.0 Mr.RT2.0	January 1994~ December 1997	KRW 59 billion/55 people	• Object-oriented DBMS • Full-text save and search	• Participation in international DB show in August 1996 • Technology transfer to 7 companies including Daeshin Information and Communications • Supply to postal financial system
BADA-IV, Mr.RT3.0	January 1998~ December 2000	KRW 57.6 billion/55 people	• Object relational DBMS • Internet multimedia document DBMS • Image saving and search • Data saving system up to terabyte units	• Technology transfer to 3 companies including Onebase • Establishment of 3 companies including RTbase
iBASE (BADA-V)	March 2001~ December 2002	KRW 26 billion/25 people	• Cluster-based DBMS • Database combined middleware	• Displayed in Linux Expo Korea • Participation of 3 joint research companies
Total	**15 years**	**KRW 17.31 billion/223 people**		**No. of technology transfers: 21 (as of end of 2003) Technology fees: KRW 1.45 billion**



Research on Digital Twin using Big Data

Big Data

In the 2010s, core technology for the Fourth Industrial Revolution such as big data and AI experienced rapid development. ETRI thus began to research platforms and analyze technology that treats big data using database-related technology obtained since the 1980s.

First, the big data edge analytics was developed to overcome the current limits of server-centered processing methods and was transferred to multiple SMEs. Thus, the domestic big data analysis market was able to secure an opportunity for groundbreaking growth.

Also, by starting development on a big data analysis system to support public decision-making such as traffic policies, population policies, city and social policies from the mid-2010s, the analysis system for future population change (ABCD) was developed in 2016, and the world's first cloud-based traffic prediction simulator, SALT, was developed in 2019. From 2018, the digital twin (virtual Sejong) for city administration is being developed for Sejong's science policy decisions.

Workshop for population-change forecast and analysis technology

ETRI has led the evolution of the domestic data sector over the past 30 years from database management systems (DBMS) to big data analysis. From here on, ETRI is working on forming a country that uses data well, transforming Korea as a future data powerhouse, and spreading the knowledge obtained over the years for the government, SMEs and the public to use.

Intelligent SW forum for solving traffic congestion

3-4-1. DBMS

3-4-1-1. Relational DBMS (BADA-I, BADA-II)

Workshop for 'Internet multimedia document DBMS, Bada-I'

ETRI began developing an independent relational DBMS technology in 1988. The goal was to prevent foreign SW from dominating the domestic DBMS market. Researchers spent many nights with the mission of developing an independent DBMS, and finally succeeded in developing the relational DBMS BADA-I and BADA-II.

BADA-I is an independently developed relational DBMS that supported the SQL1 (1987) standard designated by the ISO. BADA-I consists of three subsystems. The multi-index data access subsystem (MiDAS), which stores data in the disk and manages indexes, the database language processing subsystem (DBLP), which processes the database language SQL, and a user interface with various application tools.

For secondary development, BADA-I was redesigned into a client server structure to create BADA-II. BADA-II was developed with the goal of supporting SQL2. Also, in a multi-user environment, a data storage system was newly implemented based on the Aries algorithm suggested by IBM for efficient concurrency control and recovery. Researchers then succeeded in developing a system with high specifications thanks to drastic trials and consistent efforts. This system was used constantly for the basis of databases of future projects. BADA-I and BADA-II were then transferred to joint research companies. Additionally, through the process of fulfilling tasks, the creation of numerous experts for complex core technologies consisting of database systems were also major achievements of BADA-I and BADA-II.

3-4-1-2. Multimedia DBMS (BADA-III, BADA-IV, BADA-V)

Showcase for 'Bada-V'

ETRI developed the multimedia DBMS BADA-III from 1994. BADA-III connected existing database systems and information search systems to manage storing original information and searching as a single database system. ETRI composed BADA-III as object-oriented database engine which makes it easy to extend new data type and processing functions. It also has a C++ binding system that binds database language to object-oriented programming language. Thus, from 1998, BADA-IV was developed as a multimedia DBMS that supports XML and image management. BADA-V was developed starting in 2001, and it is a cluster DBMS that provides an environment for continuous service regardless of the location of various users. Based on multimedia DBMS technology, the establishment of Conan Technology, RTBase, and Realtime Tech was a great achievement.

3-4-1-3. Main Memory DBMS (Mr.RT)

ETRI developed a test product by conducting research to modify BADA-I into a real-time DBMS in 1991 but came to the result of being unable to satisfy real-time demand as a disk-based DBMS. The main memory data storage system Mr. RT (real-time main-memory resident) was developed from 1994. This is a data storage system that stores and manages data in the memory, with the addition of concurrency control and recovery for multiple user support. RTBase commercialized the Mr. RT DBMS in 2000 to create the Altibase, and Realtime Tech commercialized the main memory DBMS Kairos, which specializes in real-time temporal and spatial information service. Also, Seoul National University, which participated in the Mr. RT research, developed a main memory DBMS technology called PTime. Later, PTime was merged and used with Hana DBMS.

3-4-1-4. Real-Time Streaming Data Processing Technology (UbiCore)

ETRI developed DSMS technology from 2004 to 2006, focused on sensor data, particularly RFID data processing, for ubiquitous computing. Researchers developed technology to prevent unnecessary data from becoming the target of consecutive query and reuse of intermediate results during query evaluation. Also, a technology showcase is held every year to collect various suggestions from participants to reflect in the final products. Through the advertising effect of the showcase, UbiCore technology was transferred to seven companies including PosData, Hanul, Ubitech, etc. Companies applied the UbiCore technology to logistics, materials, asset management, and information on exhibits and tourism.

In 2008, the demands of Ubitech were applied to modify technology by conducting the development of a sensor data stream processing modification that allows various sensors to be connected, which aided the commercialization of the produced results.

3-4-2. Heterogeneous DB Integration/Analysis

3-4-2-1. Heterogeneous DB Integration Technology

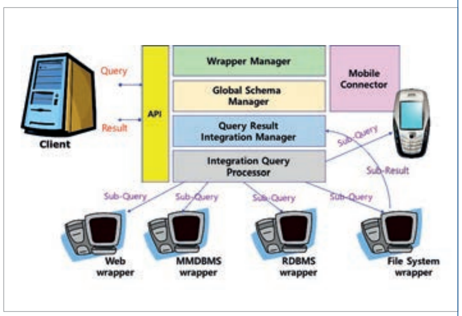
ETRI developed a DataBlender system based on XML-based document searching technology obtained through the BADA-IV development for two years since 2002. DataBlender used the XML model to combine various databases distributed across the Internet such as RDBMS, MMDBMS, and web pages, based on a heterogeneous DBMS integration technology from mediators and wrappers to combine them in one model and create a virtual DB to allow users to search the DB.

DataBlender supported an integrated schema definition language and XQuery language, and the search results were generated in the form of an XML document. Additionally, a standard DOM interface was provided to access the resulting XML document. Even in situations where there were frequent data changes in local DBMS, ETRI continues to provide the newest integrated DB services, and by selecting the XML model as its integrated data model, ETRI was able to solve the difficulty of combining unstructured data.

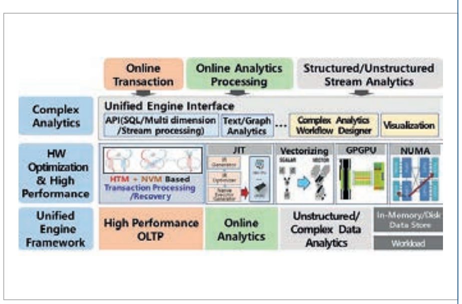
3-4-2-2. Unified DBMS Technology

ETRI has developed a unified data platform that combined large-scale transaction processing and real-time complex analysis since 2015. To solve the problems that occur when supporting transaction and analysis at the same time, research was conducted by maximizing the strengths of next-generation HW.

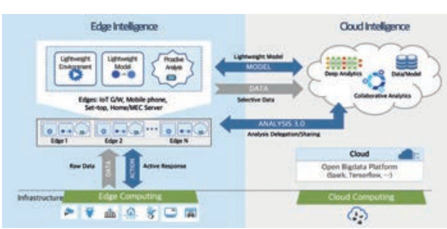
Researchers improved transaction processing abilities through hardware transactional memory (HTM) support and developed various retry policies and its selective apply



Conceptual diagram for 'XML-Based DB Integration Middleware, DataBlender'



Conceptual diagram for 'Unified DBMS Technology'



Conceptual diagram for
'Big Data Edge Analysis Technology'

Showcase for 'Big Data Edge Analysis'

method according to transaction characteristics. Also, they can improve analysis performance along with just-in-time (JIT) compiling technology, vector calculation and GPGPU utilization technology, and processing based on non-uniform memory access (NUMA) structure recognition.

Thus far, companies had to copy data created from transaction processing system to a data warehouse and analyze it once again, making it difficult for real-time data usage. However, thanks to unified DBMS technology, large amounts of transaction data were analyzed in real time, enabling the creation of an environment that allowed for immediate response. The technology was transferred to joint research institutes and companies such as Realtime Tech to be used in improving existing products or commercializing new products. It is expected to be applied in almost all industries including financial security, distribution, manufacturing, communication, etc.

3-4-3. Big Data

3-4-3-1. Big Data Edge Analysis Technology

To process streams fast based on cloud storage in 2015, ETRI applied an edge-based conventional statistical analysis algorithm and a complex deep learning algorithm based on neural networks to develop a lightweight edge analysis technology. In particular, focus was placed on neural pruning that can be applied to lightweight machinery and quantum and binary technological development. We also reached the achievement of ranking high on the podium in a global lightweight neural network challenge. From 2018, for an edge-based analysis that is even lighter, big data analysis systems were applied to existing infrastructure such as train facilities, energy monitoring, power, or optical communication based on Fast Data stream analysis technology that increases the precision and speed of analysis.

Traffic analysis using ETRI traffic simulator, SALT

3-4-3-2. Traffic Big Data Analysis Technology

Simulation for Analyzing Loads in Traffic (SALT) is a mesoscale traffic simulation SW developed by ETRI in 2019. SALT can efficiently simulate large road networks by adopting cloud-based distributed processing. SALT promotes scalability and produces up to 18 times higher speeds compared to the highly portable conventional open-source traffic simulator, SUMO. In SALT, it is possible to perform traffic environment analysis, which machine learning or deep learning-based prediction methods cannot. One of the key aspects of SALT is that if traffic environments such as traffic signals change, SALT can be conventionally used with new input variables while deep learning-based methods should create and learn a new model in new environments. Additionally, SALT also enables verification of the efficiency of traffic signaling systems in advance, and ETRI proved its feasibility in Seoul by applying public and private traffic data.

From 2020, SALT is evolving into the city traffic brain in order to provide traffic control intelligence through cloud-edge-based real-time traffic analysis and large-scale traffic simulation. It includes the edge-cloud collaborative technology for fast and accurate traffic analysis, and traffic optimization technology to improve the global traffic of large-scale road networks.

3-4-3-3. Population Change Prediction/Analysis Technology (ABCD)

ETRI developed an analytics technology for future population change called the agent-based computational demography (ABCD) system in 2013 based on the 10 million agent tier agent-based modeling and simulation (ABMS). Using a parallel computing environment, the processing speed for the simulation was enhanced, creating a function where various simulation models can be controlled and synchronized in a single system. It requires mere seconds for each step of processing to predict the change in population for 17 megacities across the country. After signing an MOU with Chungcheongnam-do in 2016, the application demonstration project for Chungcheongnam-do future population-welfare simulation system was conducted. Through this, marriage behavior, changes in age, employment, marriage, and divorce percentages are predicted for each city, district, sex, and age group along with how the size and structure of the population will change over time, which can support the creation of various population-related welfare policies.

3-4-3-4. Digital Twin Technology (Virtual Sejong)

Through modeling based on actual data from the city, ETRI established a digital twin for virtual cities from 2018 and is developing a core technology for city administration’s digital twin that simulates new policies before they are released. The results are to be used to support decisions by officials for coming up with solutions for city and social problems within Sejong. First, a population-based digital twin is under development to support decision-making on policies for transport. In 2019, a digital twin prototype was developed that can represent a virtual city with around 500,000 agents. Based on the distributed system environment for digital twin establishment, we are developing a high-speed engine that supports high-speed simulation processing. This engine is expected to be able to simulate up to 100 million agents in real time by 2022.

Application of Digital Twin on Sejong city

3-5. Server Computing – From an Unexplored field in Computing to a Global Leader

ETRI began conducting computer technology development in the early 1980s when Korea was still an underdeveloped nation in the field of computers, but it has led the computer technology and industry in Korea for nearly 40 years. In particular, the development of the TiCom series that was conducted for more than ten years since 1987 raised domestic computing technology to the global level and rapidly progressed the computerization of national administration. Even after that, by developing a high-speed multimedia server, SANtopia based on SAN; the next-generation Internet server, SMART; the massive global Internet general solution, GLORY; supercomputer MAHA for analyzing genomes; the low-power Microserver, KOSMOS; ETRI was able to lead Korea as a globally acknowledged leader in computing technologies.

Main Computer

In 1985, the government released the National Backbone Computerized Administration Plan, which focuses on five backbone computerized networks for administration, finance, education research, national defense, and national security. Here, a mid-to-large sized computer was to be developed using domestic technology, to be used as the center for a system that connects multiple computers.

At the time, only a few countries could create a mid-to-large sized computer, including the US, Japan, France, etc. However, ETRI evinced the potential by developing a 32-bit UNIX computer, Korea's first standard computer, and through the passion of ETRI's researchers. In 1987, ETRI was designated as the leading institute for the domestic computer development project, and dived into research with four of the largest computer companies in Korea. As a result, the first main computer for national administration network II (TiCom) was successfully developed in 1991, enlisting Korea as a mid-so-large size computer manufacturer. ETRI proceeded to develop the main computer III

ETRI 32-bit UNIX computer system

(TiCom III, high-speed mid-sized computer) in 1994, and the main computer IV (TiCom IV, high-speed parallel computer) in 1998.

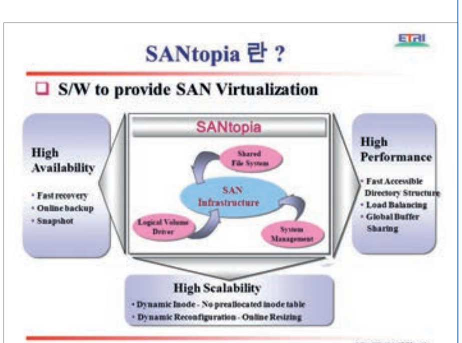
The development of mid-sized computers blended into the general computer industry and revolutionized the level of domestic ICT knowledge. This became the foundation for Korea’s computer industry to develop into one of the greatest in the world from its past as a PC and OEM manufacturer. Also, not only did it lay the cornerstones for an electronic government, but it also raised numerous computer-related professionals to lead the rapid development of the computer industry.

High-Speed Server

ETRI made efforts to develop multimedia computers to respond to the world’s fast conversion to an informational-oriented society. A smart computer was developed in 1990 that can perform various multimedia tasks including graphics, voice, and videos. It also strived to vitalize the system SW.

In 2000, SANtopia, a SAN-based storage that greatly reduces the cost to create storage, was developed using purely Korean technology and created the opportunity for domestic companies to develop within the domestic storage market that was previously dominated by foreign companies. This was upgraded into the object-based cluster file system, OASIS, in 2006. Also, the media server, SMART, which provides high-quality HDTV multimedia content to 1000 users, was developed in 2005, and from the late 2000s, ETRI focused on green computing technology, where the energy used for computers and its peripherals is reduced to minimize carbon footprint.

Meanwhile, when the era of personal broadcasts opened with the creation of YouTube in 2005, ETRI jumped into the development of low-cost, large-scale Internet service technology from 2007 to 2011 to complete the general global Internet solution, GLORY. In 2012, a new concept called the "custom supercomputer" was created, and the bio-specialized supercomputer, MAHA, was developed in 2016 to allow the analysis of big data related to the structure of genomes and proteins. MAHA is a low-power, high-performance supercomputer equipped with a powerful general-purpose graphics processing unit (GPGPU) that supports a massive 36,000 cores (the theoretical performance being 105 teraflops), while the energy usage is a mere 50% compared to



ETRI network-connected data storage system conventional systems. It can analyze up to 150 times faster than conventional genome analysis systems that only use the CPU. Thus, ETRI was able to create an opportunity for Korea to become a global power in the field of supercomputers as well. The MAHA system was designated as one of the six greatest data centers by the ICGC, and it has been providing computing resources since 2014.

Also, in 2017, the low-power micro server KOSMOS was successfully developed by increasing chip density by over ten times based on ATOM and ARM processors.

ETRI plans to continue advancing its domestic computing technology and the industry by securing high-performance cloud technology and establishing an autonomously computing infrastructure.

3-5-1. Main Computer

3-5-1-1. Main Computer II–IV (TiCom Series)

Main Computer II(TiCom)

Leading the High-Speed Development of the Domestic Computer Industry

Through the development of the TiCom series, Korea was able to not only secure the foundation for an electronic government, but was also able to raise domestic computer system technology to the global level and break free from the dominance of foreign computers. Also, computer-related professionals were trained, accelerating the development of the domestic computer industry.

— Performance and characteristic comparison between main computer II, III, and IV

Comparison	Main Computer II	Main Computer III	Main Computer IV
Nickname	TiCom	TiCom III	SPAX
System structure	Multi-processing type	Multi-distributed processing type	Parallel processing type
Processor	MotorolaMC68030/40	Intel Pentium	Intel P6/P7
Maximum number of processors	20	10	256
Performance (Based on VAX-MIPS, TPC)	160MIPS 40tpsA	1,000MIPS 200tpsA	20GIPS 10,000tpmC
Storage size	Maximum 512MB	Maximum 2GB	Maximum 64GB
Connection structure (connection speeds)	Bus (100MB/s)	Bus (264MB/s)	Crossbar (34GB/s)
Input/output structure	Single input/output board	Separation of sequential input/output and block input/output	Parallel input/output
Operating system	UNIX SVR 3.1	UNIX SVR 4.0MP	MISIX (UNIXWARE2 / MK)
Date of commercialization	1992	1995	1998

IA-64 server system

Fiber channel storage system

High performance low power micro server

\3-5-2. High-Speed Server

3-5-2-1. High-Speed Multimedia Server

Success in Developing a Multimedia Server of World-Class Quality

Through its research, ETRI developed the IA-64 server system for the first time in Korea, and also succeeded in developing the fiber-channel hi performance storage system (FC-HiPSS) with independent technology, making Korea the fourth country to develop this system.

3-5-2-2. Next-Generation Internet Server (SMART)

Creating the Foundations for the Development of Domestic Server Technology

SMART is a Korean Internet server that has a layered service structure specialized in the provision of HDTV video streaming for dense residence environments via high-speed Internet. It is a unique computing system not found anywhere else in the world. It was applied for DMB, WiBro, and ambidirectional IPTV, etc. It was also transferred to specialized companies such as CoreBrid, to provide services to Gangnam Cable TV, Ulsan Cable TV, etc. Meanwhile, the ubiquitous service platform developed in 2006 became the technological cornerstone for the large-scale global Internet solution GLORY that began development in 2007.

3-5-2-3. Large-Scale Global Internet General Solution (GLORY)

Development of the Global Internet Service General Solution "GLORY"

Video-based large-scale Internet services such as UCC, IPTV, and web video page search were developed, and a resource security system was established to support these services. Meanwhile a large-scale global dispersed computing platform was developed based on cheap nodes and public SW to complete the global Internet service general solution GLORY (GLObal Resource management sYstem for future Internet service).

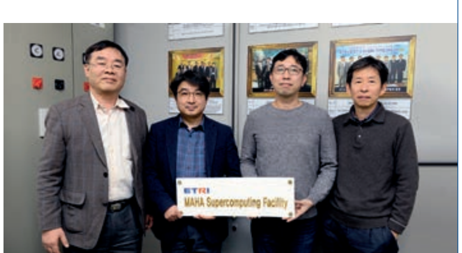
Creation of Approx. KRW 30 Billion Due to Effects of Sales Replacement

After its initial commercialization in 2009, GLORY quickly spread among cloud services, public institutions, educational institutions, broadcast companies, design, game portals, CDN, and genome analysis businesses. Thus, the monopoly of global companies (HP, Dell, EMC) could be mitigated. GLORY is expected to establish 100 PB of storage, conduct 26 cases of technology transfer, and KRW 2.4 billion in technology exports, and is expected to have about KRW 30 billion in sales replacement effect.

3-5-2-4. Supercomputer for Genome Analysis (MAHA)

Development of a World-Class Supercomputer "MAHA"

MAHA consists of an internally developed distributed file system, cluster general management SW, secondary resource management SW, and bio workflow management SW, and boasts around 36,000 cores and 104.5 petaflops in performance. In particular, the distributed file system is a technology that provides tens of PB worth of storage for processing genome data of hundreds of people at the same time. The establishment costs were reduced to less than 50% of its competitors using a commercial storage server compared to an expensive dedicated storage server. It was also developed to reduce operation fees using low-power technology.



ETRI MAHA supercomputer

Providing the Foundations for the Development of an Exascale Supercomputer

Based on the developed technology, the establishment of research company Syntekabio, Inc. in 2014 was one of the achievements. The acquired technology is expected to be

100 teraflops MAHA system and prototype


ETRI KOSMOS project

used in the future as an important core technology for the development of an exascale supercomputer system.

Also, the abilities of the supercomputer can greatly contribute to cancer diagnosis, personalized treatment, new medicine development, and developments in future medicine.

3-5-3. A New-Concept Server

3-5-3-1. Microservers

Development of the ATOM/ARM-Based Microserver "KOSMOS"

KOSMOS can mount up to 64 servers in one chassis (48x22 cm), an increase of over tenfold based on conventional x86 servers. Thus, it is possible to greatly reduce the space required for servers. Also, power usage reaches 1/7 that of x86 servers, with almost three times higher performance per watt, and ten times faster input and output speeds compared to conventional Ethernet methods. Through a separate system connection network (SRIO), communication speeds within the server were also enhanced by about ten times.

Continuing Future Tasks with Strong Technological Experience

ETRI is continuing to conduct follow-up tasks with the technology obtained from the development of KOSMOS. From 2018, the task for memory-oriented next-generation computing system structure research (codename MOCA) is being conducted, which is planned to be completed by 2025.

Also, with a total research cost of KRW 10.4 billion, the development project for massive parallel processor-based supercomputer calculation node technology is being conducted from 2020 to 2024. The goal of this research is to expand the domestic supercomputing industrial ecosystem by developing data-based application and service sectors through internal development of world-class supercomputer technology including independent CPU technology.

3-6. Cloud - Reorganizing the ICT Ecosystem

As digital transformation combines high-tech ITC technology and business models, the ICT ecosystem is being restructured around the cloud. Cloud technology is now going beyond basic SW and infrastructure, consolidating its role as a key stone in IT platform and service for new businesses. The cloud refers to computing where users rent IT resources with flexible expandability through the network.

Based on previous experience in developing computing technologies, cloud computing related technological development emerged in the late 2000s, where the standard-based system virtualization management SW VINE, DaaS system, virtual desktop technology, big virtual cloud platform, SaaS platform, high-speed deep learning cloud technology, and a combined framework for multi-cloud services were developed, securing the foundation for the development of the domestic cloud technology and industry.

ETRI started technological development for the cloud in 2009 with the foundational stage for by developing the standard-based system virtualization management SW, Virtual INfrastructure Environment (VINE). VINE is a system where multiple users who require more resources can access idle computing resources at a low cost.

Consecutively, the cloud virtualization desktop (DaaS) technology was developed to increase cloud processing power, reduce establishment fees, and secure the foundations of domestic cloud industry. In 2016, ETRI developed the in-memory based modular virtual desktop system technology to enhance the performance of large-scale user environment. Additionally, the SaaS platform developed to provide SW online services to SMEs was distributed in 2011, which greatly raised the cloud usage rate for domestic SMEs. It also provided the opportunity to raise the technological level of domestic SW online services from ASP to SaaS-based.

Cloud DaaS project

As deep learning technology based on neural network machine learning experiences rapid

Cloud DaaS technology

development after 2016, ETRI jumped into the field of deep learning cloud. As a result, the high-speed deep learning cloud technology optimized for dispersed deep learning was developed in 2019, succeeding in reducing learning times by up to four times.

Meanwhile, in 2019 ETRI started the technological development for a multi-cloud service common framework for the usage and distribution of various multi-clouds. ETRI organized Cloud-Barista, a public SW community, and has been conducting a new open-SW technology where multiple participants can develop technology together and any consumer can use these results for commercialization.

ETRI will continue to focus on core technologies for cloud platforms and application services to overcome the threat of foreign dominance in the domestic cloud market. ETRI will lead Korea to become a global power in the cloud computing sector.

3-6-1. Cloud Infrastructure/Platform

3-6-1-1. Virtual SW Technology

Discussion on the Method for Public SW Expansion

Public SW is a SW where the developer publicizes the source code for anyone to freely edit or redistribute the code. In Korea, it started to truly gain popularity when ETRI developed Booyo Linux in 2005.

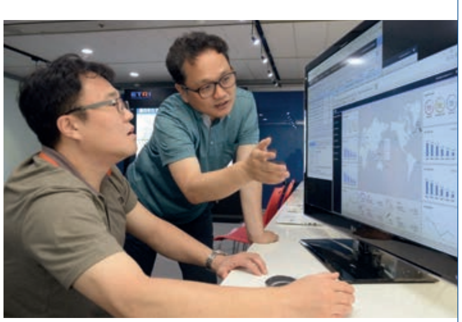
ETRI conducted technological development for virtual infrastructure environment creation based on standardized public SW by the Distributed Management Task Force (DMTF) and the Data Center Linux (DCL) by the Linux foundation. Then, in 2009, the standard-based system virtualization management SW VINE was successfully developed. Based on the VINE technology, various standards are being contributed to TTA, and through active standardization activities, it has led the international standardization community of OpenDRIM (www.opendrim.org). It also had its performance acknowledged through function and safety testing by the TTA.

Demo for Cloud DaaS

3-6-1-2. Cloud Infrastructure Technology

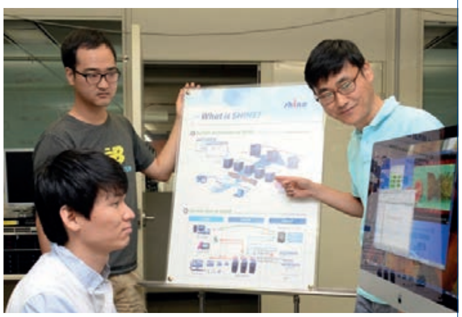
DaaS System/Virtual Desktop Technological Development

ETRI started the Cloud DaaS[12] system and device technological development project from 2010 to 2014 to secure cloud infrastructure. The goal of the project was to develop a virtual desktop system technology for cloud infrastructure services that has a technological edge compared to conventional global solutions, and while obtaining standard patents through international standard approval of the technology, the goal is to have the developed technology commercialized through domestic companies. This DaaS technology is applied to high-speed IOV, high-quality protocol, and desktop virtualization technology to increase FHD processing performance by two times, reduce installation fees by 30%, and support over 50 people per server. ETRI also secured 26 domestic patents and 11 international patents, led the ITU-T SG13 international standard conference for the cloud



Big virtual platform technology

12) Desktop as a Service (DaaS): A cloud infrastructure technology where one's own cloud PC services can be used in any place at any time.



ITU-T approval of international standard(DaaS)

sector, and submitted 47 items for international standards. This technology was approved as the ITU-T Y.3503 international standard and was also selected as one of the "Top 100 Achievements in National Research and Development" in 2014.

From 2014 to 2016, the technological development project for in-memory based modular virtual desktop system was conducted to increase the performance of the secured DaaS system. Through the project, the developed virtual desktop technology boasted a 9-second boot time, 150 users per server, and three-second image generation, which was superior to that of other global solutions. It was also transferred to and commercialized by four domestic companies including SK Broadband. ETRI secured 18 patents in and outside of Korea through this project, and the ITU-T Y.3503 international standard was approved in 2014, while six international standard patents were obtained for cloud technology.

3-6-1-3. Cloud Platform Technology

Big Virtual Platform Technological Development

ETRI started the big virtual platform technological development project to provide adaptive cloud services with 100 Gbps I/O to one million users in 2013. The goal was to develop virtual API bridge-based multi-platform application program technology to provide adaptive cloud services such as virtual desktop services to provide a user-centric virtual platform to millions of mobile and lightweight device users.

In order to secure concurrent connections, a cloud platform expansion and control technology was created that could provide virtual platform services based on various hypervisors. The HW direct allocation technology and lightweight transfer protocol technology was developed to support non-bottlenecking of the network.

3-6-1-4. SaaS Platform Technology

SaaS Platform Development and Distribution

ETRI started the technological development project for Software as a Service (SaaS)

MOU for estabilishment of FTA origin management services

platform in 2009. This core element's technological development was conducted to vitalize the domestic SW online service while solving the cost problem for purchasing, maintaining, and repairing SW used by SMEs while enabling reduction in reluctance of SMEs to store information in exterior sources.

The developed SaaS platform provided an online service based on multi-tenant (where the user SW can be set) for the first time in Korea. It created the opportunity to raise domestic SW online services from being based on application service provider (ASP) to being SaaS based. Although ASP remains in the stage where SW is simply provided online, SaaS can be set in a dedicated range for user convenience for SW provided online to enable it to maximize online user friendliness while allowing the service provider to greatly reduce operation expenses through multi-tenant technology.

3-6-1-5. High-Speed Deep Learning Cloud Technology

Developing High-Speed Processing Technology Optimized for Distributed Deep Learning

It takes a lot of time for a computer to train large-scale deep learning models from several videos, images, and voice data using deep learning technology. Thus, a distributed processing technology is used where training data are divided into multiple computers to train a single model. However, distributed deep learning inherently has a communication bottleneck problem, which makes it difficult to achieve high-efficiency and high-speed model training. ETRI conducted the development of HPC system for accelerating large-scale deep learning from 2016 to 2019 and developed the high-speed deep learning cloud technology to greatly reduce training time for large-scale deep learning models. The shared memory technology for computer systems and a memory box device that reduces the amount of communication were developed to mitigate the bottleneck problem during distributed deep learning, and it succeeded in reducing training time by up to four times. This is faster than the world's best deep learning platforms (TensorFlow, PyTorch, Horovod, Caffe, etc.). ETRI transferred the high-speed deep learning cloud technology to five companies, and it produced achievements

High-speed deep learning cloud technology such as the establishment of two research companies (DeepInspection Co., Ltd. and Intuworks Co., Ltd).

3-6-1-6. Multi-Cloud Shared Platform Technology

Developing a Multi-Cloud Platform Through the Cloud-Barista Community

Cloud-Barista 1st open seminar
(Novemver 22, 2019, Sheraton Gangnam Palace Hotel)

ETRI also started the technological development project for a multi-cloud service general framework for the usage and distribution of various multi-clouds from 2019. The goal of the project is to develop a general framework technology for multi-cloud services that provide open API. A public SW community, Cloud-Barista[13] was established so that domestic cloud infrastructure businesses can participate whenever they wish. Various participants develop technology together from the development stage based on the community, and anyone can commercialize the final product.

The multi-cloud service general platform that the Cloud-Barista community is developing is a SW that is required to generally operate multiple public cloud infrastructure services and allows flexible placement and operation of the cloud. In November 2019, the first version, Americano[14], was released; the second version, Cappuccino in June 2020; and the third version, Espresso in November 2020. Through Espresso, key cloud infrastructures in and outside of Korea were synchronized including Amazon Web Services (AWS), Microsoft (MS), Google Openstack, Cloudit (Innogrid), Alibaba, Doker, etc. A total of eight versions are expected to be released up to the "Handdrip" version in 2022. ETRI is planning on converting to a self-sufficient community by implementing the gradual transfer to operators of sustainable communities. The ultimate goal is to develop technology where cloud services from all around the world can be interconnected.

13) Cloud-Barista: The foundation required in creating a multi-cloud service sand solution, which refers to the common SW technology multi-cloud, while also being the name of the public community.

14) Americano: The first public version of the multi-cloud service general platform under development by Cloud-Barista. A total of 8 versions from Americano -> Cappuccino -> Espresso -> ... -> Handdrip etc. are planned to be released until 2022.

3-7. Terminals - Moving to the Future with UI/UX Technology

From the development of 8-bit educational Computers in 1982, ETRI started technological development for computer device technology and regularly developed with the main computer II (TiCom) project. Afterwards, multimedia computers from the 1990s, PDAs from the mid to late 1990s, wearable computers, human-computer interface technology were developed from the mid-2000s to lead the development of the domestic device technology and industry.

PC and Mobile Computing Devices

ETRI started the technological development for devices by conducting the development of 8-bit educational computer from 1982 to 1984. At the time, Sambo Computer, Samsung Electronics, Gold Star, and others, who had obtained technology from this project, quickly released various projects, marking the beginning of computer popularization of in Korea. Later, from 1987, the development of mid- to large-sized computers accelerated with the development of TiCom.

As the supply of computers became normalized and the move into the information age accelerated, ETRI jumped into multimedia computer development from the 1990s. From the start of ComBiStation I in 1993, the smart multimedia workstation, ComBiStation II, and multimedia input and output device, HandyComBi II, were consecutively developed. These technologies have significance in providing the foundations for domestic products competing with foreign counterparts in the early stages of the multimedia computer market. Towards the mid-1990s, the main means for Internet information services moved from PCs to PDAs, and the Internet information device industry grew rapidly enough for the government to produce a general plan for fostering the Internet information device industry in 2000. Within this background, ETRI developed the intelligent personal client (IPC) in 2001 and led the IPC sector with the universal information appliance (UIA) in 2002.

From multimedia computers to mobile computing devices (①Video conference ComBiStation ②HandyComBi ③Wrist PC)

Wearable Devices

From the 21st century, as interest in post-PC increased, development began for wearable computers in Korea as well. The Ministry of Science and ICT designated next-generation PCs as one of the IT839 project in 2004 and focused on the related businesses. ETRI started development of a wearable personal station under these governmental policies from 2004 and developed a wristwatch PC and standardized technology. In the 2010s, a wearable personal companion, a clothing-type wearable device and wearable gesture technology based on biological signals were consecutively developed, expanding the horizons of the domestic wearable device industry.

Meanwhile, starting from 2017, development of a physical ability enhancing technology using high-tech ITC is being conducted to aid the elderly and people with physical disabilities for enhancing physical abilities and rehabilitation. Through this, danger-predicting technology and sensory replacement technology are being developed for persons with hearing disabilities, along with a muscular support system for the elderly.

Wearable personal station

Human Interface

ETRI started development of a human interface starting from the smart haptic interface in 2004.

To express touch information for mobile devices with touch screens such as smartphones and smart pads, a small touch module in a pin arrangement, haptic pen, and film-type touch display device are developed and standardized to contribute to the haptic interface technology in Korea.

Meanwhile, from 2012, a film-type transparent display, a transparent touch sensor, and a transparent interface system consisting of transparent actuators are under development through the ETRI Creative Research Laboratory. This technology is expected to provide users with a new interface experience by evolving the current user interface technology geared to the senses of touch and sight.

ETRI has actively secured device technologies required by the time for the past 40 years. ETRI will continue to develop device technology that can provide never-seen-before UI/UX technology to improve the people's quality of life.

3-7-1. PC

3-7-1-1. Educational PCs


8-bit educational PC

ETRI started device technology development by leading the development of 8-bit educational computer project from 1982 to 1984. The initial goal of the project was to supply affordable small computers in large quantities to businesses and middle and high schools, as well as to ultimately form the foundations of the domestic computer industry and prepare for the upcoming information era. This project was the spark of rapid development of the domestic computer industry. Participating companies who had obtained technology through these projects started to release various products, marking the start of the popular age of computers.

3-7-2. Multimedia Computer

3-7-2-1. Multimedia Computer (ComBiStation/HandyComBi)

ComBiStation I

In July 1990, the development of PC-tier (486 or better, MS-DoS) intelligent computer project started with ETRI as the supervising research institute. Researchers secured core technology for multimedia SW and HW for multimedia information search by conducting this project. ETRI succeeded in developing the multimedia workstation, ComBiStation I in 1993, which selected the Pentium CPU, the high-speed local bus PCI, and the expansion bus EISA.

As a follow-up project, ETRI conducted the development of intelligent multimedia workstation from 1994 to 1998 to develop the intelligent multimedia workstation ComBiStation II and the mobile device for multimedia input and output HandyComBi II.

Intelligent personal client (IPC)

Universal information appliance (UIA)

Wearable personal station (wrist PC)

3-7-3. Personal Computers

3-7-3-1. Intelligent Personal Client

ETRI conducted the development of IPC technology from July 1998 to June 2001 where it developed various low-power multimedia processing technology such as intelligent user interface technology using pen, voice, gestures, JPEG and H.263 codecs for graphics, voice, video information processing engine development, low-bit audio codec technology, data sync and personal information management application SW.

ETRI conducted the technological development project for universal information appliance (UIA) from September 2000 until December 2002. By compensating for low reliability, low transmission, and delay time for various wired and wireless communication network support, ETRI focused on developing a protocol that supports mobility, and as a result, a mobile TCP/IP, bluetooth protocol, and wireless application protocol (WAP) were developed.

3-7-4. Wearable Computers

3-7-4-1. Wearable Personal Station (Wrist PC)

ETRI conducted the project for developing a wearable personal station (WPS) from March 2004 to February 2008. With the goal of developing WPS that provides a gateway for networking anywhere, anytime, various devices were developed such as wristwatch PCs, modular wearable computers, a wrist platform that supports gesture interface, and a personal mobile gateway.

Not only for technological development, but to change people's perception of next-generation PCs, ETRI hosted "The 1st Wearable PC Fashion Show" at IT-SoC 2004 & Next-Generation PC Industry Fair, and advertised new technologies through exhibits in and outside of Korea every year.

Copper fabric circuit board (top) and fabric watch (bottom)

3-7-4-2. Wearable Personal Companion (Clothing-Type Wearable PC)

The "Wearable Personal Companion for U-computing Collaboration" project was newly planned and conducted in 2011. The goal was to create wearable devices that are lighter and can provide services near the body.

KAIST focused on developing wearable SoC specializing in fabric circuit boards as a joint research institute, and participating institutes, BITcomputer and UBridge, focused on measuring biological signals, emergency situation monitoring, etc. ETRI developed system-on-textile (SOT) technology and clothing-type wearable computer technologies with joint research institutes.

3-7-4-3. Stretchable/Transformational Wearable Technology

ETRI conducted the development of smart skin patch system with flexibility (stretchable by more than 30% and applicable on the skin) from 2012. Taking on the flexible connection between electronic devices using the bundled and intorsion structure of conductive fabrics, ETRI produced results which exceeded the durability of previous technologies.

This technology was used to create patch-type ECG devices and wireless ear set devices that can be adhered on the skin. From 2014, the development of transformational and slap-on wearable device and UI/UX was conducted to produce a wearable device which is easy to wear and can provide natural interaction for the user.

3-7-4-4. Physical Ability Enhancement Technology

ETRI started the project for core technological development for hearing and physical function enhancement to overcome physical problems or deterioration in 2017. The danger-predicting technology consists of technology for people with hearing disabilities, such as predicting the direction and distance of the sound source, perceiving audio events and scenes in real time, perceiving and predicting user situation based on user

Wearable walking assistance system reflecting the user's intended movement

activity, location, nearby sound information, etc. ETRI is also developing a sensory substitution technology[15] that transmits all sounds to the sense of touch for people with hearing disabilities. The core technology of wearable walking assistance system based on functional electrical stimulation (FES) can naturally and individually control muscles by understanding the intended movement of the user.

3-7-5. Human Interface

3-7-5-1. Haptic Interface Technology

ETRI's development of haptic interface technology began in 2004 when it conducted the development of smart haptic interface devices for touch as an information and communication-based technological development project.

The haptic pen is a stylus-type haptic interface that allows users to feel various touch sensations in an electronic device with touchscreen, and is designed to deliver multisensory information with visual, auditory, and tactile cues.

The film-type tactile display device is a tactile output device developed in the form of a film that allows local tactile output only where the user is in contact. The device was able to generate fast response speed and a wideband vibration frequency, and produced a variety of tactile patterns, including the feeling of clicking a button.

ETRI secured the editorship of standard document, which is ISO TC159/SC4: ISO/WD 9241-910 Framework for Tactile and Haptic Interaction, along with technological development, and set the cornerstones for Korea to secure a key proportion in the WC9.

Haptic pen

3-7-5-2. Transparent UI/UX Technology

From 2011 to 2020, ETRI conducted research for a new user interface with transparent film-based vision-haptic input/output functions through the development of transparent actuator and UX interface technology. To maximize the haptic effect, a transparent film-type and flexible display was created based on an optical waveguide

15) Sensory substitution technology: Converts the information of senses that were damaged or deteriorated with a different sense for forwarding or application.

Transparent and flexible input/output interface system

made of polymer material. The transparent touch sensor simultaneously detects the intensity and position of the touch force by measuring the amount of light loss in the area that is sensing as light from the light source progresses along the optical waveguide. The transparent actuator is a combination of functional polymer films and flexible electrodes, which are soft materials with excellent flexibility.

Researchers succeeded in creating a user-experienced transparent tactile input/output system that combines conventional input/output devices and displays excellent performance and stability even when bent. Many of the results were posted in global journals such as Advanced Materials, IEEE Transactions on Industrial Electronics, etc.

3-8. Conclusion

SW

ETRI has led the domestic software technology development since the mid-1980s, and created the foundations for a SW technological drive. In the future, ETRI will develop new and more innovative SW for upgrading core technologies in the Fourth Industrial Revolution such as AI, big data analysis, and IoT.

Approaching the era of digital transformation where reality and the virtual word coexist, ETRI will focus on developing a cyber physical system (CPS) that can safely control various objects in the real world in the future and continue to apply it to sectors such as smart factories, IoT, and digital twins. In particular, as the importance of contact-free technology rises due to COVID-19, interest in CPS is rapidly increasing, and ETRI is planning to put efforts into expanding and upgrading this technology.

Additionally, ETRI focused on developing a safety-critical system (SCS) for the country and people's safety, and applied an avionic SCS Qplus-Earth to drones. ETRI is also developing technologies to apply to urban air mobility (UAM), which has recently been drawing attention. The goal is to apply domestic commercial UAM in 2021.

Through these efforts, ETRI will put its utmost effort into securing the status of Korea as a leader of the Fourth Industrial Revolution and lay the foundations in becoming an AI powerhouse.

Artificial Intelligence

ETRI has been researching mixed AI to integrate language, voice, and visual intelligence since the early 1990s. In the future, ETRI plans to expand the language understanding and question-and-answer technologies developed so far into areas of specialization such as law and patenting by further upgrading the Exobrain project (2012–2021). Moreover, ETRI will focus on the spread and commercialization of KorBERT, a language model that greatly reflects the characteristics of Korean language. ETRI will also focus on developing technologies related to artificial intelligence knowledge avatar (official name to be decided) that can communicate more closely with users by conducting a question-and-answer not only through text but also through voice.

The technology for neural network automatic translation will expand to B2C business models such as multilingual interpretation services and Hallyu content interpretation, whereas the technology for artificial intelligence teaching will be expanded to elementary schools and the Sejong Institute across the country. In addition, ETRI aims to lead the increasingly demanding field of visual intelligence by boosting the performance of the visual intelligence, DeepView platform, and demonstrating it in various fields.

