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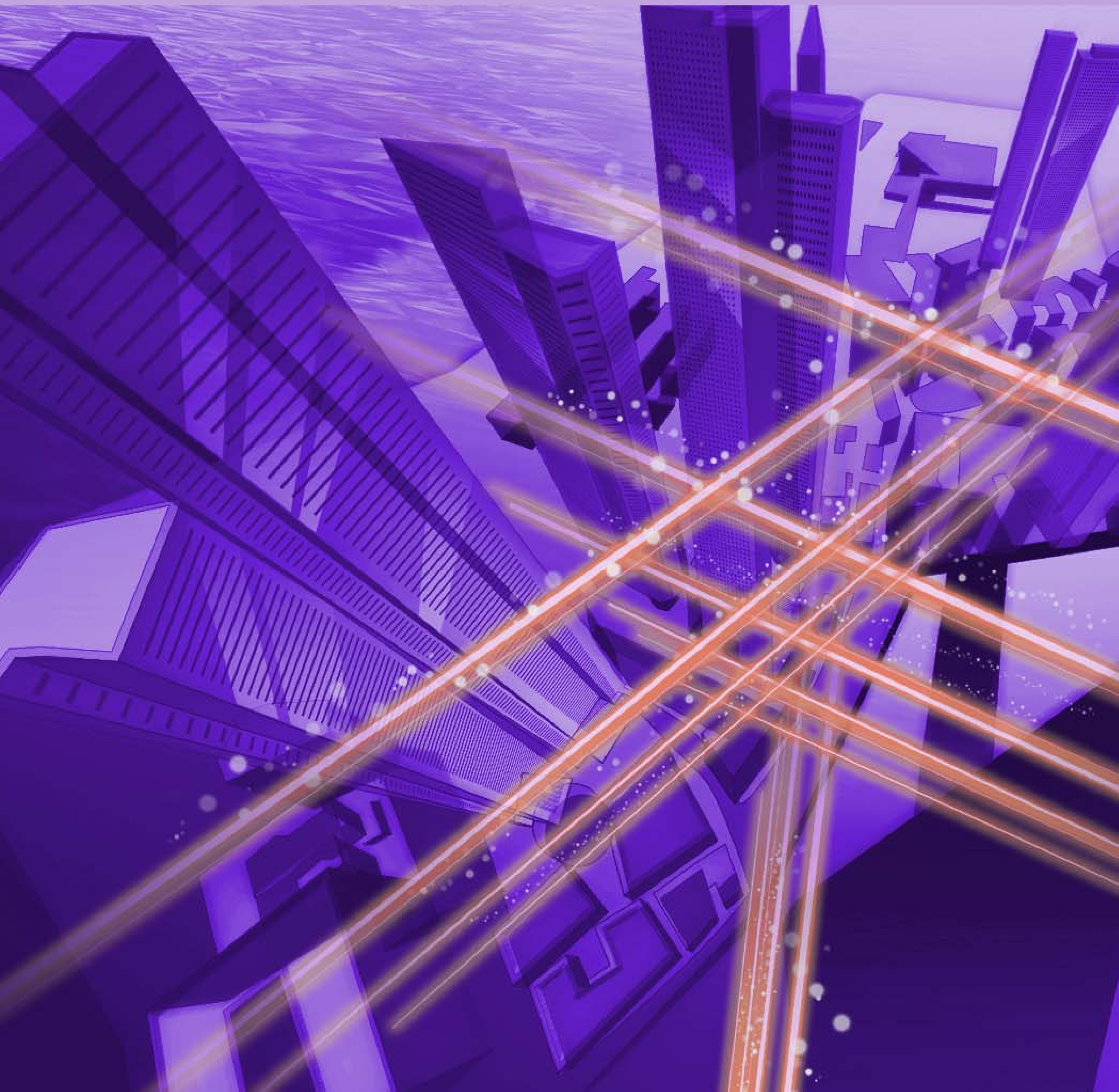

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Supporting the Future of Regional Communities through "Management from the Heart" by Practicing Empathy, Cooperation, and Gratitude

Naoki Shibutani
President, NTT EAST

Abstract

Accompanying the daily evolution of information and communication technology, artificial intelligence and other digital technologies, the rise of diverse business models and the expansion of remote work fast-tracked by the COVID-19 pandemic has changed society dramatically. Under these circumstances, birthrates are declining and populations are aging at higher rates, social infrastructure is deteriorating, and countermeasures against global warming are becoming ever more urgent. To address such social issues facing Japan, NTT EAST is promoting empathetic digital transformation (DX) in conjunction with traditional problem solving. We asked President Naoki Shibutani about how empathetic DX is important to drive social innovation as well as the secret of "management from the heart" that he is pursuing.

Keywords: digital transformation, social innovation, empathy

Social innovation for supporting the future of regional communities

—Congratulations on your appointment as president. You came back to NTT EAST after an interval of two years, right?

Thank you very much. I go to work with the feeling that I have returned to my hometown. As soon as I became president, I composed, scripted, and produced a video tracing the origins of our telegraph and telephone business, which dates back to around the Meiji Restoration in 1868, and explaining NTT EAST's DNA of connection and down-to-earth style as well as the direction in which the company will transform itself with an eye on the future of society. At the same time, I made it a top priority to meet face-to-face with as many employees as possible by, first, visiting six regional business divisions to give presentations and hold dialogues.

The two years I have spent at the NTT holding company have been a period of great learning for NTT. I myself have reconsidered governance, transparency, and corporate culture, and while pursuing those important themes, I reaffirmed our social role when I recalled the words of an outside director who said,

"NTT's mission is not just that of our company. NTT can lead the transformation of society as a whole and thereby change Japan. Let's not forget that NTT has that mission, too." I take those words seriously and intend to put that mission into practice at NTT EAST.

In the situation where fiber-optic networks cover 99% of the population in Japan, aiming to help solve local issues, NTT EAST has launched new companies in the fields of agriculture, the arts, and e-sports, and we are striving to provide solutions that go beyond the boundaries of a telecommunication carrier.

By using these assets, we believe that now is the time to embark on initiatives to build a new recycling-oriented society and bring social innovation to support the future of regional communities. For instance, we are striving to provide consulting services on empathetic digital transformation (DX) developed from our community-based sales practice as well as strengthen practical on-site engineering that evolves our DNA of connection.

—The new vision is inspiring. What kind of expectations do your customers have?

Our assets are our abundant human resources. Our employees—who work in the community and love the community—are doing their best for the community. These employees include more than 10,000 front-desk sales staff, who are eager to make a difference in society, and engineers with a sense of mission, who are quick to rush to the scene of disasters to support the community. We will accelerate the construction of a new digital social infrastructure while digitalizing and transforming existing services and business operation systems by leveraging our rich human resources, telecommunication facilities, fiber-optic networks, and other assets.

Regarding this vision, I received feedback from our employees in the form of a questionnaire after distributing the video and visiting business sites for employee dialogue. The feedback was overwhelmingly positive, as exemplified by about 95% of employees agreeing with the vision. While some have commented on the gap between the vision and on-site reality or on the lack of a concrete roadmap for materializing the vision, it is important to start moving first so as to contribute to the community and lead the transformation of the community. To close gaps between the vision and on-site reality as we move forward, we are working with regional executives to begin developing workplace-specific directions and practical activities.

I also heard from customers who wanted us to solve social issues such as the declining birthrate, aging population, and lack of human resources and successors in agriculture, fisheries, and other sectors. Some customers are earnestly asking if there are any successors to preserve the cultural heritage and folk crafts that they have cultivated over the years so that they can pass them on to future generations as well.

Of course, we have listened to such voices, analyzed the issues faced by our customers, and proposed solutions. We have also been vigorously involved in solving the problem of lack of successors, working toward a recycling-oriented society, and revitalizing regional communities. From now on, however, we will address the challenges faced by customers with a new approach: social innovation that supports the future of the community. We are meeting local customers face-to-face, thinking together, and implementing our ideas through trial and error. We call these activities "empathetic DX consulting."

Each region of Japan has its own wonderful traditions and culture. Our empathetic value creation involves understanding that great value exists in a region and making that value even greater. Surely, it's more heartening to get people to understand your value and support you than to have them point out issues here and there and ask how to address them. In other words, we are orienting toward this type of DX that values the hearts and minds of customers. We will throw ourselves into regional communities, find value, and work with the local people to develop a mechanism that will lead them to the future. I believe that this approach is unique to NTT EAST, which has close ties to regional communities, and will help us create new value.

Look at issues with a zero mindset without being bound by a fixed viewpoint

—It is encouraging to see your positive frame of mind. What concrete initiatives for social innovation have you already started implementing?