Additionally, ETRI will take on the challenge of developing the autonomously developing complex intelligence that simultaneously processes various senses (multimodal) such as sight, hearing, and touch based on various single intelligence core technologies including voice recognition, language intelligence, and perceptual intelligence, which were accumulated for over 20 years. The final goal is to implement automatic growth that learns procedural knowledge to solve problems by understanding and mimicking human knowledge, methods, and processes, as well as human understanding that understands user experiences and situations, and predicts behavior and emotions. On top of this, an automatic adaptation technology, which can independently adapt to situational changes as humans do, and finally, a talking AI, which can naturally talk with all humans and systems, are ETRI's main goals in this process.

ETRI will continue to strive to lead the artificial intelligence technology sector to propelling Korea to take a huge leap beyond ICT, and become an artificial intelligence powerhouse.

DBMS/Big Data

ETRI led the evolution of the domestic data sector over the past 30 years, from the database management system (DBMS) to big data analysis. From here on, the future population change prediction and analysis system (ABCD) will be expanded and applied not only to population and welfare but also to all areas requiring large-scale actor-based simulations, helping governments to improve quality of life by quickly establishing accurate and effective policies. The technology for a digital twin (virtual Sejong) for city administration will also expand its use for other local governments, providing scientific policies through data analysis and allowing citizens to enjoy its practical benefits. It also aims to induce rapid growth nationwide by supporting companies in all industries to make use of data and data analysis technologies that have previously been used by universities.

ETRI will continue to develop new technologies in the field of big data analysis and actively transfer them to push Korea in becoming a data powerhouse as well as a country that efficiently uses data.

Server Computing

ETRI led Korea to become a leading nation in computer technology for approximately 40 years. In the future, ETRI will continue to upgrade the domestic computing sector by focusing on securing high-performance cloud technologies that can satisfy various future computing needs and establish computing infrastructure for autonomously operating computers.

First, ETRI plans to open a new paradigm in the computing field by focusing on the memory-oriented next-generation computing system structure that was started in 2018 and converting existing computer structures in CPU memory storage form into CPU storage class memory (SCM).

Based on the technology accumulated from the development of MAHA, a super-computer for genetic analysis, ETRI will focus on developing world-class supercomputer technology, including independent CPU technology through the technological development project for new hyper parallel processor-based supercomputer calculation node. Through this, not only with the computing sciences, but by developing the data-based application and service sector, the domestic supercomputing industrial ecosystem will expand to form the foundation for future exa-class supercomputing system development.

Through these challenges, ETRI will strive to help Korea's computing technology and industries overcome existing limitations and secure the highest competitiveness in the world.

Cloud Computing

Since the late 2000s, ETRI has been leading as a developer of Korea's cloud technology and industries by creating DaaS systems, virtual desktop technologies, big virtual cloud platforms, SaaS platforms, and high-speed deep learning cloud technologies.
Starting from 2020, ETRI plans to newly take on the challenge of cloud edge SW and develop a core technology for ultra-low latency intelligent cloud edge SW platform that guarantees less than 10 ms of response time while focusing on developing a high-speed cloud computing system for the AI field. It also plans to focus on developing multi-cloud service common framework technology to maximize the utilization and spread of various multi-clouds centered around the Cloud-Barista community and sync all global clouds by 2022.

Devices

ETRI has been leading the development of related industries since the early 1980s by preemptively developing computer terminal/device technologies that are newly required according to the times.
In the future, ETRI plans to continue developing a user-experience type transparent visual and touch input systems while also focusing on technology using high-tech ICT for enhancing physical ability and rehabilitation, a danger-predicting technology and a sensory substitution technology that replaces sound with the sense of touch for people with hearing disabilities, and a mobility strength assistive system for the elderly, and expand it into various fields.
ETRI is planning to push forward with future device technology by expanding the existing user interface technologies, which have been focused on vision and hearing, into various senses such as touch. By providing high-tech UI/UX that has never been seen before, ETRI will strive to enhance the quality of life for every citizen.

PART 4

Semiconductors/ Materials/Components

4

Semiconductors/Devices/Components

4-1. Outline

Semiconductors

The 1970–1980s was a very competitive era globally for semiconductor technology. Technological leaders such as US and Japan were confident that semiconductors would lead the industry of the future. They invested intensively in semiconductors, while preventing emerging countries from entering the field by raising technology protection policies such as the Semiconductor Chip Protection Act of 1984 (SCPA).

Even in Korea, the KIST semiconductor device research lab was set up in the early 1970s to start developing semiconductor technology. This research lab was established as the Korea Institute of Electronics Technology (KIET) in 1976, and it became a backbone of ETRI. From then on, MOS technology, Bipolar IC technology for VTR, ROM chips, semiconductor design technology and production support technological development were conducted.

The Korean government, which gradually began to acknowledge the importance of semiconductors, established the 4M DRAM joint development plan in 1986, and started the ultra-high density semiconductor joint research project with Samsung Semiconductor & Telecommunications, Gold Star Semiconductors, Hyundai Electronics, etc. Through this, Korea was able to develop the 4M DRAM and 16M DRAM, and succeeded in developing both the 64M DRAM and 256M DRAM for the first time in the world. Also, the experience and technology acquired through the process of conducting the project became crucial foundations for Korea's semiconductor legacy. Since then, Korea has maintained the top position in the global memory semiconductor market.

From 1982, ETRI initiated the development of system ICs. Starting with 5 μm nMOS process development in 1982, ETRI developed the 8-bit microprocessor (K8048), which became the starting point for Korean microcomputer chip design in 1983, and continued to develop ASICs for TDX-1/TDX-10/ISDN and optical CATV systems in 1992, baseband analog chips for cellular CDMA and analog chips (OE/EO, Tx/Rx) for 155/622 Mbps ATM in 1995, cellular CDMA and RF CMOS chips for PCS in 2001, the world's first DMB chipset for mobile broadcasting services in 2004, embedded DSP development in 2010, designation of human body communication technology as the international standard in 2012, HEVC codec SoC development in 2014, and intelligent radar chip for drone detection in 2020.

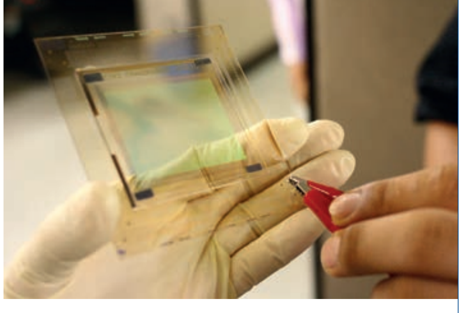
Also, by beginning development of power semiconductors since 1997, silicon (Si) power semiconductor (VDMOS, LDMOSFET, TDMOS, IGBT) devices, ICs (data and gate driver ICs for PDP and FED), and SiC power semiconductor (SiC Diode and MOSFET) devices were developed. After proving the Mott Metal-Insulator Transition (Mott MIT) phenomenon for the first time in the world in 2005, ETRI began developing two-dimensional semiconductor technology that could overcome the limitations of the existing silicon materials and manufacture it at large scale since the mid-2010s. Also, in the late 2010s, the CNT (carbon nanotube)-based digital x-ray source was developed and commercialized for the first time in the world.

From 2010s, entering the AI era, ETRI began developing an AI semiconductor. By starting the development of a high-performance artificial intelligence embedded processor called Artificial Brain (AB), which automatically controled energy usage, ETRI succeeded in developing the AB3, an artificial intelligence processor for unmanned vehicles, and the unmanned vehicle AI processor AB5 in 2017. In February 2020, we developed the AB9 Chip, an artificial intelligence processor specialized for deep learning computing. ETRI has been developing the AB, and is planning to develop a 1000 teraflop rated processor by 2029.

Displays

ETRI quickly began developing the next-generation displays from 1995. In the era where LCD started to expand to an industry, research for flat-screen displays beyond LCD began, securing the world's greatest technology for OLED and inorganic EF and FED within a short time.

In the 2000s, ETRI started transparent and flexible display research, and created the foundations for transparent displays, foldable smartphones, and rollable TV technology. Continuing into the 2010s, it began research on holographic display technology, and in 2017, succeeded in developing 16K-class phase modulation spatial light modulator panels with 3 µm pixels, the world's smallest pitch. 1 µm pixel pitch spatial light modulator devices



Transparent AMOLED prototype

were successfully developed in 2019. This technology is predicted to be implemented for holographic display products in the form of AR and VR in the near future.

Meanwhile, since the mid-2010s, ETRI took on the challenge of implementing a new concept of display that could sense and recognize human biological signals. The results of this research were expected to be commercialized as a biological signal sensing product and tactile and five senses display by around 2030.

Energy

Based on the acquired semiconductor technology, ETRI began technological development for energy material components such as lithium secondary batteries, solar cells, body heat energy conversion technology, etc.

Lithium secondary batteries have been developed for mobile terminals, RFID sensor tags, USN sensor nodes, ubiquitous terminals, flexible ultra-thin film secondary batteries, and bipolar full-solid lithium secondary batteries. Subsequently, ETRI took on the new challenge of solar technology in the beginning of the 21st century to develop dye-sensitized solar technology, color transparent double-sided silicon solar technology, and color transparent CIGS solar technology with non-toxic buffer layers. Also, from 2012, technological development for body heat energy conversion began to develop a body heat-based heat transfer comprehensive module for energy production. ETRI transferred the developed technology to 19 companies (23 cases total), and led the development of the domestic energy material components industry.

Sensors/Actuators

ETRI has been developing ultra-small, low-power, high-performance sensors and actuators through the convergence of semiconductors, MEMS, and nanotechnology. Furthermore, ETRI focused on developing new algorithms as well as HWs, and has achieved the results in the developing intelligent sensors and various applications of actuators.

ETRI succeeded in developing uncooled high-performance infrared imaging sensor, digital high-SNR MEMS microphone, sound field security sensor, complex environment sensor, contactless ultra-sensitive humidity sensor, ultra-thin piezoelectric ceramic speaker, and ultrasonic wireless power transmission technology through human skin. ETRI is making efforts to enable domestic sensor and actuator companies to secure a competitive advantage in the global market through these technological developments.

Photonics

ETRI started developing optical component technology by developing semiconductor lasers for optical communications in the early 1980s. At the time, ETRI began developing optical technology early on with the thought that it was important to secure optical communication technologies to prepare for the upcoming age of information. Later, development of optical device with LPE for crystal growth was completed in 1984, and MOCVD, which had an absolute advantage for high-quality crystal growth and mass production, was introduced to establish its related infrastructure in 1998. In the 2000s, ETRI developed tunable semiconductor lasers and high-resolution visual safety LiDAR. Meanwhile, in the optical device sector, after developing the WDM-PON system in 2006, ETRI demonstrated the leading global technology by continuously developing 400 Gbps coherent photo-detection technology, 25 Gbps C-band EML chip technology for fronthaul, and 400 Gbps light transmission and reception engines.

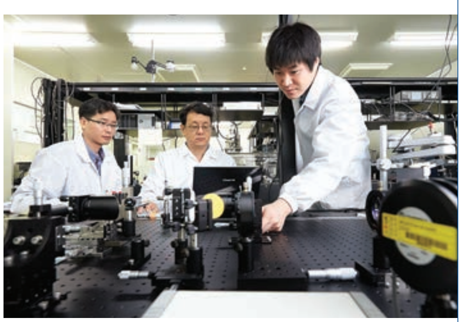
RF/Terahertz

For the continuous development of wireless communications technology and industries, the development of RF and microwave semiconductors should be supported as core technologies. Thus, ETRI established a three inch clean laboratory of compound semiconductors for the first time in Korea in 1991, and began researching RF devices based on silicon semiconductor technology accumulated from the 1980s. Accordingly, RF devices based on compound semiconductors such as GaAs, InP, and GaN were developed to lay the foundations for the domestication of RF devices, components for wireless communications, and millimeter wave systems. ETRI also secured millimeter-wave MMIC technology independently and succeeded in developing GaN-based integrated circuits and high-power devices rated at hundreds of watts operating from the S-band to the Ka-band range.

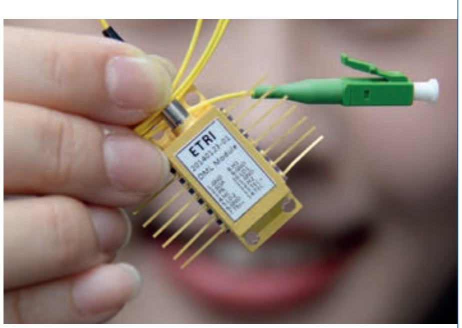
Demonstration of THz wireless transmission (2015)

Meanwhile, ETRI began THz wave research from the late 2000s. Starting from the establishment of the Photonics Creative Research Center (currently the Terahertz Research Section), it has become the only institute in the world that conducts research that covers the whole area in the terahertz field from materials and devices, to modules and systems, in one group. Based on photonics-based THz technologies, ETRI succeeded in developing a THz continuous wave technology that includes core components which can generate and detect broadband CW THz waves from 0.2 to 1.5 THz. From the mid-2010s, ETRI has been focusing on applying THz waves to application areas such as nondestructive testing, security imaging, short-distance wireless transmissions, etc.

Quantum Technology



Setting up of the THz high precision measurement system (2016)



ETRI's dual mode laser module as the THz beating source (2017)

Entering the 21st century, quantum information and communication began to attract attention as a future ICT that can overcome technical limitations of conventional information and communication technologies. In response, ETRI began developing quantum information and communication technology starting from the mid-2000s based on world-class semiconductor technology, photodetector technology, and silicon photonics technologies that have accumulated over nearly 40 years.

In the quantum communication sector, starting with Korea's first 25 km fiber-based quantum key distribution technology in 2005, ETRI has been researching core technologies such as entangled light sources, single photon detectors, and quantum random number generators. As a result, the integrated four polarization splitter, combiner chips and modules were developed, proving for the first time in Korea in 2018 that free-space quantum cryptography communication is possible even in real-life environments with strong sun light at a distance of 300 m. Additionally, technology that applies free-space quantum communication to mobile platform and fiber-based quantum communication continues to be developed.

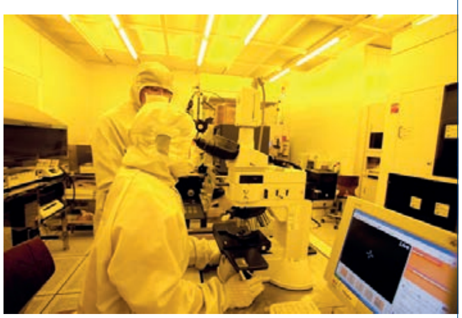
In the field of quantum computing, ETRI has been developing quantum compilation and virtual quantum machine technology, quantum computing system design, analysis, evaluation, verification, and visualization technology since 2015. It is also building a quantum computing platform based on semiconductor quantum dots (QDs).

Based on these technologies, ETRI has been conducting development for single photon light sources, single photon detectors, and quantum gate devices since 2017.

4-2. Semiconductors - The Birth of the Korean Semiconductor Legacy

ETRI has been developing technologies on memory semiconductor, system IC technology, artificial intelligence semiconductor, nano-electronic source, two-dimensional semiconductor, power semiconductor, and MIT semiconductor for the past 45 years.

Memory Semiconductors



16M DRAM Joint Development Progress Meeting

The backbone of Korean semiconductor technological development was the Korea Institute of Electronics Technology (KIET), which later became the basis for ETRI in 1976. From then on, ETRI conducted development of MOS technology, bipolar IC technology for VTR, ROM chip, semiconductor design technology, and production support technology from October 1982. ETRI succeeded in developing a 32K ROM memory device. It was due to this that the semiconductor industry in Korea experienced a revolutionary turning point.

The Korean government, which had gradually begun to acknowledge the importance of semiconductors, established the 4M DRAM joint development plan in 1986, and started the ultra-high density semiconductor joint research project. It was a massive joint development project where ETRI supervised technological development, and joint research companies and institutions participated such as Samsung Semiconductors & Telecommunications, Gold Star Semiconductors, Hyundai Electronics, and the SNU Inter-university Semiconductor Research Center. Through this project, Korea succeeded in developing the 4M DRAM in 1988 and 16M DRAM in 1991, joining the ranks of the leading semiconductor countries. Subsequently, in 1992 ETRI succeeded in developing the world's first 64M DRAM, catching up with Japan's technology, and in 1994, succeeded in developing the world's first 256M DRAM. Since then, Korea has maitained the top position in the global memory semiconductor market.

Based on the foundations established by ETRI, Korea has emerged as the world's leading supplier of memory semiconductors, and semiconductors has been Korea's leading export since 1995.

System ICs

ETRI has developed system IC technology for almost 40 years since 1982. Starting with 5 μm nMOS process development in 1982, ETRI developed the 8-bit microprocessor (K8048) in 1983, which became the starting point for Korean microcomputer chip design, and continued to develop ASICs for TDX-1/TDX-10/ISDN and optical CATV systems in 1992, cellular CDMA and RF CMOS chips for PCS in 2001, the world's first DMB chipset for mobile broadcasting services in 2004, embedded DSP development in 2010, designation of human body communication technology as the international standard in 2012, HEVC codec SoC development in 2014, and an intelligent radar chip for drone detection in 2020. In addition, ETRI developed an artificial intelligent radar chip that detects multiple targets and drones in 2020, and is currently developing a special radar chip technology that can detect survivors in disaster situations. ETRI’s efforts raised Korea's system IC industry into a global leader.

High-performance autonomous driving processor "Artificial Brain"

AI Semiconductors

From 2010, entering the AI era, ETRI began AI semiconductor development. It started developing a CPU using its own independent structure with the aim of securing a high-performance AI embedded processor technology that can automatically control energy consumption, and named it "Artificial Brain (AB)."

As a result of this research in 2016, ETRI succeeded in developing the AB3, a low-power, high-performance artificial intelligence processor dedicated to unmanned vehicles, and AB5, a processor for unmanned vehicles in 2017. In February 2020, ETRI developed the AB9 chip, an artificial intelligence processor specialized for deep learning computing. The AB9 chip can conduct 40 teraflops (100 billion floating point calculations per second) of calculations with a low power consumption of 15W. This is up to 25 times higher computational capacity per unit of power and 20 times lower power consumption compared to conventional commercial products.

Meanwhile, ETRI developed a low-power, high-speed deduction perceptual fast inference processor, “VIC (visual intelligence)”, for mobile edge and IoT. The VIC chip can identify and extract locations of 100 items on the level of human perception 30 times a second using a mere 0.5W of power.

Next-Generation Semiconductors

Also, by starting the development of power semiconductors from 1997, silicon (Si) power semiconductor (VDMOS, TDMOS, IGBT) devices and silicon carbide (SiC) power semiconductor (SiC Diode and MOSFET) devices were developed over the course of about 20 years. In particular, SiC semiconductor diode and MOSFET individual device technologies are highly likely to be commercialized, and this is expected to greatly contribute to the localization of SiC power device components, which have relied on foreign technology thus far. ETRI is establishing a power semiconductor platform with its accumulated Si/SiC power semiconductor device technology, and is providing support to domestic SMEs related to power semiconductors for test product manufacturing and troubleshooting.

After the mid-2010s, ETRI uncovered two-dimensional materials that are being seen as the new material that can overcome limitations of existing silicon semiconductors. Thus, ETRI started developing two-dimensional semiconductor technology that can manufacture these materials. It researched two-dimensional oxide semiconductors and applied device technologies that have more stability compared to MoS_2 (transfer metal chalcogen compounds), and manufactured various two-dimensional materials such as MoS_2, WS_2, WSe_2, VSe_2, and Cu_2S. These results are expected to be useful for developing future semiconductor application technologies. In 2018, ETRI added NaCl in the exfoliation of two-dimensional nanosheets for the first time, and succeeded in producing nanosheet aqueous dispersions at very high-efficiency.

In the late 2010s, the carbon nanotube-based digital x-ray source was developed and commercialized for the first time in the world. This is a technology that can make electron beams from CNT instead of high-temperature filaments more efficiently and for a longer time by using only electric signals. Although conventional X-ray tubes and related imaging equipment were monopolized by certain American, Japanese, and German companies, the road to domestication opened when ETRI succeeded in commercializing

CNT-based digital X-ray source development

the digital x-ray technology. It is expected that if digital x-ray technology is applied to medical diagnosis, industrial nondestructive testing, and security inspection, it will greatly change the paradigm of related industries.

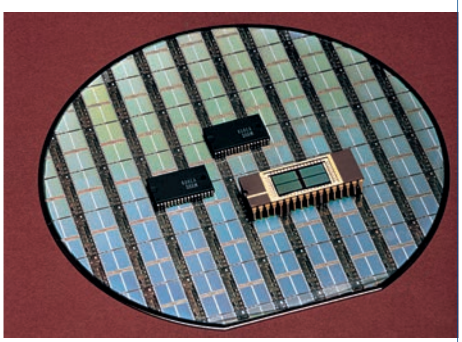
Meanwhile, after verifying the Mott Metal-Insulator Transition (Mott MIT) phenomenon for the first time in the world in 2005, ETRI has been focusing on continuing to develop related technologies. It achieved NDR-MIT switching in 2016, and developed MIT transistors for the first time in the world. Through this, ETRI succeeded in developing high-efficiency LED driver boards at a tenth of the size of existing commercial products, with an increased photo efficiency of more than 14%.

Centering around ETRI, Korea was able to secure its place as the undisputed leader in the world semiconductor industry over the past 45 years. ETRI will continue to contribute to national development by securing world leadership in future semiconductor technology and industry by developing various semiconductor technologies including AI semiconductors.

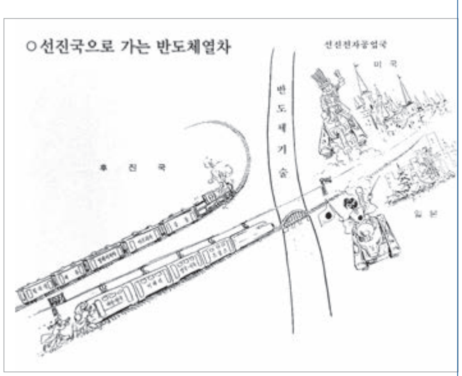
4-2-1. Memory Semiconductors

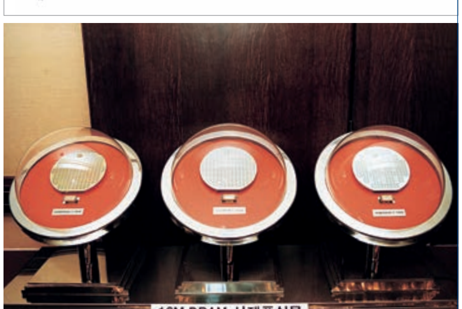
4-2-1-1. 4M–256M DRAM

ETRI, Leading Korea to Become the Global Leader in Semiconductors



4M DRAM prototype

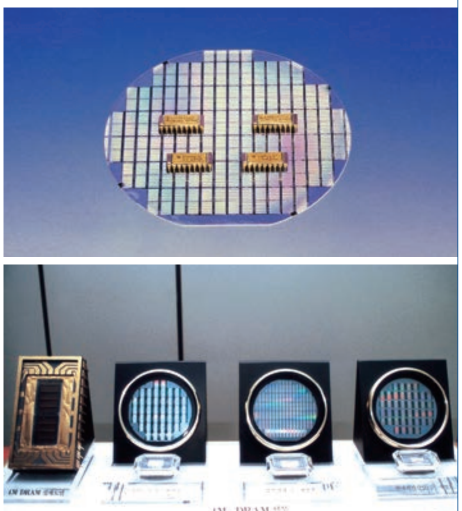




16M DRAM prototype

Korea's technological development for semiconductor started in KIST's semiconductor device research lab in the early 1970s. The semiconductor equipment research lab was later expanded and reorganized as the semiconductor technology center, and the Korea Institute of Electronics Technology (KIET) was officially launched in December 1976, then merged with ETRI on a later date. Along with the launching of KIET (ETRI), the development of MOS technology, Bipolar IC technology for VTR, ROM chip, semiconductor design technology, and production support technology was conducted in earnest. In 1982, VTI of the US introduced the necessary technologies for developing 32K memory ROM and designed it based off of this technology, and developed process and testing technology for mass production. As a result, ETRI successfully developed 32K ROM memory devices in October 1982. It then succeeded developing 64K ROM in 1983, then went on to develop 128K ROM and 256K ROM. These consecutive successes gave faith in the potential of technological development to domestic companies that had been reluctant to invest. In particular, Samsung Semiconductors & Telecommunications (currently Samsung Electronics) jumped into the semiconductor business and succeeded in developing the 64K DRAM in 1983 and the 256K DRAM in 1984.

The government determined that a joint research system was needed compared to the current company or lab unit research to reduce the technological gap between global leaders, and established the 4M DRAM joint development plan with experts from the industrial, academic, and research fields in July 1986. Thus, the high-density semiconductor joint research project started as a massive government-funded project in 1986. This was a massive joint development project where ETRI supervised technological development, and joint research companies and institutions participated, such as Samsung Semiconductors & Telecommunications, Gold Star Semiconductors, Hyundai Electronics, and SNU Inter-university Semiconductor Research Center. For the architecture of DRAM,



4M DRAM developed in 1989

DRAM memory semiconductor '70th representative scientific and technological achievements of the 70th anniversary of liberation' selected certification plaque

research and development were conducted by distributing both performance-enhanced trench methods and stack methods that can be used for mass production for each company. In February 1989, ETRI succeeded in developing the 4M DRAM with a line width of 0.8 μm. In March, it developed a test product for the mass production of 20% yield through process improvement, and also completed the development of inspection and assembly technology. Due to the early development of the 4K DRAM, Korea was able to reduce the technological gap against US and Japan by six months.

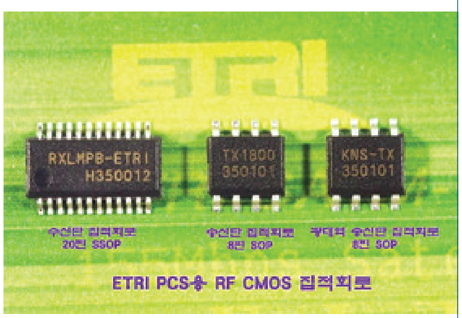
Joint development for the 16M DRAM also started from 1990. ETRI once again supervised the development, and six more companies, two institutes, and 19 universities also participated as joint research institutions along with the previous three companies that were part of the project. In March 1991, the development of a test product for the 16M DRAM was completed. ETRI was able to succeed in developing the 16M DRAM in a similar timeframe as Japan, the leading nation in semiconductors at the time. With this, Korea was able to rank well among the semiconductor-leading nations. Later, in 1992, ETRI succeeded in developing the world's first 64M DRAM, catching up with Japan's technology. In 1994, it succeeded in developing the world's first 256M DRAM. Since then, Korea has maintained a top position in the global memory semiconductor market. DRAM technology was selected as one of the "70 S&T Achievements for the 70th Anniversary of the Independence of Korea" and "National Pride Technology" in 2015.

4-2-2. System ICs

4-2-2-1. System IC Technology

ETRI secured 5 μm silicon gate nMOS processing in 1982 and 4 μm CMOS processing in 1983. This technology was immediately applied to the production of 4-bit SRAM, 2K/64K ROM and 8-bit microcomputers, producing successful results. In particular, the 8-bit microprocessor (K8048) developed in April 1983 became the starting point for domestic microprocessor chip design. In September 1985, ETRI started developing

Development of custom semiconductor technology



Transceiver RF chip for CDMA PCS

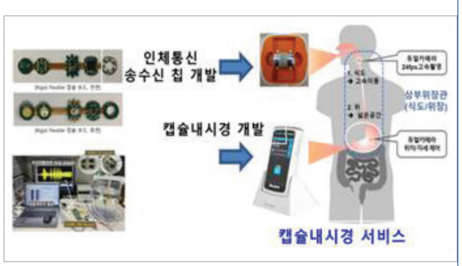
Opening of ASIC Support Center

application specific IC (ASIC) technology with a KRW 33.3 billion contribution from KT Corporation. Over seven years of business, ETRI developed and transferred ASICs for the TDX-1, TDX-10, ISDN, and optical CATV systems. Also, in 1989 it developed the 0.8 μm CMOS standard process (4M DRAM-class) using its own independent technology. Based on this, ETRI introduced an innovative method of implementing CDMA RF components that were manufactured in a combination of various components into a single chip using CMOS. This technology was applied to develop RFCMOS chips for cellular CDMA and PCS in 1999 and 2001, and it succeeded in the calling test for the first time in the world.

With the establishment of ETRI ASIC Development Center in 1993, the CMOS standard process was actively used to support ASIC production requested by companies. The center provided support so that companies could participate and develop ASIC from 1994 to 1998. As a result, around 72 types of ASIC were successfully commercialized out of 109 requests including ASIC design and chip manufacturing. ETRI established the ETRI ASIC Support Center in 1997 to expand the system ICs base and foundations. This center was later named the IT-SoC Support Center, and has since been renamed to the Seoul SW-SoC Convergence R&BD Center in 2012. It has served as the headquarters for fostering and supporting system ICs startups.

From 2004, the Ministry of Science and ICT requested the IT 839 Strategy, which led to the development project for SoC technology for receiving terrestrial DMB. The goal of the project was to integrate digital circuits and RF reception circuits in one chip. ETRI has implemented low-power, low-cost terrestrial DMB terminals using the developed DMB SoC technology, which laid the cornerstones for the establishment and spread of DMB services in Korea. In 2006, it started developing the embedded DSP technology, and developed both a compiler and software development environment as well as a low-power embedded DSP core, which produced significant import replacement effects. The DSP cores have been commercialized as touch sensors that minimize chip area and products that implement audio sound effects. In 2007, ETRI began developing a multi-core SoC platform that can produce various multimedia codecs (SVC, VC-1, AVS, H.264, MPEG4) in the same environment, securing 4GOPS/mW multi-core SoC design technology, which was transferred to a total of 14 companies.

Terrestrial DMB receiving SoC and prototypes of DMB terminal



Commercialization of capsule endoscope for monitoring upper gastrointestinal tract based on human body communication

Meanwhile, a human body communications technology using the human body as a medium began development in 2007. This technology enables easy data communication between communication devices or sensors around the human body based on the characteristics of where data signals from electronic devices around the human body can be transmitted. The human body chip technology developed by ETRI was selected as the international standard by the body area network (BAN) of IEEE in February 2012. Human body communication technology continues to be commercialized through capsule endoscopes, elderly care services, etc.

The government recently designated system ICs as a field of innovative growth strategies, announcing the development strategy for artificial intelligence's semiconductor industry. It aims to achieve a 20% market share in the AI semiconductor sector by 2030 and produce 20 innovative companies, as well as 3,000 talented workers to become a leading nation in AI semiconductors.

4-2-3. AI Semiconductors

4-2-3-1. AI Processor Technology

The Explosive Development of AI Processors

With the rapid growth of AI technology, more and more electrical devices in the world are equipped with AI. As the technology domain requiring AI expands its boundary more and more, the market for AI processors is also rapidly expanding.

The government started unprecedented large-scale research and development project for the early commercialization of AI processors (NPUs) aiming the "leading nation in AI semiconductors" through cooperation among institutions including the academic, industrial, and research fields.

As the computational complexity of AI grows exponentially, the semiconductor technology or AI processor[16] with superior power efficiency and computational performance is becoming essential. ETRI is developing AI processors for autonomous

16) Artificial Intelligence Processor: An artificial intelligence semiconductor group that includes graphics processing unit (GPU), tensor processing unit (TPU), and neural processing unit (NPU).

AI server-class AI processor (AB9)

driving cars, medium AI servers, and large-scale AI supercomputer servers that are expected to stimulate the early market of the Fourth Industrial Revolution.

Development of the Low-Power, High-Performance AI Processor Artificial Brain 9 (AB9)

ETRI began developing a CPU using its own independent architecture with the goal of acquiring the national technology of high-performance embedded processors in 2010. It also developed the AB3 for unmanned vehicles in 2016 and AB5 for autonomous driving cars in 2017. In February 2020, ETRI developed the AB9 chip, an AI processor achieving superior performance in deep-learning artificial intelligence applications. The AB9 chip achieves high computational power of 40 Tera FLOPS, $40\text{x}10^{12}$ operations per second, with average power of only 15W. ETRI's AI processor architecture gives AB9 25 times higher computational efficiency as well as 20 times lower power consumption compared to conventional commercial products.

The development of the AB9 has made real-time perception of cars, pedestrians, car lanes, and movement in the autonomous driving cars possible. This unique artificial intelligence processor technology is applicable to a wide range of fields requiring high-performance low-power AI computing such as AI speakers, unmanned autonomous vehicles, high-performance servers, remote treatment, financial services, surveillance, and facial and behavior recognition.

ETRI is now developing ABK AI processor targeting 1 Peta FLOPS, 10^{15} operations per second per chip. The development of ABK would be a historical monument in the field of AI processors. The development of ABK is the cornerstone for national achievement of exascale supercomputer.

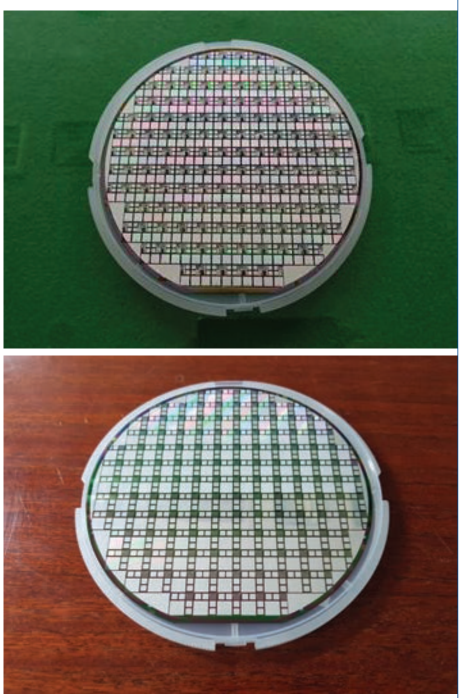
AB9 board

Development of the Visual Intelligence Processor(VIC)

The industrialization of visual AI processing on edge devices requires dedicated AI processor chips with ultra-low-power optimized AI processing. The VIC AI processor was developed for mobile edge and IoT applications. It is an ultra-low-power, high-speed, edge-specific AI processor for visual perception. It recognizes over 100 objects simultaneously with a performance of 30 frames per second consuming 0.5W only.

4-2-4. Next-Generation Semiconductors

4-2-4-1. Power Semiconductor Technology



6-inch trench-type SiC diode (top) and
SiC MOSFET (bottom) prototype

ETRI began research on power semiconductor devices from the late 1990s when the importance of power semiconductor devices for automation, miniaturization, light weight, and energy efficiency for various systems became increasingly important due to the rapid transition into the information era. Based on the only semiconductor laboratory in Korea capable of conducting CMOS batch processing and using the technology and manpower accumulated by researching various semiconductor devices since the 1980s, various governmental-funded research projects related to power semiconductors have been conducted for 20 years.

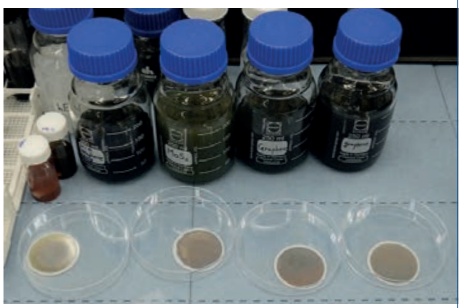
In 1997, ETRI began research on power semiconductors through the for 300V DMOS (high-voltage device) and high-speed BCD[17] power device as part of the leading technological development project by the Ministry of Information and Communication. This project had a total of KRW 4.628 billion in research funding, with 34 researchers working on the project until 1999. Researchers developed 100V class data and 300V class scan drive IC technologies for plasma display panel (PDP), which are compatible with 5V CMOS devices.

In the 2000s, the rapid increase in energy use led to the demand for power efficiency. Starting from 2010, ETRI conducted the development project for high voltage and current power modules and ESD technology for BLDC Motors to develop power modules for 1-chip BLDC motors that are integrated with 100V/100A power devices and motor drive circuits for home appliances and automobiles. ETRI conducted research projects for silicon carbide (SiC) power semiconductors to overcome limitations of power utilization efficiency for silicon (Si) power semiconductors.

One representative task is the development of core technology for SiC-based trench-type next-generation power device launched in 2015, which developed the first six-inch-based SiC Diode and Trench MOSFET in Korea. These technologies are at a level that can be applied to electric vehicles and photovoltaic power generation, which have recently become an issue.

17) Bipolar-CMOS-DMOS (BCD): A process technology that implements bipolar processing for analog signal control, CMOS-DMOS process for digital signal control, and high-power processing on a single chip.

4-2-4-2. Two-Dimensional Semiconductor Technology



Development of nanosheets dispersions for two-dimensional semiconductor materials by mixing water and sodium ion

Development of two-dimensional semiconductor material nanosheet-coated film

Conventional silicon semiconductors reached a point where they could not become any smaller. To overcome these limits, two-dimensional semiconductors began to gather attention globally. ETRI conducted the core technology development for two-dimensional materials and devices for next-generation smart device platforms since 2016 based on the technology acquired from leading Korea's semiconductor legacy. ETRI developed low-temperature manufacturing techniques for high-mobility metastatic chalcogen compounds and stable two-dimensional oxides. ETRI also researched on transistor and new functional device using two-dimensional materials.

To lower the growth temperature of MoS_2, a technique was developed for chalcogenization of metal ultra-thin precursors at 350°C or below by generating high-energy chalcogen particles through thermal cracking. Furthermore, TiO_2, a two-dimensional oxide semiconductor, was successful for developing photosensitive, nonvolatile memory devices, long-term memory synaptic devices, and metal insulator transition characteristics-based synaptic devices. In 2018, ETRI added NaCl in the exfoliation of two-dimensional nanosheets for the first time, and succeeded in producing nanosheet aqueous dispersions at very high-efficiency.

4-2-4-3. Digital X-Ray Source Technology

Digital X-ray source technology development

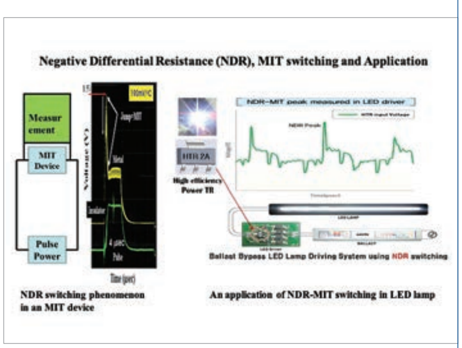
X-rays are electromagnetic waves with a short wavelength used for medical diagnosis and industrial nondestructive testing. ETRI has secured the source technology for the lifetime of CNT emitter by discovering the fundamental mechanism of their field emission behavior and developed the world's first commercial-grade digital X-ray tube through specialized vacuum sealing technology. Digital X-ray tube reduces unnecessary radiation exposure by generating X-rays exactly as needed, in the required amount of time. In addition, it is possible to operate at a much faster speed than the conventional analog X-ray tube, like a camera with a fast shutter speed, so that a clearer X-ray image can be obtained. Digital X-ray tube technology was successfully commercialized for the first time in the world in 2016 through technology transfer to a dental X-ray imaging device company. It is expected that if digital X-ray technology is applied to medical diagnosis, industrial nondestructive testing, and security inspection, it will greatly change the paradigm of the related industries.

4-2-4-4. MIT Device Technology

World's First Demonstration of Mott MIT(Metal-Insulator Transition) and Research for Its Applications

In 2004, ETRI succeeded in observing the Mott MIT that does not have structure change by simultaneously measuring MIT and SPT (structural-phase transition) in a correlated material, vanadium dioxide, which was a problem first proposed in 1949 by British physicist Mott's theoretical model called the "Mott MIT", where nonconductors changes to metal or metal changes to nonconductors without experiencing SPT, in other words, a phenomenon where electricity runs through insulators.

Also, this phenomenon can be applied to create high-sensitivity sensors which utilize the boundaries between the semiconductor and MIT area, and emerging devices that form the basis for future new-concept neuromorphic devices using Negative Differential Resistance (NDR)-MIT switching. This phenomenon can also be achieved with vanadium dioxide and Si, which consists of the MIT material.



NDR-MIT switching and applications

ETRI's MIT material and device design and manufacturing technologies are among the best in the world. Around 20 key papers published by our researchers are cited for around 1,000 times annually, and 55 patents registered in the United States have been secured including 79 domestic patents and 244 international patents from various countries.

4-3. Displays - Evolving Into a Display Beyond Displays

Starting with display research from the 1990s, ETRI led the development of display technology and industries in South Korea by developing OLED, inorganic EL and FED, flexible, holographic, tactile, five senses, and bio-signal recognition displays.

Display is a visual output device that generates various information on a screen for humans to see. The display industry is immense, including not only display panels and modules, but also all of the activities necessary to produce input devices, user interfaces, related materials, and equipment.

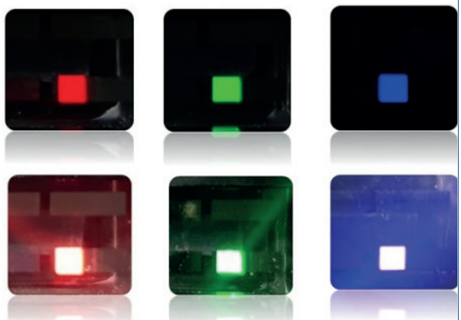
Display can be classified into various categories based on operating principles, shape, and its application. In terms of operating principles, it can be classified by displays that control light transmission or reflection like LCD[18)] and displays that produce light from display pixels like OLED[19)]. In terms of shape and form, displays can be divided into flat, flexible, and micro displays. It can also be classified into public, embedded, spatial, mobile, wearable displays and so depending on the convergence sector. Likewise, displays can be classified in a variety of ways, which also imply that it is a field which requires great technological development.

ETRI began to study the next generation of flat-panel displays beyond LCDs in the 1990s, when the LCD technology industry started to actively develop. Some key examples are OLED and inorganic EL and FED. The technologies that were secured at that time became the foundations for developing OLED TVs and OLED smartphones, which are currently at the center of the display industry in 2020.

Starting from 2000, it has taken Korea's display technology to the next level by researching transparent displays with new functions and flexible displays that can be transformed freely. This technological advance was the cornerstone for the development of current transparent display products, foldable smartphones, and rollable TVs.

18) Liquid crystal display (LCD): A display device which uses the concept of an electric field, intervening external waves and modulating changes to the molecular structure using electromagnetic waves.

19) Organic light-emitting diode (OLED): A self-emitting organic material that uses the field light-emitting phenomenon, which produces light when a current flows into the fluorescent organic compound.


Development of High-luminance and low-power OLED technology

Also, in 2013 we began researching holographic display technologies that can produce three-dimensional displays. As a result, in 2017 ETRI succeeded in developing 16K-class phase modulation spatial light modulator panels with 3 μm pixels, the world's smallest pitch. The 1 μm pixel pitch spatial light modulator device was successfully developed in 2019. This technology is predicted to be used for holographic display products in the form of AR and VR in the near future.

After 2015, a new trend began in display technology. ETRI started research for implementing a new display concept that allows users to feel senses and recognize a person's biological signal beyond a technology that merely satisfies viewing. The results of this research are expected to be commercialized as a biological signal-sensing product, as well as tactile and five senses display by around 2030.

ETRI continues to go beyond its own achievements with the current technology and contributed greatly to securing Korea's status as the world's leader in display technology by developing technology preemptively through anticipation of display trends 10 to 20 years in advance. ETRI's development of display technology will continue into the future.

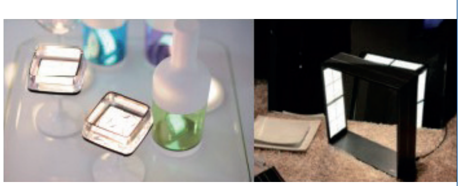
4-3-1. Flat Displays After LCDs

4-3-1-1. FED Display Technology

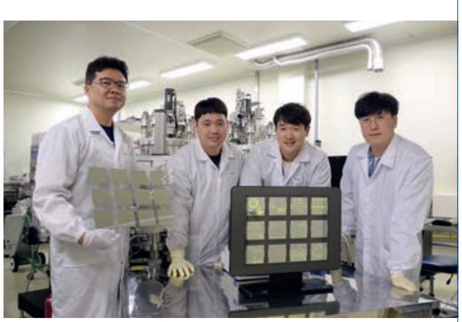
ETRI formed an internal TF in 1995 to conduct basic technical research on field-emission display (FED), the next generation flat-panel display device. Based on this, the FED technology for information communication was developed from 1996 to 1998, and the 300cd/m^2 tier high brightness low power FED technology was developed from 1999 to 2001 under the Ministry of Science and ICT. Afterwards, further research on high-reliability low-price AM-nFED technology was conducted.

ETRI initially focused on developing small devices of around one inch in size. Although packing technology based on silicon tips using fab was jointly developed with other companies, it was difficult to solve the lifespan problem where conventional Mo-tips were used as an electron emission device. Thus, they started to introduce the active matrix (a method of high-resolution LCD display technology with low afterimage phenomenon). Also, research was conducted on combining CNT electric sources and active matrix methods.

As a result, Orion Electric developed a 3.5-inch color FED test product in January 1999. In September 2001, ETRI developed the world's first active matrix FED test product, and Samsung developed the world's first 7-inch CNT FED test product in November 2001. Korea went on to secure the world-leading FED technology.



Development of OLED mood lighting



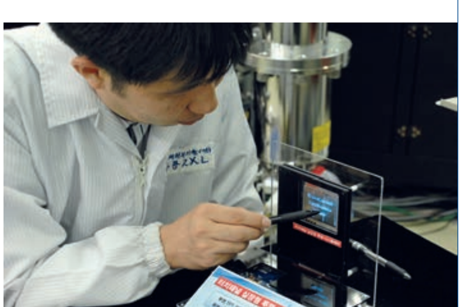
Development of OLED display with graphene transparent electrode

4-3-1-2. OLED Display Technology

OLED technological development in Korea began in 1994 when ETRI published its first research paper on OLED in the Synthetic Metals journal. Since then, we have continued with basic research and began researching OLED by developing the flexible PM-OLED in 2000.

OLED lighting is thin and flexible, which opens up a whole new world of design potential previously thought impossible, and it produces less eye fatigue due to its similarity with natural lighting, while also being environmentally-friendly as it does not contain heavy metals. ETRI developed white OLED for high-efficiency lighting and transparent and

OLED lighting design contest



Development of transparent smart window technology

flexible OLED lighting technology to lay the foundation for Korea's OLED lighting technology. In particular, it started the OLED Lighting Design Contest in 2008 to create an opportunity for the public to better accept OLED lighting as mood lighting.

Also, in 2018 ETRI developed an active matrix organic light-emitting diode (AMOLED) panel technology using chemical vapor deposition (CVD) graphene, well known for being the carbon material of the future, to lay the foundation for next-generation display technology competition with the rest of the world. Graphene-applied OLED panel technology was awarded the National Outstanding Research and Development Achievement in 2016. Also, the graphene nanomaterial transparent electrode technology developed by ETRI was selected as one of the “Top 10 Nanotechnologies” in 2017.

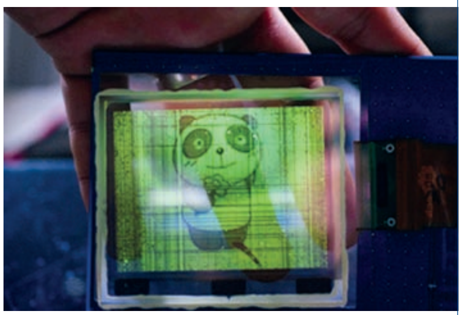
Furthermore, OLED micro-display panel process technology was developed by taking on the challenge for virtual augmented reality technology, which is part of ultra-realistic device technologies. In particular, it led to the development of realistic OLED future technology by securing military micro-display technology and 32:9 scale micro-display technology for people with limited vision.

4-3-2. Displays Beyond Flat Display

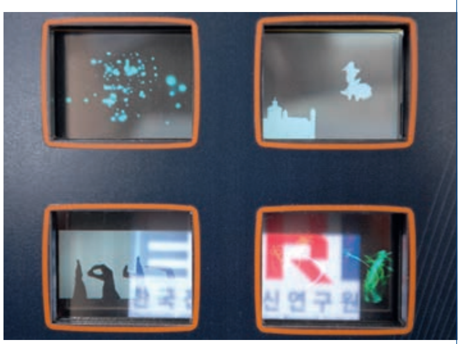
4-3-2-1. Transparent Display Technology

Since transparent display was something that was not yet achieved globally, ETRI developed technology by establishing its own basic concepts, applications, implementation methods, and features. In particular, the negative bias illumination stability (NBIS) phenomenon, which was discovered while testing the stability of oxide TFT for transparent display incident light, was presented for the first time in the world through the ETRI Journal. Also, the "ZnO TFT Transparent Display" paper, published for the global Society for Information Display (SID) in 2008 and has been cited 640 times internationally. Moreover, it was published in the Advanced Materials journal in 2009 and has been cited about 333 times, boasting Korea’s technology to the world (Google Scholar, 2020).

The research and development for transparent displays was conducted with a wide



Transparent AMOLED panel with transparent oxide TFTs



Transparent OLED display panel co-worked with NeoView Kolon

Development of active-driven color electronic paper technology

spectrum. It involved developing oxide semiconductor materials, oxide semiconductor TFT device structures, transparent electronic circuits using oxide semiconductor TFTs, and transparent AMOLED panels using oxide semiconductor TFTs and transparent OLEDs. Through these achievements, ETRI announced the world's first oxide TFT-powered AMOLED at SID in 2006, which was selected as one of the "100 National Research and Development Project Achievements" in 2009.

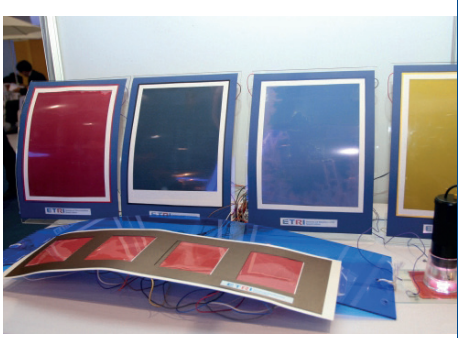
Based on excellent technical performance, the search for applications of transparent displays has also been actively conducted. ETRI presented the transparent display with double-sided touch support and transparent display with transparent RFID as functional displays that are more than merely transparent displays. In particular, the term "smart window" was coined to define a window that performs a smart function by embedding a transparent display or transparent input device in a conventional windowpane.

4-3-2-2. Flexible/Stretchable Display Technology

In 2000, ETRI showcased the 1.8-inch passive OLEDs for the first time in Korea. Later, ETRI started the research project on flexible display with the support of the Ministry of Science and ICT in 2003.

From 2008 to 2013, with the Ministry of Knowledge Economy (MKE)’s support, ETRI conducted the mobile flexible input and output platform development project with a funding of KRW 12.9 billion. This project aims to develop flexible information input and output devices with a new concept that performs both input and output functions in line with mobile devices beyond previous projects which had focused on developing the display panel itself. As a result, ETRI showcased a complex functional integrated module that integrates the output device, active-driven color electronic paper, input device, tablet, the input and output circuit, and wiring connections into a flexible form. In the future, this will form the foundation for ETRI to expand flexible electronic device research into various applications other than displays. The plastic-based active driven color electronic paper technology produced through this project was selected as one of the "100 National Research and Development Project Achievements" by the Ministry of Science and Technology in 2013.

Flexible OLED prototype (November, 2006 (top), December, 2007 (bottom))



Flexible color electronic paper (November, 2006)

From 2012 to 2017, ETRI conducted the core technology development of light- and space-adaptable energy-saving input/output (I/O) platform for future advertising service project worth KRW 39 billion under the support of the Ministry of Science, ICT and Future Planning. Beyond being bendable, the goal of the project was to secure core technology for extendable displays that can reach any desired direction according to the environment. To do this, new technologies were developed that had not been required for the conventional flexible electronic circuits, such as new flexible substrates and wiring structures, wiring materials that do not change electrical properties, TFT devices that are resistant to mechanical deformation, and circuit transfer technologies with flexible substrates. Based on these achievements, ETRI announced the 3.5 inch extendable active OLED panel production results to secure its lead in the development of extendable displays.

Meanwhile, the light- and space-adaptable (LASA) display technology, which minimizes energy use and provides ideal quality, was selected as one of the "100 National Research and Development Achievements" by the Ministry of Science and Technology in 2014 and awarded the "National Research and Development Achievement" by NST in 2017.

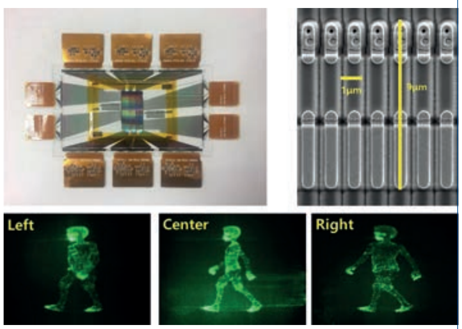
Korea secured its position as the global leader in the display industry through technological development of flexible and stretchable displays towards the 2000s.

Also, flexible and stretchable electronic device core technology acquired from research and development is expanding to completely new sectors of electronic skin, biological security, and neural interface, acting as a pillar of ETRI R&R.

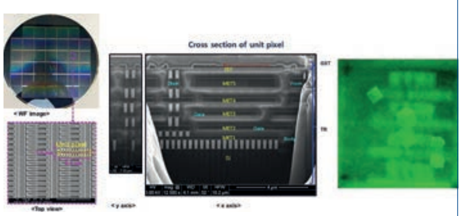
4-3-3. Realistic Display

4-3-3-1. Holographic Display Technology

ETRI, which secured the world's best display technology, showed interest in developing three-dimensional stereoscopic displays (holographic displays) to lead the next generation of displays. Thus, it began to actively develop holographic displays



1um-pixel-pitch SLM and its reconstructed holographic images



Phase change material based SLM and its reconstructed holographic images

SID2020 I-zone Best Prototype Award

in 2013, starting with the development of full-3D mobile display terminal and its contents project, which is one of the government's Giga Korea project.

Through this, ETRI focused on spatial light modulator (SLM)[20] panel development, which is a key component of digital holographic displays. SLM display the diffraction pattern of stereoscopic images to be reproduced by digitizing it, and upon irradiating the laser-like congruent light, the stereoscopic image is reproduced through a diffraction phenomenon. The biggest challenge of this technology was that the viewing angle of the stereoscopic image was limited by the SLM's pixel pitch. Thus, the development of the ultra-fine pixel pitch's display panels became the core of the research, and for this purpose, the research was concentrated on the display-driven backplane's high intensity. Also, to implement displays that satisfy large viewing angles and large screen areas, development was promoted for ultra-high resolution SLM based on glass substrates that require more advanced technology compared to silicon semiconductor processing costs.

As a result of the study, ETRI succeeded in 2017 in developing 16K-class phase modulation SLM panels with the world's smallest pitch of 3 µm pixels, and it was announced in SID. Furthermore, ETRI developed SLM with further smaller pixel pitch of 1um in 2019. In recognition of this achievement, ETRI received "I-zone Best Prototype Award" for the first time in Korea in 2020.

Meanwhile, ETRI also succeeded to develop a SLM based on the phase-change material, which is considered the way to overcome the limitation of cross-talk issue caused by the used of liquid crystal.

Holographic display technology is a key technology that can outrun the pursuit of competitors and widen the technological gap as the leader in the display industry. In particular, as contact-free communication became increasingly important since the onset of the COVID-19 pandemic, ultra-realistic holographic technology which provides a realistic communication experience between remote individuals also became significant. The technologies developed by ETRI could serve as ultra-realistic media platforms for contact-free communication.

20) Spatial light modulator (SLM): A display panel element at the core of a digital holographic display that reproduces stereoscopic images with any form of modulation (phase or amplitude, etc.) that varies spatially against incident light.

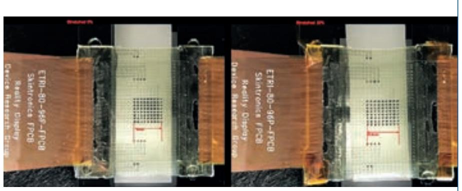
4-3-4. Display Technology Beyond Display

4-3-4-1. Tactile/Five Senses/Biological Signal Display Technology

After 2015, consumer demands for a new concept of display beyond the limits of existing displays increased. In response, ETRI began developing a display that goes beyond satisfying vision and allows users to be tactile, using their five senses and even recognizing biological signals. In other words, a "display beyond displays." Because these are new technologies that are not yet defined, ETRI is internally developing the technology starting with the establishment of basic concepts and methods of implementation.

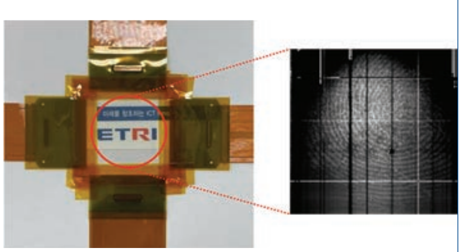
ETRI started the development project for core technologies for tactile I/O panels in skintronics[21] in 2017 with support from the Ministry of Science and ICT.

To develop I/O panel technology that can process the sense of tactile and five senses, ETRI's advanced technology, flexible electronic device technology, oxide TFT technology, sensor/actuator device technology, and input/output circuit technology were linked, enabling ETRI to secure core source technologies such as flexible active device array technologies, sensory input and output sensors and actuator device technologies for array integration, and flexible circuit and component technologies for array driving. In particular, ETRI developed a prototype of display array that senses high-resolution (25 ppi) tactile sense with 20% stretchability and provides high-resolution (25 ppi) tactile sense with a hybrid structure.



Prototype of a display array that senses high-resolution (25ppi) tactile sense with the ability for 20% stretchability

From 2018, ETRI began developing technology that can express human biological signals on a display through the development project for core technologies for transparent flexible display integrated biometric recognition device. This project was conducted to develop flexible transparent display technology that can be used for authentication and security through the use of fingerprints and intravenous signals. As a result, ETRI developed a 256x256 transparent optical fingerprint display sensor array with a transmittance rate of 77% and a pressure display prototype that shows the fine surfaces of objects.



Prototype of flexilbe transparent composite biometric recognition device (left) and fingerprint image (right)

In the future, ETRI aims to further expand these technologies to hologram five senses device technology to be used in ultra-realistic media services that can satisfy tactile, smell, and emotion, and an intelligent secure ultra-trust device technology that maximizes convenience and security.

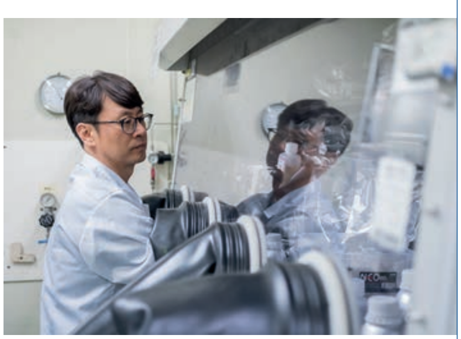
21) Skintronics (skin electronics): A device that serves the role of realistic input and output UI/UX by adhering electronic devices on the skin, and includes flexible elasticity, sensory input and output devices, and motion and signal processing units.

4-4. Energy - Taking on the Challenge for Sustainable Energy Components

Since 1995, ETRI secured dye-sensitized solar cells, high-efficiency thin-film solar cells, and thermal energy conversion technologies from lithium secondary batteries, leading the development of domestic energy material components.

In ICT, the technology for energy material components is an information power technology that drives ICT electronics and can be classified into mobile terminals, photons (that convert sunlight and indoor light into electrical energy), thermoelectric devices (that convert body heat into electrical energy), lithium secondary batteries and capacitors.

Early research on information power conducted by ETRI was mainly focused on energy storage such as lithium secondary batteries. Based on the accumulated semiconductor technology, ETRI began researching chemical materials on positive and negative electrodes in lithium secondary batteries in 1995. Since then, it has continuously developed the material technology (electrode live material technology, electrolyte technology, subsidiary material technology) to assemble lithium secondary batteries (flexible technology, form-factor free battery assembly technology, safety and reliability technology).

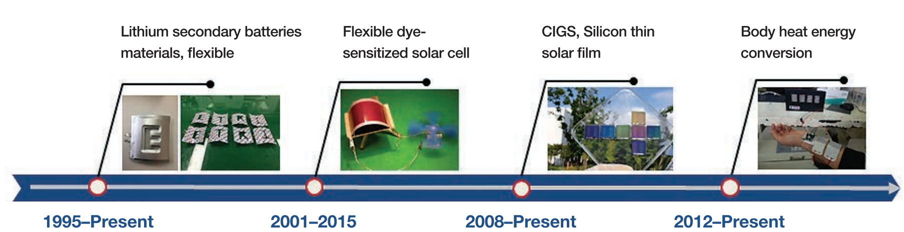


Researchers developing energy storage solution

In the 2000s, the company took on the new challenge of solar energy technology and began developing flexible color dye sensitized solar cells as independent power sources in 2001. As a result, ETRI succeeded in developing the world's best color flexible dye-sensitized solar technology with an energy conversion efficiency of more than 5% in 2005. ETRI also achieved more than double the efficiency compared to the highest technology announced at the time, which was around 2% energy conversion efficiency. Subsequently, from 2008, ETRI jumped into the development of high-efficiency thin-film solar cells, and developed transparent CIGS solar technology with non-toxic buffer layers, as well as transparent color double-sided silicon solar technology.

From 2012, the company began developing a technology to change body heat energy using the thermoelectric effect. As a result, in 2019 ETRI developed a thermoelectric composite module for body heat-based power production consisting of dry-adhesive flexible devices, high-efficiency thermoelectric devices, high-temperature mimicking heat sink, and high-efficiency power management circuits. This module technology is expected to lead the growth of the next-generation smart device industry, being used as a constant power source for wearable devices or IoT systems, which are core technologies of the Fourth Industrial Revolution.

ETRI will continue to develop energy materials and component technologies for application to IoT systems and digital healthcare devices that are expected to constantly increase throughout the Fourth Industrial Revolution.

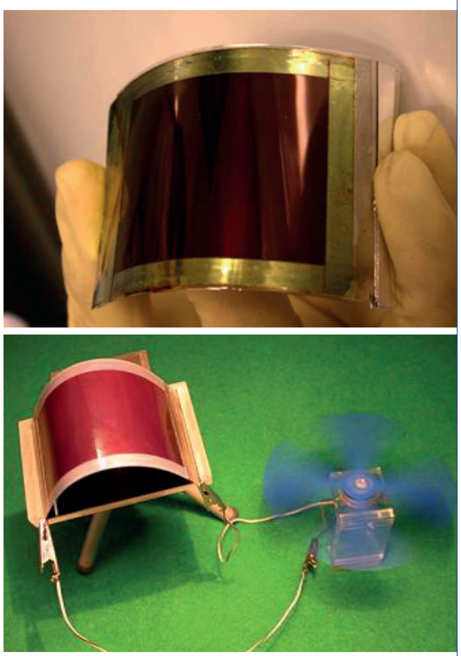


Technology transfer	Sukgyung AT (Mar 2008) Creative & Innovative (Jun 2010) JENAX (Sep 2011) Creative & Innovative (Dec 2013) Enkem (Dec 2014) Jeong Kwan Display (Nov 2015) Enkem (Nov 2017)	URi Fine Plating (Aug 2006) Iljin Materials (Nov 2006) Suntech (Jul 2007) SANG BO (Aug 2008) TGEnergy (Dec 2009) Dongjin Semichem (Jun 2012) Eagon Holdings (Jun 2012)	Jeimon (Oct 2011) Jeimon (Sep 2013) Jeimon (Dec 2015) ISAC Research (Jun 2017) Sweeokem (Sep 2018) ISAC Research (Aug 2020)	Livingcare (Sep 2015) Selakom (Sep 2015) ELT (Nov 2016)
Awards	Top 100 Achievements in National Research and Development (2017, Ministry of Science and ICT) Patent Technology Award - Chi Sog-Yong Award (March 2004, Korean Intellectual Property Office / JoongAng Daily)	Top 100 Achievements in National Research and Development (2006, Ministry of Science and ICT)		Top 100 Achievements in National Research and Development (2018, Ministry of Science and ICT)

ETRI's technology development chart for the energy components field

4-4-1. Solar Devices

4-4-1-1. Dye-Sensitized Solar Technology



Dye-sensitized flexible solar cell

World's Greatest Technological Development from a Change in Perspective

As an independent powerhouse for next-generation PC implementation since 2001, ETRI developed solar energy technology that can bend color and store lithium secondary batteries. The key to technological development was to form a nanoparticle oxide thin film with excellent electron transfer on a polymer substrates at low temperatures (below 150°C), processed at high temperatures. At the time, researchers around the world were making various attempts to form a low-temperature thin film, but the use of existing methods could not give the performance required for next-generation PCs.

It was selected as one of the "Top 100 Achievements in National Research and Development" (2003–2005) for its success in going beyond the existing notion of needing to use polymer substrates and producing world-class color flexible dye-sensitized solar technology with energy conversion efficiency of more than 5% by designing a new solar structure.

ETRI transferred the color flexible dye-sensitized solar technology to URi Fine Plating Co., Ltd. (2006), ILJIN Materials Co., Ltd. (2006), Suntech Power Holdings Co., Ltd. (2007), SANGBO (2008), Dongjin Semichem (2012), and Eagon Holdings Co., Ltd. (2012) and supported the technology's commercialization. Dongjin Semichem and Eagon Holdings are developing transparent solar windows for commercialization.

Dye-sensitized flexible solar cell invited to Green growth excellence technology(2008. 9. 11. The Blue House)

4-4-1-2. Cu(In,Ga)Se_2 Thin-film Solar Technology

Development of World-Class CIGS Thin-Film Solar Batteries

ETRI developed a highly efficient thin-film solar cell using Cu(In,Ga)Se_2 (CIGS) based on chalcogen. A total of KRW 14 billion and 56 researchers were put in to conduct the related 14 projects including CIGS thin-film solar cell technology, monolithic integrated

CIGS solar cell module technology and so on, starting with the planning and research for next-generation solar generation technology. High-efficiency thin-film solar technology was developed by manufacturing ultra-thin CIGS absorption layers, flexible solar cell technology using flexible substrates, low-damage transparent electrode processing, and ultra-light flexible substrate thin film module processing equipment.

High-efficiency tandem-type device source technology was developed using high-temperature buffer layer technology to identify causes of deterioration of solar cell performance at high temperatures. Buffer layer technology was developed and applied to tandem-type devices to overcome this. Thermal stability was identified through surface analysis of devices using dry processing nontoxic buffer layer technology and various colors were also successfully implemented by adjusting the thickness of the buffer layer and window layer. In addition, the new solar cell analysis method of using photo-pumping terahertz spectroscopy is the world's first direct explanation for improving solar cell conversion efficiency with nontoxic buffer layers.

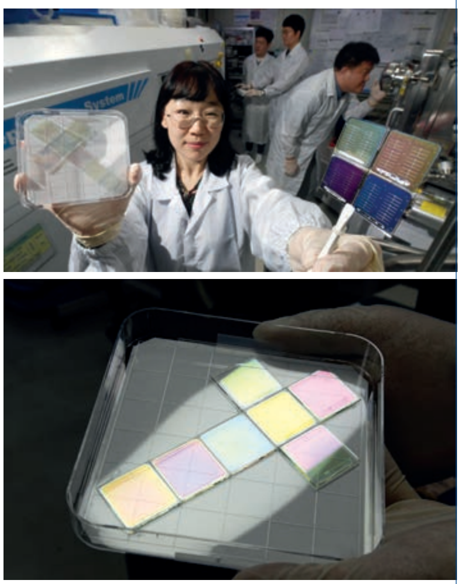
Eco-friendly color Cu(In, Ga)Se_2 thin film solar cell

4-4-1-3. Next-Generation Solar Technology Based on Thin-Film Silicon

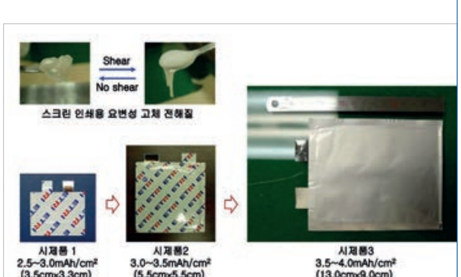
Development of Window Technology Based on Multilayered Transparent Electrodes

In low-cost and stable silicon solar cells, the amorphous Si thin-film is thinner than 1 μm, enabling the manufacture of transparent or flexible solar cells. ETRI began developing the silicon germanium (SiGe) thin-film solar cell source technology from 2008. Later, from 2010 to 2019, a 150-nm thick high-performance multi-layer transparent electrode technology with large-area, low-cotton resistance, and highly transparent was developed, and window-type transparent solar energy technology was also developed to boast a world-class performance index.

In particular, ETRI succeeded in achieving more than 8% efficiency and 20% transmittance, and achieved diverse colors through bi-double-sided power generation for the first time in the world. With this technology, around fifteen SCI-class papers and three



Eco-friendly color thin film solar cell



Flexible solid state lithium secondary battery technology

technology transfers were achieved (worth a total of KRW 250 million). In addition, it achieved world-class efficiency of 36%, with transparent indoor light generation based on thin-film silicon, which was published on the title page of the ACS Applied Materials & Interfaces journal in 2020.

Going forward, ETRI will continue to develop technology that can be widely used such as power generating windows for buildings, curtain walls, sunroofs for automobiles, IoT sensors, and coating membranes for power generation of indoor home appliances.

4-4-2. Secondary Batteries

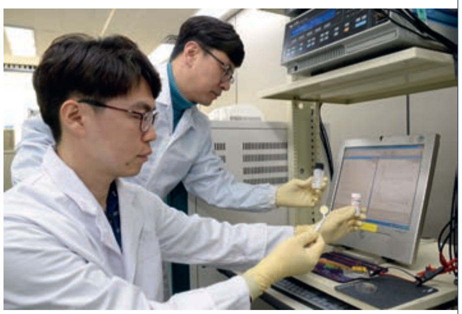
4-4-2-1. Source Materials for Secondary Lithium Batteries and Flexible Processing Technology

ETRI began research on the positive and negative electrodes of secondary batteries in 1995, the beginning stages of the commercialization of lithium-ion batteries. ETRI's project to develop technology for lithium secondary battery is divided into material technology that makes up lithium secondary batteries and processing technology that assembles lithium secondary batteries by combining them.

Electrode Material Technology

Since 1995, ETRI has focused on researching the advancement of electrochemical properties of secondary battery materials, especially oxide materials in transition metals that are part of active materials ($LiCoO_2$, $LiMnO_2$, $LiNiO_2$, $Li(Ni\text{-}Co\text{-}Mn)O_2$), Spinel $LiMn_2O_4$, Olivine $LiFePO_4$, etc. The advancement of electrochemical properties of Graphite, Lithium, and Silicon, secured around 10 related patents in and outside of Korea and publishing 20 studies in the SCI academic journal.

Following the study of vinylidene fluoride polymer gel-based organic solid electrolytes, ETRI has also been studying inorganic solid electrolytes (oxide and sulfide) materials for lithium secondary batteries since 2015. In particular, high-efficiency surfactant solid electrolytes are developed through the synthesis of shape-controlled inorganic solid



Lithium secondary battery solid electrolytes manufacturing technology

electrolytes (LLZO, LATP, LPS, etc.) that span 0 to 3 dimensions (zero-dimensional spherical, one-dimensional fibroids, two-dimensional flat, and three-dimensional cubes). With these achievements, around 10 domestic and foreign patents were secured, and around 15 research papers were published in the SCI academic journal. In 2017, these technologies were selected as one of the "100 National Research and Development Achievements" under the title of "Solid Electrolysis Manufacturing Technology for High Safety Lithium Secondary Cells."

From 2019, as part of the effort to localize materials due to trade regulations from Japan, high-performance technology development was conducted for SBR/CMC water-based binders, which are highly dependent on Japan among lithium secondary battery materials. Also, as the material for strengthening the separation membrane, domesticating of related key components and materials was conducted through high-efficiency synthesis of Alumina (Al_2O_3), separated Acrylate suspension and applied research. In particular, ETRI is focusing on being able to actually apply the binder and separation membrane, strengthening the binders at the production site.

Ultra-Thin Flexible Technology

In 2014, ETRI developed a technology to manufacture ultra-thin (less than 300 mm) flexible film lithium secondary batteries by changing the manufacturing method of lithium secondary batteries from wet to the dry-wet hybrid method. Excellent flexibility is achieved by maintaining stable performance without significant changes in the cell open circuit voltage even with bending, pulling, and folding of pouch cells repeatedly with 70% charging depth.

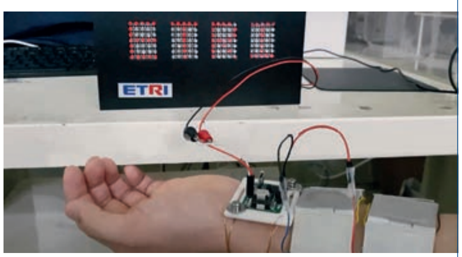
It also secured lithium secondary battery manufacturing and assembly process technology that is free from set form factors[22] as a suitable power source for various design elements. Two research papers were transferred to SCI academic journals and two SMEs in Korea. In the future, ETRI aims to strengthen the sustainability of the overall energy industry by securing an energy ecosystem that can systematically manage energy generation, energy conversion, and energy storage systems.

22) Form factor: The appearance, size, and physical arrangement of a product.

4-4-3. Body Heat

4-4-3-1. Body Heat Energy Conversion Technology

Development and Distribution of a Body Heat Conversion Module



Thermoelectric device that produces electricity from body temperature

From 2012, ETRI conducted the project for silicon-based multi-dimensional thermoelectric device technology and the development of core technology for flexible thermoelectric power generation system for wearable devices with KIST and the Korea Research Institute of Chemical Technology from 2014 to 2020. ETRI also developed core technology for thermoelectric modules which produce electricity with human body heat. The research resulted in ETRI developing a 35 $\mu W/cm^2$ thermal power production module in 2019, which is about 1.5 times higher than the world's most efficient heat-based thermal power generation device (with an output density of 20 $\mu W/cm^2$, NCSU).

In the case of dry-adhesive flexible devices used in thermo-composite modules, the materials' micro and nano layer structures are used to develop devices that maintain excellent mechanical stability while in close contact at cell-level roughness. It was also selected as the cover paper of Advanced Materials, a world-renowned journal for material engineering, by developing a high-temperature anthropomorphic heat sink device that allows for variable insulation according to ambient temperature by simulating the sweat glands.

ETRI also developed thermal electric devices for high-efficiency power management circuit for body heat that maintains an efficiency of more than 80% at low voltages and converts them into chargeable voltages, and this was applied to wearable devices. This technology was selected as one of the "100 National Research and Development Achievements" in 2018 under the title of "Design and System Packaging Technology of Ductile Thermocouple Modules Based on Thermal Analysis of the Human Body."

Unlimited Power for Various Smart Devices

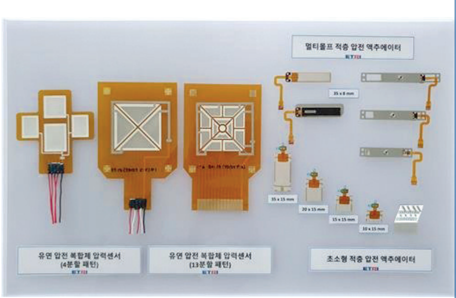
It is expected that the technology can be commercialized within two to three years by developing a thermo-composite module for heat-based power production by combining up to six devices. This is expected to have great utility due to the explosive increase in wearable devices. ETRI is accelerating the technology's commercialization through six SCI papers, six patents, and three technology transfers.

4-5. Sensor/Actuator - Emerging as a Core Technology for the Intelligent Information Society

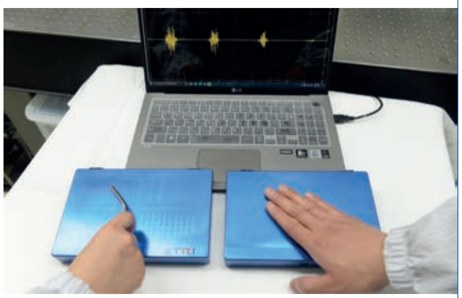
ETRI developed sensor and actuator technologies such as uncooled high-performance infrared image sensor, MEMS microphone, sound field security sensor, complex environmental sensor, contactless ultra-sensitive humidity sensor, ultra-thin piezoelectric ceramic speaker, and ultrasonic wireless power transmission technology.

Sensors are devices that detect the information on environment (temperature, image, sound, gas, etc.) and five senses and convert them into electrical signals. Actuators are devices that convert electrical energy into mechanical energy, often used to output information and transmit energy. For example, microphone/speaker and touch sensor/haptic device are sensors/actuators that interconvert sound (vibration of air) and touch into electrical signals, respectively. Likewise, sensors and actuators are highly correlated, so synergy is created when they are researched and developed together.

With the advent of intelligent information society, countless IoT devices are now needed. Sensors and actuators are becoming increasingly important as key elements in the collection and output of information from these ICT devices. Sensors are evolving from industrial bulk-type sensors not only to ultra-small and low-power sensors for mobile devices but also to smart sensors for IoT and robots. CMOS sensors, MEMS sensors, and complex sensors have been developed as ultra-small and low-power sensors, and smart sensors are achieving intelligence through the introduction of micro controller unit (MCU) and SW based on digitalization of output signals. Actuators are also being developed with the goal of miniaturization with low power, high efficiency, and high output. Piezoelectric and MEMS actuators are particularly attracting market attention. Nanotechnology is still applied to only a small part of sensors, including sensing materials, but it is recognized as the future technology that will have the greatest impact on sensor and actuator fields.



Flexible and composite piezoelectric materials based sensors and actuators developed by ETRI



Telehaptic devices for touch communication

ETRI has been developing ultra-small, low-power, high-performance sensors and actuators through the convergence of semiconductor, MEMS, and nanotechnology. Furthermore, ETRI focuses on developing new algorithms as well as HWs, and have achieved results in development of intelligent sensors and various applications of actuators.

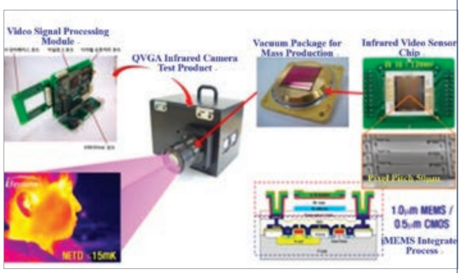
First, ETRI started developing uncooled high-performance infrared image sensor using semiconductor and MEMS convergence technology in 2001, and succeeded in developing the world's sixth uncooled infrared camera in 2010. ETRI has also developed the MEMS microphone since 2006, and in 2017 became the only research institute to have both MEMS sound sensor and CMOS ROIC chips, which are core technologies of digital high-SNR MEMS microphone. In 2010, ETRI first devised the concept of sound field security sensor to provide high-reliable security without blind spots. In 2015, ETRI introduced the world's first prototype for a complex environmental sensor that can measure temperature, humidity, and two types of gases (HCHO, CO_2). In addition, the world's first contactless ultra-sensitive humidity sensor based on new 2D nanomaterial was developed in 2020. This sensor has 660 times higher sensitivity and 12 times faster response time than conventional commercial sensors.

In the field of actuators, core technologies for thin piezoelectric ceramic speaker had been independently developed in the late 2000s, and in 2012 the world's first hybrid vibration plate structure was developed to demonstrate the application of piezoelectric speaker in subwoofer bands. In addition, ETRI began developing ultrasonic wireless power transmission technology through human skin in early 2010, and succeeded in matching ultrasonic energy to the skin by 83% in 2017.

South Korea's sensor and actuator industries mainly consist of SMEs and are still struggling to compete with global companies. ETRI will continue to research new technologies in the sensor and actuator fields and make efforts to commercialize them, so that domestic SMEs can overcome difficulties by developing new products.

4-5-1. Sensors

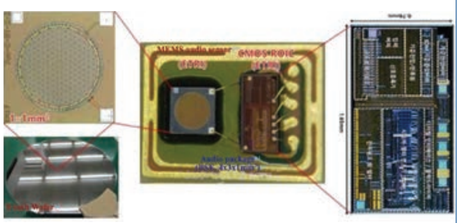
4-5-1-1. Infrared Image Sensor Technology



Uncooled thermal camera prototype using QVGA infrared image sensor

ETRI researchers developed the world's first antimony (Sb) compound, which has the advantages of higher performance and lower price than existing infrared sensing materials. Through this new sensing material, ETRI developed a bolometer-type infrared image sensor with a superior performance of 15mK NETD and a small pixel pitch of 50 μm, and produced an uncooled camera prototype to record clear thermal images.

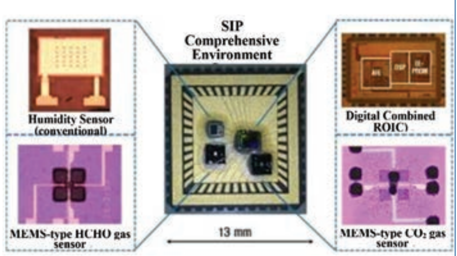
4-5-1-2. Sensors/ROIC Chips for MEMS Microphone



High-SNR digital MEMS microphone prototype

ETRI is the only research institute to succeed in simultaneously developing MEMS sound sensor and CMOS ROIC chips for high-SNR (≥64dB) MEMS microphone. The sensor chip was fabricated with the new structure of semi-floating membrane using 8-inch MEMS processes, and the ROIC chip was manufactured using CMOS circuits as a digital output type with higher technical difficulty but better applicability than analog output type.

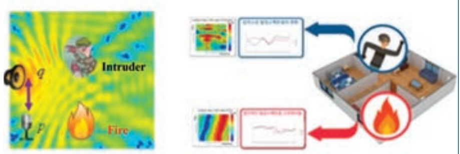
4-5-1-3. Temperature/Humidity/Gas Complex Environmental Sensor Technology



Ultra-small, low-power, digital SiP-type temperature/humidity/gas complex environmental sensor prototype

ETRI researchers developed a SiP-type complex environment sensor that integrates four chips of digital integrated ROIC with temperature sensor, HCHO gas sensor, CO_2 gas sensor, and humidity sensor in one package.

Compared to existing modules that integrate unit sensor products on top of the PCB, this prototype has a very small size and power consumption of 10% (189 mm^2) and 20% (77 mW), respectively.



Conceptual diagram of sound field security sensor technology

4-5-1-4. Sound Field Security Sensor Technology

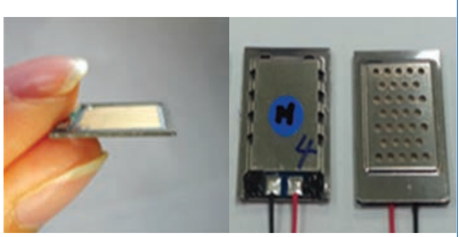
Sound field security sensor is the world's first sensor that can detect blind spot intrusion and fire outbreak by detecting and distinguishing the changes in sound field (distribution of sound waves) generated from speakers inside the secure space according to the intrusion and temperature change. In 2018, a research institute company Secu-works Co., Ltd. was founded, and succeeded in commercializing the smart sensor for detecting fires in blind spots within 50 seconds with ETRI’s technological support.

Application of ultra-sensitive humidity sensor technology to a non-touch elevator button

4-5-1-5. Ultra-sensitive Humidity Sensor Technology

In 2020, ETRI developed the world's first contactless super-sensitive nano-humidity sensor by fabricating a 2D nanomaterial based honeycomb structure with a maximized specific surface area for molecular adsorption. This sensor has 660 times higher sensitivity and 12 times faster response time of 0.5 seconds than conventional commercial sensors.

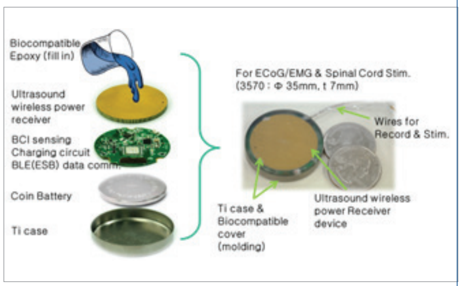
4-5-2. Actuator



Ultra-thin piezoelectric speaker technology for mobile application

4-5-2-1. Ultra-Thin Piezoelectric Speaker Technology

ETRI developed a multi-morph stacked piezoelectric ceramic structure that can significantly reduce the drive voltage to 5 Vrms but significantly improve the output characteristics of ultra-thin piezoelectric speaker to secure the high sound pressure comparable to that of conventional VCM speakers. Also, by designing the world's first hybrid vibration plate structure, ETRI succeeded in improving the output performance by more than 10 dB compared to conventional piezoelectric speakers in low-frequency band of sound below 1 kHz.



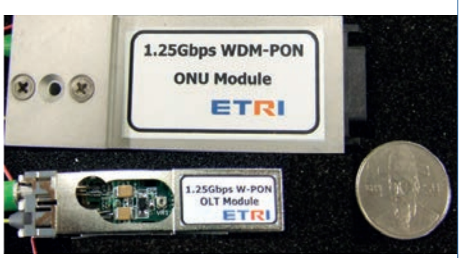
A brain computer interface module with a unified ultrasonic wireless charging device

4-5-2-2. Ultrasonic Wireless Power Transmission Technology

ETRI developed key technologies of piezoelectric-vibration direction aligned ultrasound transmission and reception devices using composite materials, matching large impedance difference between ultrasonic device and human skin, and driving circuits optimizing the ultrasonic driving frequencies. As a result, the ultrasound energy was successfully matched to the skin by 83%, the world's best performance. The development of this technology is expected to gradually solve problems in inserted medical devices such as the burden of additional surgery for power replacement and the psychological pain of patients.

4-6. Light - Becoming the Seed for Light Industry Development

ETRI contributed to the development of optical component technology in Korea for nearly 40 years. It led the optical network technology and industry by developing semiconductor laser related devices for optical communication such as WDM-PON system, 400Gbps coherent receivers for metro, and 400Gbps optical engines for data center.



Optical transceiver for WDM-PON with RSOA

Optical technology creates and controls light to perform certain functions which closely affect people’s lives. In particular, technological development is very fast for optical communication due to the increase in capacity beyond Moore's Law[23].

ETRI started developing optical component technology by developing semiconductor lasers for optical communication in the early 1980s. At the time, it was not long since Korea started technological development of semiconductors, and there was almost no infrastructure such as facilities and workforce related to semiconductor laser research. However, ETRI nonetheless began developing laser technology for optical communication due to the importance of preemptively securing optical communication technology in preparation for the information era.