Although some initiatives are already in motion, overall, they represent major initiatives that will take ten years to complete. Conventional problem-solving projects have alleviated the shortage of local labor, but they have not solved the underlying problems. Accordingly, we aim to solve the underlying problems by providing empathetic DX consulting services and strengthening practical on-site engineering to transform declining industries into those in which young people will dream of entering. As a company that is indebted to the community, we want to go as far to innovate society and change the structure of society. I'll give you specific examples of what we have already started.

First, in collaboration with Hokkaido University, Iwamizawa City in Hokkaido, NTT, and NTT DOCOMO, we are striving to (i) implement world-class smart agriculture that uses state-of-the-art autonomous driving technology for agricultural machinery, high-precision location information, 5G (fifth-generation mobile communication system), and artificial intelligence and other data-analysis technologies and (ii) create a model of sustainable regional revitalization and smart cities based on smart agriculture. Through innovation, this initiative aims to create a world in which contractors can use Iwamizawa's monitoring center to remotely monitor and control a large number of robotic farm machines and drones on local farms.

The next example is an initiative to preserve and disseminate digital archives of traditional craftsmanship and intangible cultural heritage in reginal communities as a measure to address the shortage of successors. We have created a system for preserving and sharing the decorative ceiling paintings by Katsushika Hokusai at Gansho-in Temple in Obuse, Nagano Prefecture as a digital archive and creating new viewing experiences through virtual reality. This initiative has also had the effect of increasing the number of travelers who visit the temple to see the actual paintings. We believe that we have contributed to attracting tourists to the regional community, revitalizing the town, and preserving and sharing of cultural heritage and traditional craftsmanship through DX.

We also concluded the "Tripartite Cooperation Agreement for Regional Revitalization" by using information and communication technology and new sports among Yokosuka City in Kanagawa Prefecture, NTT EAST, and NTTe-Sports to pursue new town development that promotes tourism and improve the convenience for citizen, and we provided support for planning and holding the "YOKOSUKA e-Sports CUP" tournament. We are also supporting online e-sports instruction and the creation of e-sports clubs in high schools and other institutions.

—What is your motivation behind vigorously pursuing the new value creation in regional communities?

Value in society is fluctuating, which is described as an era of VUCA (volatility, uncertainty, complexity, and ambiguity). Looking back to 1985, when I joined NTT, after the fall of the Berlin Wall in 1989, countries around the world were gradually uniting. However, we have recently entered into an era of decoupling, and despite calls for diversity, various conflicts have surfaced as a result of differences in positions and ideologies. Such situations necessitate that we better understand each other, help each other, and create a framework for efficient development on which diverse cultures can develop in a decentralized manner.

We hear a lot of voices from people in various positions in various places. To create new value in response to those voices, we need to think about what to reform and how to reform it. During that thought process, we should reset our minds to "zero (nothing)" so that we do not derive answers on the basis of hypotheses bound by a fixed viewpoint and preconceptions of the era of mass production and mass consumption as we have in the past. People's conventional sense of values since the industrial and information revolutions have not necessarily made people happy. Neither are they friendly to the global environment, and they may not be sustainable. I'd like to create new value without being bound by preconceived notions, etc., in the way that the philosopher Jacques Derrida challenged the Western philosophical tradition through his approach termed "deconstruction."

If you make decisions with your heart instead of your head, you will benefit all sides

—Since the first time we spoke, you have remained committed to "management from the heart." By the way, do you also maintain an attitude of "That's a good idea"?

My desire for "management from the heart"—which I mentioned two years ago—remains unchanged. Management is the practice of empathy, cooperation, and gratitude. If we can build a good relationship by striving to appeal to the heart rather than making decisions with our head, we can build a world in which companies can grow and contribute to society simultaneously. I also maintain a "That's a good idea" attitude, which means first accepting the idea positively. However, I have changed the slogan hanging on the wall in my office from "That's a good idea" to "The heart is important" to further emphasize the importance of the heart.

I sometimes think about "failure," which is related to the state of mind and feelings. As I mentioned earlier, when engaged in unprecedented social innovation without forming hypotheses bound by a fixed viewpoint and preconceived notions, we often won't know what lies ahead until we start trying things. No one wants to cause problems at work; however, the actual work is evaluated on a single-year or quarterly basis, and the people in charge of innovation become discouraged, thinking that innovation should be "within the scope of not failing." Therefore, if we are not allowed to fail, we will also miss the opportunity to identify problems and learn from the failure.

For that reason, I think innovation can't happen unless we become tolerant, saying, "It's okay to make good mistakes that will open up a path to new challenges." If we look at things with long-term thinking instead of short-term thinking, I believe that failure will be useful next time and lead to good results.

Having said that, I realize that even if we try to look ahead with long-term thinking, we may have to face reality and pursue profit. When confronted with reality, we tend to fall back to short-term thinking. At such times, I always try to look at things from a broader perspective in a way that balances short-term and long-term thinking. However, when I am faced with a difficult task that haunts me, I look up at the stars and think about the universe. The universe is 13.8 billion years old. Compared with the history of the universe on a timescale of 365 days, the history of humankind is less than five seconds old. Pondering

that fact and reminding ourselves that we humans are rather insignificant help me keep sight of the essence of long-term thinking.

—So it is important to look at things from a broader, longer-term perspective. President Shibutani, would you please say a few words to NTT researchers and employees as well as partner companies?

I expect researchers to make innovations that break through limitations, such as achieving nuclear fusion and building a hydrogen society. As we all know, research and commercialization of nuclear fission has progressed, but nuclear fusion is still in its infancy and is the subject of research at NTT Space Environment and Energy Laboratories. I also ask that you take on major research and development projects that will lead to breakthroughs in society such as the Innovative Optical and Wireless Network (IOWN), which aims to create a recycling-oriented society through the use of photonics-electronics convergence technologies. I hope that you will put your one achievement after another to practical use and propose them to the operating companies. Those achievements will then be implemented and refined in regional communities by us.

To partner companies, I hope you will share a purpose in regard to social innovation with us, stand on the front lines with us, and strive with us to create value for regional communities. We consider you to be part of our team and will convey our sense of purpose and our gratitude to you. I look forward to working with you as colleagues facing the same challenges.

To our employees, do not be afraid to take on the challenge of social innovation to support the future of reginal communities. I think that communities are probably watching our efforts and keeping pace with us. Again, look at a regional community in a manner you want to know well and enliven it, not with issue-oriented proposals or from a fixed viewpoint. By blending in with local customers and holding numerous discussions and making proposals, customers will recognize you as one of their own and welcome you saying "Let's do it together!" Let's do our best to appeal to the heart of customers. Employees tasked with maintenance and inspections may have few opportunities to directly interact with customers and obtain customer feedback, including appreciation. However, large-scale natural disasters are becoming increasingly common and the importance of our mission to support the communications infrastructure is increasing. I'd therefore like to continue to value having a sense of purpose to support society behind the scenes. I will be leading the way to fulfill our mission and send out messages of acknowledging your hard work.

Interviewee profile

■ Career highlights

Naoki Shibutani joined Nippon Telegraph and Telephone Corporation in 1985. He worked at NTT Department I, where he was engaged in operations targeting corporations beginning in 1999 then served as a senior manager of the Planning Department at NTT EAST starting in 2001 (and was a guest researcher at the Center for Strategic and International Studies (CSIS), Washington, D.C.). In his career at NTT EAST, he also served as the department manager of the Plant Planning Department, Plant Section, Network Business Headquarters; manager of the Fukushima branch office; executive manager of the Medium-term Management Strategies Promotion Office of the Corporate Strategy Planning Department; senior vice president and executive manager of the Plant Planning Department, Network Business Headquarters; senior vice president and executive manager of the Tokyo Olympic & Paralympic Games Promotion Office; senior executive vice president and senior executive manager of the New Business Development Headquarters; president & chief executive officer of NTT Vietnam Corporation; senior executive manager of the Digital Transformation Headquarters; and president & chief executive officer of NTT e-Sports Corporation. He became senior executive vice president of NTT in June 2020. He assumed his current position in June 2022.

Exploring Peripheral Areas with an Inquisitive Mind and Curiosity

Tessei Kobayashi
Senior Distinguished Researcher,
NTT Communication Science Laboratories

Abstract

In Japan, the Act on Promotion of Children's Reading was enacted in 2001. With the rapid increase in the number of middle- and high-school students owning smartphones and the launch of the government's GIGA School program for creating an environment in which every student has one device connected to the Internet, the impact of reading habits during infancy on the academic performance of children is attracting attention. We interviewed Tessei Kobayashi, a senior distinguished researcher at NTT Communication Science Laboratories, about the progress of his research activities to elucidate the mechanisms of children's language development and using these mechanisms to support education.

Keywords: language development, personalized picture book, social-emotional development

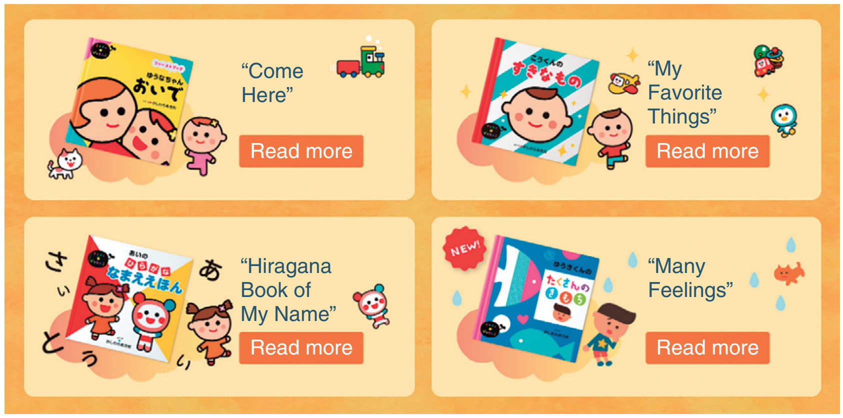
Create human-friendly interaction technology based on scientific evidence

—Could you tell us about your current research activities?

In the field of human development, I'm researching the mechanisms of children's language development and using these mechanisms to support education. With the goal of creating human-friendly interaction technology based on scientific evidence, I'm implementing systems on the basis of a deeper understanding of human development and attempting to advance such technology by verifying them in the field. Put simply, I'm trying to understand the mechanisms by which children naturally learn a language, and I'm devising enhanced methods—on the basis of this understanding—for supporting individual children's language development by, for example, using psychology, data science, and language-processing technology.

Children generally acquire the basics of their native language by approximately 3–4 years of age. Focusing on how infants learn the vocabulary, syntax, and letters that make up a language, I'm attempting to elucidate the mechanisms and factors that affect language development by conducting detailed laboratory verifications and field surveys at nursery schools and medical facilities.

I've also started research on children's social-emotional development. I'm investigating how we can measure this social-emotional skill and use the findings to support children's development. I'm also focusing on the environment surrounding children by investigating the characteristics of language development of children admitted to residential childcare



The above picture books are authored and illustrated by Akio Kashiwara.

Fig. 1. Personalized Educational Picture Books (on sale from NTT Printing).

facilities and regional differences in reporting abuse to child-guidance centers.

While striving to enhance the Japanese Word Familiarity Database that has been continuously researched and updated by our laboratory as basic language resources in fields such as psychology, linguistics, and natural language processing, I've also begun researching language development in hearing-impaired children and children with cochlear implants.

—It seems that evidence-based support for comprehensively understanding the environment surrounding children will significantly contribute to society. Could you tell us about the specific findings of your research?

I'll give some examples including projects spun off from basic research. The long-term effect of reading books to children has been attracting much attention. For example, one study [1] found that the frequency of book reading by parents to children aged 1 to 2 years is correlated with receptive vocabulary, reading comprehension, and intrinsic motivation to read at age of 8 to 9 years. This correlation remained after statistically taking into account parental education and family income (socioeconomic status: SES). Considering such previous studies, my research colleagues and I believed that supporting book reading to Japanese children from an early age would be effective in enhancing their education and social investment.

As I mentioned in the previous interview, my graduate studies in infant psychology led me to supervise an educational television program for young children after I joined NTT. In that role, I found that although the program staff had sufficient knowledge, the program was not structured on the basis of scientific evidence. I felt the need for scientific evidence on language development when one program staff commented, "It would be reassuring if we had guidelines based on scientific data on language development."

Considering this background, we built two databases that are among the largest of their kind in the world. One, called the Child Vocabulary Development Database, is based on vocabulary-checklist data collected from 1500 children aged 0 to 4 years. According to the data in this database, the first word a child understands is the child's own name, which about 50% of children can understand by the time they reach about 7 months. In terms of the age at which children can speak, about 50% of children can say the word "bow-wow" at 15 months, while it takes them until 26 months to say "dog." They can also understand and use words for social communication, such as "peek-a-boo!" at 14 months and "bye-bye" at 17 months.

This database is used to create Personalized Educational Picture Books, which is a series of individually optimized picture books that reflects each child's interests and development, including their names, favorite things, and words that the child will learn (**Fig. 1**). For example, one of the books, "My Favorite Things," for 1- to 2-year-olds, was created by selecting words to be learned on the basis of estimations

Upper left: How old are you?; bottom left: What kind of books would you like to read? (Nature/Animals/Food/Body/Vehicles/Ghosts/Princesses/Various); bottom right: The perfect picture book for you!

Fig. 2. Pitarie-Touch (left) and its screenshots.

from the Child Vocabulary Development Database.

Cooperating with local governments to verify the effect of personalized book-reading support

—The development of the largest database of its kind in the world is a significant achievement both academically and socially. Please tell us about the other database and the associated field survey.

The other database, the Picture Book and Children's Book Database, was constructed by inputting the entire text of approximately 6000 picture books. We created this database when we developed a picture-book search system called *Pitarie*, and it was initially intended to be used to clarify what words appear in each picture book and how the frequency of words in picture books correlates with the vocabulary development of young children. Pitarie is the world's first artificial intelligence system in the field of picture books and children's books and combines the Child Vocabulary Development Database with functions such as graph-indexing similarity search and natural-language processing to enable users to retrieve picture books that match children's interests and developmental stages.

Beginning in 2019, Pitarie was introduced sequentially at the Fukui Prefectural Library, nursery schools in Tokyo, and other locations. Many people have had the opportunity to use the system. As a more advanced version of Pitarie, Pitarie-Touch consists of a robot called Sota* that recommends the picture book to a user after asking a series of questions (**Fig. 2**).

The Personalized Educational Picture Book "Hiragana Book of My Name" was created on the basis of the results of using the Picture Book and Children's Book Database. Analysis of this database revealed two key points. First, when children learn letters, they learn to read from letters that appear frequently in picture books [2]; second, the degree to which they see and hear each letter is a key factor in their vocabulary acquisition. However, if we consider children on an individual basis, we see that individual children will probably also be looking at the letters of their names quite often as well. Accordingly, we decided to create a picture book in which letters of each child's name frequently appear in the text and encourage the first step of letter acquisition in a way that is adapted to each child's language environment.

This picture book contains special pages related to the child's name. For example, if the child's name is "Akari," pages such as "'A' is for *aisu-kuriimu*" (ice cream, in Japanese) or "Let's find 'A' on this page" appear (**Fig. 3**). If the child rubs or pokes the letters of their name to open the next page, the letters will become larger or smaller. I hope that by having fun reading the picture book while touching the letters of their names in this way, the child will acquire letters naturally.

—We have heard that field surveys using Personalized Educational Picture Books and Pitarie are expanding.

In the last interview, I talked about us cooperating with Onna Village in Okinawa Prefecture from January 2020 to encourage children to go to the library by

* "Sota" is a registered trademark of Vstone Co., Ltd.

Fig. 3. Hiragana Book of My Name (authored and illustrated by Akio Kashiwara).

creating a Personalized Educational Picture Book for parents and children who came for infant-health checkups. In accordance with the Joint Research Agreement on Promotion of Reading for Lifelong Learning concluded among Nishinomiya City, Hyogo Prefecture, NTT Printing, and NTT, we are investigating the possibility of facilitating parent-child picture-book-reading activities by providing the Personalized Educational Picture Books and installing Pitarie at libraries.

Specifically, at the health checkup for one-and-a-half-year-olds, we distribute application tickets for the Personalized Educational Picture Books, and applicants for the book can create their picture book online. Between October 2021 and March 2022, half of the approximately 2000 people eligible for the health checkup applied for the picture book "My Favorite Things."

About 400 application tickets for "Hiragana Book of My Name" for 2- to 5-year-olds were distributed at each library from January to March 2022, and more than 90% of the applicants signed up. A follow-up survey revealed that about 80% of the children liked the book, and about 60 to 70% of the families of those children read the book at least once a week.

In 2021, Pitarie and Pitarie-Touch, which children can use, were installed in three libraries in Nishinomiya City, and approximately 20,000 searches were conducted for the former, and approximately 30,000 people used the latter. More than half of the users of Pitarie-Touch were children aged up to 5, meaning we successfully reached the target demographic. In fact, during our observations at the libraries, we noticed many children taking the picture-book list output from the receipt printer and taking it to the counter. I wondered how the child perceive the information recommended by the robot. That is an interesting question for child psychology.

—You are also researching children's emotions and environment. What have you discovered?