ETRI developed and commercialized short-wavelength 45 Mb/s and 90 Mb/s systems through initial research. In 1984, LPE, a crystal growth equipment, was introduced for the first time in Korea, laying the foundations for light source and photodetector technologies for optical communications. In 1998, MOCVD devices were introduced that had an absolute advantage for high-level crystalline growth and mass production, enabling high-level multi-quantum well (MQW) growth.

As large-capacity WDM systems began to gain attention in the 2000s, wavelength tunable semiconductor lasers, which are a key source of light, were developed and commercialized. Also, based on the accumulated optical communication and core optical component technology, development was successfully conducted for the world's first

23) One of the three principles of the Internet economy is that the density of microchips doubles every 24 months.

high-resolution visual safety LiDAR with 240 pixels using the stud method. In 2018, the world's first test product of a drone LiDAR was exhibited at CES, drawing much attention.

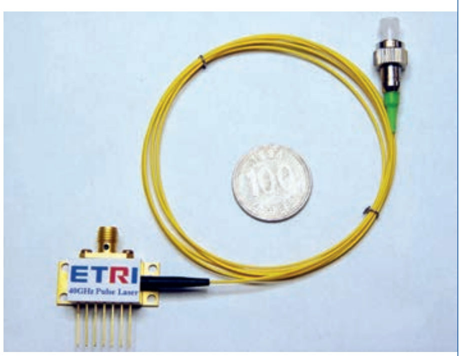
Meanwhile, with the rise of the subscriber network (FTTH) era in the early 2000s, the world's first commercial trial of giga WDM-PON systems began in 2007 by developing WDM-PON optical components that were able to distribute separate wavelengths to each subscriber.

In the 2010s, telecommunications traffic surged due to the rapid increase in high-quality video transmission, real-time streaming, cloud computing, and social media services, where ETRI focused on developing optical component technologies for high-speed optical transmission. As a result, ETRI developed 400 Gbps coherent optical detection technology (2018), 25G C-band EML chip technology for fronthaul (2018), and 25G O-band EML chip technology for fronthaul (2019). By the end of 2019, the world's first 400 Gbps optical transmission engine was developed with four light source and light detectors. Optical transmission and photodetection devices were integrated into a single package case.

In a hyper connected and hyper intelligent era, it is expected that technology for optical material components will take on an even greater role. Also, going beyond simple data transfer, ETRI will work with other sectors and rapidly expand the applications to AI, medical, bio, smart city creation, and other fields. ETRI will continue to acquire high-speed optical device technology and develop applied technologies to respond to these situations.

4-6-1. Laser/LiDAR

4-6-1-1. Semiconductor Laser Technology for Optical Communications



High speed optical module

Demonstration of optical transmission

ETRI, Leading the Development of Optical Communication in Korea

ETRI began developing semiconductor laser technology for optical communications in the early 1980s. At the time, there was no infrastructure in Korea such as facilities and workforce related to semiconductor laser research.

In 1984, the company introduced the LPE (Liquid Phase Epitaxy) equipment for crystal growth for the first time in Korea, developed the long-wavelength semiconductor (InP-based) laser, a light source for optical communication, and succeeded in implementing pulse operation of a 1.3-μm LD chip for optical communications. In 1988, we introduced Molecular Organic Chemical Vapor Deposition (MOCVD) equipment that were advantageous for high-level crystal growth and mass production to enhance the performance of semiconductor laser chips and overcome the limitations of wafer uniformity and reproducibility. With this basis, we developed a 1.55-μm single-wavelength PBH-DFB-LD chip for 2.5 Gbps optical communications systems in 1995. Since then, we have continued with development of regrowth technologies to replace all epi processes with MOCVDs. Even now, more than 30 years later, MOCVD equipments are still being used as the key equipment in developing optical device technology for optical communications.

While benchmarking the research and development technologies of leaders in the field in the beginning stage, processes were independently established such as design, processing, and performance analysis, which are at the core of the technologies. Currently, ETRI has been leading the development of optical devices for optical communications in Korea.

4-6-1-2. Wavelength Tunable Laser Technology for WDM

Securing High-level Wavelength Tunable Semiconductor Laser Technology

In the 2000s, when high-capacity WDM[24)] systems began to attract attention, ETRI conducted the "Light Output Stabilization Tunable LD Module Technology Development" project from 2001 to 2004 with the aim of commercializing wavelength-varying semiconductor lasers, and succeeded in the development of a 30-nm tunable LD module that stabilizes light output by integrating the Semiconductor Optical Amplifier (SOA) with a side tapered spot-size converter for high optical fiber coupling efficiency and low reflection and displayed identical performance with products from other leading countries in the field.

As ETRI secured wavelength-tunable semiconductor laser technology for WDM, it was able to be used as a wavelength- tunable light source for various applications as well as for WDM networks. The foundation has also been laid for future development of DWDM[25)] systems.

4-6-1-3. High-Resolution Eye-Safe LiDAR Technology

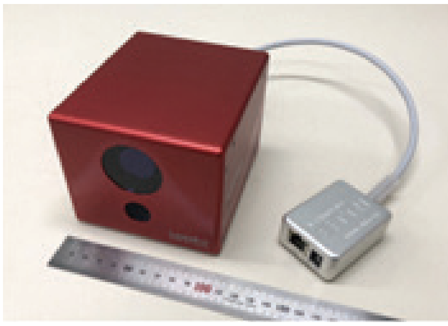
Development of the World's First STUD-based LiDAR Technology

LiDAR is a device that shoots laser pulses and accurately maps the appearance of surrounding objects by detecting the reflected light from the surrounding objects and measuring its distance.

ETRI first began developing LiDAR technology in early 2000 for technological research in the defense sector using lasers. The LiDAR research in ETRI used the optical communications and core technology of optical components which have been accumulated over the years, and finally developed it by applying Korea's unique STatic Unitary Detector (STUD) based technology to solve the various problems of conventional LiDAR structures for the first time in the world. This innovation produced a greater resolution (achieving a 240-pixels resolution in height for the first

24) Wavelength Division Multiplexing (WDM): This refers to a technology that simultaneously transmits multiple wavelengths per channel on a single strand of fiber, enabling it to respond effectively to increases in Internet traffic.

25) Dense Wavelength Division Multiplexing (DWDM): This is a technology that sends 40 to 80 channels through a single optical fiber.



High-resolution LiDAR test product showcased in CES 2018

time in the world) for three-dimensional videos with a much lower price.

This was a major achievement compared to the early days of research and development, where the maximum vertical resolution of the global LiDAR was a mere 64 pixels. Since then, ETRI has successfully integrated and modularized systems including interfaces and enable to present the world's first eye-safe LiDAR prototype for drones, which dramatically reduced the size, weight, and power consumption and successfully showed at the International Consumer Electronics Show (CES) in January 2018. At the time, ETRI's LiDAR prototype received much attention from various global makers and related organizations, including the Google LiDAR team, and Luminar Technology which had eye-safety LiDAR technology implemented in a similar way and underwent SPAC listing and achieved a market capitalization of 10 billion USD in early 2021.

4-6-2. Optical Devices

4-6-2-1. Optical Components Technology for Giga WDM-PON

In the 2000s, following the dawn of the Internet, the FTTH era began, introducing optical communication services to subscribers. Access network deployment was mainly done using TDM-PON, which had the advantage of being able to build networks at low cost but was limited in transmission speed and vulnerable in terms of security.

To compensate for this, ETRI developed optical components for WDM-PON from 2006 that could distribute separate wavelengths to each subscriber. In 2007, the world's first successful commercial trial of giga WDM-PON systems was achieved through the collaboration with the systems department by developing a "colorless light source technology" using reflective semiconductor optical amplifiers.

4-6-2-2. 400 Gbps Optical Transmission/Reception Engine

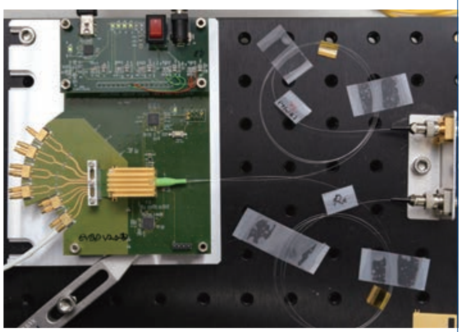
Taking on the Development of 400G Optical Transceivers

Existing data centers mainly used 100G-class optical transceivers applying 4 × 25-Gbps light sources and light detectors. However, the surge in large data traffic has also overtaken the data processing capacity demanded by data centers.

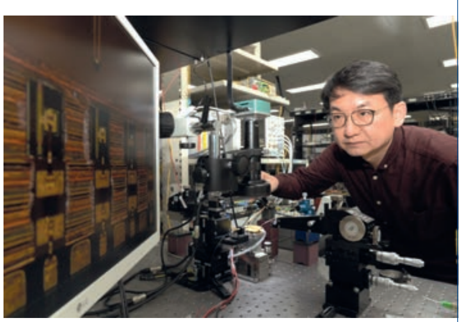
To preemptively respond to this trend, ETRI started the "Low Power On-Board 400-Gbps Optical Transmission/Reception Engine Technology Development to Increase Data Center Communication Capacity" project in 2018.

To speed up existing channels while maintaining the same four channels of 100G-class optical transceivers, we decided to significantly improve the transmission speed of each light source by four times. In other words, we decided to develop high-speed light sources and light detector devices that can transmit 100Gbps per channel.

Also, the strategy was to raise the data capacity of switching linecards by 8 times from the previous maximum of 3.2 Tbps to 25.6 Tbps by means of increasing the data transmission speed by 4x and the module installment density by 2x through placement of the on-board optical transmission/reception engine near the switch ASIC.



The 400G optical transmission/reception engine mounted on the evaluation board



Demonstration of 400Gbps optical engine transmission

Development of the World's First 400Gbps Optical Transmission/Reception Engine

After great efforts, near the end of 2019 researchers developed the world's first "400Gbps optical transmission/reception engine", in which four light sources and light detector devices, as well as optical transmitters and receivers, etc. were integrated into a single package case. 400Gbps is the speed at which 100,000 people can stream a high-definition YouTube video at the same time.

The optical engine is designed to allow mounting in an optical transceiver with the size of an adult finger, enabling four times the transmission capacity and twice the module installment density compared to the existing 100Gbps optical transceiver. If commercialization is achieved in the future, 64 optical transmission/reception engines can be installed on a single linecard. This will increase the total data processing capacity by up to eight times, from 3.2 Tbps to 25.6 Tbps.

We are planning to stabilize the technology by securing the reliability of the 400G optical transmission/reception engine, and to further develop the 1Tbps-class optical transmission/reception module.

4-6-2-3. 5G Fronthaul Optical Device Technology

Taking on the Challenge for 5G Optical Components Based on Acquired Technology

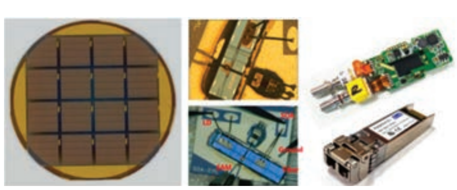
ETRI, which predicted that the 5G era would bloom in the late 2010s, began reviewing 5G photovoltaic components in 2015 and participated in the development of the digital fronthaul[26] for 5G base station based on optical link technology that began as part of the government-funded Giga Korea project in 2016. It was organized by the network company HFR, Inc., while ETRI, SKT, and OES participated as joint research institutes.

Development of 25G Fronthaul Optical Devices, A Core 5G Technology

In the mid-2010s, 10G-class optical transmission and reception components were the main focus, while 25G photons were incomplete in terms of technology and marketability, leading to negative reviews on fronthaul photon technology over 25G. Moreover, the standard of eCPRI[27] based on 25G was not in a completed state.

Despite these difficulties, researchers focused on issues based on long-established photon chip technology, and the willingness to commercialize was strong among participating companies OES and HFR. Most importantly, development proceeded smoothly through flexible but close cooperation between participating institutions beginning with the Giga Korea Business Group.

As a result, ETRI succeeded in developing the 25G EML chip technology for fronthaul in 2018. Later, ETRI transferred technology to companies, actively engaged in human and technical exchanges, and supported technology commercialization. The 25G fronthaul photovoltaic chip and optical transceiver technology was selected as one of the "Top 100



25G EML optical chips and 25G EML SFP28 module for 5G mobile fronthaul

26) Fronthaul: A link that connects digital units (DU) with radio units (RU) in mobile communications networks.

27) Enhanced CPRI (eCPRI): A global standard based on Ethernet that was established to reduce traffic in the CPRI section.

Achievements in National Research and Development" in 2019, and was awarded the Minister of Science and ICT award in the same year.

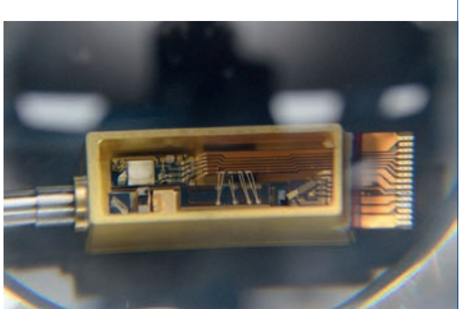
The 25G-class fronthaul optical device chip developed by ETRI played a key role in Korea's launching of the 5G service for the first time in the world in April 2019. In addition, companies participating in joint development produced visible results, generating tens of billions in sales. This was an opportunity for revolutionary growth not only in the domestic 5G mobile communication industry but also in the optical network industry as a whole.

In the future, wavelength bands applied to fronthaul networks are rapidly expanding beyond O-band to E-band and C-band, and the use of full-scale 28 GHz moving frequency is expected to form a broader and larger market for optical components.

4-6-2-4. High-Speed Coherent Optical Device Technology

The Need for a High-Speed Optical Device to Respond to Increased Traffic

Since the early 2000s, ETRI conducted research on devices and components for high-speed data transmission, reception, devices and components for signal processing. As communication traffic greatly increased recently due to the rapid growth of high-quality video transmission, real-time streaming, cloud computing, and social media, ETRI is focusing on developing photon and optical component technologies for ultra-fast optical transmission.



100Gbps optical module

Technology Development for a 100 Gbps Coherent[28] Optical Device

ETRI independently developed a 90° optical hybrid technology that separates the polarization of light and phase modulation signals, which had been nonexistent in Korea, and was able to obtain integrated photon technology and components combined with optical detector array chips. In February 2013, this technology was applied in the Korea Advanced Research Network (KOREN) to transmit and receive 100 Gbps

28) Coherent: When the frequency and phase of multiple light waves are the same.

of data through optical cables and a total distance of 510 km between Seoul and Daejeon.

Technology Development for a 400 Gbps Coherent Optical Device

ETRI continued to develop its existing technology, succeeding in developing 400 Gbps coherent photo detection technology in February 2018 that can transmit 50 HD movies in one second. By successfully developing core device and component technologies that increase the speed of long-distance optical Internet at low cost, it raised the component technology of the national telecommunications network to a global level.

4-7. RF/Terahertz - Innovating Materials and Components with RF/Terahertz

Since 1991, ETRI developed RF devices based on compound semiconductors such as GaAs, InP, and GaN, establishing the foundation for localization of RF devices and components for wireless communication and millimeter-wave systems. In the late 2000s, terahertz (THz) wave research began, establishing itself as the world's only institute to secure all THz wave technologies from materials to devices, modules, systems, and applications.

RF Technology

ETRI established its own process equipment infrastructure such as a 3-inch clean laboratory of compound semiconductors for the first time in Korea in 1991 and began researching RF devices for wireless communications in earnest. This laboratory was upgraded to the 4-inch base in 2000.

The development of RF devices required by wireless communications and millimeter wave systems mainly uses compound semiconductors such as GaAs (gallium arsenide) and indium phosphide, which had the advantages of high-speed, high-frequency and high-power characteristics. In the early stages of RF device development, ETRI focused on developing GaAs-based RF devices such as MESFET, HEMT, HBT, and developed MESFET power devices for mobile phones, low-noise PHEMT devices, 40 GHz/60 GHz transceiver MMICs for picocell communications and wireless LANs, and 10 Gbps/20 Gbps HBT ICs for optical communications.

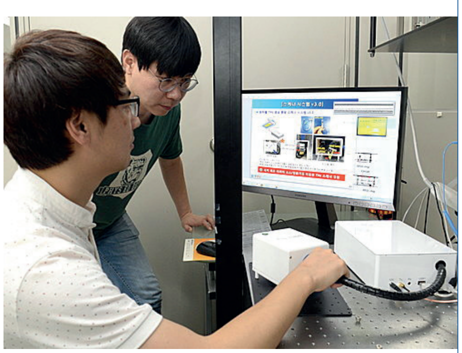
ETRI's UTC–PD module

From the late 1990s, ETRI focused on developing millimeter wave band MMIC by using InP-based HEMT and HBT device technologies. As a result, ETRI developed 77 GHz MMICs for vehicle anti-collision radar and 94 GHz low noise-MMICs radiometers, respectively, using InP-based MHEMT technology. Furthermore, ETRI developed a high-speed InP HBT ICs for 40 Gbps optical communications using InPHBT device technology. As ETRI succeeded in developing InP-based millimeter wave HEMT and

HBT device technology, Korea was able to secure millimeter wave MMIC technology independently.

As gallium nitride (GaN) began to attract attention as the next-generation material that can overcome the limitations of Si and GaAs, which were used as semiconductor wafer materials after 2010, ETRI started to conduct related research. Thus, S-band and Ku-K-band GaN power amplifier devices, Ka-band GaN power amplifier MMIC for 5G mobile communication, and S-band 150W GaN power amplifier devices for defense weapons systems were developed. These technologies made the independent development of GaN-based high-power RF semiconductor devices for wireless communication possible within a short period of time.

Terahertz Technology



Handheld THz scanner prototype (2017)

ETRI established the THz Photonics Creative Research Center (currently the Terahertz Research Section) as part of the Creative Laboratory Program in 2009, and is continuously conducting research on terahertz (THz, frequency 0.1 to 10 THz) technologies including the generating and detecting devices, and their application systems. Starting from the development of highly-integrated dual-mode laser diode as a beating light source for the continuous wave THz generations that can be minimized using laser diode technology for optical communications, ETRI developed THz photo-mixers and Schottky Barrier Diodes (SBD) to cover all THz wave generation and detection technologies.

From the mid-2010s, core devices and application system technologies that were developed have been transferred to domestic industries. Currently, ETRI is focusing on applying THz waves to areas such as nondestructive testing, security imaging, and short-distance wireless transmissions. ETRI is also conducting tests for applying its own THz application technologies to production lines in mega corporations, which is expected to be the first example in the world of actually applying THz wave nondestructive testing to mass-production of motor vehicles.

Meanwhile, ETRI is also focusing on developing core devices and components for THz communications based on the traditional photonics-based communication technologies in order to accommodate the rapidly growing data demands and new communication services. Photonics-based THz communication technology makes it easy to generate broadband THz links that can be directly linked to the wired networks. ETRI is now extending the research field through converging the photonics-based and electronics-based THz technologies in variety of application fields such as THz communications and THz imaging.

ETRI will strive to lead the B5G and 6G mobile communications era based on RF and Terahertz technologies accumulated over the past 30 years and enhance the competitiveness of domestic companies in materials and components by applying the related technologies in various fields.

4-7-1. RF Semiconductors

4-7-1-1. GaAs Based RF Semiconductor Technology for Wireless Communications

ETRI established its own process equipment infrastructure including a 3-inch clean laboratory of compound semiconductors for RF device research for wireless communications in 1991 which was upgraded to four inches in 2000.

Based on this infrastructure, ETRI began developing GaAs-based RF devices such as MESFET[29], HEMT[30], and HBT[31] for wireless communications. It succeeded in developing ion implantation-type GaAs MESFET devices in 1992, 3.3V GaAs MESFET power devices in 1994, transmission MMIC for CDMA/AMPS dual-mode mobile phones in 1995, and transceiver MMIC[32] for mobile phones in 1998.

In 1993, ETRI developed a unique T-gate process technology to develop 0.25 mm GaAs PHEMT devices for low noise applications, 0.13 mm GaAs PHEMT devices in 1995, and 27 GHz power amplifier MMIC for LMDS using 0.25 mm GaAs PHEMT devices in 1999. The 40 GHz/60 GHz band MMIC was developed by establishing 0.25 mm GaAs PHEMT library technology in 2001. Also, in 2007, a 0.12 μm GaAs PHEMT library technology was established to develop transceiver MMIC for 60 GHz picocell communications and an RF switch MMIC for 60 GHz WLAN.

Meanwhile, in 1998, 10 Gbps LD drivers were developed using AlGaAs/GaAs HBT, and limiting amplifiers and pre-amplifier development was conducted. In 2000, limiting amplifiers for 20 Gbps optical communications were developed using InGaP/GaAs HBT devices, and power amplifiers (PA) for IMT-2000 terminals were developed. From 2008 until 2011, the development of InGaP/GaAs HBT power amplifier MMIC for wireless communications and wireless LAN laid the foundations for independent development in the field of RF devices and components.

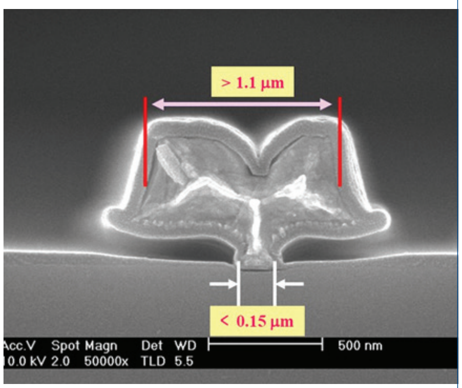
29) Metal-semiconductor field-effect transistor (MESFET): A device that has contact characteristics between metal and semiconductors.

30) High-electron mobility transistor (HEMT): A device that has high electron mobility characteristics using heterojunction semiconductor characteristics.

31) Heterojunction bipolar transistor (HBT): A device that has heterojunction properties between heterogeneous semiconductors.

32) Monolithic microwave integrated circuit (MMIC): A microwave integrated circuit that simultaneously places active and passive devices on a monolithic semiconductor substrate.

4-7-1-2. InP-Based High-Speed/High-Frequency RF Semiconductor Technology



Wide-head T-gate process for high-frequency RF devices developed using ETRI's original patent technology

InP HEMT and InP HBT devices based on InP are widely used as key elements in the millimeter wave applications due to their ultra-high frequency and high-speed switching properties. ETRI began developing millimeter wave MMICs in the late 1990s based on InP-based HEMT and HBT device technology.

From 2002 to 2006, the 77 GHz transceiver MMIC for vehicle collision avoidance radar was localized with 0.15 mm MHEMT device technology and applied to the 77 GHz radar module to verify the performance of MMIC. In 2007, a 50-nm InP-based HEMT device was developed for millimeter wave passive image sensors. Along with this, 40 Gbps optical communication TIA amplifiers, limiting amplifiers amplifiers, and modulator driver IC were developed using InP DHBT devices. In 2010, ETRI developed the 94 GHz low-noise amplifier MMIC for millimeter wave passive image radio meters using 0.1 mm MHEMT device technology. In 2019, it developed 94 GHz low-noise amplifier, frequency multiplier, mixer, and down converter MMICs for seekers.

ETRI succeeded in developing InP-based millimeter wave HEMT and HBT device technologies, enabling it to achieve millimeter wave MMIC technologies. This technology is expected to contribute to commercialization of next-generation B5G and 6G mobile communications, including vehicle collision avoidance system, airport scanners system, military image radiometer, and next-generation B5G and 6G mobile communications.

4-7-1-3. GaN Based High-Power RF Semiconductor Technology

Since the 2010s, gallium nitride (GaN) started to attract attention as the next-generation material that can solve the limitations of Si and GaAs, which were used as semiconductor wafer materials. ETRI began developing GaN-based power amplification devices in 2010, and developed S-band 100W and X-band 30W power devices to develop S-band 200W semiconductor power amplifiers (SSPA) and X-band 100W SSPA.

From 2014, GaN power devices operated from Ku to K-band (18–27 GHz), GaN power devices operated from Ka-band, and 12W power amplifier integrated circuits (MMIC) in the 28 GHz band were developed using Ka-band GaN power devices.

From 2012 to 2015, ETRI developed the X-band 50W GaN power device module, where the GaN RF integrated circuit technology for 5G mobile communications was successfully developed in 2015. Also, GaN RF power amplifiers with the 200W-class output power characteristics of S-band were successfully developed from 2015 to 2019. Starting from 2020, ETRI is developing 28 GHz and 39 GHz band GaN integrated circuit (MMIC) technology that will be applied to 5G mobile communications while also focusing on developing GaN RF device technology for the sub-THz band for B5G and 6G mobile communications.

4-7-2. Terahertz

4-7-2-1. Terahertz Materials and Components

Dr. Kyung Hyun Park, founder of ETRI's THz research section, awarded SPIE fellow in 2020

THz Technology Will Be in the Core of Future Society

The terahertz (THz) wave[33] has the nickname, "the dream frequency," because it was a nearly unexplored electromagnetic wave band, and research on it is in an active competition across the world. Due to its shorter wavelength than that of the millimeter waves, it is possible to obtain high-resolution images with THz waves that penetrates through plastics or ceramics that cannot be penetrated with visible light. Therefore, it can be applied in nondestructive inspection techniques or advanced sensor technologies. Also, as the commercial 5G mobile communication technology includes 28 GHz band utilizations, the interest in THz frequency band is increasing. THz technology is recognized as one of the key technologies of the future security, telecommunications, and healthcare.

Development of THz Wave Materials, Devices, Modules, and Systems

ETRI continuously conducted research on developing devices for THz wave generations and detections since 2009. In its initial stages, results were produced from research on

33) Terahertz (THz) waves: Electromagnetic waves with a wavelength between visible light and micro electromagnetic waves (frequency 0.1 to 10 THz).

ETRI's THz research section hosted international conference of ALT'17 in 2017

photovoltaic materials with high-speed properties. Afterwards, the research area expanded to various devices, modules, and system technologies that are for applied technologies such as imaging, spectroscopy, and communication.

ETRI developed several types of semiconductors beating light sources, which are the core of ultra-small THz continuous wave generation module. It also developed the antenna-integrated THz light source (photomixer) based on a high-speed photodetection device, uni-traveling carrier photodiode (UTC-PD). The Schottky Barrier Diode (SBD), a super-fast rectifier with integrated THz broadband antennas as a THz receiver, was also developed. The development of the sub-harmonic mixer based on the SBD device has also been conducted. R&D for short-distance THz wireless link transmissions is currently underway.

ETRI's Ten Years of THz Research

From the early stages, ETRI developed THz technologies under a systematic technology roadmap, showing remarkable achievements in a relatively short period of time, developing all the technologies from materials to devices, modules, and systems.

Recently, ETRI is planning to extend its research field to THz electronics while staying competitive in photonics technology. In the future, ETRI plans to develop its own security checking system based on THz electronic devices, THz LiDAR for next-generation vehicles, and THz inter-building free-space communications to explore new paths that no one has ever visited.

4-7-2-2. Terahertz Nondestructive Testing Technology

THz Waves, Strengths in the Nondestructive Testing

A key example of the application of THz waves is nondestructive testing[34)]. The main advantage of THz wave is that its photon energy is significantly lower than that of x-ray, which makes it harmless to the human body. In addition, its ability to analyze material properties without being affected by the external environment is a great advantage.

34) Nondestructive testing: A type of structural product testing method that determines whether something should be used, such as detecting defects or verifying quality or shape without changing the shape or function of the product.

ETRI's portable water leak testing system to monitor the water-leaking failure in the car manufacturing

Multiple Successful Commercialization Cases

Starting from the technology transfer to two companies in 2014 and 2015, ETRI commercialized THz nondestructive testing technology by transferring THz generation technology for nondestructive measurement in 2016 and high-speed nondestructive imaging technology in 2018.

In particular, ETRI created an ultra-mini-sized THz scanner for various nondestructive testing purposes in automotive quality and safety management. It is expected that the scanner developed by ETRI will be widely used due to its small size and affordable price.

Not Only Technological Development, But Even Commercialization

The Terahertz Research Section provides industrial solutions for components, systems and technologies related to the THz nondestructive testing, which is almost unique in KOREA.

In particular, portable ultra-small leak detection systems and low-cost, two-dimensional, high-speed imaging systems are future technologies that have not yet been commercialized worldwide.

4-7-2-3. Terahertz Communications Technology

THz Communications, the Next Generation of Wireless Communications

THz waves are attracting attention worldwide as a frequency band for the next generation of wireless communications due to their high frequency, enabling large-capacity and high-speed transmissions. In the approaching 6G era, the frequency band will increase up to 1 THz, where the maximum transmission speed of data will also increase to 1 Tbps accordingly.

ETRI's portable THz spectroscopy system

Photonics-Based THz Communications Technology

Photonics-based THz components for wireless transmissions can naturally merge with existing photonics-based wired communication links. Because it is easy to reach high

ETRI's Handheld THz scanner prototype

frequency bands and a wide bandwidth, photonics-based THz communications are emerging as one of the key technologies for 6G communications, which is expected to exist as a mix of wired and wireless communication links.

In 2010, ETRI developed continuous THz wave technology that can generate wide-band THz waves from 0.2 to 1.5 THz. As a unique technology, ETRI developed a dual-mode laser (DML) that can independently tune two wavelengths in one beating source, and obtained patents for the core technology of small- and light-weight continuous THz wave generating devices.

Since 2011, ETRI conducted continuous developments for Tx modules based on DML and UTC-PD, Rx modules based on SBD-based sub-harmonic mixer (SHM), THz antennas and wavefront controlling technologies for beam-forming. In 2018, ETRI demonstrated 2.5 Gbps THz wireless transmission, and recently, it is conducting component development to achieve 100 Gbps THz wireless communications by 2023.

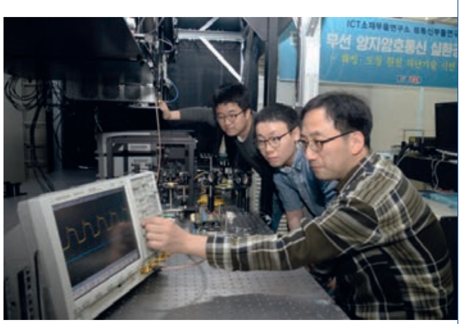
Evolving Into A Core 6G Technology

Along with the development of active semiconductor components, ETRI is also developing techniques for passive components and module packaging including optical components, optical systems, and antennas. Utilizing these abilities in the design and manufacturing will allow ETRI to provide flexible responses to technological demands from the industry.

It is expected that the THz communication technologies would be the core of the next-generation 5G data communications. New technical demands such as transmission of uncompressed holographic images and data transmission with almost-zero latency would be provided via THz communications. Developing reliable THz components and THz data processing technologies, ETRI is expecting technological expansion into other fields such as industrial nondestructive testing, security imaging, and medical imaging.

4-8. Quantum - Beyond the Limits of ICT Using Quantum

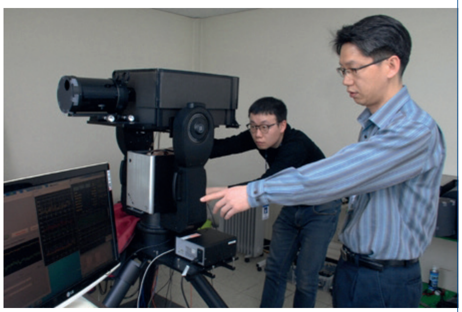
Quantum information and communication technology is a next-generation technology that protects ICT infrastructure by using the physical characteristics of quantum (uncertainty, superposition, irreversibility, entanglement, no-cloning, etc.) and realizes ultra-high-speed, large-capacity computation and ultra-precise measurement. It is attracting a lot of attention as a future ICT that can change the paradigm by overcoming technical limitations of existing information and communication, and is divided into fields such as quantum communication, quantum sensing/measurement and quantum computing.



Free-space quantum key distribution study

Quantum communication guarantees the unconditional security between transmitters and receivers by using the characteristics of quantum mechanics, while quantum sensing/measurement uses ultra-fine quantum state changes due to electromagnetic fields, gravity, and light. The ultra-fine accurate and sensitive measurement ability can be significantly increased compared to present technology. In addition, quantum computing enables ultra-high-speed and large-capacity calculations based on quantum bits (qubits) by using the superposition and entanglement of quantum states.

Beginning with the demonstration of the 25 km fiber based quantum key distribution (QKD) technology for the first time in Korea in 2005, ETRI has been studying key technologies for quantum communication such as entangled photon sources, single photon detectors, and quantum random number generators, etc. Free-space QKD started in 2015 and the integrated 4-polarization beam splitter/combiner chip and module was developed for the first time in 2017. It was capable of holding a live demonstration even in the daytime with strong sunlight at a distance of 300 m in 2018. Subsequently, since 2019, it is developing the transmitter/receiver integrated module in polarization-based free-space QKD for short-distance moving quantum communication, quantum channel transmitter/receiver chips and module for ultra-



Daytime transmission of free space quantum key distribution

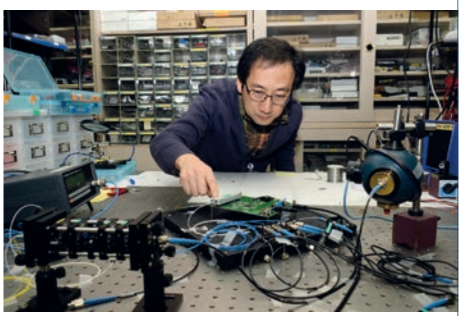
small size fiber-based QKD technology since 2020.

Meanwhile, since 2015, it has been developing various key technologies for quantum computing such as compiler, system synthesizer, building block synthesizer, virtual quantum machine, visualization technologies and a quantum computing platform based on semiconductor quantum dots. Also, ETRI has been developing quantum optical integrated circuit technology, single photon sources, single photon detectors, and quantum gate devices since 2017.

Quantum information and communication is applied in various fields such as backbone communication network, new ICT industry fields such as big data and cloud, ultra-precision medical imaging, chemistry, etc. to create the new industry. ETRI will continue to challenge new technologies in the future to secure domestic quantum information and communication technology to a world-class level.

4-8-1. Quantum Communication

4-8-1-1. Quantum Communication Technology



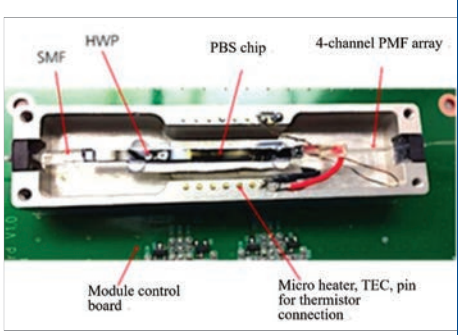
Quantum communication research

Quantum Communication Guaranteeing Unconditional Security

Modern cryptography, such as the RSA algorithm, can be threatened by the development of quantum computer. Accordingly, the world is making great efforts to develop quantum communication technology that guarantees unconditional security by quantum physics.

Demonstration of Daytime Free-Space Quantum Key Distribution at Distance of 300 m

For the first time, with the demonstration of the 25 km fiber based quantum key distribution (QKD) technology in Korea in 2005, ETRI has been studying key technologies for quantum communication such as entangled photon sources, single photon detectors, and quantum random number generators, etc. Free-space QKD technology started through ETRI's internal project for preliminary technologies for transceiver key components and system control in polarization-based free-space quantum key distribution in 2015. Through this project, the integrated 4-polarization beam splitter/combiner chip and module in 2017, ultra-fine beam alignment, ultra-intensive sunlight noise rejection technology and a live demonstration even in the daytime with strong sunlight at a distance of 300 m in 2018 were performed. Subsequently, since 2019, it is developing the transmitter/receiver integrated module in polarization-based free-space QKD for short-distance moving quantum communication, and quantum channel transmitter/receiver chips and module for ultra-small size fiber-based QKD technology since 2020.



The first 4x1 polarization encoding chip and module for free-space QKD

4-8-1-2. Single Photon Detector Technology

Ultra-Sensitive Single Photon Detector Technology

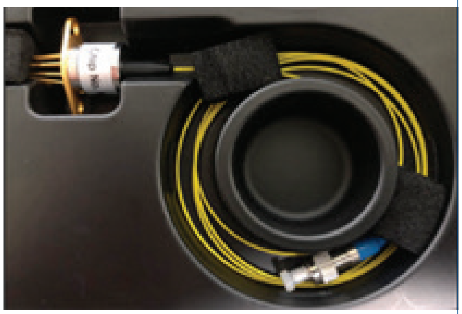
Since 2005, ETRI has been performing research on chip fabrication, performance, measurement and evaluation of a single photon detector based on Geiger mode InGaAs/InP APD of 1.55 µm and Si APD with the wavelength region of 0.7 µm.

4-8-2. Quantum Computing

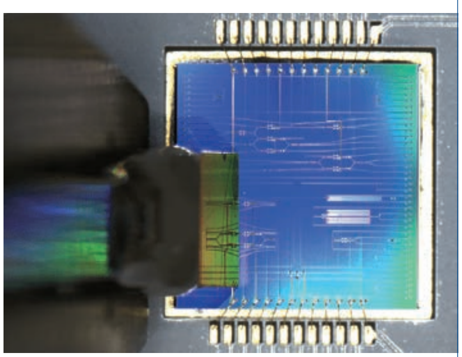
4-8-2-1. Quantum Photonic Integrated Circuit Technology

Development of Original Technology for Quantum Photonic Integrated Circuit

ETRI began research about quantum computing using photons through a project called, "A Generic Technology Study for Quantum Photonic Integrated Circuits" in 2017. This project included research on single photon sources, single photon detectors, and photonic qubit gate devices for qubit operation.



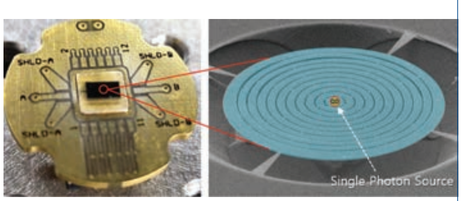
Optical module of InGaAs/InP single photon detector



Quantum source and optical integrated circuit development

Development of Single Photon Source

ETRI performed the semiconductor quantum dot laser project in the early 2000s. Based on this technology, research about single photon source since 2017 and a free-space QKD project since 2019 were conducted. As a result of the study, researchers identified the single photon source in optical telecommunication wavelength band ranging from 1,300 nm to 1,600 nm using InAs/InP quantum dots. Resultingly, ETRI secured the compound semiconductor quantum dot epitaxial technology and nano-optical structure design technology for high-efficiency that focuses on single photon sources.



Nano optical structure and single photon source chips

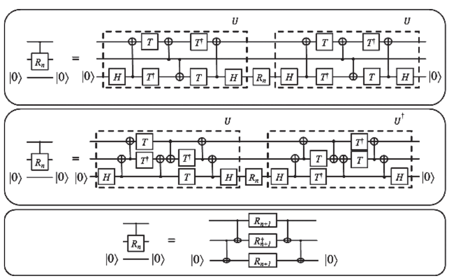
Development of Quantum Gate Device

ETRI has been studying about silicon photonics technology since the mid-2000s. Researchers implemented a quantum gate device that adjusts the phase of the qubit according to the current application on silicon photonics chip. Currently, ETRI's technology is capable of fabricating and verifying quantum gates with single and double qubit operations.

4-8-2-2. Quantum Computing Technology Based on Virtual Machine

Independent Technology Development of Quantum Computing Based on Virtual Machine

From 2015 to 2019, ETRI performed quantum compiler and virtual machine development through the R&D on quantum computing platform and cost-effectiveness improvement via one of ETRI's internal research project. To reduce the required computing resources, three efficient compiler methods have been developed for a basic quantum operation called conditional rotation gate (controlled-Rn). Patents related to core contents of this technology were registered in the U.S. in 2019, and were also published in Scientific Reports. Virtual machine is a technology that simulates a given quantum assembly code with a bit-based computer. A typical virtual machine can operate on 30 qubits level, but it has been raised to 40 qubits and continues to expand and accelerate.

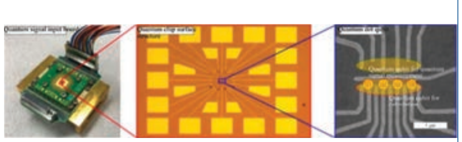


ETRI's controlled rotation gate circuit diagram

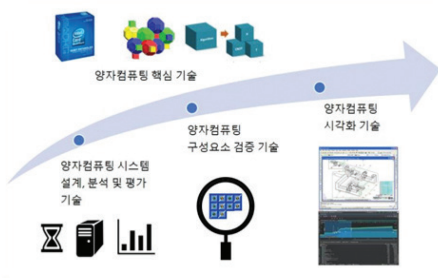
4-8-2-3. Quantum Computing Based on Semiconductor Quantum Dot

The Challenge to Develop Quantum Computing Platform Based on a Semiconductor

ETRI has been promoting research to design, manufacture, and measure gate-based semiconductor quantum dots since 2015. It is cooperating with Japan's Institute of Physical and Chemical Research (RIKEN) since 2016 to exchange accumulated quantum technologies and secure high-purity samples. ETRI is currently designing a quantum dot that can be used with four qubits as an array of quantum dots. This is being tested using Si- and GaAs-based semiconductor substrates, and the technology to capture and measure single electron in quantum dots has been obtained.



Quantum signal input board of four quantum dot (left), surface structure (center), quantum dot qubit (right)



Quantum computing system design/analysis/evaluation/verification/visualization technology

4-8-2-4. System Design/Analysis/Evaluation/Verification/Visualization

Quantum Computing System Design/Analysis/Evaluation/Verification/Visualization

Technology on quantum computing system design, analysis, and evaluation analyzes the quantity of quantum resources (quantum gates and physical qubits) of a quantum computing system required to execute a specific quantum algorithm and evaluate the performance. Quantum computing visualization technology provides users with visually useful information about elements constituting quantum computing. ETRI is conducting a development project on element technologies for programming, running, verifying, and implementing fault-tolerant quantum computing systems by 2028.

Quantum Computing to Lead the Fourth Industrial Revolution

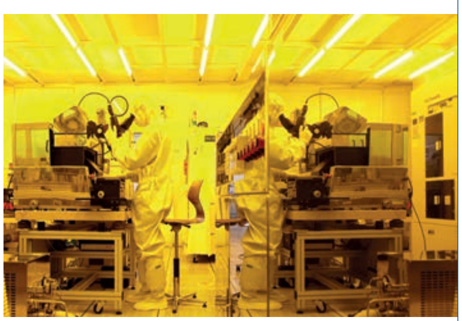
Technologies related to quantum computing are expected to be widely used in many industries. In addition, there is a high possibility of creating a new market while leading the Fourth Industrial Revolution.

4-9. Conclusion

Semiconductors

ETRI has led Korea's success in semiconductors for the past 45 years. It plans to continue developing semiconductor technologies in various sectors such as low-power high-performance AI processor technology, body signal processing technology for implantable active devices, semi-permanent beta battery module and special encrypted chip technology using beta sources, two-dimensional semiconductor technology, MIT device mass production technology, and more.