We examined differences in the types of language conveying emotions ("emotion words" hereafter) and their tendency to appear in parental speech and picture books. We first created a list of 770 emotion words for Japanese-speaking children by referring to previous studies and emotional-expression dictionaries. We then analyzed the frequency degree to which these emotion words appear in a database of picture books and children's books (about 6000 books) and in a corpus of parent-child conversations (448 conversations). The results of the analysis showed that picture books contain a greater variety of emotion words than parental utterances. Looking at the top-twenty words with the highest frequency, we also found a qualitative difference; namely, positive-emotion words appeared more frequently in picture books, whereas negative-emotion words appeared more frequently in parental utterances.

We also compared data on vocabulary development of children raised in family environments and those raised in residential childcare facilities to analyze how environment affects the vocabulary development of children. The results of the analysis showed that there was no significant difference between both environments in terms of the number of words they could speak and the order in which they acquired words [3]. Among the children raised in residential childcare facilities, however, those who had been abused showed some delay in vocabulary acquisition.

Considering these results and looking at the picture-book initiative, I feel the importance of creating a support system that reaches parents and children who really need it. During the COVID-19 pandemic, I heard a speech therapist say in regard to remote training, "The digitization of existing language training tools has not been progressing, and since it violates copyright law, we can't digitize such tools without permission, and we haven't been able to provide enough training." Therefore, our next challenge is to create a system, including original digital support tools, that supports the development of children by collaborating hand-in-hand with medical professionals and people in the social-welfare field.

A researcher is someone who deciphers the laws of nature

—What is important to you in your research activities?

I believe that an attitude of inquiry is critical and place great importance on conducting research by switching between field and laboratory work. Inquiry-based learning has been included in the curriculum guidelines for high school students in Japan, and I believe that its importance has been felt throughout our country. Even the youngest children have curiosity or a budding spirit of inquiry, don't they? I have been wondering lately about how to nurture and support children's spirit of scientific inquiry, and I believe that if I conduct research without this spirit of investigation, I will not be able to make discoveries or create technologies through my research.

With that thought in mind, I'm applying an inquisitive mind and curiosity to not only my area of expertise but also to related areas. Of course, it is essential to delve deeply and profoundly into specific research topics; even so, in pursuing my area of expertise, I want to observe not only the children but also their environment and their social, historical, and geographical backgrounds to understand things from a broad perspective. In that sense, field surveys and cooperation with researchers and others in peripheral areas are necessary.

I'm fortunate that my superiors and others around me allow me to pursue research themes (such as infants and education) that are rare at NTT and that I can conduct research that contributes to society. To gain an understanding of those around me regarding my research activities, I try my best to set research themes that strike at the essence of the subject and explain to them my research purpose and significance.

For that reason, passion is more important than anything else, and even at the proposal stage, a plan without passion will be noticeable. Recently, I've been having a lot of discussions with the younger group members about how to make other people understand our research plans. I think that repeating these discussions fosters skills to communicate with passion.

—Finally, what do you think is the essence of being a researcher? What would you like to say to the younger generation?

I believe that a researcher is a person who deciphers the laws of nature. In that sense, in my research on human development, I want to support the development of children by deciphering their naturally nurtured rules while considering environmental factors.

Research is a time-consuming activity; that is, research planning, data collection and analysis, writing papers, and preparing materials for presentation; it takes time to get it right. In other words, it is not so easy to plan, analyze, write papers, and prepare materials, so you have to spend much time and gradually develop your skills as a researcher.

During those activities, researchers listen to the words of many people, but in the end, they follow what they believe in. That belief is the "sense" of each researcher. What I mean by "sense" is the ability to notice things that are not visible. Even when people with the same level of knowledge, skills, and experience look at the same thing, some people will notice what is hidden in it, while others will not. I want to become a researcher who can decipher the laws of nature as much as possible with the ability to notice those invisible things.

I hope to work with young researchers who are full of vitality and take the challenge of conducting research that overturns established theories and proposing methods that strike at the essence of the subject, no matter how difficult it may be.

Selecting a research theme is therefore critical. I want to conduct research that strikes at the essence of the subject; however, I don't know how to conduct such research and where to start to reach the goal. As I mentioned, I also conduct field surveys outside the laboratory, but that approach is not always the right one. In other words, I myself have not yet found the answer to the question of how to conduct research that strikes at the essence of the subject.

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■ Interviewee profile

Tessei Kobayashi received a Ph.D. in psychology from the University of Tokyo in 2004. His research interests include child language development, specifically vocabulary spurts and syntactic bootstrapping.

Understanding Brain Mechanisms by Integrating AI and Brain Information Analysis toward an Inclusive Society

Tomoyasu Horikawa
Distinguished Researcher, NTT Communication Science Laboratories

Abstract

Artificial intelligence (AI) based on deep learning technologies has been appearing in many social situations in recent years, and research using these technologies has been progressing even in the research field of brain data analysis. We sat down with NTT Distinguished Researcher Tomoyasu Horikawa to talk about his research on "understanding brain mechanisms by integrating AI and brain information analysis" that aims to achieve an inclusive society by combining deep learning and brain information decoding technology.

Keywords: brain decoding, deep learning, fMRI

Achieving a deeper understanding of brain information representation by combining AI and brain information analysis

—Dr. Horikawa, please tell us about your research on "understanding brain mechanisms by integrating AI and brain information analysis."

My aim in "understanding brain mechanisms by integrating artificial intelligence (AI) and brain information analysis" is to deepen our understanding of brain mechanisms by combining machine learning-based AI models and "brain decoding" technology. The machine learning-based AI models have come to be used in many practical situations in recent years, and deep neural network (DNN) technology, or deep learning, which has been a typical AI model, has recently come to have an even greater impact on brain research. For a deeper understanding of the brain, I have studied means of combining such DNN technology and brain decoding, which statistically analyzes brain signals and deciphers the information represented in the brain (**Fig. 1**).

When I began my research, brain decoding technology was mainly applied to simple categorization problems with a limited set of objects (or classes) to be predicted, as in "let's guess if the object that a person is viewing is a human face or the image of a house by analyzing brain activity measured when an image of another human face was being presented." As technology has advanced, I have come to realize that an approach that deciphers an even greater diversity of objects could be achieved by treating the signals of an AI model (DNN), which approximates the information processing in the human brain, as the target of brain decoding.

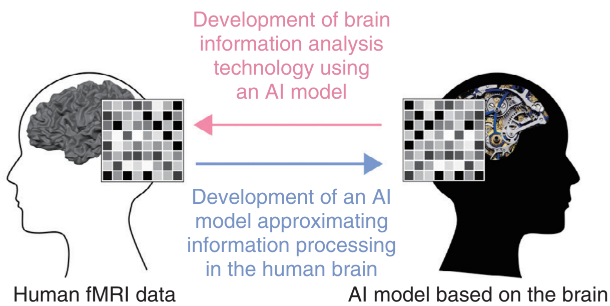


Fig. 1. Concept of understanding brain information representation using an AI model representation.

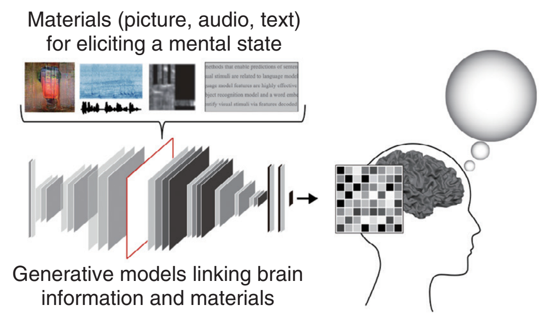


Fig. 2. Research goal: induce intended information by generating optimal stimuli based on brain information.

—What kind of method do you use in "understanding brain mechanisms by integrating AI and brain information analysis technology"?

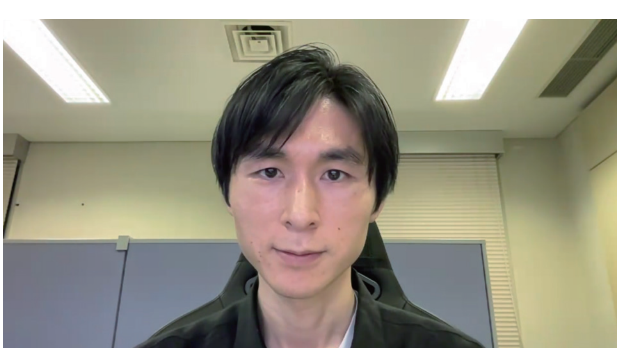
The specific method that I'm using to advance my research uses data from functional magnetic resonance imaging (fMRI) that measures brain activity and a DNN model (artificial brain) that mimics the information processing in the brain. Our approach compares information representations between the human brain and the artificial brain and analyzes the human brain using the artificial brain. Based on this method, I am studying how a variety of perceptual elements are combined and represented in the brain, as in the relationship among multiple elements in a situation like "a person is riding in a car" and not simply "Is the thing that is being viewed a person or a car?" In short, in addition to individual perceptual objects in isolation, my research seeks to answer how individual elements relate to and interact with each other and how recognized information on overall meaning is represented in the brain.