In particular, the AI embedded processor, Aldebaran (AB), is currently updated to the 40-teraflop AB9 and is planned to be upgraded to 100 teraflops in 2024 and 200 teraflops in 2027. A 1000-teraflop processor is set to be developed by 2029. Also, according to market demand, a low-power AI processor for movement and edge that enables reinforcement learning, unsupervised learning, and on-chip learning is being developed to form the foundations of domestic companies that are preoccupying the market. Through these efforts, ETRI will contribute to national development by securing the position as the global leader in future semiconductor technology and industry.



ETRI semiconductor laboratory

Displays

ETRI’s display technology is evolving into futuristic displays beyond flat display. It is expanding into the sensory display sector beyond conventional visual displays, with flexible and stretchable electronic circuit technology combined with neural interface technology. In addition, the ultra-realistic holographic display technology is constantly undergoing technological advancement while also evolving into a contactless interaction technology that provides a new UI/UX by combining with space and touch technology.

ETRI plans to contribute to Korea’s efforts in becoming the undisputed, no. 1 country in the display industry by focusing on developing displays that will allow users to feel with their five senses beyond visual pleasure and realize a person's biological signals, a holographic sensory device technology that satisfies the sense of touch, smell, and emotions, and the intelligent security ultra-reliable device technology with maximized convenience and security.

Energy

By reaching the Fourth Industrial Revolution, IoT systems, digital healthcare devices, and other technologies are expected to increase at a rapid rate. Also, the demand for eco-friendly power such as renewable energy is expected to grow.

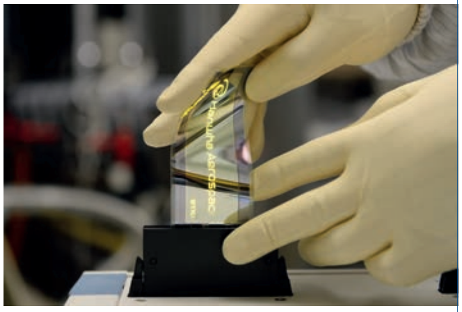
Following these new demands, ETRI plans to focus on expanding the high-efficiency thin-film solar battery and body heat energy conversion technology to various sectors. It is also planning to reinforce the continuous growth of the energy industry in general by securing an energy ecosystem that can be systematically managed, including not just the enhancement of energy storage performance, but also energy production (solar cells), energy conversion (fuel cells, hydrogen cells), and energy saving (secondary batteries) systems.

Sensors/Actuators

ETRI will continue to research and commercialize new technologies in the sensor and actuator sector so that Korean SMEs can secure a competitive advantage in the global market by developing new products. In particular, as countless IoT devices are needed due to the recent advent of the intelligence information society, it is planning to focus on developing intelligence sensors that introduce micro controller unit (MCU) and SW based on digitalization of output signals. In addition, the actuator technology is to accelerate miniaturization, low power, high efficiency, and high output, and to overcome the limitations of existing technologies by actively introducing nanotechnology.

Photonics

Global IP traffic increased at an annual rate of 26% each year, from 1.5ZB in 2017 to an expected 4.8ZB in 2022. ETRI will continue to acquire high-speed optical device technology and develop applied technology to respond to these situations. In particular, we plan to take on the challenge of development of 1Tbps optical communication modules and reinforce the use of fronthaul optical device chips. Also, going beyond simple data transfer, we will combine with other sectors and rapidly expand the applications to AI, medicare, bio, smart city creation, etc.

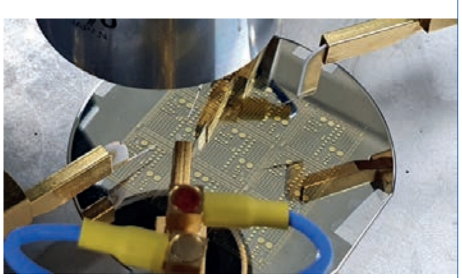


Flexible OLED panel test

RF/Terahertz

With the foundation of RF device technology based on GaAs, InP, and GaN compound semiconductors that were developed since the early 1990s, ETRI has been developing a 28 GHz and 39 GHz GaN integrated circuit technology applied in 5G mobile communications since 2020. ETRI is also planning to focus on technological development for GaN RF device for Sub-THz frequencies required by B5G and 6G mobile communications. Sub-THz has a wider frequency compared to conventional millimeter waves, enabling it to conduct high-speed and high-capacity communications. It is in demand for various applications such as B5G and 6G mobile communications, smart search systems, radar, etc. Along with these and THz technologies, ETRI is focusing on developing technologies that can be used in industrial or practical fields, like detecting hidden objects such as faults, harmful chemical substances, weapons, bombs, and even cancer. ETRI is also developing technologies for THz wireless links as the next generation of communications.

Quantum



2-inch vertical GaN power semiconductor

Since the mid-2000s, ETRI has been striving to lead the domestic quantum information and communication technology to a global level. In the future, in the field of quantum communication, ETRI plans to develop the free-space quantum communication technology applicable to various fields of mobile flatforms and fiber-based ultra-small quantum communication technology. In the field of quantum computing, it will continue to develop various quantum chips while advancing quantum computing system design, analysis, evaluation, verification, and visualization technology, and will focus on developing the best in-class quantum chips in Korea, including 8 qubits in 2021 and 16 qubits in 2024.

Through this challenge, quantum information and communication technology will spread to various fields such as communication, computing, chemistry, medical care, and meteorological prediction. This will inspire to raise the competitiveness of related industries to the next level.

PART 5

ICT Convergence

5

ICT convergence

5-1. Outline

IoT

Personalized IoT service (Smart Home)

The Internet of Things (IoT), first named by Kevin Ashton of MIT, began to rapidly develop when ubiquitous society made its advent in the 2000s and became a worldwide issue.

ETRI defined its vision, "realizing a hyper-connected society," and focused on the development of core technologies such as RFID, WSN, USN, and M2M, which were considered the predecessor of IoT since 2004. ETRI sequentially developed the common open IoT service (COMUS), self-learnable IoT common software engine (SLICE), massive IoT networking (mIoT-Net), IoT device software (IoTware), and IoT device integrated development environment (IoTware-IDE) in the 2010s. ETRI then applied IoT technologies to various fields including smart city/factory implementation, algae monitoring, landslide detection, remote identification of vessels, augmented firefighter safety, etc.

ETRI will continue to contribute to the acceleration of digital transformation by advancing IoT technology and expanding the application of such technology to various fields.

Intelligent Robotics

Since Unimate, the first industrial robot developed in the world was operated in factories, robots have mainly been developed for means of replacing human labor. Robots grew into the form of directly and indirectly supplying services to humans in various living spaces beyond factories in the 1990s. This changed into a familiar identity performing interactions with humans through AI and big data analysis technologies.

ETRI has committed its best endeavors to the development of intelligent robotics technologies converged with advanced ICT and AI technologies since 2004. The institute succeeded in developing ubiquitous robotic companion (URC) technology to provide users with services whenever and wherever they were needed. ETRI also successfully developed human-robot interaction (HRI) technologies and autonomous robot navigation technologies. Furthermore, the institute is constantly developing autonomous driving

49) Ubiquitous: Environment allowing access to networks regardless of location

technology for a safe driving through autonomous recognition for assisting human mobility, V2X communication technologies, autonomous valet parking technology, and autonomous driving AI technologies.

Biotechnology/Healthcare

ETRI has consistently driven research on convergences with ICT in the domain of biotechnology and healthcare, starting with the development of the osteoporosis diagnostic technology through a simple X-ray image analysis in 1998. The institute has continuously developed technologies contributing to the improvement of health and quality of life of many citizens, including computer-assisted diagnosis that analyze medical images, cancer diagnosis SW components, biosignal processing such as bio-shirts, smart diagnosis, an individual initiative health platform, the AI doctor ("Dr. AI"), noninvasive biosensors for point-of-care diagnostics, a biometric system, e-Nose for disease diagnosis, and laser-based particulate beam generation.

ETRI will continue its research in medical intelligence, point-of-care diagnostics technology, image diagnostic technology, and personalized precision treatment technologies in pace with the development of the healthcare paradigm that have shown rapid individualization, intellectualization, and routinization.

Postal Logistics

ETRI led the development of the national postal business by converging ICT with the fields of postal logistics (receiving, sorting, transporting, and delivering) since 1999. The institute has 26 core technologies and has registered 227 patents through development of sequence sorters and the Hangul address recognition system (including road address) mounted on the sorters, and transferred them to SME(small- and mid-size enterprises) to generate economic effects at the scale of KRW 1.3 trillion. ETRI also developed the automatic registered mail sorter in 2005 to save KRW 100 million on mail processing per sorter annually. ETRI has contributed to advanced postal logistics by developing an unmanned post office, mobile navigation for mailmen, and logistics drone delivery technologies since the 2010s.

Energy/Safety/National Defense

ETRI accelerated the conversion of ICT with various fields such as energy, safety, and national defense since the late 2000s. Since commencing development of energy-ICT conversion technologies in 2009, ETRI developed the energy trade technology and electric power agency platform for new and renewable energy. It also developed the one-click disaster information transfer system and complex disaster prediction expansion platform, K-MDDS, since 2013 when the government switched the main line of accident control from response-centered policies to a prediction-oriented smart accident control system in 2010. The institute was also appointed as a support institute for new IT by the Ministry of National Defense, and developed the virtual training system (ODM-I) and multi-media multi-path (MMMP) adaptive network technology.

Convergence Research Departments

In 2014, the National Research Council of Science and Technology (NST) launched a sunset-type convergence research group project with participating researchers from institutes, industries, and academic circles to resolve issues faced by the state-society relations. Sunset-type research is that researchers from multiple organizations gather and research specific subjects, and return to their organizations once the task is complete. ETRI governs convergence research departments such as Under Ground Safety (UGS), NST's the first convergence project, Knowledge-converged Super-Brain (KSB), Smart Defense for Foot-and-Mouth Disease (SDF), and Defense Materials and Components (DMC). ETRI also serves backbone roles for activation of open R&D through collaborative research with nine institutes.

Signboard hanging ceremony of
KSB Convergence Research Department

5-2. IoT - Advancing the Era of Autonomous IoT

ETRI secured the core technologies of RFID, WSN, USN, and M2M, which are considered the predecessor of IoT since 2004, and has been leading the development of IoT and core technology of the Fourth Industrial Revolution by developing and applying it in various fields since 2010.

IoT device software framework 'IoTware'

The whole world is on the verge of becoming a hyper-connected society where everything is connected and everyone shares information to each other with the best services being provided to anybody. The IoT world has already opened, where a car and a washing machine can talk to each other and deliver information to its owner as required. And now, beyond connecting things, IoT is moving to the autonomous IoT stage, where things equipped with intelligence create useful information on their own, communicate with artificial intelligence, and provide services for humans.

ETRI predicted such changes in the era, and has consistently secured core technologies of the predecessors of IoT since 2004, including radio frequency identification (RFID), wireless sensor network (WSN), ubiquitous sensor network (USN), machine to machine (M2M), and IoT platforms. Based on these technologies, a large-scale task of applying SAN technology to ship maintenance was driven in 2008.

ETRI sequentially developed the common open IoT service (COMUS) platform, self-learnable IoT common software engine (SLICE), massive IoT networking (mIoT-Net), IoT device software (IoTware) framework, and IoT device integrated development environment (IoTware-IDE) in the 2010s, and applied IoT technologies to various fields including smart city/factory implementation, algae monitoring, landslide detection, and remote identification of vessels. ETRI also succeeded in developing various augmented IoT technologies to augment physical capabilities of humans such as collecting and analyzing information of a living body, augmenting recognition helmet system, creating a smart helmet for firefighters, and augmenting location and space recognition technologies.

IoT technology will take on the roles of advanced infrastructure for future society's faster and more precise responses compared to that of humans by creating valuable data between things and human beings, and things and spaces, while analyzing such data in real time. ETRI will continue developing IoT technologies to keep people safe and provide a more convenient living by protecting people from threats such as climate change, environment pollution, expansion of new epidemics, and natural disasters.

5-2-1. IoT

5-2-1-1. Developing Technologies for Remote Vessel Maintenance Based on SAN

Success in Developing Technologies for Remote Vessel Maintenance Based on SAN

ETRI developed the remote vessel maintenance technology based on SAN[35] and applied it to an alarm monitoring system (AMS) of vessels together with Hyundai Heavy Industry and Ulsan University for three years in 2008. In 2010, the institute succeeded in developing the remote vessel maintenance technology based on SAN, which remotely monitors vessels in the ocean (office on land) to determine failure, and remotely repairs any software failures. ETRI secured the 61142-450 standard IEC TC80, and registered the international standard patents. The standard was selected as one of the "Top 100 Achievements in National Research and Development" and won third place in the "Korea Technology Awards" in 2011.

5-2-1-2. IoT Open-Source Software Framework

Leading Intelligent IoT, Continuous Development of SLICE/IoTware/IoTware-IDE

In 2017, ETRI secured base technology that is capable of recognizing user behavior and change in environment among objects through the development of the self-learnable IoT common software engine (SLICE). It also secured base technology that can deduce and optimize intelligence through online learning's real environment.

ETRI also developed the IoT device software (IoTware) framework and launched it in October 2020. IoTware is a framework composed of microservice architecture and provides task control function, five lightweight operating systems (OS), firmware such as sensors and communication, and resource management and low-power control modules. All of these software are being released through GitHub, an open source code sharing site.

IoTware application device

35) SAN(Ship Area Network) is a technology that connects facilities and equipment in a ship to a network.

5-2-1-3. Development of the Integrated Algae Monitoring Platform for Algae Control

USV-based mobile sensor system

Minimizing River Algae Damage and Reducing Water Treatment Costs

ETRI developed a real-time algae monitoring system that can stably monitor data by enabling and controlling an unmanned surface vehicle (USV) at a distance of 6 km (previously 300 m). Development of the integrated platform for controlling green algae in Nakdonggang River will keep damages minimal by detecting green algae in advance and promptly responding, which will provide people the opportunity to secure stable water supply even if algae grows.

5-2-1-4. Developing Technologies for 5G-Based Smart City Services

Screen of integrated control center demonstrating 5G smart city (Daejeon City)

Developing Technologies for Smart City Service and Spatial Data

ETRI developed infrastructure technologies and integrated service platforms for supporting 5G-based intelligent CCTV terminals, drone systems, IoT sensor technologies, and service supports in Daegu and Daejeon since 2018.

ETRI developed an on-device AI CCTV technology for intelligently recognizing risky situations in urban areas and promptly relaying this information with peripheral equipment in wireless zones to prevent accidents and respond to such situations in real time.

5-2-1-5. Wireless Sensor Network Technology for Rapid Landslide Detection and Monitoring

Developing Rapid Landslide Detection and Monitoring System

ETRI developed a low-power sensor platform operation technology based on energy

36) Energy harvesting: A conversion technology that collects vibration, weight, light, heat, or any form of energy produced in daily life and transforming this to electricity.

Rapid landslide detection and monitoring system (Jirisan Mountain)

harvesting[36] from low-power wide area (LPWA) in mountainous areas where operation of in-house networks and power supplies are not allowed. ETRI installed these in Seoraksan Mountain, Songnisan Mountain, and Jirisan Mountain. The development of this technology enables real-time monitoring of earth and sand conditions in mountainous areas, protecting the lives and assets of people from landslides.

5-2-1-6. Establishment of Remote Identification System for e-Permits of Fishing Boats from China

Developing Remote Identification System for e-Permits

In 2018, ETRI developed a low-power, long-distance communications technology for over 30 km through analysis of oceanic wave environments, technology of wireless control of antenna and multi-channel, adaptive data rate (ADR) technology, remote identification communication protocol, and security technology for preventing forgery of small terminal communication systems such as e-permits for fishing. Consequently, the properties, ID number, and change in conditions are detected remotely to identify fishing vessels without permits, significantly reducing illegal operation of vessels from China.

5-2-1-7. Augmented IoT Technology

Smart helmet for firefighters

Advent of Augmented IoT Era

ETRI developed diverse augmented IoT technologies such as ones that can collect and analyze information on living body, the augmented recognition helmet system, smart helmet for firefighters, location and spatial recognition augmentation, and object tracking. In 2018, BodyFriend, Inc. commercialized a smart massage chair that provides optimal massage programs by analyzing the user's physical condition.

5-3. Intelligent Robotics - Forming a Society for Human and Robot Symbiosis

ETRI committed its best efforts to the development of intelligent robotics technologies converged with advanced ICT and AI technologies since 2004. ETRI puts in the work for developing intelligent robotics technology at a global level, such as the human-robot interaction (HRI), autonomous robot navigation, V2X communication, autonomous valet parking, and autonomous driving AI starting with the development of ubiquitous robotic companion (URC) technologies.

Human-care robot

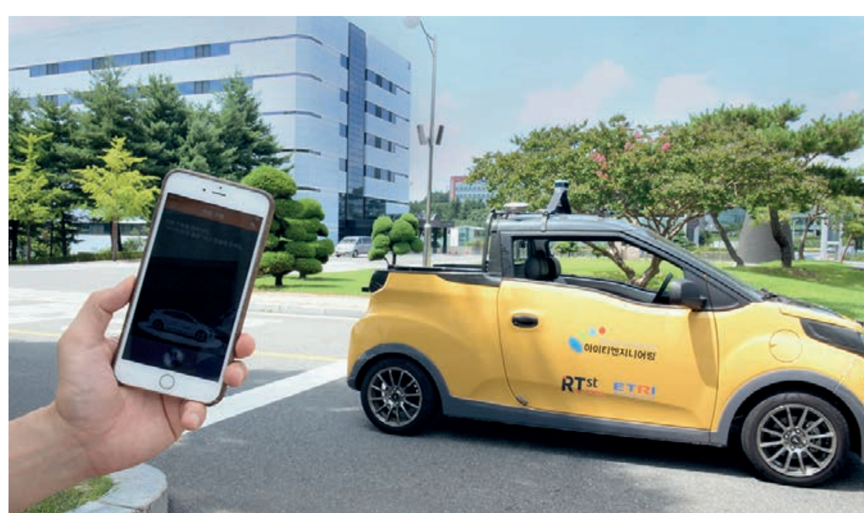
In 2004, ETRI launched technological development in the fields of intelligent robotics starting with ubiquitous robotic companion (URC) technologies that provide required services anywhere, anytime. The URC project holds significance in suggesting the concept of a network-based service robot for the first time in the world, and provided industrial cultivation strategies for creating new blue ocean markets. Also, the scope of robot industry expanded from the fields of machinery and electronics to content and service businesses, bringing in more participants and greatly expanding the overall size of markets.

The institute concentrated on development of HRI technologies for safe, natural, efficient, and sustainable interaction between humans and robots since 2008, and succeeded in realizing commercialization of these technologies such as face, gender, and age recognition, facial image-based heart-rate measurement, human motion recognition and assessment, human pose estimation, object detection and pose estimation, and synthetic dataset generation for deep learning.

Meanwhile, the institute commenced development of indoor/outdoor autonomous robot navigation technology, supporting effective movement of robots as a part of the URC project and secured core technologies then transferred these technologies to around 20 companies. In particular, the dynamic object recognition and tracking technology developed by ETRI won first and second place at the Visual Object Tracking (VOT) challenge by the International Conference on Computer Vision (ICCV) in 2015 and the European Conference on Computer Vision in 2016, respectively. The technology is currently advancing to robot navigation technology that can be applied even in unstructured environments not learned beforehand based on multi-modal data.

Furthermore, the institute developed vehicle-to-everything (V2X) communication technology from 2007 to improve safety and convenience. In 2013, ETRI succeeded in developing the autonomous valet parking technology for parking and retrieving vehicles via smart phone anywhere, anytime as required. The institute has also been working hard since 2015 to create an autonomous driving AI at level four for safe autonomous driving in various road environments (structured/unstructured environment, tunnel, and unpaved road) and climate environments (day/night, rain, snow) by applying AI technology for autonomous driving.

The institute will continue development of AI technology for safe and convenient intelligent robotics required for realizing a society where humans and robots coexist.



Calling an autonomous driving vehicle by smart phone

5-3-1. Robots

5-3-1-1. Ubiquitous Robotic Companion (URC)

The Ministry of Information and Communication (MIC) has driven the ubiquitous robotic companion (URC) R&D project as a part of cultivation strategies for new growth drivers since 2004. All functions of a standalone robot so far should be implemented on their own, and such robots suffered technological restrictions and increases in unit price. However, URC is a robot with an innovative concept that handles major processes on an external high-performance server connected to the network, which resolves such restrictions and enhances the usability of user services as well. R&D has been actively conducted for the new concept of converging robots and ICT starting with URC.

The URC project bears significance in suggesting the concept of a network-based service robot for the first time in the world and provides industrial cultivation strategies for creating new blue ocean markets. The scope of robotics industries expanded from machinery and electronics to content and service businesses, bringing in more participants and greatly expanding the overall size of markets, and narrowing the technological gap with the US, an advanced country in robotics technologies from four years (2003) to two and a half years (2006) through the development of URC robots' core technologies.

Intelligent robot "WEVER"

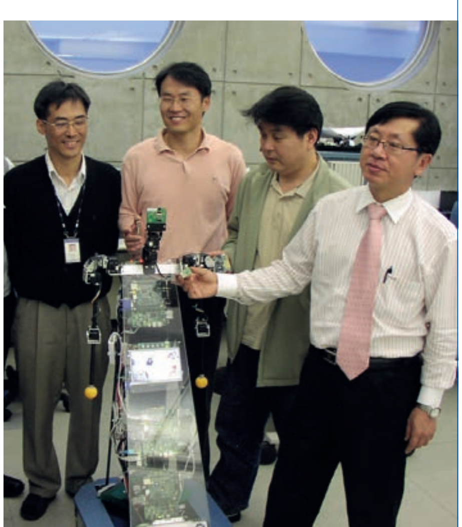
Five robot models (serving, porter, guide, patrol, and promotion) implemented through core component technologies developed by ETRI showed stable operation for 24 hours a day at various events such as the "Songdo—Tomorrow City," which was held for 80 days at the Global Fair & Festival 2009 in Incheon, and achieved the promotion of ETRI's robotics technologies to the world.

5-3-1-2. Human-Robot Interaction (HRI)

AI advancement allows sharing of workspace and living space between humans and robots, and accordingly, the demand for research brought the advent of HRI technology for safe, natural, efficient, and sustainable interaction between human and robot. To this end, ETRI has driven diverse projects to develop HRI technologies since 2008, and a total of KRW 77.1 billion in research funding will be invested by 2021.

Non-verbal social behavior generation of robot

Emotional robot "KOBIE" and "RABIE"



Leaders of URC R&D project

The HRI research project was recognized for its good quality control, and ETRI acquired the ISO SPICE Level 3 certification for the automatic user information extraction and recognition technology based on perception sensor network development project at the end of 2014 as the first among institutions. The technology of user face recognition for interacting with robots was first certified based on deep learning technology by a local certification institute (Korea Internet & Security Agency) in Korea in April 2017.

ETRI concentrated on developing HRI technologies through multiple projects for ten years, and succeeded in realizing commercialization of various technologies such as face, gender, and age recognition, facial image-based heart-rate measurement, human motion recognition and assessment, human pose estimation, object detection and pose estimation, and synthetic dataset generation for deep learning.

5-3-2. Autonomous Driving

5-3-2-1. Indoor and Outdoor Autonomous Robot Navigation

As a part of the URC R&D project, ETRI undertook the technological development project of indoor and outdoor autonomous robot navigation supporting the effective movement of service robots, and developed “StarLite,” which is a sensor-based location recognition technology and “Navi-guider,” which facilitates map creation and manual operation of robots. ETRI also developed “Quick-Map” (QMap), which is an integrated high-speed environment map-creating system that can quickly create maps for indoor spaces and “LION” (LiDAR and inertial odometry mapping), which can quickly build maps for large spaces using low-cost 3D LiDAR system by expanding QMap. The institute also developed “uRon” (universal robot navigation), a universal robot navigation framework for easy development and application of various path planning and driving control algorithms to provide environments for applying autonomous driving robot SW on products even for companies not familiar with robots.

In particular, the dynamic object recognition and tracking technology developed by ETRI that are essential technologies for services demanding limited computing environment and the real-time nature of robots won first and second place at the Visual Object Tracking (VOT) Challenge of the International Conference on Computer Vision (ICCV) in 2015 and the European Conference on Computer Vision (ECCV) in 2016, respectively.

ETRI also developed a technology for robot safety assessment that complies with ISO 13482, the international standard relevant to autonomous robots' driving and motion, and established it as a KS standard to contribute to the robot industries' activation and globalization.

Robots with uRON applied

5-3-2-2. Communications Technologies for Vehicles

ETRI undertook the vehicle multi-hop communication (VMC) project from 2007 for innovative improvement of functions and capabilities of a vehicle's communications technologies. The goal of the project was to develop communications technologies for vehicles that satisfy the international standard IEEE802.11p including the wireless access in vehicular environments (WAVE) standard. This project received KRW 13.6 billion in research funding for four years. Joint research participants included large companies such as Hyundai Motors, LG Electronics, and medium-sized companies such as IT TELECOM and RANIX.

Meanwhile, with the increase in demand for communications technologies for vehicles, ETRI conducted a development project the high-speed V-link communication technology for real-time control of autonomous vehicles, which took three years starting in 2016, to secure the technology of a modem for data transmission at large scale of 100 Mbps level and self-organizing TDMA base technology for ultra-low delay. In 2017, the institute participated in the Horizon 2020 AUTOPILOT, an international joint research consortium in Europe, and has been performing a development project for safety services at crossings for autonomous driving jointly with the Korea Institute for Advancement of Technology (KIAT) for three years since June that year. ETRI established a pilot site in ETRI campus and the K-City (autonomous driving experimental city), and performed tests for traffic light violation warning systems and pedestrian warning services based on the IoT device and platform.

G-WAVE communication modem chipset for vehicle (2020, RANIX Co.)

5-3-2-3. Autonomous Valet Parking Technology

Overview of autonomous valet parking system

When the Intelligent Green Vehicle was selected as one of the six-star brands in the “Roadmap Technologies of the New Growth Industry (IT Convergence System)” announced by the Ministry of Knowledge Economy in April 2009, the development of the autonomous valet parking technology has been driven as one of the strategic product. Autonomous valet parking is a technology for automatically guiding a vehicle from a departure point to a parking space using vehicle-mounted sensors and infrastructure sensors, saving time and energy for parking and minimizing environmental pollution.

ETRI succeeded in implementing the autonomous valet parking technology for parking and retrieving vehicles using a smart phone as required anywhere, anytime based on developed technologies in 2013. Five camera sensors and ten ultrasonic sensors were mounted on a vehicle, and sensors were also installed on parking spaces to achieve full autonomous parking. This type of parking is distinguished from the conventional parking assistant system (PAS) because it never requires the driver to operate the pedal or brake. ETRI estimates saving approx. KRW 18 trillion annually in social costs incurred from traffic accidents caused by unskilled parking, and 75,000 liters in gasoline consumed annually for searching for available parking spaces through the expansion of the autonomous valet parking technology.

5-3-2-4. Autonomous Driving AI

ETRI began development of core technologies of perception, planning, and control for safe autonomous driving in 2015. Specifically, AI is one of the core technologies for enhancing autonomous driving to its full extent. ETRI collects mass learning dataset and performs machine learning to apply perception and prediction AI technology in various driving environments. It also develops technology that recognize the position of autonomous driving vehicles with high precision, 3D moving object, and signal lamp appropriate for local environments, as well as collision-avoidance driving technology by recognition of vehicle taillights.

Autonomous driving vehicle

Safety testing is very important for autonomous driving vehicles along with their technological development. ETRI performed autonomous driving with the Prime

Demonstration for autonomous driving vehicle at the completion ceremony of the K-City test site for autonomous driving (December 11, 2018)

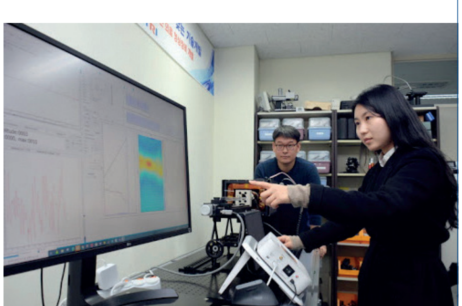
Minister riding in the vehicle for four km at the completion ceremony of the K-City test site for autonomous driving in December 2018, and continuously performs testing at Gwanghwamun Plaza, Daedeok Innopolis, Cheonggye Plaza, and within ETRI campus to enhance the safety and integrity of the technology. In addition, the institute directly implements data collection vehicles mounted with cameras, LiDAR, and GPS in order to secure enough data, which is the core of AI, and drives on roads between Daejeon and Sejong to collect data. The research group performs machine learning based on collected data, and implements autonomous driving technologies of higher levels by integrating conventional perception, planning, and control SW. ETRI discloses the AI learning dataset accumulated for activating the development of autonomous driving technology by startups and universities.

5-4. Biotechnology/Healthcare - Opening a New World of Biotechnology and Healthcare with ICT Convergence Technologies

ETRI has driven convergence research for ICT and biotechnology/healthcare for 20 years since 1998, and has developed technologies including computer-assisted diagnosis that analyze medical images, cancer diagnosis SW components, biosignal processing such as bio-shirts, smart diagnosis, a personal-driven health platform, and the AI doctor (Dr. AI), non-invasive biosensor for point-of-care diagnostics, biometrics system, e-Nose for medical diagnosis, and laser-based particle beam generation. The institute works hard to improve the health and quality of life through the development of these technologies.

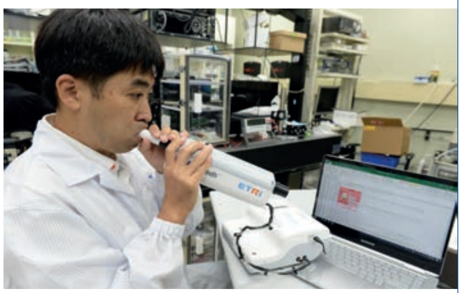
When ICT was applied on patient data management and medical image management in the medical field through rapid advancement of computer technologies, ETRI launched ICT and bio-medical convergence research in 1998 starting with the development of osteoporosis diagnostic technology using simple X-ray image analysis.

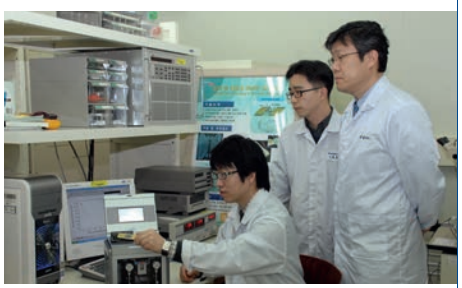
When the genome project for detecting information of the human genome and the concept of ubiquitous healthcare (u-healthcare), an important discussion in science and technology came up and ETRI was able to greatly expand its scope of convergence research.



Cancer diagnosis without radioactive substances

ETRI developed a computer-aided diagnostics technology such as the automatic lung cancer detection technology mounted on picture archiving and communications system (PACS) in the early 2000s, then succeeded in developing the core SW components required for bioinformatics analysis, showing a soaring demand in Korea by developing the core SW for biodata mining and integrated management. Furthermore, the institute began development of physical measurement systems in wearable form for performing simple measurement of biosignals anywhere, anytime,


Lung cancer diagnosis test using e-nose


Cancer diagnosis biochip developed by the research team

and succeeded in producing “bio-shirts” for the first time in Korea in 2006. The institute then expanded the wearable biosignal measurement technologies to the biometrics fields to develop a biometrics sysem based on transferring characteristics of the human body, fundamentally not allowing duplication by making use of the structural characteristics of the body.

When demands grew for diagnosis technology of diseases at the point-of-care, ETRI started the development of non-invasive biosensors in the early 2000s, and established the research company Aqugene Healthcare (currently Sugentech, Inc.) in 2011 based on these technologies. Sugentech was listed on KOSDAQ in 2019, ETRI’s first listed research company. This technology continuously advanced, and “e-Nose” was developed in 2013, which is capable of diagnosing lung cancer using exhaled breath component measurements. Genesystem, the third listed research company of ETRI exclusive for PCR device and reagents, was established based on these technologies in 2015. GeneSystem Co., Ltd. is set to be listed on KOSDAQ in 2021.

The institute also started to develop smart diagnostics technology in 2006 for conveniently testing diseases by simply detecting biomarkers relevant to the disease contained in bodily fluids. With these technologies, ETRI developed the super-high-speed blood preprocessing chip for point-of-care diagnosis and the testing sensor technology for point-of-care diagnosis for myocardial infarction.

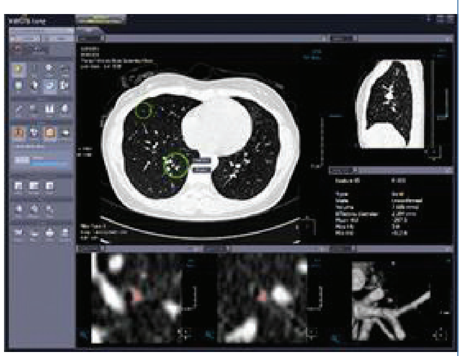
When there were numbers of attempts for applying ICT in healthcare for individuals in the 2010s, ETRI developed the open health platform (healing platform) in 2017 for managing individuals’ health information in an open environment. The institute also succeeded in developing “Dr. AI”, an AI doctor for early diagnosis of diseases by learning multifold medical intelligence based on a high-capability cloud. The expansion of contactless medical services amidst the COVID-19 pandemic will further accelerate the evolution toward the era of AI doctor. ETRI started the development of core source technologies for a laser-based particle beam treatment system for curing cancer without aftereffects in 2017.

ETRI will continuously advance the convergence research of ICT and biotechnology/healthcare to achieve the vision of "development of medical intelligent solutions for living a healthy life for 100 years". The institute will continue research on the technologies of medical intelligence, point-of-care diagnosis, image diagnosis, and patient-tailored precision treatment to lead the paradigm of personalization, intellectualization, and routinization in every field of healthcare.

5-4-1. Biotechnology/Healthcare

5-4-1-1. Computer-Aided Diagnostics Technology

Lung cancer diagnose system by analyzing exhaled breath components



Automatic lung cancer detection SW(Xelis® Lung)

Developing Technology for Computer-Aided Diagnosis of Osteoporosis and Lung Cancer

The starting point of ETRI's medical image research was the development of technology for osteoporosis diagnosis through simple X-ray imaging in 1998. This was a development project for computer-aided diagnosis algorithms that automatically detect symptoms of osteoporosis contained in an X-ray image. The commercialized products were supplied to hundreds of hospitals and clinics and registered as part of medical fees in the National Health Insurance.

Since 2002, ETRI has been developing computer-aided diagnosis(CAD) technology for lung cancer which is a CAD technology in the true sense and automatically detects lung cancer symptoms in chest CT images. This technology shows a mutually supplementing nature with clinicians, and will yield high-synergy effects. The technology was transferred to INFINITT Healthcare Co., Ltd. in 2006, which commercialized the technique under the brand name "Xelix Lung" mounted on PACS.

5-4-1-2. SW Technologies for Cancer Diagnostics

Developing Core SW for BioData Mining and Integrated Management

ETRI began a convergence project between ICT and BT called the "Development of Core SW Components for BioData Mining and Integrated Management." Based on the research results, ETRI was able to develop the core SW for the information of human genome sequence in 2003, and developed a SW for analyzing gene chips of gene expression data to diagnose cancer, commercializing it through ISTECH.

MAny-core Hpc system for bio-Application, MAHA

Developing Core SW Components of Bioinformatics

By developing core SW for biodata mining and integrated management, ETRI succeeded in developing the core SW components required for bioinformatics analysis, which showed a rapidly growing demand in Korea. Based on the achievement of this project, ETRI started a project for developing a super-computer for genome analysis in 2011, which is a computer technology dedicated to interpreting the human genome sequence. Through this, the MAny-core Hpc system for bio-Application (MAHA) system was built to implement 36,000 cores, 104.5 petaflops, and the research company Synteka Bio, Inc. (listed on KOSDAQ in 2019) was established.

5-4-1-3. Technology of Biosignal Processing

Athletes wearing Bio Shirt at the 87th Gimcheon National Sports Festival (2006)

Developing a Wearable Biosignal Measuring Instrument in the Form of a Shirt and Patch

"Bio-Shirt", developed for the first time in Korea in 2006, is a product that applies the u-healthcare concept which provides an medical services anytime, anywhere. The bio-shirt was provided to seniors living alone in Daegu as part of a local government project in 2006 and the research team transferred this technology to six private companies. In addition, this shirt was designed in the form of sportswear by ETRI and KIKA, and applied to athletes in the 87th Gimcheon National Sports Festival (2006). Various broadcasting programs introduced the bio-shirt as an excellent product that does not affect the competitiveness of players while providing biometric information during the game. It was exhibited as one of ETRI's major achievement at the technology exhibition in the 2000s.

Developing a Biometrics System Based on Transfer Characteristics of the Human Body

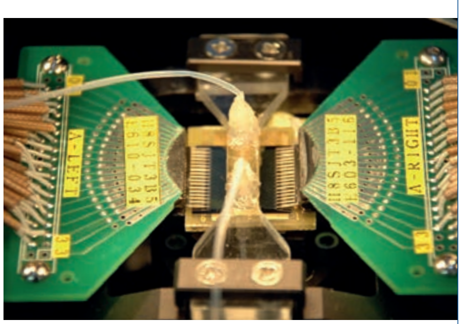
ETRI expanded the wearable biosignal measurement technologies to biometrics fields to develop a biometrics system based on transfer characteristics of the human body, fundamentally not allowing duplication, by making use of the structural characteristics of the body. The bones, muscles, fats, blood vessels, and blood in the human body differ among individuals and take highly complex forms. When applying a small vibration or minute current on the human body, other differing signals are obtained, making it possible to precisely identify specific individuals when analyzing signals using deep learning technologies.

5-4-1-4. Smart Diagnostics Technology

Bio-signal measurement complex sensor

Launching the Development of Smart Diagnostics Technology

ETRI began developing the smart diagnostics technology in a project for pervasive life-care and health monitoring system and module in 2006. The goal of the project is to develop a smart diagnostics technology, allowing anybody to conveniently test for diseases at home, work, and nursing homes by easily detecting various biomarkers in bodily fluids (e.g., blood) relevant to a disease for continuous monitoring of personal health.



Multiplex biosensor chip and automatic detection system

Development of Multiplex Biosensor Chip and Automatic Detection System

The representative achievement among developed technologies is the multi-test biosensor chip and automatic detection system developed in 2009. The system is capable of detecting multiple food toxins and cancer diagnosis from biomarkers using a single semiconductor chip, and was the first to be developed in the world. Technologies used for this system included biomarker signal amplification for detecting non-charged and low molecule with vast charged nanoparticulates, and semiconductor CMOS. The research group succeeded in increasing the accuracy of diagnosis and improving the reproducibility and yield (transport number) by statistically analyzing values measured individually from 100 nanosensors fabricated with high-integration semiconductor technology.

5-4-1-5. Non-Invasive Biosensor for Point-of-Care Diagnosis

Cancer biomarker detection semiconductor biochip and reader for point-of-care diagnosis

"e-Nose", Detecting Lung Cancer Using Exhaled Breath

ETRI developed a medical "e-Nose" in 2013 for conveniently diagnosing lung cancer using exhaled breath based on technologies accumulated in the field of non-invasive biosensors for point-of-care diagnosis. Just as the human nose senses smells through nerve cells, the e-Nose senses smell with an electronic device when exhaled breath flows in, and converts the smell into electric signals to detect a disease. It is anticipated that lung cancer is diagnosed and prevented early with this simple method and at affordable cost without risk of radiation. A joint venture will be established with this technology (set for 2021).

5-4-1-6. Personal-driven Health Platform and "Dr. AI"

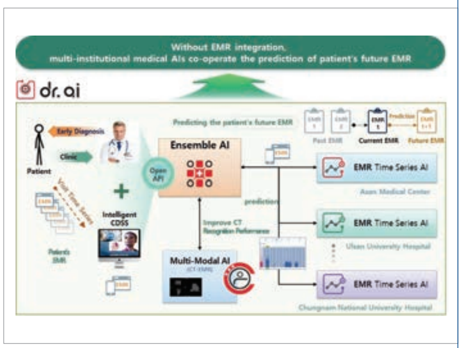
Personal-driven health information managment

Dr. AI SW

Development of the Personal-driven Health Platform, "Healing Platform"

Active attempts have been made in the 2000s to apply ICT to individual healthcare for improving people's quality of life and saving costs for national health financing. Technologies for health platform have also been demanded based on standards for linking diversified health services.

The research results indicate that development of the healing platform was achieved by integrating the intelligent service API using an open platform and bigdata on health developed by ETRI in 2017 with technologies developed by joint research institutes. In particular, Uracle Corporation developed the healing platform-based ribbon service and succeeded in demonstrating its capabilities to 300 residents of Songdo in Incheon. The National Health Insurance Corporation applies individual-led healthcare functions on its platform called "Health IN," supplying its functions to the general public.



Medical service model for Dr. AI

Developing the AI doctor, "Dr. AI"

Dr. AI is a deep learning technology for joint-diagnosis ensemble by multiple institutions for predicting a patient's health conditions through joint diagnosis of medical functions of individual medical institutions (without integration) using EMR[37]. Currently, a specific medical team is validating the Institutional Review Board (IRB) of cardiovascular disease data and the capabilities of Dr. AI. Once Dr. AI is commercialized, all hospitals and clinics in Korea will use it as a decision-making support system for specialists to enhance the level of medical care.

5-4-1-7. Technologies for Cancer Treatment

Apparatus for laser-based multi-particle (proton+electron) beam generation

Driving Long-Term Research in Four Stages Until 2030

ETRI conducted a project for a laser-driven charged particle beam generation technology from 2010, establishing a high-intensity laser system and developing the source technology for energetic particle generation. The research group concentrated on converging proton and electron beam generation techniques to investigate its potential for cancer treatment by measuring relative biological effectiveness. ETRI developed a technology that monitors the transfer process of laser pulse onto proton-generation targets in vacuum while quickly and easily detecting the optimal conditions for laser-matter interaction. As a result, the institute succeeded, for the first time in the world, in implementing an apparatus for generating and switching proton and electron beams in the same space.

37) Electronic Medical Record (EMR): Patients' health information that are systematically collected in digital form and stored electronically.

5-5. Postal Logistics - Leading Smart Postal Services

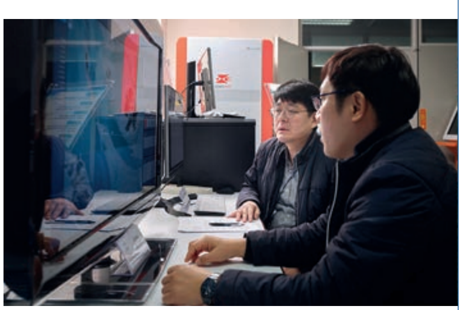
Opening ceremony of Postal Technology Research Center

ETRI has converged ICT with postal logistics for 20 years since 1999 to develop sequence sorter, automatic registered mail sorter, unmanned post office, mobile navigation for delivery, and drone delivery logistics technologies to contribute to the advancement of postal logistics.

The postal service, which is the basis of communications services, started in 1884 in Korea. The volume of mail increased explosively in the 1990s, and as mail rapidly increased in volume with fast industrialization and growth of communications and insurance businesses, changes in services were demanded through auto processing and information systems for mail.

ETRI launched a research on the field of postal logistics starting with the development for localizing a mail sequence sorter in 1999. The institute has 26 core technologies and has registered 227 patents through the development of sequence sorters and the Hangul address recognition system (including road number address) mounted on the sorters. ETRI transferred them to small and medium businesses to generate economic effects at the scale of KRW 1.3 trillion (as of 2013, Korea Post). ETRI also developed an automatic registered mail sorter in 2005 to save on mail processing per sorter of KRW 100 million annually.

The institute began development of elemental technologies for establishing Smart Post, the vision of Korea Post in 2011, and succeeded in developing an unmanned post office in 2014, providing mail services such as acceptance, delivery and banking services without tellers. Furthermore, ETRI developed a mobile navigation for delivery and logistics drone delivery technology for searching and guiding the optimal delivery paths for each mailman since the mid-2010s to promote efficiency of mail collection and delivery.



Delivery system using drone

ETRI will continue technological developments for automation and efficiency in the field of postal logistics to lead the advancement of the national postal business.

5-5-1. System Automation

5-5-1-1. Technology for Automatic Mail Sorter

Postal delivery sequence sorter with Korean address recognition system

Sorting delivery sequence of letters and sharing most types of mail used to be fully performed manually and there was a demand for developing sequence sorters that are capable of automatically recognizing addresses in Korean and sorting mail according to mailmen's individual delivery points and routes registered in the address DB.

ETRI began the development and localization of a mail delivery sequence sorter. Research at the initial stage focused on developing a high-speed recognition system for addresses in Korean mounted on a sequence sorter through joint research with Siemens ElectroCom, a supplier of automatic sequence sorters. The institute developed technology that extract character codes from images of a mail. It then validates character codes and acquires delivery point codes through sequential address interpretation to secure automatic recognition technology of Korean addresses and jointly developed HW such as conveyor systems for automatic sorting with local development companies of mail systems. Automatic sequence sorting speeds increased by 16 times (32,000 per hour) compared to manual sorting of 8,000 items per hour for individual routes.

Registered mail is hard to automatically sort because of varying thickness and contents, and must be securely guaranteed for fast and safe delivery. ETRI succeeded in developing an automatic registered mail sorter by combining the technology that automatically reads the registered bar code and compares it with the received postal code from the postal logistics system (PostNet) with technology conveying mails to entirely prevent erroneous sorting and damage of mail. This development allowed auto sorting of 24,000 registered mail items per hour, providing faster and perfect tracking information.

The government decided on the introduction of new road name address in the early 2010s, and the current Korean address recognition system must be updated appropriately for the new postal code system. The current land-lot number address recognition system was upgraded to additionally recognize road name addresses and was mounted with a route sorter and supplied to the postal addresses throughout the country in the first half of 2013.

Postal delivery sequence sorter

5-5-1-2. Technology for Automatic Parcel Sorter

When the volume of parcel services increased, Korea Post began introducing parcel sorters to post offices in 1999. The parcel sorter introduced then was of the tilt-tray type that rotated plates on a loop track to discharge parcels into sorting chutes capable of handling a maximum of 4,000 parcels per hour. In 2002, the sliding shoe type sorter in straight format and cross-belt type sorter in loop format were introduced, both of which were imported products.

ETRI commenced development of automatic parcel sorter in cross-belt type to save costs on introduction and maintenance, and developed control and operation technology for sorters with two inductions (parcel supply section) and 73-m track HW that had to be imported. ETRI secured technology for hourly throughput of 3,000 to 5,000 parcels for each induction, equivalent to the maximum of overseas makers, by advancing induction control technology, and additionally developing operation monitoring functions such as failure diagnosis.

A parcel sorter developed by ETRI operation at the Busan Postal Distribution Center

The developed technology was transferred to small companies to yield royalties of approx. KRW 200 million and the systems are under operation at the Busan Mail Center and the Dong Seoul Mail Center.

5-5-2. Collection and Delivery Technology

5-5-2-1. Technology for an Unmanned Post Office

Unmmanded post office

Korea Post began distributing the automatic mail receiver system from the end of 1990 and operated 154 systems. However, the system was not available on holidays and after-hours, showing its limitations in responding to various changes in mail environments. To resolve such issues, technological development for an unmanned post office commenced in the early 2010s.

ETRI launched research for the development and establishment of elemental technology for unmanned post offices through the SMART Post establishment technology development project in 2011. ETRI developed a linkage support system


Unmanned automatic receiving/delivery integrated system

between automatic mail receiver systems (mass quantity), the unmanned post office and the call center for automation of mail receiver jobs. It also developed an automatic mail receiver system mounted with an automatic labeling module and unmanned automatic receiving/delivery integrated system, and established the plan for establishing unmanned post offices.

Based on research results, the first unmanned post office in Korea started business in May 2014. The unmanned post office receives and delivers ordinary mail, registers mail and parcel, offers banking services, and attends mail inquiries from 7 AM to 11:30 PM.

Currently, nine unmanned post offices using ETRI's technology are under operation as of 2020, and five developed technologies were transferred to small companies. ETRI will continue to secure world-top postal technologies to provide more convenience to such services.

5-5-2-2. Technology for Efficient Postal Delivery

ETRI developed various automation technologies that apply ICT in postal logistics fields. Development for more efficient systems in delivery fields was also conducted in the mid-2010s and thereafter. When the technology reaches a certain level of automation, the demand for efficiency emerges, and efficiency in postal delivery was also demanded in the mid-2010s and thereafter.

To respond to such requirements, ETRI developed a mobile navigation for postal delivery for efficient delivery jobs in 2017. The navigation searches for and guides the optimal delivery route by analyzing the mailman's delivery points on a certain day. This was developed to support additional delivery (additionally handling delivery jobs in some specific areas when a mailman is absent) and for jobs of new mailmen not familiar with the geographic conditions.

A GPS for regular vehicles is capable of searching and guiding a single destination or up to five waypoints; however, for postal delivery, it must search and guide multiple points for a mailman visiting 50 to 100 points in a day. Furthermore, searching thousands of delivery routes must be completed one hour before thousands of mailmen nationwide

Mobile navigation for delivery service

set up for delivery. To satisfy these requirements, ETRI resolved the quality issue of incorrectly entered customer addresses by advancing ETRI's address analysis modules based on the basic commercial navigation modules. Additionally, ETRI developed the final solution by integrating the control server and GPS apps for those using a mobile device to manage specific elemental technologies such as geo-coding and routing, address DB, points of interest (POI) DB, map DB, and road network DB. It is anticipated that the mobile GPS for delivery jobs will support the additional delivery issue and on-the-job training for new mailmen (jobs requiring becoming familiar with geographic conditions), reducing the difficulty and labor intensity of delivery jobs which takes several months to adjust to.

5-6. Energy/Safety/National Defense - Leading Improvements in Safety and Quality of Life

ETRI accelerated conversion of ICT with various fields such as energy, safety, and national defense since the late 2000s. ETRI developed the energy trade technology and power agency platform of new and renewable energy in the energy field; the one-click disaster information transfer system and K-MDDS, a complex disaster prediction expansion platform in the safety field; and the virtual training system (ODM-I) and media multi-path adaptive network technology in the national defense field.

ETRI began developing an energy-ICT convergence technology by participating in the TF of the Committee on Green Growth in 2009. As international energy costs continued to rise in the 2010s and the smart grid (intelligent grid system for higher efficiency by applying IT on production, supply, and consumption phases of electric power) emerged as a social issue, ETRI drove Korea Micro Energy Grid (K-MEG) project and smart grid demonstration project in earnest. Consequently, ETRI developed the energy consumption metering and transfer technology for individuals for easily switching the supplier-oriented smart grid to a user-oriented smart grid. It also developed energy trade protocol technologies for allowing regular people to easily buy and sell electrical energy.

As the Moon Jae-in administration took office in 2017, several major policies were driven including expansion of new and renewable energy, efficient operation of energy consumption, and creation of new energy-related industries. To this end, ETRI has been concentrating on developing a platform business technologies for resolving technological barriers for the activation of renewable energy (photovoltaic energy), securing cost effectiveness of energy, and creating new BM. Typical platforms include the monitoring system for management and maintenance of photovoltaic plants to optimize operation and management in its entire processes such as prediction of power generation volume, monitoring, automatic restoration, and disposal diagnosis of photovoltaic plants; VPP

Energy trading system

platform, which support trade of energy resources such as photovoltaic power and wind power in power markets by power agency businesses; and optimal linkage technology of photovoltaic power and energy storage system (ESS), which support operation of photovoltaic power at the optimal cost linked with the storage system.

In the 2010s, the government changed its scheme for disaster management from response-oriented to prediction-oriented to keep damage from disaster minimal, and began developing technologies and systems at the national level. To respond to this government policy, ETRI commenced research for the purpose of building a Korea to safeguard the people from disaster in 2013. Additionally, ETRI recorded achievements including the one-click disaster information transfer system, a prompt and precise disaster information system for all citizens; development of K-MDDS, the first platform in Korea for complex disaster prediction propagation; and the accident management convergence information platform, which controls fire or accident risk in buildings.

ETRI was appointed as the "expert technology support institute of new IT" by the Ministry of National Defense in 2013 pursuant to Article 24 of the Act on Establishment of Infrastructure for Informatization of National Defense and Management of Informational Resources for National Defense. It performs missions such as support of establishment of new IT polices for national defense informatization, identification and support of technologies for early introduction of new IT to the national defense fields, expert technological consultation for excellent new IT, and support for education of new IT. ETRI also focuses on developing convergence technologies between ICT and the national defense field, such as the world-class virtual training system ODM-I, and the multi-media multi-path adaptive network technology (MMMP) that has high reliability and survivability.

ETRI will continue to identify and develop convergence technologies to maximize synergy by converging ICT in the fields of energy, safety, and national defense to contribute to people's safety and quality of life.

5-6-1. Energy System

5-6-1-1. Technology for Maintenance and Management of Photovoltaic Power Systems Based on Big Data

DER(Distributed Energy Resources) remote & realtome monitoring system

Photovoltaic monitoring & AI-based maintenance system

ETRI launched the project for developing technology that reduces maintenance costs of local photovoltaic plants for expanding distribution of photovoltaic power using big data. It also developed intelligent platform technology capable of optimally performing operations and management throughout the processes of predicting power generation volume, monitoring, automizing restoration and diagnosing disposal of photovoltaic plants. ETRI performed a demo on monitoring technologies for around 3,000 photovoltaic power plants in Korea. Moreover, it is collecting and monitoring data on individual plants' operations in real time, as well as analyzing big data.

The platform for remote monitoring and maintenance of photovoltaic power plants saved maintenance and management costs and reduced energy loss. It is also expected to cultivate expertise of companies and create new jobs accordingly. In particular, the e-map system will be expanded to local photovoltaic map systems and will be utilized as a public data portal for photovoltaic systems. In addition, the secured disposal diagnosis technology will be linked with the photovoltaic recycling center to promote the reuse and recycling of energy for saving production costs and resolving environmental and social issues.

5-6-1-2. Technology for Small-Scale Power Resource Trade

Renewable energy control center

Since 2016, ETRI developed a back-end system technology for managing prototypes of operation support systems and distributed resources for small-scale power agency business. It also developed prediction technology for photovoltaic power generation volume and optimal operation technology for energy storage systems through the development project for BM identification of agency systems that vitalize small-scale distributed resources and electrical power trade. Moreover, ETRI established a test bed based on Korea Power Exchange's trading system.

Through this project, ETRI has developed several technologies including an energy trading business platform, distributed energy resources (DER) management system,

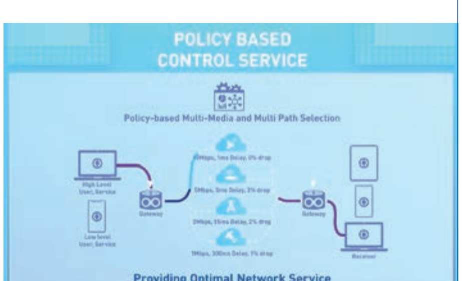
Small-scale renewable power resource trading system

blockchain based trading system, photovoltaic generation AI prediction, etc. In addition, ETRI proposed a plan/rules to improve the power market and power brokerage market, and led the ITU-T international standard for power brokerage reference model (RM), architectures, and service/interface requirements.

5-6-1-3. Development and Demonstration of CES-Based Microgrid BM

Since 2016, ETRI performed a project for development and demonstration of microgrid BM that utilizes distributed resources based on community energy supply (CES) facilities to integrate energy elemental technologies (metering, sensor network, energy consumption and generation prediction, and optimal control for energy saving) with system and service technologies (xEMS integrated management, microgrid operation, demand response management, big data processing, and energy trade) to establish the integrated CES-microgrid platform. It then conduct a demonstration of the platform in around 3,000 households.

Once the platform is expanded and distributed to heat-annexation power generation, 20–30% energy savings and 30–40% greenhouse effect reduction will be achieved. While conventional energy polices focus on simple distribution and expansion of photovoltaic and wind power generation, advanced metering infrastructure (AMI), energy storage systems (ESS), the establishment of the microgrid and integrated operation platform linked with CES will be the new standard model for energy savings in areas of high population density.



Policy-based Multi-Media and Multi-Path Selection

5-6-2. National Defense System

5-6-2-1. Reliable Network Technology

ETRI conducted a project for developing the multi-media multi-path (MMMP) technology from 2017. The project involves developing technologies of TRL7 (level 7 of technical maturity) used in national defense communications networks. The goal of the project is

AI based MMMP Networks

to develop a network technology with high reliability and survivability by intelligently and simultaneously utilizing all communications infrastructures in the dynamic mission-based network environments such as the national defense network, demanding absolute connected survivability and security. Research costs of KRW 11.25 billion were invested in the project, and some of the technologies were verified for applicability through experiments and demonstrations within the project period.

Through this, ETRI developed several technologies including a conformation system enabling integrated use of all communication resources, simultaneous MMMP data transfer applicable in dynamic mission-oriented network environments, network optimization for selecting multiple networks dependent upon requirements of applicators and users, division of infrastructure resources in missions and groups, and multi-dimensional data protection for individual applications and grades.

5-6-2-2. Virtual Training Platform Technology

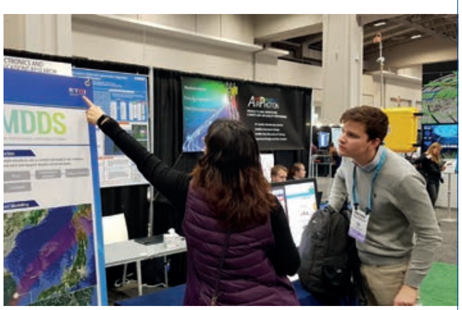
From 2013 to 2019, ETRI carried out an interactive SW technology development project (Project ODM-I) for omni-directional movement support that provides soldiers with a virtual training environment similar to the real situation. The purpose of the project was to develop a hyper-realistic world-class virtual training system by researching innovative technologies that go beyond the physical and technical limitations of existing VR training technologies. Locomotion is a key technology that has been needed for a long time in the field of virtual reality. The project combined locomotion interface with four core technologies to increase the immersion of the virtual reality system. The core technologies are precise posture recognition and prediction using multi-modal sensors, deep learning-based action recognition, intuitive user interface for commercial game and military tactics training content, 360 degress of omni-directional locomotion interface and precise locomotion control. During the project the soldiers on the field contributed to improving the immersion to the level of the actual battle situation. As a result, the Project ODM-I enables highly immersive tactical team training by allowing soldiers infinite omni-directional movements such as walking, running, and crawling in a virtual environment that represents a target operational area they are visiting for the first time.

Virtual Training Platform with commercial game interface

5-6-3. Disaster and Safety

5-6-3-1. Smart Technology for Disaster and Safety Management

Starting in 2013, ETRI is conducting research to build a country that safeguards its citizens from disaster. ETRI performed several projects, including R&D for a customized intelligent integrated alarm system for three years from 2013, R&D for scenario-based large-scale disaster dissemination prediction from 2017 to 2019, and development of a multiple media-based disaster information transfer platform from 2018 to 2021. Notable achievements through this include the Mega Disaster and Damage estimation System (K-MDDS) developed in 2019, which is the first complex disaster diffusion prediction platform for Korea's environment, and is mounted with various prediction models including 12 natural disaster models (earthquake, landslide, flood, heavy rain, etc.), 8 social disaster models (infectious disease, livestock disease, etc.), an automatic model scenario generation and integration of complex disaster, and a GIS engine developed by convergence of ICT with culture, science, and engineering technologies.



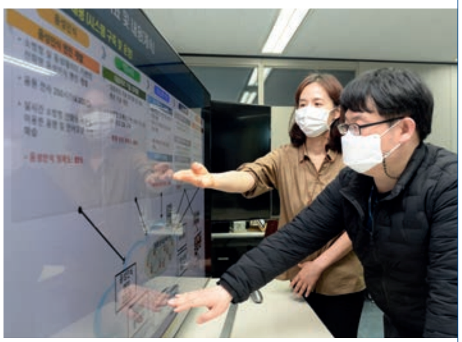
Mega disaster & damage estimation system

5-6-3-2. Prevention and Response to Fire with ICT

The connected smart helmet technology is developed for firefighters when extinguishing fire and rescuing victims.

ETRI is developing a convergence information platform for accident control for fire or accident risks in buildings. The platform supports acquiring and storing accident control information such as firefighting system inspection and firefighting response information based on spatial information. ETRI will share such vital information with stakeholders. The information convergence platform for accident control is linked with the 3D-based Virtual Seoul Project

ETRI was also the first in the world to commence a development project for fire detection technology, which identifies causes of smoke and determines the possibility of fire outbreak. In addition, ETRI strives to identify fields appropriate for applying ICT,



119 intelligent emergency call system for disaster context awareness and disaster response support

such as prediction and prevention of accidents using AI, intelligent safety control, and intelligent evacuation (from accidents).

5-7. Convergence Research to Solve National Issues

In 2014, the National Research Council of Science & Technology (NST) launched the Convergence Research Department Project, in which government-funded research institutes (GRIs) and industry-academia researchers joined together to solve national social issues. ETRI is in charge of four research departments (UGS, KSB, SDF, and DMC) out of a total of 15 convergence research departments promoted by NST.

The UnderGround Safety (UGS) Convergence Research Laboratory was selected in the first year of the Convergence Research Department project and operated until 2017, consisting of ETRI, Korea Institute of Civil Engineering and Building Technology (KICT), Korea Railroad Research Institute (KRRI), and Korea Institute of Geoscience and Mineral Resources (KIGAM). In the 2010s, as people's anxiety increased due to the occurrence of a sinkhole accident in the downtown area, the demand for comprehensive analysis and prevention technology for the possibility of ground subsidence increased. Accordingly, the UGS Convergence Research Laboratory developed an IoT-based underground grid system that constantly manages the safety of urban railway structures and detects leakage in water systems and groundwater to predict and prevent ground subsidence. This system was selected as one of NST's 2018 “Top 10 GRI Technologies.”
The Knowledge-converged Super Brain (KSB) Convergence Research Department consists of ETRI, Korea Institute of Energy Research (KIER), Korea Atomic Energy Research Institute (KAERI), and Korea Research Institute of Standards and Science (KRISS). The research group was organized to resolve issues in securing technology for implementing a human-centric hyper-connected society to respond to the advent of the Internet of Everything (IoE), and will operate from 2015 to 2021. The group disclosed the KSB AI framework (BeeAI), the first AI service framework in the world, and various AI solutions for verifying BeeAI’s efficiency. Currently, multiple companies and universities use BeeAI software to develop AI services.

The Smart Defense for Foot-and-Mouth Disease (SDF) Convergence Research Department is led by ETRI with the participation of the Korea Research Institute of Bioscience and Biotechnology, and is operating from 2018 to 2021. This department concentrates on establishing a biosecurity system (or ADIOS), which capable of comprehensively responding to foot-and-mouth disease in all of phases including outbreak, diagnosis, prevention, and quarantine using ICT intelligent information technologies such as AI and big data.

The Defense Materials and Components (DMC) Convergence Research Department will perform research for three years from 2020 with the goal of developing a self-sustaining platform for core semiconductor parts for national defense weapons systems. This department establishes fab infrastructure jointly with the National NanoFab Center and Korea Advanced NanoFab Center, and develops materials and parts for national defense through technological collaboration with the Korea Institute of Machinery and Materials, Pukyong National University, and Chungnam National University. In addition, they focus on securing industrial competitiveness by establishing supply chains in the field of national defense together with participating companies. The department currently develops monolithic microwave integrated circuits (MMICs) and the localization and platform of high-voltage switch and optical sensors.

ETRI intends to take the lead in solving national and social issues by successfully completing the ongoing KSB, SDF, and DMC research department projects, spreading the results to the entire industry.

Cooperation agreement for convergence research

5-7-1. UnderGround Safety (UGS) Convergence Research

5-7-1-1. UnderGround Safety Management Technology

Convergence research for ground subsidence prediction

The UGS Convergence Research Laboratory consists of ETRI, the Korea Institute of Civil Engineering and Building Technology (KICT), the Korea Railroad Research Institute (KRRI), and the Korea Institute of Geoscience and Mineral Resources (KIGAM), and was supervised by ETRI. In addition, seven domestic companies participated, including SK Telecom, and from December 2014 to December 2017, research funding of KRW 31.5 billion was invested for three years with around 100 researchers participating per year.

The UGS Convergence Research Laboratory promoted the project with the goal of developing an IoT-based underground grid system to constantly manage the safety of urban railway structures and detect water leakage in order to predict and prevent ground subsidence.

As a result of the study, ETRI is researching UGS frequency-shift keying (FSK) wireless communication technology, and manhole cover-type omnidirectional antenna technology (900 MHz, 2.4 GHz band) to connect sensor information in underground space with the communication network on the ground. An underground space information integration and 3D visualization technology was also developed for three-dimensional analysis of underground spaces.

ETRI implemented the IoT-based underground grid system based on technologies it previously developed. This is a system that preemptively detects, predicts, and responds to underground space conditions by constantly monitoring waterworks, sewers, urban railroads, and groundwater, which are buried materials by checking and monitoring dangerous areas underground. It was also selected as one of NST's 2018 “Top 10 GRI Technologies.”

Concept diagram of IoT-based underground grid system

5-7-2. Convergence Research for Super-Brain

5-7-2-1. Core Technologies of the Super-Brain


KSB AI platform demonstration

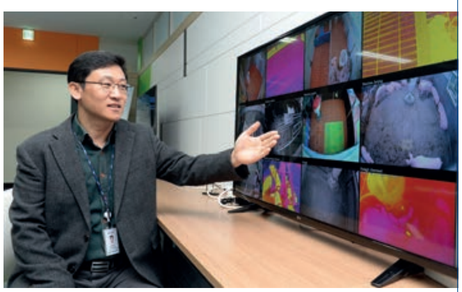
BeeAI is a framework for developing AI services in various application fields by training and analyzing data collected in real time through IoT. Based on workflow, BeeAI can support multi-modal data processing, simultaneous training and inference, automatic machine learning, distributed parallel processing, trained model serving and domain knowledge interworking.

The KSB AI platform provides execution and control functions for deploying and operating engines configured in accordance with defined workflows, and it is composed of KSB artificial intelligence edge platform and KSB artificial intelligence cluster/cloud platform to form an artificial intelligence ecosystem from edge nodes to clouds. The KSB edge device AI technology allows for very fast inference with high training precision, and it is easily applicable for low-graded HW platforms and in real-time IoT fields. Moreover, it is an easy-to-configure lightweight training model.

The edge computing technologies jointly developed by ETRI, SKT, and the National Radio Research Agency of Korea based on the achievements from this project were adopted as international standards at the Geneva ITU International Conference in 2018. Currently, the KSB Convergence Research Department is focusing on research and development to present the effectiveness of the BeeAI based application services, such as the autonomous distributed building energy management system, intelligent plant leak prevention systems and application services, and IoE-based elderly health (stroke) monitoring systems and application services. Meanwhile, In2Wise, a technology investment research company of the KSB Convergence Research Department, was founded in January 2021 and will continue to support the commercialization of BeeAI based application services in the future. Currently, BeeAI is being applied and evaluated to the next-generation budget accounting system by the Ministry of Economy and Finance, the artificial intelligence-based future transport operation system by the Ministry of Land, Infrastructure and Transport, the next-generation life and health ecosystem by the Ministry of Trade, Industry and Energy, and the intelligent water management system establishment project by the Waterworks Headquarter of Daejeon, and will be utilized for deploying AI services in various fields.

5-7-3. Convergence Research for Responding to Foot-and-Mouth Disease

5-7-3-1. ICT Convergence Technologies for Foot-and-Mouth Disease



ICT convergence research for foot-and-mouth disease

Foot-and-mouth disease (FMD) is a viral livestock disease affecting artiodactyl animals such as cows and pigs, and the standard operating procedure (SOP) manual is applied to solve this health issue. However, it has been reported that there are significant difficulties in real-time response and further epidemiological surveys due to the commanding system being jeopardized by subjective determination and reports not based on correct data.

To resolve such issues, ETRI conducts a technological development for efficient response to FMD by applying ICT, configuring living labs, and performing demonstrations for application in the field with certain companies participating in the project for commercialization.

The department concentrates on establishing a biosecurity system (or the Animal Diseases Management Operating System; ADiOS) that is capable of comprehensively responding to FMD in all phases including monitoring the occurrence of livestock diseases, diagnosis, quarantine, and blocking of FMD using intelligent information technologies such as AI and big data.

First, ETRI develops the technology for analyzing the probability (risk level) of inflow of the disease from foreign countries. In addition, artificial intelligence analyzes the occurrence of livestock disease including FMD using big data acquired from CCTVs, microphones, feed/water quantity measurement and environmental sensors installed in domestic livestock farms.

CG of ICT convergence research for foot-and-mouth disease

Second, ETRI is developing a highly sensitive molecule and immunity diagnosis technology for FMD when abnormal symptoms of livestock are reported to a public veterinarian or farm owner. The SDF Convergence Research Department is also developing a field diagnosis system for determining FMD quickly with high sensitivity in the field through the utilization of antibody engineering technology based on high-speed gene amplification technology in nano scale.

Signboard hanging ceremony of SDF Convergence Research Department (November 14, 2011, ETRI)

This department is also establishing a spread blocking system for initial disinfection activities and blocking of secondary infection by restricting movements of humans, livestock, and vehicles that may transmit the disease. Furthermore, they are developing a virtual reality-based education system for farm workers enabling individual farmers to efficiently respond to the disease.

ADiOS will be linked with the Korea Animal Health Integrated System (KAHIS) for operation.

There is currently not one country that operates a national integrated response system for livestock diseases such as FMD. Thus, once the SDF convergence research project is complete, Korea will be the first county to operate an integrated bio-security system.

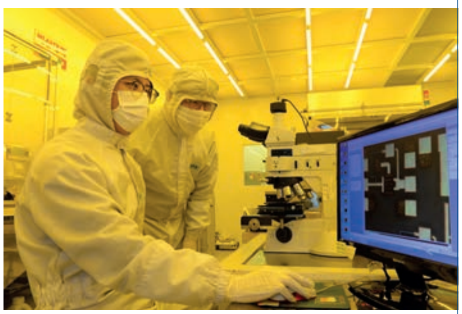
ADiOS has high potential for application to other diseases as well and uses the national disinfection system. In this case, the system will have various functions such as relieving the unease and discomfort regarding the outbreak of malicious livestock diseases, securing stable supply of livestock food products, saving national disinfection costs, and resolving environmental issues caused by eradication.

5-7-4. Convergence Research for National Defense

5-7-4-1. Technologies of High-Power/High-Efficiency Compound Semiconductor RF Parts for National Defense

Signboard hanging ceremony of DMC Convergence Research Department (May 29, 2020, ETRI)

NST launched the Defense Materials and Components (DMC) Convergence Research Department led by ETRI to commence the development of a self-sustained platform for core semiconductor parts for the national defense weapon system. This department performs a project for developing high-frequency power devices and single monolithic microwave integrated circuits (MMICs) used in radar, a core component of the reconnaissance surveillance weapon systems. MMIC is a core semiconductor chip for the transmit/receive module in the C-/X-/Ku-band applied to reconnaissance surveillance fields. ETRI aims to secure manufacturing technologies for core semiconductor parts of



DMC convergence research for GaN semiconductor chip

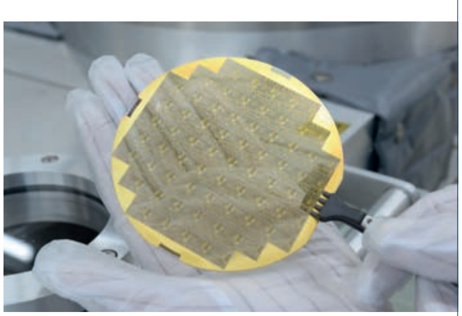
the reconnaissance surveillance radar, all of which have been imported, to contribute to the strengthening of national defense capabilities through the projects.

Before launching the DMC Convergence Research Department, ETRI had driven development of GaN RF semiconductor power devices applied to the national defense weapon systems through compound semiconductor-based RF device and integrated circuit design, and technologies accumulated for the past 30 years. As a result of the department's research, ETRI succeeded in developing the world-class S-band 200-W grade GaN RF power amplification device for the first time in Korea, far exceeding the original goal of a 150-W grade GaN RF power amplification device.

5-7-4-2. Technology of Silicon High-Power Semiconductor for National Defense

ETRI conducted a research on the localization feasibility of a high-voltage switch (2012 and 2016) and research for development and testing of a high-voltage switch package (2016-2017) based on various semiconductor technologies of Power MOSFET, IGBT, and high-efficiency rectifier accumulated over the past several decades based on the silicon semiconductor laboratory infrastructures. As a result of such research, ETRI succeeded in developing a silicon MOS controlled thyristor (MCT) with withstand voltage of 1,400V and pulse current of 2 kA, which is the core part of the detonation assembly of the Electronic Safe and Arm Devices (ESAD) for missile fuse, and the developed prototype is currently under testing and assessment for system applicability at the Agency for Defense Development (ADD).

This research department is developing a silicon high-sensitivity optical sensor (PD and APD) of near-infrared ray band (900 nm–1,100 nm), infrared image sensors that are used as major parts in 2,500-V grade MCT, missile/airplane laser trackers, autonomous LiDAR and thermal image systems consistently demanded by ADD and the defense industry. They also concentrate on technological development for an integrated package of core defense part modules for mounting the developed parts.



GaN switch MMIC wafer for radar transceiver

5-8 Conclusion

IoT

IoT will evolve from phase 1 (connectivity), through phase 2 (intelligence), to the final phase 3 (autonomy). ETRI aims to safeguard people from unpredictable threats such as climate change, environment pollution, spread of new epidemics, and natural disasters, and makes their lives more convenient and richer by leading this evolution. To achieve these goals, ETRI will solve many technical challenges such as high-reliability IoT networking, intelligent actuators, device autonomous collaboration/cognition, and artificial intelligence, leading the IoT 2.0 era.

Intelligent Robotics

ETRI has committed its greatest efforts to the development of intelligent robotics technologies converged with advanced ICT and AI technologies since 2004. Furthermore, ETRI will concentrate on developing technologies for service robot applications as a core element of a human-robot symbiotic society, robotic intelligence that expands based on experience while adapting itself to user reactions, and AI-based human-robot interaction based on the technologies developed by ETRI until now.

ETRI will also work hard to expand and apply the autonomous robotics technology developed so far to road navigation and the fields of postal services and agriculture, and will connect V2X communication technology to traffic infrastructure, vehicles, and pedestrian crossings to enhance safety and convenience. The institute is also working hard to achieve AI autonomous driving at level four for safe autonomous driving in various road environments (structured/unstructured environment, tunnel, and unpaved road) and climate environments (day/night, rain, snow). The institute will continue with the development of AI technology for safe and convenient intelligent robotics required for realizing a society where humans and robots coexist.

Automatic analysis technology for cardiovascular disease

Biotechnology/Healthcare

ETRI has changed the local healthcare paradigm through the development of convergence technologies between ICT and biotechnology/healthcare over the past 20 years. Treatment methods change to more precise and customized medical services. Attempts are made to derive significant insight from accumulated medical big data and the medical service paradigm changes from "diagnosis and treatment" to "prevention and care."

ETRI will continue to develop innovative intelligent technologies for diagnosis and treatment supporting personalization, intellectualization, and routinization in the overall fields of healthcare such as disease prevention, examination, diagnosis, prediction, treatment, and rehabilitation for the purpose of achieving the vision of developing intelligent medical solutions for living a healthy life of 100 years. The institute plans to work hard to improve people's health and quality of life through the development of these technologies.

Postal logistics

The Korea Post branch that belongs to the Ministry of Science, ICT and Future Planning operates a network of around 3,500 post offices throughout the country and handles around 3.7 billion mail items annually with around 20,000 mailmen as of 2020. Various automation and efficient delivery technologies developed by ETRI over the past 20 years are key to streamlined handling for such high volumes of mail through the massive postal logistics network.

ETRI will continuously apply advanced ICT for delivery efficiency right up to the last mile zone that is most difficult for automation in postal logistics, and will profoundly develop technologies to respond to the drastic increase in parcel services volume due to expansion of contactless culture in the midst of the COVID19 pandemic. ETRI will lead the advancement of the local postal logistics through these endeavors.

State-of-the-art AI technology for crime detection

Energy/Safety/National Defense

Demands for ICT convergence technologies continue to grow to respond to climate change and reduction of greenhouse gas, safeguarding society from ever-increasing natural accidents and disasters, and keeping the strongest combat capabilities intact. To respond to these demands, ETRI organized ICT research departments for energy and environment, urban and traffic issues, and national defense and safety to commit its endeavors of satisfying technical demands in public sectors. The institute will do its best to secure safety and improve the people's quality of life.

Convergence Research Departments

ETRI leads four research departments (UGS, KSB, SDF and DMC) since 2014 out of the 15 departments organized by NST. The institute will continue to lead the successful completion of ongoing research groups KSB, SDF, and DMC, which are resolving national and social issues by disseminating its achievements throughout various industries. ETRI will also commit its greatest efforts to planned research for identifying new agendas required for improving the people's safety and quality of life and commercialization of convergence research departments.

PART 6

Basic Research

6

Basic Research

6-1. Outline

ETRI has decisively and positively driven technological development for traditional research fields such as communications, semiconductors, computers, and broadcasting media, and has conducted research for source and basic technologies in these fields as well. The main fields of the basic research include information security technology, blockchain technology, creative research, standard research, and technology policy research.

Information Security

ETRI began researching communications security for the first time in Korea when it opened the wireless communications research center in 1984. Research activities then were concentrated on technologies for capturing radio signals forwarded to North Korea and wired communications security and encryption technologies for national defense security. ETRI then continued research in two sections, one for encoding technology for developing security systems for the government and the other for developing information security for civil sectors. While the former section was integrated with some sections of the Agency for Defense Development (ADD), the National Security Research Institute (NSR) was established in 2020. NSR is still operated under ETRI.

Research for the information security section began in earnest when the Information Security Research Division (hereinafter referred to as “Div.”) was opened in January 2000. The objective of the Div. is to respond to intellectual threats and secure core prevention technology for protecting the country, society, and infrastructure from threats of hackers.

In the early stage in the 2000s, the Div. developed various technologies for securing basic technologies for the country’s information security such as public authentication certificates, side-channel password prevention, USIM, Secure OS, blocking of harmful content, biometrics, mobile terminal security, network security’s 3D visualization, high-performance IPS, and DDoS response.

Demonstration of FIDO technology

Since the 2010s, the Div. applied and advanced basic technologies for information security to focus on technological development for ensuring society's safety and service reliability. The Div. also developed technologies and applied them in various industries including the industrial firewall, KMIP encoding key control, bio-based FIDO authentication, DB encryption, cyber self-variation, vessel control, autonomous driving V2X security, cloud security, lightweight OS for IoT, and intelligent CCTV. ETRI will commit its greatest efforts to establishing smart, self-controlled, intelligent cyber self-defense systems for keeping pace with the ICT's rapid evolution.

Blockchain

With the rise of the blockchain concept, it has continuously attracted great attention in ICT when the digital currency Bitcoin made its appearance in 2009. Blockchain is a technology that allows reliability without agency by recording, verifying, and storing movement of information and value, performed jointly by participants in a network without intervention of a third reliability body. It allows realizing an Internet of value[38] due to transparency by disclosing transaction specific to all participants. More importantly, its technological features, such as constancy, make it difficult to modify or delete a block once it is connected.

ETRI acknowledges the features and advantages of blockchain and has performed research on blockchain since 2017 based on encryption technologies and P2P network technologies accumulated thus far. ETRI provides the technological basis by analyzing the structure and issues of blockchain and by employing experts, while also developing core technologies such as distributed consensus algorithm and decentralized identity (DID) management of the new concept to lead the technological and industrial ecosystem of blockchain in Korea.

Creative Research

ETRI opened the Creative Research HQ (currently the ICT Creative Research Laboratory) exclusive for decisive creative and venture research in 2010 for innovation toward creative and ambitious institutions. The institute also sought for a growth drive for the country’s future. Accordingly, ETRI has recorded world-class achievements in a variety

38) Internet of Value: Environment where all of individuals and institutes around the world exchange assets (values) without an agent such as bank or government, like exchange of information over Internet.

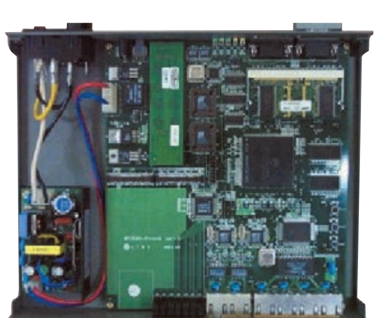
of technological fields such as various next-generation new materials and devices based on semiconductors and nanotechnologies, ultra-realistic new-concept displays, optical devices and parts for ultra-fast transmission, RF devices and parts based on composite semiconductors, MIT devices, low-power and high-performance sensors, THz wave generation and detection, and quantum information and communications.

Standards

White paper of Standards & Open Source Research Division

The world started committing efforts for ICT standardization in the mid- and late 1980s when ICT showed rapid development. Standard technology generates a “locking effect” of being difficult to replace with other technologies once the technology is accepted as the standard, and the ripple effects are great. Accordingly, standardization activities are called a “war without gunfire,” and international standards and essential patents are considered the “golden goose.”

The government then established the Protocol Engineering Center (PEC; currently the Standards & Open Source Research Division) in October 1989 for the purpose of national development and application of standard technology for open systems interconnection driven internationally, and has been continuously carrying out standardization activities at the national and global levels by reflecting market demand in Korea’s ICT and convergence technology fields. ETRI actively promoted standard technology development efforts for the IPv4/IPv6 address converter, Voice over Internet Protocol (VoIP), WiBro, terrestrial DMB, vehicle gateway, web, cloud desktop, IoT interoperability, automotive emergency response system (e-Call), big data, audio/video encoding, and other core ICT. Many of the developed standard technologies were actively proposed and adopted as domestic and international standards. In addition, ETRI has secured a number of international standard essential patents that have a very large industrial ripple effect. There are total of 943 international standard essential patents registered by ETRI as of December 2020. ETRI has made numerous international standardization achievements in de-jure international standard bodies such as ISO, IEC, and ITU as well as major de-facto standard development organizations such as IETF, IEEE, W3C, 3GPP, ATSC and OCF.



Ipv6 address converter

Technology Policies

ETRI has continuously sought its best roles to satisfy the requirements of paradigm shift in the global economy, industries, markets, and the demands of the country and the people, and has developed leading policies for such requirements for the past 45 years. ETRI promptly localized technologies and systems in the fields of communications and computing to meet the government's fast-follower policies in the industrialization policy period (early 1960s to mid-1980s). It provided the foundation for fostering Korea as a global ICT champion nation in the fields of semiconductors, mobile communications, ultra-high-speed Internet, and broadcast media by driving renovating management, innovating management, new management, and intellectual capital management with the vision of a "World-Class ICT Research Institute" in the informatization policy period (mid-1980s to mid-2000s).

In the convergence policy period (mid-2000s to mid-2010s), ETRI heavily drove R&D convergence projects such as ICT+automobile, ICT+shipbuilding and ICT+national defense with the visions of becoming a world-class technology partner and ICT innovator to secure new growth drives for the national economy by overcoming stagnation. ETRI is concentrating on driving institutional R&R (Role and Responsibility) by establishing the basis for a hyperintelligent information society, implementing super-capable computing and hyperconnected infrastructure, and converging technology development for national intellectualization in the intellectualization policy period (since the mid-2010s).

6-2. Information Security - Establishing an Intelligent Cyber Self-Defense System

People are experiencing incomparable conveniences thanks to advanced ICT; however, these are prone to counterproductive issues of information intrusion such as hacking, malware, and breach of intellectual property rights. To respond to such situations, ETRI has committed its greatest efforts to the development of technology for information security since the late 1990s and has succeeded in developing technologies for public certificates, FIDO certification, USIM, distributed subchannel analysis, response to intellectual invasion, vulnerability analysis, image security, convergence security, and IoT security. ERTI has also led the establishment of safeguarded and convenient information environments with such technologies.

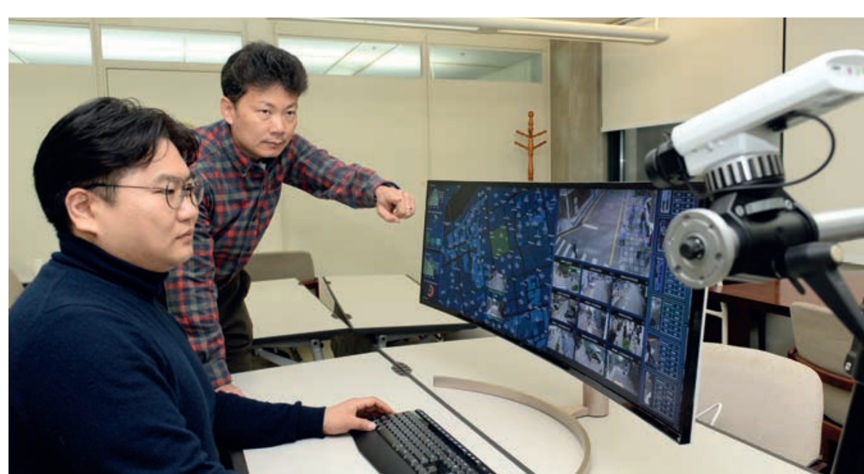
FIDO

ETRI began researching communications security for the first time in Korea when it opened the Wireless Communication Lab in 1984. Research activities then were concentrated on technologies for capturing radio signals forwarded to North Korea and wired communications security and encryption technologies for national defense security. Since then, as the Internet environment propagated in the mid- to late 1990s, information security technologies gradually became indispensable in the fields of communications, e-commerce, and online banking services. ETRI began development of information security in earnest after organizing the Information Security Research Division for developing security technology for civil sectors in January 2000. The current objective of the Div. is to respond to intellectual threats and secure core prevention technology for protecting the nation, society, and infrastructure from threats of AI hackers.

In the early stage in the 2000s, the Div. developed various technologies for securing basic technologies for information security of the country such as public authentication certificates, side-channel password prevention, USIM, Secure OS, blocking of harmful content, biometrics, mobile terminal security, network security's 3D visualization , high-performance IPS, and DDoS response. As a result, ETRI succeeded in achieving large values such as commercialization of public authentication systems at a nationwide scale for the first time in the world, commercialization of 3G USIM (third in the world), and commercialization of smart cards for preventing subchannel analysis.