In one of my previous research projects, I investigated how various types of information related to emotions are represented in the brain. A previous psychological study from another group has shown that human emotional responses could be described not only by a few categories of basic emotions such as sad or happy but also by a variety of finer categories with greater accuracy. For example, it is said that negative emotions can be classified into finer categories such as fear, horror, or disguise. Our previous study has further shown that such information related to a variety of emotions is represented in the brain based on a rating score given by a subject in response to a video. Even for this research topic, I expect that using an artificial brain, such as a DNN model, could provide an effective means of understanding emotional representations in the brain.

The research goal shown in **Fig. 2** is to generate material that induces an intended image or emotion by creating optimal pictures, audio, or text that explain specific brain states based on brain data. For example, if it can be determined how information related to emotions is represented in the brain, it may then be possible to generate images that induce targeted emotions by using brain data and DNN to generate images that intensely induce certain patterns in brain activity corresponding to those emotions.

At the laboratory that I previously belonged to, a pioneering study was being conducted on reconstructing visual images that a person was viewing based on brain data. In the early stages of that research, a visual image that was being viewed was successfully reconstructed based on brain activity data when viewing a simple pattern such as a letter or diagram as the target image. Then, in the research that I was involved in, we successfully visualized visual images for more naturalistic pictures with higher resolution using DNN technology. In past research, pictures that could be reconstructed were monochrome images 10 × 10 pixels in size, but in recent research, it has become possible to reconstruct a picture with a resolution of about 200 × 200 pixels in size reflecting detailed patterns consisting of color, object shapes, eyes or faces of animals, etc. Here, to achieve this level of accuracy, we have proved to be effective to use the knowledge that visual information is processed in a hierarchical manner in either the human brain or artificial brain (DNN). It is known that information of different levels of complexity is hierarchically represented in the brain. For example, simple visual features such as "line segments with a certain slope" are represented in low-level regions of the brain, while features having complex shapes or patterns are represented in high-level regions. In the same way, we are coming to understand that each layer in a DNN model acquires information representations related to features that gradually increase in complexity. I believe that we have achieved such high accuracy by making use of this similarity in hierarchical representation between the human brain and artificial brain and reconstructing images using all hierarchical information from low to high levels represented in activity in the human visual cortex.

In the course of conducting such research, I am careful "not to be fooled by chance variations in the data" and to "correctly grasp what information is really represented in the brain." In particular, as brain data are often high-dimensional and are analyzed by complex analytical procedures, there is the risk that a slight change somewhere to analysis parameters might generate what appears to be a positive result at first glance. It is certainly difficult to ascertain whether experimental data happens to show a chance positive result or reflects the true state of the brain, but we must be extremely careful not to be fooled. For this reason, I constantly ask myself, "Am I really getting correct information?" while keeping in mind the importance of correctly and faithfully carrying out the experimental plan and the procedures for data collection and statistical analysis. In addition, recent advances in AI technology enable the information decoded from the brain to be skillfully modified. For example, it is now possible to use AI to show reconstructed visual images from the brain with finer resolutions. Extracting (translating) information represented in the brain in a form that can be easily interpreted is itself important in terms of applications. However, when we consider the use of DNN with the goal of understanding the brain, it is important to correctly understand to what extent are the obtained results based on brain information and where those results have been modified by AI.



Creating an inclusive society by understanding brain mechanisms

—Please tell us your outlook for the future using "understanding brain mechanisms by integrating AI and brain information analysis technology."

Looking to the future, I would like to expand my research in the direction of extracting information on subjective experiences represented in the human mind, developing new technologies related to my research themes such as visualization and externalization, and making practical use of technology for quantitatively evaluating information in the human brain. For example, in relatively new research conducted over these last ten years, it has been found that, when asking people to think of an apple, there are individuals who can vividly imagine a red apple with a fresh surface, whereas there are individuals that cannot imagine anything due to a condition called "aphantasia." In my research up to now, I have been quantitatively evaluating how mental images visualized by people are represented in the brain. So using the same technique, I would like to investigate what state the brain is in when people with aphantasia attempt to generate mental imagery. Understanding the state of the brain in people without mental imagery and widely reporting our findings may help society obtain a better understanding of aphantasia and people with this condition. I hope that promoting such an understanding will lead to a more inclusive society.

—Dr. Horikawa, please leave us with a message for researchers and students.

At present, I am a member of the Sensory Representation Research Group in the Human Information Science Laboratory of NTT Communication Science Laboratories, and the full support that NTT has given me in conducting my research has been great. For example, the MRI that I use for making brain measurements is equipment that generates a powerful magnetic field, so it is necessary when presenting a subject with stimuli such as an image or audio to use a special non-magnetic device that can be used even in a high-magnetic-field environment. In addition, repeating experiments many times under a trial-and-error process and collecting large amounts of data can incur high experimental expenses. However, over the one year since coming to NTT, the company has supported the installation of that experimental equipment and associated experimental expenses, although there had previously been no experimental environment for brain research at all in the institute. NTT has also been quite generous in procuring for me the software and hardware necessary for brain analysis. I feel that being able to pursue one's research freely and energetically in such an environment is NTT's strength. In this research environment, there are certain feelings of "joy when a paper is accepted" and "happiness when obtaining a deeper understanding of a research target." However, rather than working hard day in and day out to once again experience such joy, I feel that living a life in which I go to bed every night having thoughts like, "If I try that tomorrow, things should go well!" and wake up every morning excited about getting out to my research laboratory thinking, "OK, let's try this idea today!" is also what makes research worthwhile and even delightful. Within my long research life, I can now enjoy my research every day thanks to this NTT research environment.

On the other hand, if society is not running well, cuts may occur in the national budget for research, and it may be hard to obtain the understanding of people working in ordinary companies or of the general public with regard to research. Many other difficult situations can arise as well, such as a lack of young people who would like to become researchers or the inability of excellent researchers to continue their research. Nevertheless, I firmly believe that research has value regardless of the time or era. Conducting research by a correct method based on a variety of ideas by many people has value, and even if there are only a few people who consider a certain research theme interesting, I think that an accumulation of research conducted by individual researchers can go on to create the world of the future. No matter how small in scale research may be, I believe that an accumulation of research projects carried out by correct methods has value. My message to everyone, and to myself as well, is "Let's do our best while believing in our own personal value!"

■ Interviewee profile

Tomoyasu Horikawa received his Ph.D. (Doctor of Science) from the Graduate School of Information Science, NARA Institute of Science and Technology in 2013. He entered NTT in 2021 and is currently a member of NTT Communication Science Laboratories. He has been a distinguished researcher since 2022. His research aims to integrate computational models inspired by the brain and brain data analysis technology. He is the recipient of the 33rd Telecommunications Advancement Foundation Award (Telecom System Technology Award) and the Best Paper Award of the Japanese Neural Network Society among other awards.

Overview of Space Integrated Computing Network

Kosei Suzuki, Shigehiro Hori, and Tomoyuki Kanekiyo

Abstract

There is an urgent need to ensure the sustainability of social activity. This makes it all the more important to use space for information and communication technology (ICT) infrastructures. This involves creating ICT infrastructures that support a number of fields, including energy, environment, and disaster prevention. To this end, NTT and SKY Perfect JSAT have established a joint venture company, Space Compass Corporation, that will launch a novel space ICT infrastructure, the Space Integrated Computing Network. This article gives an overview, business outline, and future prospects of this network.

Keywords: space, computing, network

1. Challenge for new space infrastructures

There is an urgent need to ensure the sustainability of economic and social activity. This makes it all the more important to effectively and fully use stratospheric and near-Earth space for information and communication technology (ICT) infrastructures. This involves creating ICT infrastructures that support a number of fields, including energy, environment and climate change, disaster prevention, marine infrastructure, and security. Novel technologies and architectures are needed to build these ICT infrastructures in outer space.

NTT and SKY Perfect JSAT established a joint venture company, Space Compass Corporation, on July 20, 2022 to expand the utilization of space by humankind, building on the knowledge they have gained over many years spent on technological development and in commercial activity as terrestrial and space infrastructure companies [1, 2].

The establishment of the joint venture is a step toward building the Space Integrated Computing Network announced in the 2021 collaboration agreement [3]. By taking on the challenge of creating new infrastructures, starting with the optical and wireless communication network to be built in space and the mobile network to be built in the stratosphere, the joint venture will contribute to the development of the global space industry and actualization of a sustainable society.