In the 2010s, the Div. applied and advanced basic technologies for information security to focus on technological development for ensuring society's safety and service reliability. The Div. also developed diversified technologies including the industrial firewall, KMIP encoding key control, bio-based FIDO authentication, DB encryption, cyber self-variation, vessel control, autonomous driving V2X security, cloud security, lightweight OS for IoT, and intelligent CCTV. Consequently, the lightweight security OS developed by ETRI for the first time in the world was applied to intelligent remote metering devices in Europe, achieving commercialization records of KRW 120 billion, while the industrial firewall is used in nuclear power plant systems and FIDO authentication technologies are applied to several banking services such as Samsung Pay and BC credit cards.

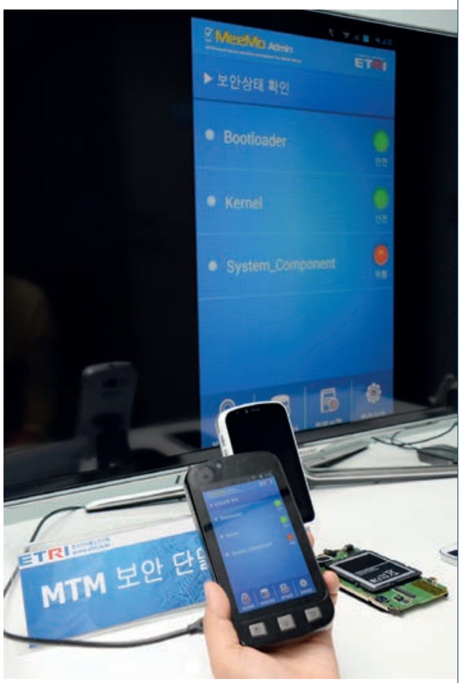
ETRI will continue to work hard to establish smart, autonomous, intelligent cyber self-defense systems to keep pace with the high speed of ICT evolution, and will commit its greatest efforts to building a hyper-connected society while ensuring safety and security.



Intelligent CCTV

6-2-1. Cryptography/Authentication

6-2-1-1. Public Authentication Technology



Security chip technology for smartphones developed by ETRI

ETRI commenced development of Public Key Infrastructure (PKI) technology in 1997, two years before enforcement of the Digital Signature Act, and succeeded in developing PKI technology for the first time in the world in 2000. ETRI's PKI technology was transferred to the Korea Financial Telecommunications and Clearing Institute (KFTC), Koscom, Korea Information Certificate Authority (KICA), and to 39 local businesses in early 2000. It has since been widely used as information security technology that provides certification and digital signatures for banks, security companies, insurance companies, and online clearing. A total of 44.18 billion public certificates were issued until April 2020. The PKI technology has significantly contributed to the improvement of security for local online banking industries, and has yielded export achievements and development and operations for local technologies in establishing the PKI systems in Asian countries including Vietnam and the Philippines. In addition, economic effects of creating previously unknown PKI markets were realized for a scale of approx. KRW 66 billion as of 2019.

6-2-1-2. FIDO Authentication Technology

Fast IDentity Online(FIDO) alliance

Founding general assembly of the Biometric Council

ETRI developed convenient authentication solutions based on various authentication technologies including biometrics technology in 2015 for the first time in the world. It passed the authentication test of the Fast Identity Online (FIDO) Alliance, an international online biometrics certification consortium. ETRI also succeeded in developing FIDO 2 Certification Technology for applying FIDO technology in PC, laptop, and web browser environments, and passed the inter-networking test in 2018. The FIDO2 technology was called "FIDO authentication technology based on user-friendly technology with passwordless authentication," and was selected as one of the "Top 100 Achievements in National Research and Development" in 2019.

ETRI's FIDO authentication technology was applied for most convenient payment services in Korea (e.g., Samsung Pay and BC Paybook) through 38 technology transfers

(KRW 2.298 billion) from 2015 to 2019. It is used in the Ministry of the Interior and Safety's e-government authentication services and Hyundai Motor Group's internal security services. In addition, ETRI supported 64 local products and solutions to pass international authentication tests to contribute to the globalization of local companies, and transferred internationally authorized FIDO technology to local markets to derive replacement effect on foreign products.

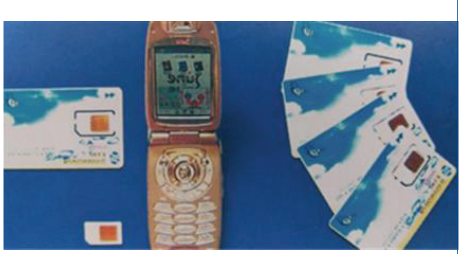
An example of FIDO commercialization
(June, 2017, BC Card)

6-2-1-3 USIM for Mobile Communication Authentication

ETRI started development of a third-generation USIM in earnest from the end of the 1990s by expanding the security technologies of the smart cards and terminal security it had researched so far.

ETRI developed technologies for the Java-based USIM chip and USIM platform, chip design for authentication of mobile communication users, chip OS, safety assurance and verification, chip-based mutual authentication, global roaming, authentication server, key control, wireless PKI, and terminal conformity. Furthermore, ETRI passed testing for around 6,000 items such as safety test items of 3GPP and USIM application items as well as Qualcomm's 3G authentication test to demonstrate its excellent technologies. ETRI also passed the benchmarking test for 3G W-CDMA and WiBro commercialization of SK Telecom and KT. Such records demonstrate that the technologies are fully commercialized, passing all tests by authentication institutes and terminal security within the local infrastructures.

The developed USIM was applied to WiBro, a portable Internet service, in 2006. This was when Korea was the third country in the world to succeed in commercializing the 3G USIM. Meanwhile, ETRI is the first in the world to secure technology for supporting 2G, 3G, WiBro, and public WLAN using a single USIM.

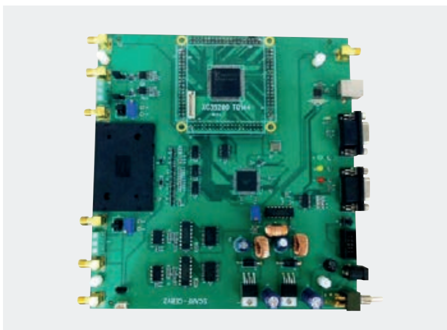


First prototype of USIM (2003)

6-2-1-4. Analytic Technology for Distributed Side-Channel

In 2009, ETRI started development of the side-channel analysis resistant framework (SCARF), a software platform for analyzing distributed side-channels, and completed its development in 2012. ETRI developed the contact-type smart card side-channel validation board in 2012, and the electromagnetic wave side-channel validation board for the contactless IC card in 2013. KFTC used the SCARF platform for the side-channel validation test of the banking IC card in 2013.

ETRI concentrated on developing the HW password module side-channel validation board for verifying side-channels while developing the HW password module since 2014, and provided the basis for designing safe password modules for local businesses. ETRI has now become an institution that has truly succeeded in localizing the validation technology of side-channels for power and electromagnetic waves. The SCARF platform is still very well used in local testing and certification authorities.



Side channel validation board

6-2-1-5. Quantum security analysis technology for cryptographic algorithms

Since 2019, ETRI built an exclusive research office for analyzing and studying quantum stability for calls in 2019, and is currently developing <Q|Crypton> until 2026 as a validation and analysis platform for quantum password power based on complex quantitative quantum calculation for such analysis algorithms together with for research on quantum analysis algorithms for major passwords. In 2019, ETRI used the quantum platform under R&D by the Quantum Technology Research Department to establish a development and testing environment for quantum password analysis supporting up to 40 qubits, and developed the initial version of the analysis platform for quantum password stability based on 2020.

ETRI plans to develop <Q|Crypton> Version 1.0 by 2022 as a platform for visually measuring and verifying quantum security power quantified for passwords by developing an analysis program for quantum password with a quantum library individually selected by research including that of quantum libraries of various versions for current PQC password operation through continuous functional improvement and research. ETRI is currently seeking methods for contributing to standardization of NIS QPC through the <Q|Crypton> platform by driving cooperation with the NIST Cryptographic Technology Group, led by Dr. Lily Chen, which currently drives PQC standardization.

Quantum security technology global research collaboration

6-2-2. System/Network Security

6-2-2-1. Technology for Intellectual Invasion

The July 2009 cyberattacks disabled a total of 40 sites including the Blue House, the Ministry of National Defense, and major portal sites. Upon recognizing the significance of the outbreak of the July 2009 DDoS disaster, ETRI commenced full development of the technology for responding to intellectual invasion, and conducted 10 projects in advance for responding to changes with the times. In the initial stage, ETRI concentrated on improving processing speeds of network traffic for real-time detection and response to DDoS attacks. ETRI is currently advancing technologies for artificial intelligent vaccines.

The following are the representative technologies developed by ETRI to respond to intellectual invasions:

• **DDoS response:** nanotechnology that guarantees bidirectional processing capabilities of 20 Gbps, independent of packet processing delay time of 50 µs or lower and packet size.

• **High-performance IPS:** high-performance intrusion response system based on hardware developed for the first time in Korea.

• **Cloud security:** provides cloud-based custom security demonstration services for the first time in Korea.

• **Network security 3D visualization, cyber self-mutation, and industrial firewall:** ETRI localized the IPS and DDoS security technologies based on hardware with high performance to enhance the competitiveness of local security businesses, relieve technical gaps and avoid dependence on foreign technologies.

Launching ceremony for cloud-based custom security demonstration services (November, 2017, ETRI)

6-2-2-2. Analytic Technology for Vulnerability

Security analysis at the hardware level has a high barrier to entry that demands large investment, and is difficult to implement in civil sectors. As a government-funded research institute, ETRI attempted to develop applicable technologies to succeed in establishing a security analysis system at the level of the IC chip, PCB, and firmware in 2018.

ETRI's analytical system and technology for vulnerable security at the hardware level was recognized as the top level in Korea, winning the "National Safety and Security Award" from the National Intelligence Service in December 2019.

6-2-3. Applied Security

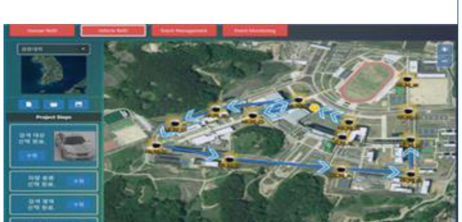
6-2-3-1. Technology for Image Security

Human re-identification demonstration scene

ETRI has been performing multiple projects since starting the projects for intelligent CCTV technology for real-time crime detection in 2009. ETRI currently has significantly improved the technological level by applying artificial intelligence (Deep Learning) for intelligent CCTV. Accordingly, ETRI succeeded in developing several technologies: re-identification technology, tracing traffic lines by recognizing identical persons and vehicles from multiple CCTV; remote facial recognition technology, from common CCTV environments; technology that recognizes vehicle being driven; and Number Plate Deep Resolution (NPDR) technology. In addition, ETRI has consistently researched (image) privacy masking technology to prevent adverse effects of CCTV security as well as image encryption and decryption technology for protecting images throughout the service life of CCTV for ten years. It has also secured source technologies and intellectual property rights at the top level in Korea.

AI vs. Humans - Challenge for NPDR recognition (November 7, 2019, Jeju)

In the early 2000s, ETRI began developing biometrics technology in earnest and succeeded in developing a facial/iris recognition embedded system in 2007. It developed multiple biometric chips using two biometric data or more in 2008. Furthermore, ETRI developed multiple biometric technology for e-passport and e-visa, high-performance biometric information search technology for finding suspects, biometric technology for privacy protection, and unconstrained remote human recognition for CCTVs.



Vehicle re-identification technology

6-2-3-2. Technology for Convergence Security

ETRI started localization of VTS for the Ministry of Oceans and Fisheries and the Korean

VTS system established on Gunsan VTS center field (May, 2016 – March, 2019)

Demonstrate autonomous V2X security in real-vehicle and road environments (2018)

Coast Guard, and developed a tracing system connecting a single radar site in 2012. In 2013, ETRI developed a tracing system making multiple connections of two radar or more, a multiple sensor convergence processing system, and a decision-making support system that calculates the risk level of collision of vessels and alerts the controller. It also developed the integrated information system for storing and playing all received data at high speed to implement a basic control system in 2014. The developed technology was commercialized by joint research organizations including GMT, applied to the coastal monitoring system of the Navy, the Army, and the Korean Coast Guard, and was supplied to the National Information Society Agency for their informatization project.

ETRI has developed technologies for the fields of automotive security such as autonomous V2X security, high-speed vehicle authentication, and hacking prevention (joint international research with the University of Warwick's WMG department in UK) since 2016. Additionally, it has performed practical demonstrations on actual roads and vehicles as well as international mutual operability tests. Some of the technologies are currently applied to the C-ITS project of the Ministry of Land, Infrastructure and Transport.

6-2-3-3. Technology for IoT Security

In 2002, ETRI conducted a project called the "development of a safety operating system for protecting information and communication infrastructures" by expanding the model project of "secure Linux development" that had begun in 1999. ETRI then began full development of secure OS for servers, and has continuously developed security routers and gateways, immersive smart work terminal security OS, MTM-based smart terminal security OS, virtualization-based military smart terminal security OS, and security OS for smart lightweight IoT devices.

In addition, ETRI succeeded in developing the security OS for global standard-based IoT devices in 2017 for the first time in the world. The developed lightweight security OS applied to the infrastructure security of advanced metering infrastructure (AMI) at the scale of KRW 120 billion demonstrated the world's first top-class technology

Security DCU and smart meter applied with commercial AMI (250,000 households in Bergen, February, 2018)

(Norway SORIA Project of Europe, June 2016 to January 2019). The technology was also commercialized for intelligent remote water metering, school bus alert services, and a prediction system for boiler conditions in smart buildings in Korea. The technology was selected as one of the “Top 100 Achievements in National Research and Development” under the name of “core technological development for an industrial IoT wireless platform” in 2019.

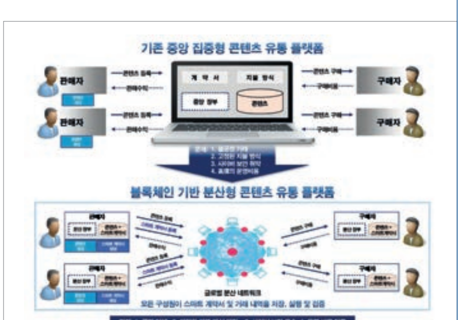
6-3. Blockchain - Realizing the Internet of Value (IoV)

Beginning its earnest research on blockchain in 2017, ETRI built the technological basis of blockchain by analyzing its structure and issues, employing experts, and developing core technologies such as the distributed consensus algorithm and the new-concept management of decentralized identity (DID) to lead the technological and industrial ecosystem of blockchain in Korea.

Blockchain is a technology that ensures dependability among participants in a network without agency by jointly recording, verifying, and storing the movement of information and value without a trusted third-party organization. It allows realization of IoV by transparency of trade specifics disclosed to every participant and technological features of constancy that are difficult to modify or delete. In June 2018, the government announced the "Strategies for Blockchain Technology Development" in order to drive R&D activities. In June 2020, the government once again announced the "Strategies for Diffusion of Blockchain Technologies for Hyper-connection and Contactless Society."

ETRI conducted a project for developing the distributed hyper-connected ICT infrastructure configuration technology in 2017 in order to analyze the structures and issues of blockchain, and employed experts for establishing the basis of technological development. ETRI opened the Blockchain Technology Research Center in early 2018, and restructured the blockchain technology development project by combining fragmented factors within the institute to strategically concentrate on the research.

ETRI also began full development of blockchain technology based on the encryption technologies and P2P networking technologies that were developed since 2018. These activities allowed our institute to secure top technologies throughout the blockchain field such as the technology for distributed consensus algorithm for Proof-of-Nonce



Overview of blockchain-based content distribution platform

(PoN) mode, protocol for low-delay peer-to-peer (P2P) transmission, and trusted third party (TTP)-free data transactions.

ETRI will develop the core technologies of challenging fields to overcome the limits of the current blockchain, and will work hard to activate a local blockchain technological/industrial ecosystem by converging technologies to lead the Fourth Industrial Revolution, such as IoT, artificial intelligence, and big data.

6-3-1. Blockchain

6-3-1-1. Technology for Distributed Hyper-Connected Trusted ICT Infrastructures

Technologies for Overcoming Limits of Blockchain

Blockchain has attracted attention as an innovative technology suitable for the era of data economy with its technological features of transparency, constancy, and availability. However, the demand for technological development that can overcome its technological limits such as scalability, personal information protection, and interoperability was brought up.

ETRI's First Blockchain Development Project

ETRI launched research on blockchain starting with the project for developing the technology of distributed hyper-connected trusted ICT infrastructures as part of the policy-specific technology development project within the IoT convergence technology development project in June 2017. ETRI prepared the Blockchain Technology Analysis Report V1.0 for about a year and a half until December 2018 and committed its greatest efforts in establishing a research basis by updating the version to V2.0 during the research period.

Establishing the Basis for Developing Core Technologies for Blockchain

ETRI organized the Blockchain Technology Research Center in April 2018 and led the preliminary feasibility survey for its projects. The survey was finally approved in June 2020 and a large-scale national research project in the field of blockchain was accelerated for the first time in Korea.

6-3-1-2. Technology for Distributed Consensus of Blockchain

Taking on the Technologies for Distributed Consensus to Solve the Trilemma

A "distributed consensus algorithm" is a function unique to blockchain that ensures data consistency and irreversible results among participants who do not trust each other. It is also a source technology that supports the sharing of precise data records despite the Byzantine Fault. The distributed consensus technology bears the "blockchain trilemma" where the three factors of decentralization, security, and scalability cannot be resolved simultaneously, and overcoming this trilemma is the key to commercializing blockchain. ETRI has taken the challenge to build a new distributed consensus technology for resolving the trilemma since 2018.

Technological Development of the Platform for Highly Dependable PoN-Based Information Transactions

ETRI drove the technological development for distributed consensus of blockchain through the project involving the platform for highly dependable blockchain (PoN algorithm)-based information transactions in 2018. The objective of the project was achieved by mathematically verifying the consensus algorithm of the participating node qualification verification mode (PoN) to overcome the limits of the current consensus method and provide all the participating nodes with fair probable opportunities for generating blocks. This allowed the basis for developing source technology capable of supplying both decentralization and scalability simultaneously with the least consensus costs. These results will significantly contribute to overcoming the blockchain trilemma, securing the world-class blockchain technology competitiveness from Korea.

Research direction of blockchain

PoN Algorithm on the Verge of Commercialization

The developed PoN algorithm was verified for application by multiple patents. It was also published in SCI-J, and won the "2020 Grand Prize" at the Fourth Industrial Revolution Festival.

The output of the algorithm PoC was transferred to small blockchain companies for commercialization, and a research company was established based on PoN consensus in 2020. One consensus technology is also under active commercialization with investment by ETRI Holdings.

6-3-1-3. Distributed Self-Sovereign Identity Information Technology

DID technology overview

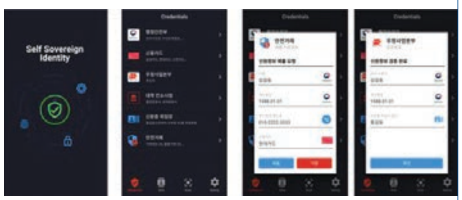
Rapid Advent of Self-Sovereign Identity Information Management (DID) Technology

Decentralized identifiers (DID)[39] has rapidly attracted attention as a core technology of blockchain since the founding of a community called Rebooting the Web-of-Trust (RWoT) in 2015. Many countries in the world are currently working hard to develop technologies, and standardization organizations such as W3C, DIF and OASIS promote the establishment of international standards. In Korea, the "Initial DID Association" led by SK Telecom was organized in 2019, after which the four alliances competed in DID platform technologies, including the DID Alliance led by RaonSecure, MyiD Alliance by ICONLOOP Inc., and MYKEEPiN by Coinplug, Inc.

Establishing the Basis for DID Platform Interlock

In 2019, ETRI launched the project for developing a distributed self-sovereign identity information management using the current blockchain technologies. The research group organized a consortium for simultaneously achieving the purpose of "developing and applying a common platform" and the vision of "developing world-class technology" in a relatively short period of one year and nine months. Both Coinplug and ICONLOOP, mutual competitors in the DID platform technology, were invited to the consortium. Throughout these tasks, ETRI secured two types of blockchain platforms developed at a significant level already achieved at the contract bidding step, and concentrated development on common platform technology and

39) Decentralized Identity (DID): Decentralized distributed ID based on blockchain. This method distributes and stores personal information in individual organizations and individually controls information for identity in lieu of a centralized control system that stores information for identifying individuals in a specific organization or company.


Distributed identity information management app

publishing anonymity technology based on these platforms.

Meanwhile, ETRI tried to develop a publishing anonymity technology through this project for the first time in Korea. DID technology is applicable to special services such as blind hiring. An example of applying this technology is record-keeping of educational background only, without including the school name. The research group applied the group signature to the randomizable signature in step 1 and the threshold cryptosystem in step 2 for resolving the issue of disclosing the publisher, a shortcoming of the randomizable signature. As a result, the group signature technique distributed for the issuer anonymized credential system was secured as an intellectual property right. This technology applied to the DID platform is under development.

6-4. Creative Research - Securing the Drive for Future Growth with Powerful Creative Research

ETRI opened the Creative Research HQ (currently the ICT Creative Research Laboratory) in 2010 with vision of "leading future ICT source technologies through powerful creative research," and has consistently taken on challenges and ventures for creative research until today.

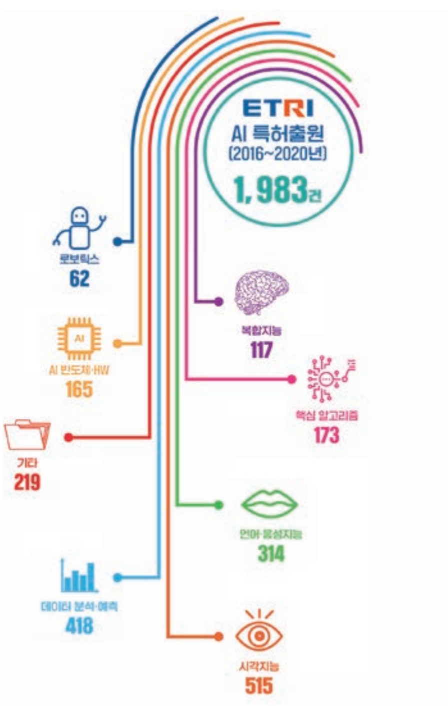
In the late 2000s, there were numbers of indications that the research efficiency of government-funded research institutions is lower than that of universities or private businesses. To respond to such indications, ETRI profoundly discussed the roles and future orientation of ETRI as a government-funded institute, particularly as the national representative. ETRI then established the Creative Research HQ (currently the ICT Creative Research Laboratory) in 2010 exclusively for a purposeful creative and venture research.

ETRI has taken on diversified creative research to succeed in developing various next-generation new materials and devices based on semiconductors and nanotechnology. It developed elongated display beyond folding and holographic displays implementing 3D holograms, optical devices/parts for super-high speed transmission, composite conductor-based RF devices/parts and world-class MIT devices. ETRI has also succeeded in implementing miniature, low-power, high-performance sensors through convergence of semiconductors, MEMS, and nanotechnology, as well as in securing THz wave generation and detection technology from materials to device/module/system. ETRI commenced development of quantum information and communication technologies that are considered future technologies capable of changing the ICT paradigm beyond the technological limits of current information and communications since the mid-2010s. ETRI continues identifying and developing brand new technologies through these creative studies to form the nation's future growth engines.

ETRI will continuously commit its greatest efforts to secure the nation's future growth engines by identifying explosive potential technologies for the future and preparing for the development of those technologies.

6-4-1. Creative Research and Major Achievements

6-4-1-1. Creative/Challenging Research



Number of ETRI AI patent applications

Discussion on Restructuring of Government-Funded Research Institutes

Korea’s economy and industries developed at a rapid rate based on the government’s strong drive for science and technological development and several institutes’ research achievements established since the mid-1960s. In the mid- to late 2000s, there were numbers of indications that government-funded institutes' research efficiency is lower than that of universities or private businesses. Also, institutes were targets for convergence and integration when technological convergence with industries made its advent as a global trend.

In such situations, discussion began in earnest for vitalization of institutes by restructuring institute governance through unification, partial integration, and privatization since 2008. This issue became a topic for heated discussion among ministries, institutes, academic circles, and industries for years. In 2011, the National Science and Technology Commission was officially launched under the direct control of the President, which would gather research policies and developments scattered between ministries and public authorities into a single space and exercise overall control over the budget as one of the restructuring methods of governance.

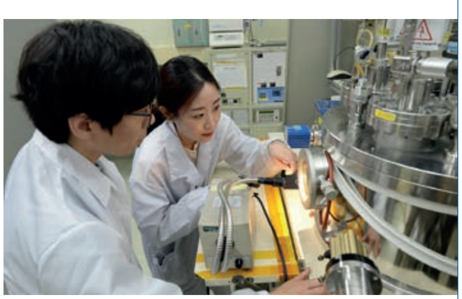
Preparing for Future Growth by Vitalizing Creative and Challenging Research

ETRI performed profound discussion on the roles and future orientation of ETRI as a representative government-funded institute. It was in this moment when opinions that research should be focused on creative research among the three business structures of the institutes (e.g., national mission, industry support, and creative research) were presented. The opinions emphasized that institutes should be institutes capable of performing research that are not affordable for universities and private companies beyond the conventional business structure of national mission businesses. Additionally, the research should identify explosive potential for future technologies and prepare for development of such technologies even if there are no such markets or goods yet.

Based on the discussion, ETRI established a new vision called “An ICT innovator that creates the future.” It defined “creativity” and “productivity” as concepts of management. ETRI also opened the Creative Research HQ exclusive for taking on challenges and venture research. The HQ was an organization that creates new technologies with creative ideas and research systems to secure the nation’s future growth engines.

In February 2011, ETRI fully organized and operated three creative research centers from the opinions of its people (Creative Research Center for Graphene Electronics, THz Photonics Creative Research Center, and the MIT Research Center). ETRI introduced an acceptance system for any failure during their research to allow researchers to decisively devote themselves to creative research, and provided the head of each research group with exceptional autonomy and discretionary in organizational operation such as for workforce recruiting and appointing of job position.

As of 2020, the ICT Creative Research Laboratory is devoting itself to the identification and research of new future technologies with the vision of “leading ICT source technologies through powerful creative research.” The specifics of the center’s research include R&D activities of advanced future core technologies that will bring innovation and revolution to current industries such as those of human augmentation devices, cloud intelligence augmentation devices, neuromorphic devices, quantum computing software/hardware, space-interactive hologram devices, and super-lightweight AR and VR devices. They are also researching basic and source technologies such as terahertz devices/parts, synapse-based emotion recognition devices, nanoelectronic sources, 2D/nano semiconductors, metamaterials, and quantum devices.

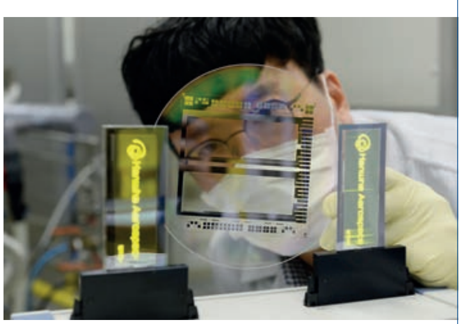


ETRI researchers using vapor deposition to control the thin-film thickness of metamaterials

6-4-1-2. Major Achievements of Creative Research

Next-Generation New Materials/Devices

ETRI combines nanotechnology with the world's leading ICT to implement previously unknown new materials and devices, and expands them into the industries through active support for technological commercialization. Major achievements include the graphene-based plasmonic optical wave device (2011), high-performance gas sensor-heater fused device for measuring minute gas with graphene (2014), fiber-type gas sensor with fiber formed to serve the role of gas metering sensor by coating fiber such as cotton and nylon with graphene (2014), flexible neural electrode capable of measuring neural signals for an extended period without corrosion inside a living body and providing electrical stimulus efficiently to cells (2017), perfect absorber of wide bandwidth metamaterials capable of rendering clear and varying colors (2019), carbon nanotube (CNT)-based digital X-ray source commercialized for the first time in the world (2019), and thin film with versatile shrinkage and expansion according to ambient environments by mimicking the sweat glands of human skin (2020).



ETRI using new material developed by Hanwha Aerospace and graphene transparent electrode to create flexible OLED panels

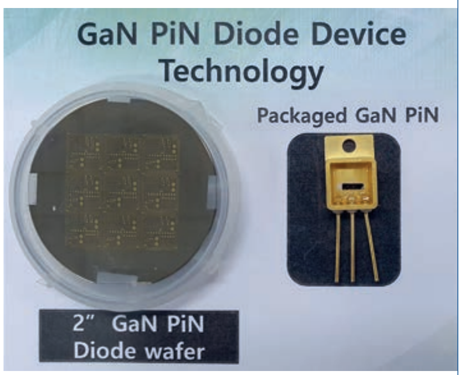
Realistic Display

ETRI has been developing foldable and expandable displays based on OLED display technologies accumulated thus far. It also developing holographic displays with 3D holograms, and displays capable of recognizing texture and the five senses and humans biosignals. Major achievements include the 3.5-inch elastic active OLED panel (2017), 1-μm pixel pitch spatial optical modulator device (2019), high-resolution (25 ppi) display array shrinkable and expandable by 20% capable of detecting texture, and high-resolution (25 ppi) hybrid structure shrinkable and expandable display array providing texture (2019).

ETRI researchers discussing 400G optical transmission engine and measurement results

Optical Devices/Parts for Super-High Speed Transmission

ETRI focuses on developing optical devices and component technologies for super-high-speed transmission and reception. Major achievements include 400-Gbps grade coherent optical detection technology capable of transmitting 50 HD-grade movies



Packaged vertical GaN electrical semiconductor wafer (left) and GaN electrical device developed by ETRI researchers (right)

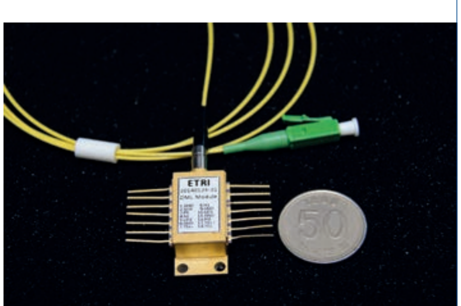
in one second (2018), 25G C-band EML chip for fronthaul (2018), 25G O-band EML chip for fronthaul based on C-band technology (2019), 400-Gbps grade optical transmission/reception engine with four light sources, optical detector device, and optical transmitter and receiver integrated in a single package casing (2019).

Compound Semiconductor-Based RF Devices/Parts

ETRI is building the basis for localizing RF devices/parts for wireless communications and a millimeter wave bandwidth system through the development of radio frequency (RF) devices based on compound semiconductors such as gallium-arsenic (GaAs), indium phosphide (InP) and gallium nitride (GaN). Major achievements include an 800-V grade vertical power semiconductor that uses gallium nitride (GaN) single-crystal substrate for minimizing power loss while providing high performance at high voltage (2020).

Sensors Leading the IoT Era

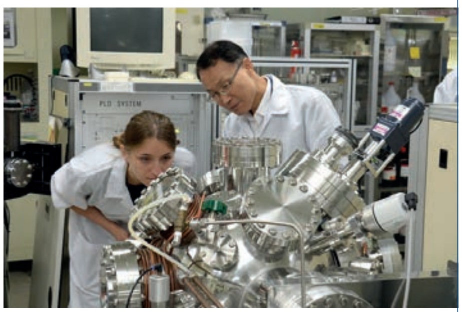
ETRI is developing miniature, high-power, high-performance sensors based on convergence of semiconductors, MEMS, and nanotechnologies. Major achievements include a waterproof fiber pressure sensor of high conductivity even when bending and pressing frequently by coating a combination of graphene and CNT on cotton fiber (2018), a rubber-type pressure sensor that can be used immediately by attaching it on the skin (2018), a contactless super-high-sensitivity humidity sensor based on 2D new materials developed for the first time in the world (2020), and a super-high sensitivity transparent pressure sensor with sensitivity of up to 50 times that of existing pressure sensors (2020).



ETRI's dual mode laser module as the THz beating source (2017)

Terahertz, the Dream Frequency

ETRI has been researching terahertz waves, called as the "dream frequency" (frequencies from 0.1 to 10 THz) since the late 2000s, and succeeded in securing technologies of THz waves over the whole related areas of generations, detections, materials, devices, modules, and systems in a relatively short period of time. Including the development of small beating light source (2014), and high-output THz

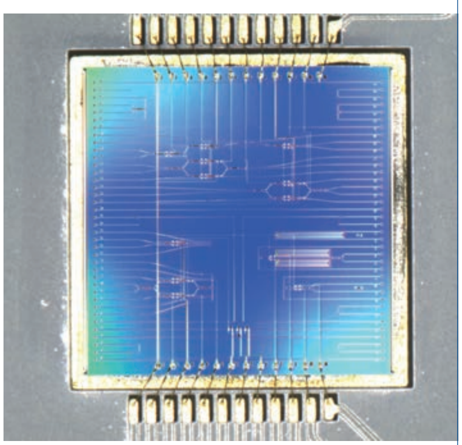


ETRI researchers researching new MIT elements

generation devices (photomixers) and highly-efficient THz detection devices, ETRIs THz technology now has become the level of developing industrially applicable THz application technologies.

World-Class MIT Devices

ETRI experienced success in validating the Mott MIT [40] free from structural phase transition by simultaneously measuring MIT and SPT on vanadium oxide in an MIT laboratory in 2005. ETRI has since concentrated on developing the applied technology and mass production technology of MIT devices since the 2000s. Consequently, ETRI succeeded in developing mass production technology for the dissemination of MIT devices of vanadium oxide in 2016, implementing NDR-MIT [41] switching on Si-based MIT transistor, and developing the MIT transistor for the first time in the world.



A silicon optical integrated circuit chip that can implement quantum gates developed by ETRI researchers

Quantum Information and Communication

ETRI has begun full development of quantum information and communications since the mid-2010s. Major achievements include the integrated 4-polarized light division and merge chip and module that divide or merge the 4 types of polarized light required for quantum encrypted communication (2017), the light source module for quantum communication generating a pulse at the level of a single photon (2017), silicon avalanche photodiode (ADP)-based single-photon detector module capable of receiving single photons of 785-nm wavelength bandwidth (2017), virtual quantum machine[42] based on quantum computing technology for efficient research of quantum computer (2019), and implementation of a silicon nitride (Si_3N)-based quantum gate for the first time in the world (2020).

40) Mott Metal-Insulator Transition (MIT): Phenomenon of switching nonconductor into meta, and metal into nonconductor, essentially conducting electric power on an insulator without Structural Phase Transition (SPT)

41) Negative Differential Resistance (NDR) MIT: Phenomenon of voltage drop caused by resistance drop during MIT phenomenon at a certain current.

42) Quantum machine technology: Technology simulating quantum computing using conventional digital computers.

6-5. Standardization - Establishing the Global Standards of ICT

ETRI has been continuously carrying out standardization activities at the national and global level by considering various market demands in ICT fields since mid-1980s. ETRI has committed its greatest efforts to developing the standard technologies for core ICT and applications such as the IPv4/IPv6 address translation mechanism, Voice over Internet Protocol (VoIP), number portability, WiBro, terrestrial DMB, vehicle gateway, web, cloud desktop, IoT interoperability, automotive emergency response system (e-Call), big data, and audio/video encoding. ETRI also has been focusing on securing standard patents for major technologies that have a large industrial effect. ETRI has registered 943 international standard essential patents as of 2020, and has achieved numerous international standardization records in de-jure standardization bodies such as ISO, IEC and ITU as well as de-facto standard development organizations such as 3GPP, IETF, IEEE, W3C, ATSC and OCF.

ETRI members attending the ITU-T SG13 meeting in 2019

Since establishing the Protocol Engineering Center (PEC; currently the Standards & Open Source Research Division) in October 1989, ETRI has consistently performed standardization activities at the national and international levels by reflecting market demands in Korea's ICT fields including cable/wireless networking, mobile communications, broadcast media, Internet of Things (IoT) and ICT converged services and applications. ETRI is leading the activities of proposing standardization strategies and policies at the national level, establishment of domestic/international ICT standards, and promotion of standard essential patent registration. It is also supporting industry to secure standardization competitiveness in global markets.

In the early stage, the Standards & Open Source Research Division concentrated on de-jure standardization activities performed by international standardization bodies such as ITU and ISO. It has also committed its efforts to activities of market driven standardization with the emergence of de-facto standardization[43] organizations since the mid-1990s.

ETRI currently actively performs national and international standardization activities in all fields of ICT to improve people's convenience and benefits by creating the industrial and social value of achievement in standardization, securing leadership of global standardization through advanced standardization of future core technologies, innovating open source-based open R&D, and forming an industrial ecosystem.

The Intelligent Information Standards Research Section drives preemptive standard development activities for technologies of intelligent information, future networking and 5G mobile communication networks, cloud computing, edge computing, wearable devices, medical devices, 3D printing, IoT, blockchain, autonomous vehicles, finance information technology, web, media transmission and application, and quantum information and communication to develop the market and industry (de-facto)-oriented technology standards for future emerging technologies based on intelligent information.

The Convergence Standards Research Section has heavily driven the standardization of technologies for digital twin, smart manufacture, smart city, smart energy, smart agriculture/forestry, fishery and livestock food products, smart transportation, smart welfare, public safety and emergency response, and research for ICT convergence technologies for the purpose of resolving issues encountered by society and people.

ETRI also established an Open Source Center that governs open source activities in 2017 to enhance enterprise-wide open source governance response system and support open source-related R&D activities. With these achievements, ETRI enforces the linkage system among R&D, open source, and standardization to derive best standardization outcomes with high value for market and people.

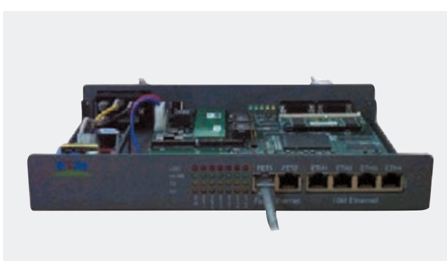
ETRI will continue leading the global standardization of Korea's ICT in the new normal era through preemptive standardization and strengthening global leadership in international standardization organizations for the core and application technologies of the Fourth Industrial Revolution as well as future information and communications technologies.

43) De facto standardization: As opposed to the de-jure standardization performed by official international standardization bodies such as ITU and ISO, standardization activities driven by forums and consortiums such as the mobile communication standardization technology cooperation organization (3GPP), Institute of Electrical and Electronics Engineers (IEEE), international web consortium (W3C), Open Connectivity Foundation (OCF) organized by businesses, industries, experts, and stakeholders in specific technological fields.

6-5-1. Standards

6-5-1-1. Standardization of IPv4/IPv6 Translation Mechanism

Global IPv6 summit



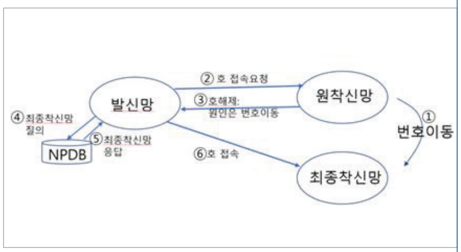
IPv4/IPv6 translator

In 1994, Internet Engineering Task Force (IETF) commenced standardization of IPv6 using 128-bit address system to resolve exhaustion issues of IPv4 addresses using the 32-bit address system, and began research from early 2000s on IPv6 transition mechanisms for supporting of interworking between the IPv4 Internet and IPv6-based next generation Internet.

In 1998, ETRI the test address of 6Bone for the first time in Korea to deploy 6Bone-KR, an IPv6 experimental network, and began operation of the network. In 1999, it acquired commercial address of IPv6 2001:0220::/35 in Korea. ETRI succeeded commercializing the IPv4/IPv6 address translator such as the NAT-PT in 2001. ETRI suggested this translation mechanism to IETF in 2002, and standardized the technology as RFC-3338 (Dual Stack Hosts Using "Bump-in-the-API" (BIA)). This standardization is the achievement from ETRI's first participation in IP technology area standardization and has the significance of being the first RFC document in Korea, developed by the working group (WG) within IETF.

6-5-1-2. Standardization of Number Portability Technology

ETRI commenced development of technologies and standards for commercializing number portability in 2010 pursuant to the government's policies on number portability for eliminating phone number lock-in issue and enabling competition between businesses in the early 2000s. The results were that mobile phone number portability services began on January 1, 2004. The policies were disseminated to all phone services, communications services/mobile phone users, cable phones, and VoIP were allowed to switch to a different communications provider while still using the same phone number. Users were able to enjoy true freedom by having the option to select a communication service provider they want, and an environment of fair competition was set up for various providers. According



Concept of number portability call processing by QoR method

to the data of the Korea Information Society Development Institute, the benefits people can gain through number portability was at approx. KRW 600 billion annually as of 2004.

6-5-1-3. Standardization of WiBro IMT-2000 Technology

In 2002, the Ministry of Information and Communication established a new policy to utilize the 2.3 GHz band, which had been extremely poorly used, for portable Internet purposes. And from 2003 to 2005, the 'WiBro (Wireless Broadband Internet) mobile communication system R&D' project using 2.3 GHz band frequency has led by ETRI and participated by Samsung Electronics, SKT, KT, KTF, Hanaro Communication.

The 2.3 GHz frequency band technical standard went through the following three-step process. The first stage was approved in June 2004 as TTA (Korea Information and Communication Technology Association) standard jointly proposed by ETRI and Samsung Electronics in June 2004. The second stage became the IEEE (Institute of Electrical and Electronics Engineers, American Society of Electrical and Electronics Engineers) 802.16d/e standard through cooperation with Intel and others. In phase 3, it was finally approved as the 6th standard of IMT-2000 at the ITU-R radio assembly October 2007 in cooperation with the United States, Israel, and Canada.

Yoo Young-hwan, the Minister of Information-Communication, assessed the achievement, saying "The standardization is a significant event in the history of mobile communications in Korea, and another turning point is realized for Korea in leading the world's mobile communications market."

View of WiBro research lab

6-5-1-4. Standardization of Terrestrial DMB Technology

In the early 2000s, the government established the policies for digital multimedia broadcasting (DMB) services as mobile DTV broadcasting and drove the DMB technological development. In October 2003, ETRI finally succeeded in developing terrestrial DMB in cooperation with broadcasting companies, broadcasting equipment manufacturers, and broadcasting solution providers for the first time in the world. Commercial terrestrial DMB service has been started around Seoul metropolitan area

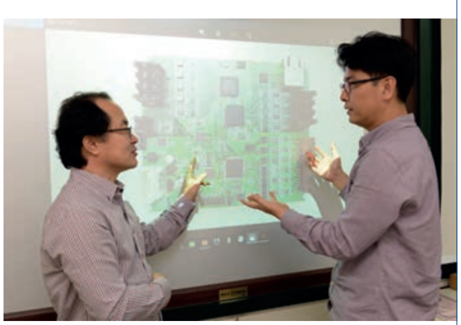
Terrestrial DMB terminal

since December 2005. Users can watch TV programs anytime, anywhere, without interruption even at high speeds of 150 km/hour. It brought about "TV in My Hand, My Own Broadcasting" era.