2. Space Integrated Computing Network

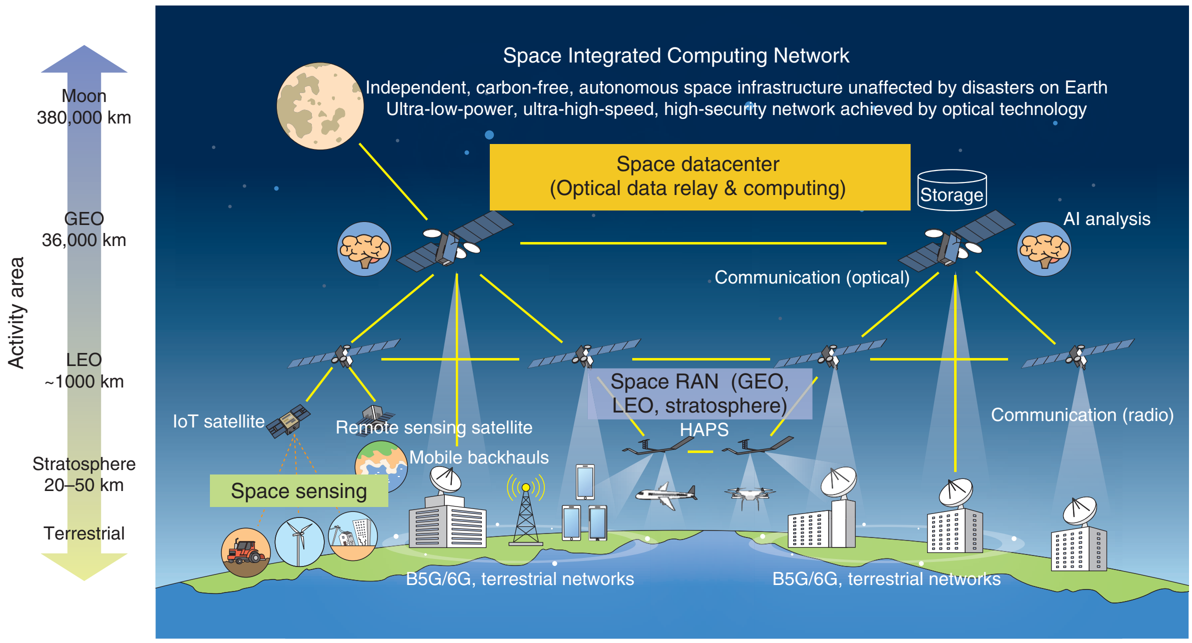
The Space Integrated Computing Network is a novel infrastructure to be built by combining NTT's network/computing infrastructure and SKY Perfect JSAT's space assets/business (**Fig. 1**). It will integrate multiple orbits from the ground to high altitude platform stations (HAPSs) flying at high altitude, low Earth orbit (LEO) satellites, and geostationary orbit (GEO) satellites. They will be connected to the ground through an optical wireless communication network to form a constellation to enhance various data processing by distributed computing. It will also provide access to terrestrial mobile devices for ultra-wide service coverage.

3. Outline of planned business projects

The following is a summary of the business activities to be undertaken toward the actualization of the Space Integrated Computing Network.

(1) Space datacenter project: high-capacity communication and computing infrastructure in space

Using photonics-electronics convergence technology,



AI: artificial intelligence
B5G: Beyond fifth-generation mobile communication network
IoT: Internet of Things

Fig. 1. Space Integrated Computing Network concept.

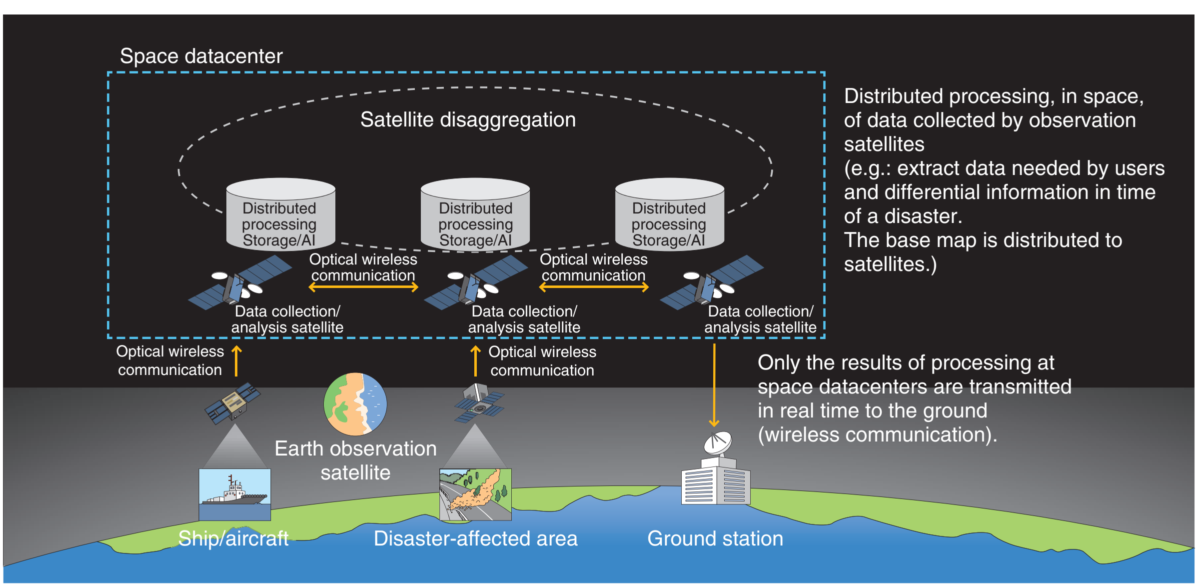


Fig. 2. Space datacenter project.

which reduces power consumption, and high cosmic ray resistance of computing resources, we will establish a computing processing platform in outer space and launch a service using this platform (**Fig. 2**). Distributed computing using high-capacity optical communication technology will enable a variety of

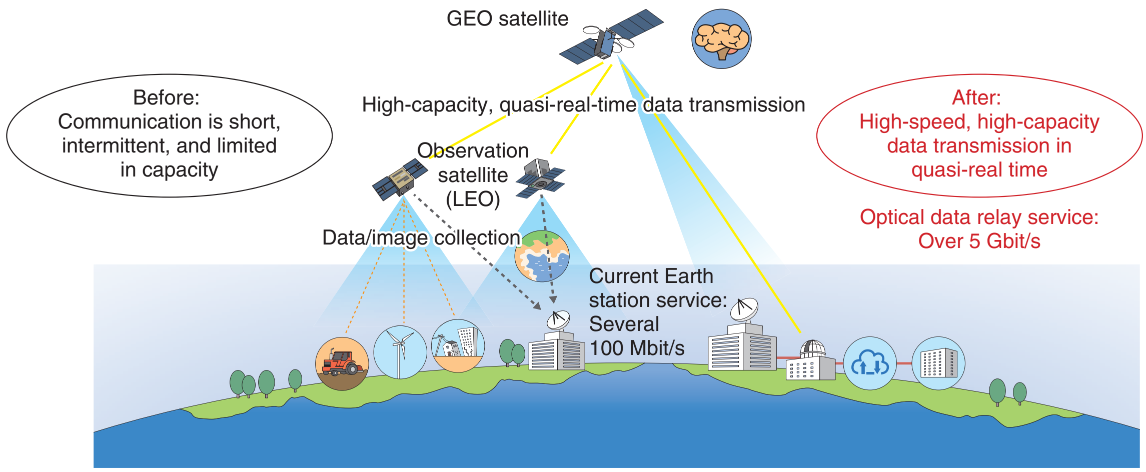


Fig. 3. Space optical data relay service.

advanced data processing. For example, a huge volume of diverse data collected in outer space will be instantly gathered and analyzed over a high-speed optical communication network, and only essential information will be delivered to users who need that information. This will dramatically enhance both real-time usage of space data and user convenience.

In FY2024, Space Compass will launch an optical data relay service (**Fig. 3**) for high-speed transmission to the ground via a GEO satellite as its initial business activity. This will carry a vast amount of diverse data collected in space by Earth observation satellites. Current services, which transmit data directly to ground stations, have communication-capacity limits imposed by the use of radio waves as well as limits on the time at which ground stations can communicate with observation satellites. In contrast, optical transmission via a GEO satellite will enable high-capacity, quasi-real-time data transmission. The communication speed is about 10 times faster than current services, and data can be transmitted immediately at any given time. The use of optical wireless communications has the advantage of eliminating the need for licensing adjustments required for conventional wireless communication services. For Earth observation satellite operators as customers, there is the advantage of improved observation satellite capabilities and increased operational efficiency.

(2) Space radio access network (Space RAN) project: communication infrastructure for Beyond 5G/6G

Using satellites (LEO, GEO) and HAPS [4, 5] expected to be used for Beyond fifth-generation mobile communication network (5G)/6G, we will establish a mobile communication platform and use it to launch an access network service (**Fig. 4**). This will further enhance the convenience and value of mobile communication. For example, a highly reliable messaging service can be provided, and ultra-wide-area service coverage can be achieved.

Space Compass will use HAPSs to provide low-latency communication services in Japan in FY2025 as its initial business activity. HAPSs make it easy to expand communication-service coverage to a wider area. Thus, it is possible to provide highly reliable communication in times of disaster, high-capacity communication for ships and aircraft, and communications services for distant islands and remote areas. Mobile carriers can improve the overall cost-effectiveness and energy efficiency of their mobile networks by combining HAPSs with an increase in the number of their terrestrial base stations to expand their service coverage. HAPSs will enable end users to better communicate via smartphones for everyday use in distant islands and remote areas.

(3) Space sensing project: terrestrial and space sensing data integration infrastructure

In addition to observation data captured by conventional observation satellites, we will establish an integrated space and Earth sensing infrastructure that uses the world's first LEO satellite multiple-input and multiple-output (MIMO)* technology to collect data

* MIMO: A technique for multiplying the capacity of a radio link using multiple transmission and receiving antennas to improve the quality of wireless communication.

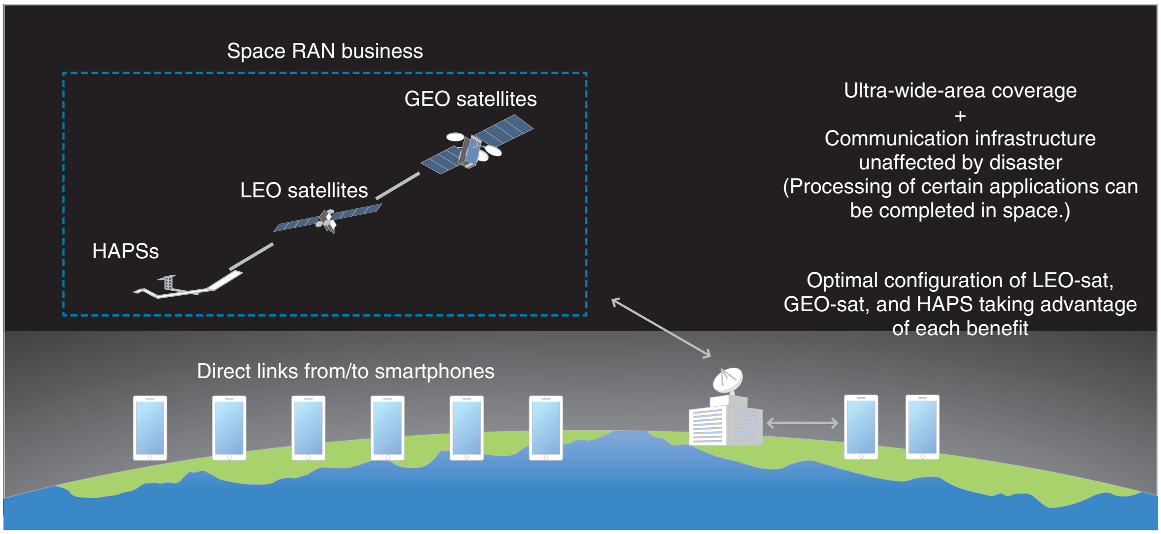


Fig. 4. Space RAN project.

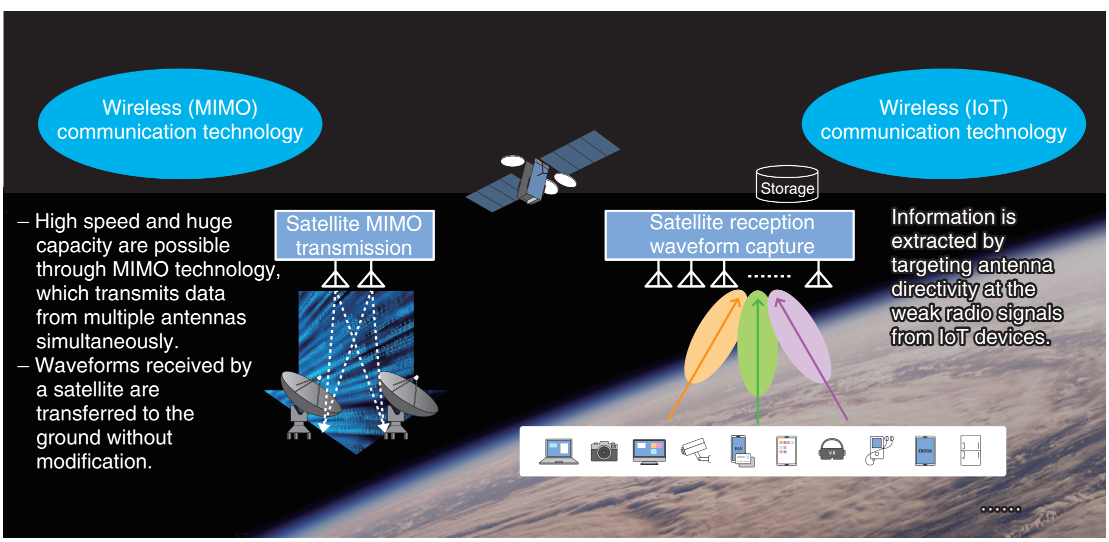


Fig. 5. Space sensing project.

from Internet of Things (IoT) terminals installed around the Earth and provide a service using this infrastructure (**Fig. 5**). This technology is scheduled to be demonstrated in orbit by the Japan Aerospace Exploration Agency (JAXA)'s Innovative Satellite Technology Demonstration No. 3, which is scheduled for launch in 2022. We will also develop a sensing technology that uses terahertz radio waves to visualize information that would ordinarily be invisible, thereby enhancing the value of space data and expanding its potential use.

4. Research and development for commercialization

There are various technical issues to be addressed for the commercialization of the Space Integrated Computing Network. The Feature Articles in this issue introduce the main technologies that have been researched and developed to address these issues, including technology overviews, use cases, and value to be provided.

(1) Event-driven inference for space computing: An overview of computing technology for edge processing of a huge volume of data in space by distributed computing to improve real-time performance and user convenience of space data utilization [6].

(2) Efforts toward commercialization of HAPS in Space RAN: An overview of use cases of HAPS, and configuration and control technologies of HAPS and terrestrial coordination network for providing super coverage, high reliability, and low-latency communication services [7].

(3) Satellite sensing platform: An overview of satellite sensing technology that extracts weak radio waves from inexpensive IoT terminals by targeting antenna directivity, and high-capacity transmission technology that transmits received satellite waveform data directly to the ground, as well as in-orbit demonstrations, to provide ultra-coverage and low-cost sensing [8].

5. Future prospects

Space Compass will start the two businesses/services mentioned above as the first step in the Space Integrated Computing Network initiative then gradually strengthen them. For the space datacenter, the company will steadily increase the number of satellites equipped with advanced computing functions to build a high-capacity communication/computing processing infrastructure in space. The company will also demonstrate NTT's high-capacity optical communication technology in space at Expo 2025 Osaka, Kansai, Japan and plans to deploy its services globally thereafter.

For Space RAN, Space Compass plans to study the provision of image sensing using HAPSs. The company will also add and integrate GEO and LEO satellites to expand service-area coverage and increase the communication capacity per HAPS by developing radio communication band broadening technology.

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Kosei Suzuki
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He received an M.E. in electrical engineering from the University of Tokyo in 1998. He joined NTT the same year and was engaged in research and development on an Internet protocol-virtual private network, network application system and network virtualization, and network planning and communication equipment procurement. Since 2021, he has been engaged in an alliance-promoting project in the area of space in the Research and Development Planning Department at NTT. He was transferred to Space Compass in 2022 and has been engaged in space datacenter business.

Shigehiro Hori
Co-CEO, Space Compass Corporation.
Since joining NTT in 1996, he has led multiple interdisciplinary projects on new business and service development in NTT WEST. In 2017, he became responsible for designing and building a space business in the Research and Development Planning Department at NTT, which led to establishing Space Compass, a joint venture between NTT and SKY Perfect JSAT. He received an MBA from the University of Washington.

Tomoyuki Kanekiyo
Vice President, Research and Development Planning Department, NTT.
He received a B.E. in applied physics engineering from Osaka University in 1992. Since joining NTT the same year, he has been researching video-distribution systems and ultra-realistic communication systems and developed a commercial IP television system. He assumed his current position in 2021.

An Event-driven Inference Approach for Space Computing

Takeharu Eda, Ichibe Naito, Ikuo Yamasaki, Keiichi Tabata, and Xu Shi

Abstract

NTT Software Innovation Center (SIC) has started research and development on a space computing platform on the basis of its experiences in cloud computing and artificial intelligence (AI) inference platforms. This article introduces SIC's views on space-computing-platform requirements, related technologies, and an evaluation of an event-driven AI inference in space computing. As a result of preliminary experimentation, we found that our event-driven AI inference technique may reduce latency and transfer-data size and achieve almost real-time analysis service using observed data in space by further optimizing and improving event-detection models for space.