ETRI led terrestrial DMB technology development and its standardization. The standard of terrestrial DMB was published as a TTA standard in 2004 and later was published as an ETSI standard in 2005. At the same time, ETRI developed the technologies and the standards of Advanced Terrestrial DMB (AT-DMB), guaranteeing backward compatibility with terrestrial DMB. AT-DMB can improve transmission efficiency up to twice the terrestrial DMB and video resolution up to four times higher than the video of terrestrial DMB service. AT-DMB transmission standard and its video standard were published as ITU-R recommendations.

Going through the domestic and international standardization of terrestrial DMB, Korea became one of the leading countries in the area of mobile broadcasting technology and standardization.

6-5-1-5. Standardization of Automotive Gateway Technology



ETRI researchers discussing vehicle security network technology

When full development of smart vehicle technologies was conducted in the early 2010s, the conventional vehicle safety system was advanced to a cooperative active safety system by combining with V2X communications technology. ETRI developed an automotive gateway technology with funding from the government to further preemptively develop the ISO 13185 [44] international standard for automotive interface that provides data exchange format for monitoring and controlling automotive networks to obtain essential vehicle data and provide optimal approach for the configuration theory of In-vehicle networking used for cooperative vehicle safety services[45] by ISO TC204 (intelligent transport system).

The ISO 13185 standard was recognized as a technology that can transfer real-time vehicle data in Cooperative ITS by the ISO TC204, and has been used thereafter as the essential reference for relevant standards such as ISO 21184, ISO 21185, and ISO 21177.

44) ISO 13185: Intelligent transport systems (ITS). Automotive interface standard for service provision and support.

45) Cooperative automobile safety service: Safety service for avoidance and reduction of accidents based on V2X communication. Such services include front collision alarm, safety support at crossings, emergency brake warning, and lane change warning.

Opening ceremony of W3C Korea office

6-5-1-6. Standardization of Web Technology

Since the World Wide Web Consortium (W3C) was established for international standardization of the web in 1994, several members around the world have positively participated in W3C to bring about the rapid expansion of the web ecosystem. ETRI joined W3C in 2001 and exerted powerful leadership for web technology in Korea by opening the W3C Korea Office in 2002.

ETRI has driven technological research for web standards since 2002 to lead web technologies in evolving quickly to Web 2.0, mobile web, semantic web, media web and HTML5, and has positively participated in standardization activities. The standard for defining the relationship between different metadata formats with ontology was registered as W3C Ontology for Media Resources 1.0 in February 2012, and a single interface standard for easy mutual access by different metadata format such as MP4 and YouTube based on these ontology standards was registered as Metadata API for Media Resources 1.0 in March 2014.

ETRI has led the development of automotive information service standards, the core standard interface for accessing information of autonomous vehicles, since 2015.

Major ITU-T Recommendations on cloud computing developed by ETRI

6-5-1-7. Standardization of Cloud Computing Technology

ETRI involved the standardization for cloud desktop service since September 2010, positively driving standardization of the cloud ecosystem and requirements, cloud reference architecture, and cloud resource management.

With ETRI's leadership, standardization in ITU-T SG13 for cloud desktop services, published ITU-T Y.3503 (Requirements for desktop as a service) in 2014, the world's first international standard for cloud desktop service technologies, and the registration of major recommendations such as ITU-T Y.3504, Y.3506, Y.3507, and Y.3509 proved its success.

Along with ITU-T, ETRI continued its standardization activities for cloud computing through JTC 1/SC 38, another major official standards organization. In particular, ETRI significantly contributed to the establishment of collaboration team for common texts on cloud computing (ITU-T Y.3500, ISO/IEC 17788) jointly driven by ITU-T SG13 and JTC 1/SC 38 from 2012 to 2014, and the standards for cloud computing reference structures (ITU-T Y.3502, ISO/IEC 17789).

6-5-1-8. Standardization of IoT Technology

Open Interconnect Consortium (OIC), an IoT de facto standardization organization, was established by IoT manufacturers in 2014. Its goal is to provide connection mechanism between devices and/or clouds regardless of theirs OS, service providers, or transports. OIC was re-launched as Open Connectivity Foundation (OCF) by merging AllSeen Alliance in 2016.

ETRI joined OIC in 2014 and has actively participated in standardization activities. Especially ETRI has concentrated on development of healthcare device modeling and bridging mechanisms between OCF and other IoT ecosystems.

ETRI proposed healthcare WG with Samsung in 2015 and has developed many healthcare device data models. ETRI also got vice-chair position of healthcare WG in 2016.

OCF-BLE Bridging demo in CES 2017

ETRI organized BLE (BLE Low Energy) bridging PG (Project Group) to develop bridging mechanism with BLE, and also proposed Z-Bridging PG with Samsung to develop bridging with ZigBee[46] and Z-Wave[47]. In 2018 ETRI got chair position of OCF Bridging TG (Task Group) that controls all four ecosystem bridging TGs (BLE, ZigBee/Z-Wave, oneM2M, and Haier U+). Since then ETRI has also completed bridging mechanisms with EnOcean and LwM2M in 2019 and 2020 respectively.

6-5-1-9. Standardization of e-Call Technology

ETRI conducted the development for the standard for automotive emergency response system (e-Call) and vehicle device a multi-ministry project led by ETRI for four years from 2015, and drove the Korean vehicle e-Call development and international standardization.

ETRI promoted local standard development of the e-Call system's reference architecture, e-Call device requirements, e-Call center requirements, and minimum set of data (MSD) related to the accident. It also suggested and established the international standards of

46) ZigBee: Technology for wireless network requiring only low speed, cost, and power.

47) Z-wave: Wireless communication protocol typically used for home automation.

Smartphone type e-Call service device developed by ETRI

ITU-T Y.4119 (requirements and capability framework), ITU-T Y.4467 (MSD structure), and ITU-T Y.4468 (MSD transfer protocol).

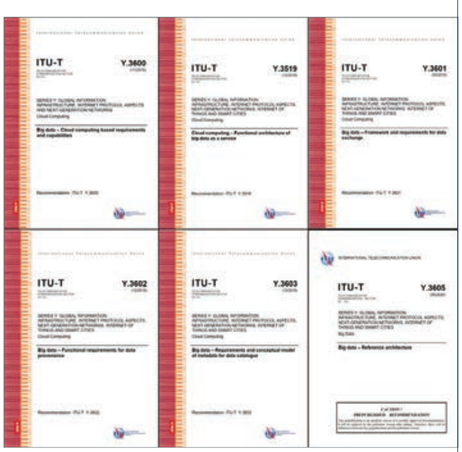
The Korean e-Call systems (based on the international standards) were installed in Korea Post's courier vehicles, demonstrating their capabilities in the Okcheon and Yeongdong areas of Chungcheongbuk-do and the Mujo area of Jeonbuk to improve its integrity. ETRI also drives the commercialization of e-Call by transferring it to participating joint companies, and will transfer it to the Korea Transportation Safety Authority for its application on the real-time monitoring system for vehicles transporting hazardous materials. The current domestic and international revision of laws and policies stipulates the mandatory mounting of the e-Call system in vehicles. It is expected that the development and certification business of Korean e-Call devices will be activated quickly.

6-5-1-10. Standardization of Big Data Technology

The official standardization organizations began discussions on standardization of big data from 2013 to enhance the versatility and value of big data. ETRI commenced development of standard technology for supporting big data services in cloud computing environments. The ITU-T Y.3600 was approved in 2015 as the first official international standard for big data.

ETRI has since aggressively driven the establishment of major standards through continuous standardization activities, including the ITU-T Y.3601 framework and functional requirements for big data exchange, the Y.3602 functional requirements for big data provenance, the Y.3519 functional architecture for big data services in the cloud environment, and the Y.3603 metadata requirements and conceptual model for big data cataloging. ETRI also led the development of international standards of ISO/IEC 20546 (overview and terminology of big data) and the 20647 (big data reference architecture) at ISO/IEC JTC 1 since 2014.

In the situation where big data WG is merged with SC42 while establishing JTC1/SC42 (AI) in 2018, ETRI plans to positively drive the standard development for data quality, reliability, and data interoperability for big data analysis and artificial intelligence.



Major ITU-T recommendations on big data developed by ETRI

ETRI member participating as ITU-T workshop panelists

6-6. Policies - The Think Tank of National ICT

ETRI has continuously sought its best roles to satisfy the requirements of paradigm shift in the global economy, industries, markets, and the demands of the country and the people, and has developed leading policies for such requirements over the past 45 years. Through these activities, ETRI has established its firm position as the ICT think tank of Korea by driving all ICT processes including industrialization, informatization, convergence, and intellectualization.

The civil sectors played significant roles in positioning Korea as one of the powerful countries in ICT. However, the government's role is to effectively drive ICT policies without interruption, and ETRI's roles should also be valued highly as a representative government-funded research institute in the ICT field.

The world' ICT history can be divided into six periods from the standpoint of human history: 1) The revolutionary period of personal computers (1976–1985), 2) the revolution period of software (1985–1995), 3) the revolutionary period of the Internet (1993–1999), 4) the revolutionary period of navigation and social program (1999–2006), 5) the revolutionary period of smart phones (2007–2010), and 6) the revolutionary period of cloud and the future (2010–).[48] This classification was made based on ICT or consumption trends emphasized in each period. In Korea, its ICT history can be divided into four periods (paradigms) in accordance with the ICT policies of the government.

Changing the name of Electronics and Telecommunications Research Institute

First is the industrialization policy period. The industrialization period spans from the early 1960s to the mid-1980s, when national networks for telephones and power were established to drive modernization and industrialization, while computer-based computerization was strongly promoted at the national level. In this period, ETRI was first launched as the Telecommunication Research Institute under the Korea Institute of Science and Technology (KIST). It was then reformed into the Korea Electronics and Telecommunication Research Institute by integrating the Korea Telecommunications Research Institute with the Korea Electric Research and Testing Institute in 1981. In 1985, it was launched under the title of the Electronics

48) Jung Ji-hun (2010). History of Almost All of IT. MEDICIMEDIA.

and Telecommunications Research Institute by merging with the Korea Electronics Technology Institute.

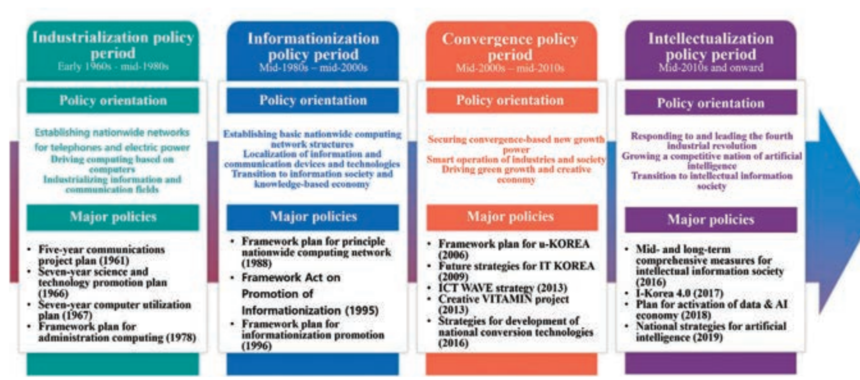
Second is the informatization policy period. The informatization period spans from the mid-1980s to the mid-2000s when Korea grew as a powerful ICT country based on ultra-high-speed Internet, semiconductors, and mobile communication services. ETRI also experienced changes during this period in government policies: the System Engineering Research Institute was merged in 1996 and changed its name to the current one as the Electronics and Telecommunications Research Institute, with National Security Research Institute being established in 2000 as its affiliate institute.

Third is the convergence policy period. The convergence period spans from the mid-2000s to the mid-2010s when ICT was conducted with two keywords: convergence and smart. ICT in Korea was successfully developed due to its fast follower strategies for fast growth by mimicking and chasing advanced countries. However, the GDP and technologies stayed stagnant at a certain level since the end of the 1990s. To overcome such stagnant growth, a new paradigm named convergence made its debut, and the concept of "smart" emerged for further enhancement of ICT's technological level. During this period, ETRI heavily concentrated on projects for convergence R&D such as ICT+Automotive, ICT+Shipbuilding and ICT+National Defense. ETRI also responded to government policies by establishing convergence research centers such as the SW SoC Convergence R&BD in 2013.

Fourth is the intellectualization policy period. The intellectualization period spans from the mid-2010s onward when the ICT paradigm dramatically changed once development of intelligent information technology was advanced and the Fourth Industrial Revolution emerged.

ETRI expanded its investment in intelligent information technologies and declared its vision of leading the Fourth Industrial Revolution and intellectualization to keep pace with the intellectualization paradigm. It is also heavily promoting R&D strategies for national-level intellectualization such as the "ETRI AI Strategies."

Furthermore, ETRI will do its best as a leader and companion in implementing nationwide intellectualization based on refinement of R&R and ETRI AI Strategies. ETRI will also commit its greatest efforts to the development of policies for creating new AI services converged with software and content, hyper-connected communication, super-capable computing, broadcasting media, and ICT materials and parts researched by ETRI until now.



Paradigm shift of ICT policies in Korea

6-6-1. Periodical Policy Changes and Major Achievements

6-6-1-1. Industrialization Policy Period

Changes During the Industrialization Policy Period (mid-1960–mid-1980s)

Korea's economy made its way toward the era of high and condensed growth called the "Miracle on the Han River," where necessity and significance of communications were rapidly emphasized. To this end, the government established a plan for a five-year communication project in four stages from 1962 to fully drive the distribution of communications networks and modernization of telecommunications facilities. In 1967, the Ministry of Science and Technology established a seven-year plan for development of use of electronic computers to introduce, develop, and propagate computers.

In such situations, requirements for establishing professional research institutes became urgent for localizing communications technologies, and the Korea Electronics and Telecommunications Research Institute was established in December 1976 under the leadership of KIST. KTRI, KERTI and KIET were then merged to launch ETRI in 1985.

Meanwhile, demands significantly grew for automation of nationwide telephone services in the 1980s. At the time, demand for telephones increased by one million lines annually just to meet the requirements from residential areas expanding to wider regions, as well as the rapid increase in volume of information exchange. To respond to such situations, the government and Korea Telecomm began full development of a domestic switching system. Development of TDX was driven for realizing self-sustaining communications network operation technology led by ETRI, and trial operation of TDX-1X, the first in Korea, began in July 1982.

Korea-made TDX-1A was installed in all telephone companies in large scale from 1985, and the era of "one-household, one-phone" began in Korea.

TDX-1A in the 'one-household, one-phone' era

Discussion on infocommunications policies

ETRI's Policies in the Industrialization Period – Pioneering Localization of Communication and Computing Technologies

Korea strongly utilized the fast-follower strategies for obtaining advanced technologies when it barely had any of the fundamental science and source technologies until the mid-1980s. Accordingly, the mission assigned to ETRI by the government was fast localization of technologies and systems used by advanced countries in the fields of communication and computing. Since the mission was very clear, R&D was promoted by relying on enterprise-wide capabilities to achieve the mission rather than establishing separate strategies and visions.

After succeeding in developing the TDX, localization of semiconductors and mid-size microcomputers, ETRI commenced the establishment of its visions, objectives, and strategies from the mid-1980s.

Launched in 1985, ETRI defined its visions and objectives of "cultivating a world-class research institute by 1996" and the management philosophy of "Spirit of Excellence." To achieve the goal, ETRI promoted several projects including development of human resources, activation of basic research, internationalization of R&D, development of public support technologies, and improvement of R&D schemes. This promotion system of vision-objective-strategy continued until 1993.

Major achievements by ETRI during the industrialization policy period includes TDX, as the tenth in the world (1986); 32K ROM, as first in Korea (1982); 64K ROM (1983); and the HAN-8, Korea's first 8-bit microcomputer (1983). The mainstream R&D method used for developing these technologies was importing products developed in advance countries, disassembling them to analyze the structure, then developing technologies and implementing functions like those based on operational theories found by repetitive experimenting and testing. R&D was conducted by relying on the passion and endeavors of researchers in situations when Korea lacked source technologies.

6-6-1-2. Informatization Policy Period

Changes During the Informatization Policy Period (mid-1980s–mid-2000s)

32K ROM development successful; production technology presentation held with Former President Chun Doo-hwan and relevant personnel

Presentation of the first-ever Korean midsize Host Computer II

The main paradigm of global ICT industries following the 1980s was "informatization." The basis of informatization was rapid growth of computing power and the advent of mobile communication services. The Korean government also began fully driving informatization policy from the mid-1980s. The starting point was the enactment of the Act on Promotion of Information and Communications Network Utilization and Information Protection in 1986 and the establishment of the Basic Plan for the National Main Computing Network in 1988. The Framework Act on Informatization was enacted in 1995, and the Basic Plan for Informatization Promotion was established in 1996, firmly positioning the policy paradigm of the government's attempt at informatization.

Technologies and systems of ICT industries in Korea were, however, relying heavily on those of advanced countries, and it was predicted that the stronger informatization was driven, the deeper the reliance would become. To resolve this issue, the government commenced development of local host computers in 1987, and ETRI and four major computer manufacturers of Korea succeeded in developing the midsized computer Main Computer II (TICOM), the first midsized computer developed in Korea. Then, the Host Computer III, a high-speed midsized computer, was developed in 1994. Having succeeded in developing the TICOM series, local research institutes and computer manufacturers added investment into the development of computer peripheral devices and software as well. Consequently, ETRI and the big four computer companies, namely Samsung Electronics, Daewoo Communication, LG Electronics, and Hyundai Industrial Electronics, jointly developed the ComBiStation, a multimedia workstation, at almost the same time as US and Japan's computer development. The MISIX developed by ETRI was a core technology for operating parallel computers of medium and large size, boasting top technology in the world.

In the 1990s, advanced countries in the world were busy defining policies for establishing ultra-high-speed Internet networks. Typical examples are US's establishment of an information superhighway in the US, Japan's high-performance info-communications infrastructure and Singapore's IT 2000. Korea, having been recognized as one of the top countries in information and communications, also drove policies and strategies for establishing ultra-high-speed information and communications networks to keep pace with these global trends. It did so by establishing and driving the comprehensive promotion plan for establishing the basis of ultra-high-speed information and communication networks in 1995 and the framework plan for advancement of information and communication networks in 2001 to become one of the countries that operate ultra-high-speed Internet.

Diversified changes were also attempted in the national informatization promotion systems in the late 1990s. The Ministry of Communication was changed to the Ministry of Information and Communication in 1994, and the framework plan for promoting informatization, a master plan for the national informatization promotion, was established in 1996. Since then, policies have been continuously established in accordance to changes with times and government set its visions, including Cyber Korea 21 [49)] in 1993, e-Korea Vision 2006[50)] in 2002, Broadband IT Korea Vision 2007 [51)] in 2003, and IT839 Strategies [52)] in 2004.

ETRI's Policies in the Informatization Period – A Leader for the Leap Towards Becoming an ICT Power

Grown through multiple mergers from the end of the 1970s through the mid-1980s, ETRI integrated the system engineering institute in 1996, and installed the national security technology institute in 2000 to become the representative institute in ICT fields in Korea. In particular, ETRI was assigned the R&D relevant to national informatization as the core task when the "Framework Plan for Informatization Promotion" was established in 1996. ETRI revised its visions and goals and the core strategies four times from the mid-1980s to the mid-2000s. The visions and goals were set to the direction of becoming a "world-class ICT research institute". The concept of management was to drive innovation of the organization so as to absorb shocks from worsening of external circumstances (e.g., economy under the IMF management system) from the 1990s until the early 2000s, then converted to the direction of valuing intellectual capital pursuant to the national policy objective of transition to a knowledge-based economy from the mid-2000s.

49) Cyber Korea 21: Policy established in 1999 to meet the trends in time of great transition toward the knowledge-based economy with the purposes of establishing information infrastructure, improving national productivity, and expanding employment by cultivating new industries.

50) e-Korea Vision 2006: Policy established in 2002 to enhance efficiency throughout the country and improve capability of information usage by all citizens through informatization to enhance adaptability to new changes.

51) Broadband IT Korea Vision 2007: Policy established in 2003 for the purpose of government innovation by implementing world-class open e-government, improving national competitiveness of industries through informatization in every industry sector, and implementing a digital welfare society.

52) IT839 Strategy: Policy established in 2004 with the objective of opening the era of a national income per capita of USD 20,000 by creating the new growth driver of IT. The policy contains specifics for maximizing value chain effects of ICT industries through organic collaboration between 8 major new services, 3 major infrastructures, and 9 major new growth drivers.

ETRI in the informatization policy period faithfully performed its role as a leader for taking the leap that made Korea into a global ICT power in the fields of semiconductor, mobile communication, ultra-high-speed Internet, and broadcasting media. Thus, ETRI's role as the "leader of ICT powerhouse" was recognized.

ETRI's major achievements in this period include development of the world's first 64M/256M DRAM (1992/1994), development of a midsize computer, the Host Computer II (TICOM) (1991), development of a high-speed mid-size computer, the Host Computer III (1994), commercialization of the Integrated Services Digital Network (TDX-1B ISDN) (1993), development of a 565-Mbps optical communication system (1988), trial broadcasting of a digital satellite broadcasting system (1996), the world's first commercialization of CDMA technology (1996), development of 3G mobile communication technology IMT-2000 (2001), development of the world's first 3.9-generation mobile communication technology WiBro (2005), development of 4G mobile communication technology LTE-Advanced (2011), and the world's first commercialization of terrestrial wave DMB (2003).

6-6-1-3. Convergence Policy Period

Changes During the Convergence Policy Period (mid-2000s–mid-2010s)

The selection of the first UGS Convergence System Research Section under ETRI

Convergence became mainstream in ICT fields during the 21st century. ICT convergence was first discussed in the 1990s; however, policies and strategies for ICT with convergence were implemented in the mid-2000s. In particular, ICT in Korea, which had moved as fast followers of the technologies made by advanced countries, showed stagnation upon reaching a certain level. The country only began driving convergence policies from 2006. One of the features during this period was the advent of mass strategies for cultivating software fields following the global ICT trends to overcome the limit of local ICT industries that had grown mainly with hardware.

Representative policies of the government for convergence in this period include the u-IT839 strategy [53], framework plan of U-KOREA [54], and ACE IT strategy [55] in 2006, the future strategy of IT KOREA[56] in 2009, the mid- to long-term ICT R&D strategy[57] in 2013, and the strategy for developing national convergence technologies in 2014.

In June 2014, the National Research Council of Science & Technology (NST) was launched for the vitalization of convergence among institutes. At this time, ETRI belonged to NST. ETRI's major convergence projects were conducted then, including the election of the UGS Convergence System Research Section led by ETRI as the first convergence study group of NIST in December 2014, and the Knowledge-Converged Super Brain (KSB) Convergence Research Department was selected for driving convergence R&D.

ETRI's Policies in the Convergence Period – The Leader of the ICT Convergence Technology Development

In the convergence policy period, ETRI committed its greatest efforts to convergence technology by developing the method of "ICT+other industries" to heavily drive convergence-type R&D projects of IC+vehicle, ICT+shipbuilding, and ICT+national defense. It led the convergence of various capabilities among institutes by acting as hosting institute for multiple convergence research groups driven by NST.

ETRI's visions in this period were "leader of world-class technologies" and "ICT innovator." There had been a number of changes in ETRI's organizational and business structure in accordance with the new visions. First, the SW SoC Convergence Research HQ was established in early 2013 for forming a convergence environment. ETRI introduced a duplex system for dividing R&D activities into source type and converged type dependent on the features of individual projects to research source technologies at individual research sectors. The convergence technology in sunset mode suitable for themes to aggressively drive business structures for enhancing research efficiency was also included.

ETRI also established the "SW Content Research Laboratory" to drive synergy by integrating research organizations to work on software and content research, which is typically scattered among multiple sectors.

ETRI also established the "Creative Research HQ" in 2010 for its transformation into a creative organization. The "Future Research Creative Laboratory," a future technology

53) u-IT839 Strategy: Policy of IT839 strategy upgraded and announced in 2006, focusing on promotion of commercialization and enhancement of competitiveness of software, parts, and materials for preemptively occupying the global convergence and ubiquitous IT markets

54) Framework plan of u-KOREA: Policy established in 2006 for implementing ubiquitous environment containment strategies promoting ICT convergence in diverse economic, social, and administrative areas including establishment of a real-time intellectual mobile administration system, establishment of an intellectual advanced traffic system, establishment of an RFID-based intellectual integrated logistics system, integrated management and support of u-City, establishment of a combined platform-based enterprise information system, real-time environment monitoring, establishment of a u-IT-based national defense integrated information system, establishment of an intellectual security and anti-crime system, and u-Home distribution.

55) ACE IT Strategy: Strategy established in 2006 for realizing VISION 2030, with the long-term philosophy of government participation including the 3 strategies of Advanced IT, Convergent IT, and Expanded IT.

56) Future strategies for IT KOREA: Strategy announced in 2009 for the establishment of accompanied growth system of manufacture, service, and software with major assignments on technological innovation and job creation through accompanied growth of large, medium, and venture companies.

57) Mid- to long-term strategies of ICT R&D: Also called ICT WAVE Strategy, was established in 2013. Strategies for preemptively occupying global markets by developing ten major core technologies and cultivating them as the new growth driver in the five fields of Content (C), Platform (P), Network (N), Device (D), and Information Security (S) to achieve the goal of implementing a creative economy with the new government's core economy policies.

planning organization, was established in 2013, and drove organizational restructuring that allow individual departments under their direct control to establish their own future research teams. Furthermore, ETRI established the “R&D Commercialization Department” exclusively for supporting technological commercialization of small and medium businesses in 2014.

The representative developmental achievements during this period include smart vessel technology (SAN) through ICT+shipbuilding convergence (2011), semiconductor biosensor chip through convergence of ICT and BT (2010), u-Health technologies such as bio-shirts, smart shoes, and fall safety phones, RFID and USN technology through ICT+logistics convergence, information security technology such as anonymity certification technology (2008), the world’s first next-generation image technology such as the Orchestra media service technology (2009), the world’s first AMOLED core technology (2009), the world’s first System on Chip (SoC) with embedded core module of terrestrial DMB (2005), and voice and language information processing technology such as portable Korean-English automatic interpretation technology capable of simultaneous interpretation (2011).

6-6-1-4. Intellectualization Policy Period

Changes During the Intellectualization Policy Period (mid-2010s onward)

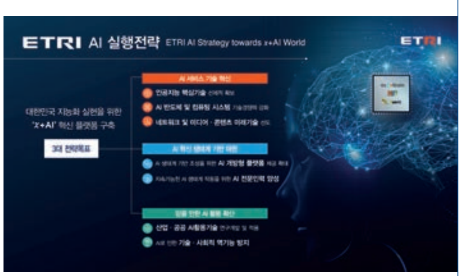
In the 21st century, advanced countries around the globe have made attempts at paradigm transformation to break stagnation in economy growth. In particular, a new paradigm replacing “informatization and convergence” in ICT fields has emerged, called “intellectualization.”

The concept of intellectualization was first emphasized in government policies for the mid- to long-term comprehensive measures for an intelligent information society established in 2016 for realizing an intelligent information society [58]. The government further drove “I-Korea 4.0” as the response plan for the Fourth Industrial Revolution in 2017, and continued establishing intellectualization-related policies such as the “plan

58) Intellectual information society: Society creating and advancing new values by utilizing intellectual information technologies in every sector of economy, society, and life which combine data and artificial intelligence generated, collected, and accumulated through advanced information and communications technology infrastructure.

for activation of a data and artificial intelligence economy" to become a powerhouse in data and artificial intelligence, the "artificial intelligence R&D strategies" to become the leading country in artificial intelligence technology, and the "strategies for data industry activation." The government announced the "national AI strategies" covering nationwide artificial intelligence strategies in December 2019. The three major fields of these strategies are AI competitiveness innovation (establishing an AI ecosystem to lead the world), full utilization of AI (become the best country utilizing AI), and harmony and coexistence with AI (human-oriented AI implementation).

ETRI's Policies in the Intellectualization Period – A Leader and Companion of National Intellectualization



AI implementation strategy

In January 2016, the World Economic Forum (WEF) declared the Fourth Industrial Revolution as a new paradigm that will lead the world economy. The Fourth Industrial Revolution is a global paradigm that applies ICT in various industrial fields to create innovative products, processes, and businesses, causing strong effects of digital transformation [59)] in every industrial field. Consequently, ICT became the core factor that determines competitiveness in all industrial fields, going beyond technology, and the effects of ICT have grown while ETRI's roles in leading national ICT development have also accordingly became more significant. ETRI defined a vision called "ICT innovator leading the Fourth Industrial Revolution" to respond to the huge wave of revolution, and suggested "4 hyper-strategies (hyper-connection, hyper-intelligence, k-hyper-realism, and hyper-materials) in 2016.

When the government commenced rapid transformation of the intelligent paradigm by announcing the "plan for data and AI economy activation" and the "AI R&D strategies" in 2018, ETRI formed the "Via Novata TFT," meaning the "Road to Innovation", and established the "ETRI transformation plan" focusing on intellectualization for 50 days from May 2019.

Based on the output, ETRI established and announced a new vision as a "comprehensive research institute for national intellectualization for the future," and suggested the four major goals of the institute's operation in June that year: 1) preparing for future growth by

59) Digital transformation: Paradigm of analyzing vast data generated from IoT to intelligently innovate all industries.

KETRI's groundbreaking ceremony
which laid the basis for the first mid- to long-term
progress plans for communications

vitalizing creative and challenging research; 2) creating world-class R&D achievements, 3) solving life issues of citizens and giving more expanded support for small and medium businesses; and 4) setting research cultures based on openness, sharing, and collaboration. ETRI also proposed the "National Intellectualization Policies" in December 2019, and in May 2020 provided the "ETRI mid- to long-term technology development map for 2035," predicting changes in the social structure and lives of people, technologies and services due to changes in the next 15 years until 2035. This is also to provide a "technology compass" for realizing national intellectualization.

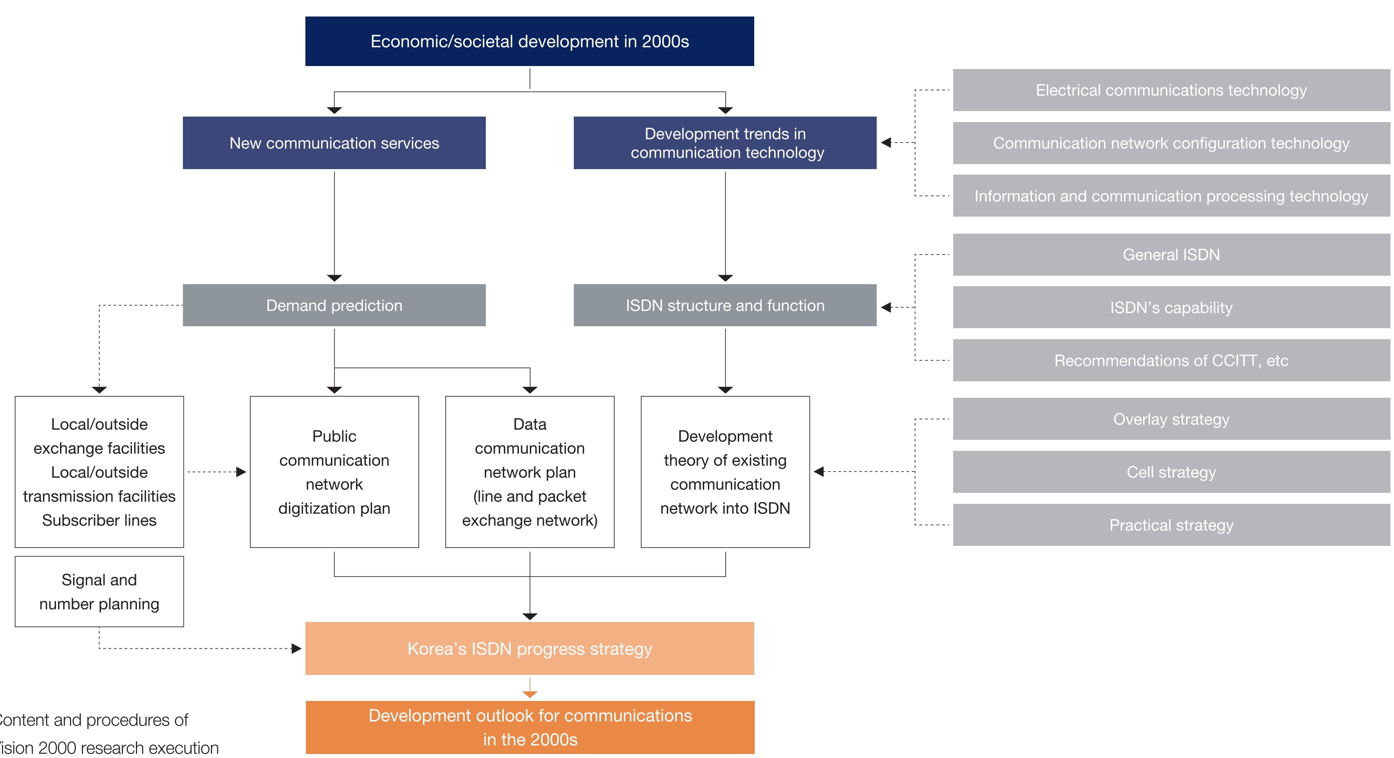
In June 2020, ETRI complied with the strategies accumulated thus far, and announced the "ETRI AI Execution Strategies," where AI was defined as a paradigm that changes people's thoughts and behaviors, rather than a single technology or service. The execution strategy is a new infrastructure leading Korea into the future that consists of the specifics of practice strategies for establishing the "x-AI innovation platform," and describes ETRI's roles in leading the intellectualization revolution era. The three major directions of the strategy are: 1) securing intellectualization technology capabilities at the global top 3 level that will lead innovation and overcome the limits of AI services and technologies, 2) establishing the basis for an AI innovation ecosystem that grow together with people and companies, and 3) expanding reliable AI utilization for resolving requirements from industries and social issues.

ETRI redefined the "ETRI Roles and Responsibilities (R&R)" upon request from the government at the end of 2019. ETRI declared its mission of "overcoming the limits faced by humankind (temporal, spatial, intellectual, linguistic, sensory, physical, and physiological) by developing future digital technologies to contribute to national intellectualization" after discussing with experts inside and outside of the institute. ETRI also defined the top five roles of the institute: 1) supplying a hyper-intelligence information society, 2) implementing hyper-capable computing, 3) implementing hyper-connected infrastructure, 4) realizing hyper-realism service, and 5) developing national intellectualization convergence technologies and establishing strategies to achieve these goals.

ETRI promptly kept pace with global changes brought by intellectualization and the Fourth Industrial Revolution in the intellectualization policy period, and defined AI as more than just a technology, but is a new paradigm that changes people's thoughts and behaviors. ETRI expand this view nationwide to provide the basis for its leap in becoming a leading nation for AI.

ETRI's major achievements in this period include development of Exobrain, a world-leading language intelligence software; GenieTalk, the world's best automatic interpretation application (2017); optics-line-packet integrated switching system (2016); DeepView, a source technology platform for visual intelligence; Aldebaran, a process chip for autonomous driving; the world's first UHD mobile broadcasting technology; and TIC-TOC, which can provide 25-Gbps grade Tactile Internet (2019).

Furthermore, ETRI will do its best as a leader and companion in implementing nationwide intellectualization based on refinement of R&R and ETRI AI Strategies. ETRI will also commit its greatest efforts to the development of policies for creating new AI services converged with software and content, hyper-connected communication, super-capable computing, broadcasting media, and ICT materials and parts researched by ETRI until now.



Content and procedures of Vision 2000 research execution

6-7 Conclusion

Information Security

A hyper-connected society was created through the development of IoT, cloud computing, AI, and 5G and 6G mobile communication technologies, where all devices are connected with each other over a network. Accordingly, humankind is able to enjoy unprecedented convenience, but this becomes prone to unimaginable damages when hyper-connected infrastructures malfunction due to hacking. In addition, cyber intrusion armed with AI may occur, and it is urgent to establish more intelligent and proactive defense systems. ETRI will continue to work hard to establish a smart, autonomous, intelligent cyber self-defense system, and will commit its greatest efforts to building a hyper-connected society while ensuring safety and security.

Blockchain

Digital transformation is happening rapidly all over the economic society and contactless culture has expanded due to the COVID-19 pandemic that started in 2020. At the same time, the significance of blockchain technologies gradually grow to being capable of ensuring reliability in mutual transactions without additional trusted devices. Accordingly, competition for developing the core source technology of blockchain becomes more relentless each day. Needing to secure technological leadership by applying diversified application services throughout the world, ETRI will continue to develop technologies capable of overcoming the limits of blockchain and converge leading technologies for the fourth industrial revolution, which will result in securing the top position in the global technology competition.

Creative Research

ETRI established and announced the new vision of a “comprehensive research institute for national intellectualization for the future,” and defined one of the four major goals of the institute's operation as “preparing for future growth by vitalizing creative and challenging research.” ETRI further emphasized creative research and restructured the

"ICT Creative Research Laboratory" (future source technology research HQ, materials and parts research HQ, realistic device source research HQ, optical wireless source technology research HQ, and quantum technology research group). Thanks to such policy support by the institute, the ICT Creative Research Laboratory will commit its greatest efforts in securing the nation's future growth drives by continuously driving unprecedented, powerful, and creative research.

Standards

ETRI has worked hard to secure competitiveness of local businesses (technologies) in the global market by driving standardization activities domestically and abroad at the institute level as well as the national level over the past 30 years. ETRI will stay in close cooperation with the Ministry of Science and ICT's DNA+ICT convergence standard innovation strategies that lead the digital new deal by to actively driving development of core technologies for the Fourth Industrial Revolution. It will also cooperate with ICT convergence standards with all ministries and open source-based open ICT standards, as well as operate the future core technology's standard research center. ETRI will maximize local technologies and standard values by enhancing standardization activities for improving consumer and citizens' convenience.

Policies

ETRI will further analyze paradigm shifts in the global economy, industries, markets and research policies and suggest R&D orientation for developing intelligent solutions for resolving issues that people encounter in their daily life. It will also continuously conduct rationalization analysis for major project planning through collaboration with the other ministries for the purpose of achieving the vision of becoming an "ICT policy think tank that lead the national intellectualization."

Moreover, ETRI will also focus on establishing methods for effective execution of newly redefined ETRI R&R, work hard to successfully achieve the institute's mission of "contributing to national intellectualization by overcoming the challenges faced by humankind (temporal, spatial, intellectual, linguistic, sensory, physical, and physiology) by developing future digital technologies."

Former Presidents of Institutions

Former Presidents of Institutions

OH, Hyun Wee	President of KIET	Feb 1997–Nov 1997
JEONG, Sung Gye	President of KERTI	Feb 1997–Jul 1980
HAN, Sang Jun	President of KIET	Nov 1997–Feb 1981
JUNG, Man Young	President of KTRI	Nov 1977–Jan 1981
CHOI, Sun Dal	President of KTRI	Jan 1981–Apr 1982
	President of KETRI	Jan 1981–May 1982
	President of KIET	Feb 1981–May 1982
PARK, Hen Suh	Acting President of KIET	May 1982–Jun 1982
PACK, Yung Hak	President of KETRI	Jun 1982–Jul 1984
KIM, Chung Duk	President of KIET	Jul 1982–Jan 1985
KYONG, Sang Hyon	President of KETRI	Jul 1984–Mar 1985
	President of KIET	Jan 1985–Mar 1985
	President of ETRI	Mar 1985–May 1992
YANG, Seung Taik	Acting President of KTRI	May 1982–Jun 1982
	President of ETRI	May 1992–Jan 1997
	President of ETRI	Jan 1997–Mar 1998
CHUNG, Seon Jong	President of ETRI	Apr 1998–Mar 2001
OH, Gil Rok	President of ETRI	Apr 2001–Oct 2003
YIM, Chu Hwan	President of ETRI	Nov 2003–Nov 2006
CHOI, Mun Kee	President of ETRI	Nov 2006–Nov 2009
KIM, Heung Nam	President of ETRI	Nov 2009–Dec 2015
LEE, Sang Hoon	President of ETRI	Dec 2015–Dec 2018

Former President of Affiliate Organization

SUNG, Ki Soo	President of SERI	Jun 1967–Feb 1992
SHIN, Dong Pil	President of SERI	Feb 1992–Aug 1992
KIM, Moon Hyun	President of SERI	Aug 1992–Jun 1996
GIL, Rok Oh	President of SERI	Jun 1996–May 1998

Korea Institute of Electronics Technology

OH, Hyun Wee
1977.2. ~ 1977.11.

HAN, Sang Jun
1977.11~1981.2.

PARK, Hen Suh
1982.5. ~ 1982.6.

KIM, Chung Duk
1982.7. ~ 1985.1.

Korea Electric Research and Testing Institute

JEONG, Sung Gye
1977.2. ~ 1980.7.

Korea Telecommunications Research Institute

JUNG, Man Young
1977.11. ~ 1981.1.

Korea Electrotechnology and Telecommunications Research Institute

CHOI, Sun Dal
1981.1. ~ 1982.5.

PACK, Yung Hak
1982.6. ~ 1984.7.

Electronics and Telecommunications Research Institute

KYONG, Sang Hyon
1984.4. ~ 1992.5.

Systems Engineerting Research Institute

SUNG, Ki Soo
1990.12. ~ 1992.2.

SHIN, Dong Pil
1992.2. ~ 1992.8.

KIM, Moon Hyun
1992.8. ~ 1996.6.

Electronics and Telecommunications Research Institute

YANG, Seung Taik
1992.5. ~ 1998.3.

CHUNG, Seon Jong
1998.4. ~ 2001.3.

OH, Gil Rok
2001.4. ~ 2003.10.

YIM, Chu Hwan
2003.11. ~ 2005.11.

CHOI, Mun Kee
2006.11. ~ 2009.11.

KIM, Heung Nam
2009.11. ~ 2015.11.

LEE, Sang Hoon
2015.12. ~ 2018.12.

Epilogue

The moment of deciding the publication of the history of ETRI for 45 years was December of 2019. It took 1 year and 6 months from the planning of compilation to printing to accurately investigate what kinds of contributions the researchers have made to the ICT growth of Korea for the last 45 years.

The tasks of reviving ETRI's forgotten history of R&D while deriving the direction of editing and setting up the structure after building the TF of the compilation committee was quite challenging. But it was very meaningful to take a broad look at the R&D fields by organizing them into 6 major categories, 30 medium categories, and 242 small categories. It was also a beneficial experience of searching for forgotten accomplishments which could be missed out and focusing on granting meaning to them.

In the process of writing, we could feel the sweat and passion of ETRI predecessors who tried to mark a milestone in Korea's ICT history all day and night. Therefore, we did our best to include all the aspects of success and failure of research and even the core know-hows which led Korea to the ICT powerhouse.

This history was written with the intention of being the core base for writing the history of ETRI for 50 years in the future. Moreover, I hope it has the role of recording the history of our institution properly and erect it upright as well as cheering up our employees. The content will be translated into English to inform the history of Korea's ICT development all over the world. Then, the status of global ETRI will be even more promising.

I hope our researchers make more contributions to the economic growth and creation of national wealth by securing core fundamental technologies in the future. Moreover, I hope there will be more researches of enriching the lives of citizens to be reborn as a more loved ETRI by the citizens.

I want to show my sincere gratitude to more than 300 researchers and compilation committee members who helped writing the history of R&D for 45 years of ETRI, the ETRI PR department, etc.

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Head of the compilation committee

Hwang, Seung Gu

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