Keywords: space computing, space datacenter, AI inference, event-driven data processing

1. Toward space computing platform

With the development of remote sensing technologies from Earth observation satellites, it has become possible to observe the ground from space and conduct advanced analysis using artificial intelligence (AI). This technology is being used in a variety of use cases using observation data that cannot be acquired on the ground. However, due to the limited number of available satellites and huge volume of observation data, it often takes several days before actual analysis becomes possible, making it difficult to provide real-time services. To tackle these challenges, NTT aims to construct a *space datacenter*, which is a space computing platform where we can analyze observation data in real time in space and send only important information to the ground using a high-speed transmission network service, reducing unnecessary data transfers and latency.

NTT Software Innovation Center (SIC) has started research and development on a space computing platform on the basis of its experiences in cloud computing [1] and AI inference platforms [2]. This article introduces SIC's perspective on space-computing-platform requirements and related technologies.

2. Technical challenges in space computing

Space computing literally means computing in space, but there are many differences in assumptions compared with computing on the ground. Since the amount of available power in space is limited by the capacity to generate electricity with solar panels, computers in space are required to be power-efficient. Once a computer is launched into space, it is not easy to repair it, so high reliability and stability are required. We also need countermeasures against space-specific difficulties such as radiation, inability to use air for cooling due to the vacuum, microgravity, and temperature. Due to the development and verification time required against these challenges, computers currently in space are several generations older and their performance is significantly lower than that of computers on the ground. These hardware limitations have made it difficult to develop software, forcing us to program in a low-level environment as in embedded systems. However, there have been efforts to tackle these technical challenges for space computing.

Server manufacturers and chip venders have started experiments in space with their commercial off-the-shelf products. For example, Hewlett Packard

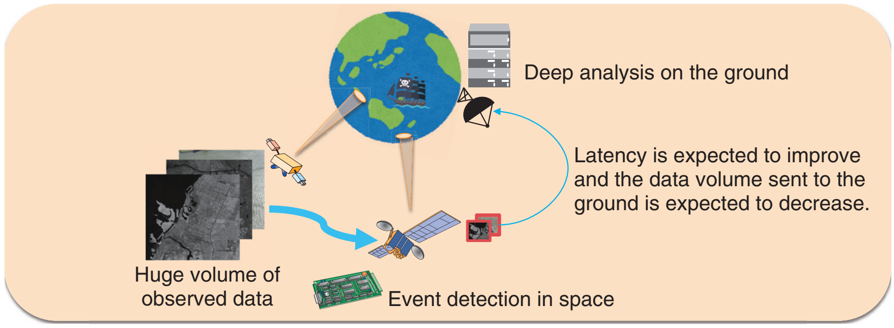


Fig. 1. Event-driven data processing in space.

Enterprise's Spaceborne Computer, which is based on the ProLiant series of computers on the ground, is installed on the International Space Station (ISS) and connected to the cloud environment on the ground to conduct various experiments such as data analysis with AI [3]. Intel is experimenting with commercial AI chips on a small satellite project called PhiSat-1 [4] for data processing in space. Such efforts aimed at providing a computing environment in space are expected to result in more advanced data processing in space as the current hardware becomes more powerful.

Along with hardware development, there is a trend to adopt modern and efficient software stacks and development/testing techniques in space, and Japan Aerospace Exploration Agency (JAXA) has launched the Satellite DX Research Group to promote satellite digital transformation (DX), which improves flexibility and reduces development cost and time with the "softwarization of satellites" [5].

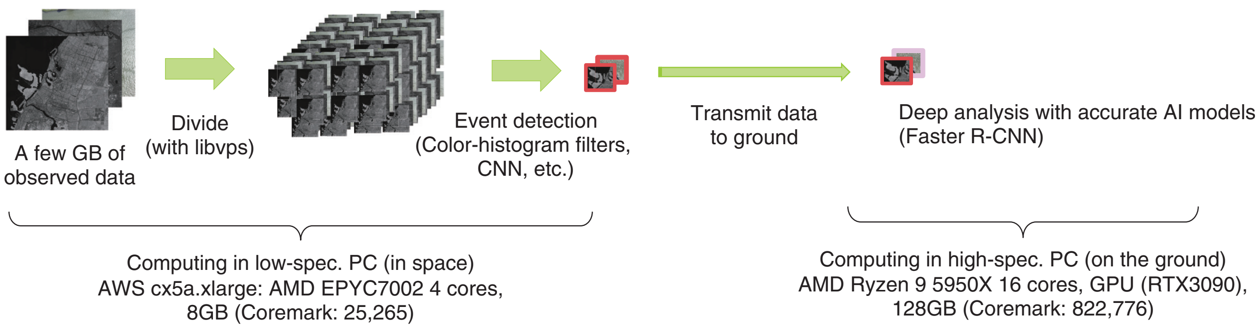
With the advances in hardware and software development environments, there are growing expectations for new services that extract useful information from observed data in space and deliver it to users in real time through advanced data analysis with AI. However, even with the advances in space computing technologies, there will continue to be many cases in which complete data analysis is impossible in space. Since the data taken by remote sensors, such as a synthetic aperture radar and optical cameras, have high resolution and large data volume (several gigabits (GB) per image, several hundred GB per day), it takes time to transmit the data to the ground even when using fast optical communication. The cost of data analysis on the ground for processing and saving is also expected to increase.

3. Event-driven data processing in space

SIC has been developing event-driven inference technology for AI services targeting on the ground [2]. In an event-driven inference, a lightweight inference, such as event detection, is carried out on the device side, and only data requiring high-precision processing are sent to the server, thus reducing the amount of transfer. This is expected to effectively reduce the amount of computation, processing, and power consumption for AI analysis. We verified whether such an event-driven inference is also effective in space computing (**Fig. 1**).

For this verification, we assumed a use case of suspicious ship detection, and conducted the verification on the basis of the assumption that a large amount of GB-class image data were captured using an optical remote sensor in space. Relatively lightweight event detection can be carried out in the low-spec computing environment of space, and only data that need to be processed on the ground are transmitted, thus reducing the amount of data transfer. On the ground, we conduct highly accurate AI processing only on the data sent to us to reduce the amount of computation.

Figure 2 shows the implemented data-processing pipeline and elapsed time for each processing. We implemented a case in which a large image is divided into a set of small patches followed by event-detection processing for all patches in space, while on the ground, deep analysis with accurate AI models is conducted on the transmitted data. Event detection, which requires processing tens of thousands of images after division, was carried out using lightweight algorithms, such as histogram-based filtering algorithms with predefined thresholds for detecting events, because of the limited computing power in space.



	Divide	Event detection		Deep analysis
Processing time [min.]	4.5	3.7		10.5–11.3

GPU: graphics processing unit
PC: personal computer

Fig. 2. Data processing pipeline and elapsed time for each processing.

Table 1. Recall rates of event detection and reduction rates of data transfer using lightweight filtering algorithms with two thresholds.

Algorithm	Recall rate of event detection	Reduction rate of transfer data	Elapsed time
Color-histogram filtering 1	75%	7.1%	2.17 min. for 10,000 images
Color-histogram filtering 2	70%	14.3%	

4. Results and discussion

In the testing environment for space computing, we confirmed that the entire processing of large observed data can be completed in about 10 minutes with proper resource utilization. Since processing on the ground can be easily parallelized with computing clusters, we can say that real-time AI inference is feasible. However, accuracy and transfer-data reduction were not satisfactory in this experiment. Generally speaking, there is a trade-off between accuracy (in this case, recall) and transfer-data reduction, but even with a 70% recall rate, only 14.3% of the transfer volume could be reduced (**Table 1**). This is due to the low accuracy of the lightweight filtering algorithms used for event detection in this setting.

We then calculated the recall rates of event detection and reduction rates of data transfer on the assumption that highly accurate AI models for deep analysis on the ground are currently in space (**Table 2**).

If there are accurate AI models (e.g., Mask R-CNN) in space, we can reduce 55.0 to 65.7% of transfer data with little accuracy degradation, but the central processing unit in our testing environment makes this almost impossible, requiring us to further improve the speed and optimization for specialized accelerators in the space environment.

5. Future direction of space computing research in SIC

On the basis of the results of the study we presented, we believe that the use of advanced AI accelerators and a system-on-a-chip with various accelerators on a single chip is essential to achieve highly efficient event-driven processing in space computing. SIC has been conducting research and development on benchmarking of AI accelerators for video analysis and optimization of AI models using an open source AI compiler (Apache TVM), which has a mechanism suitable for hetero-architecture. We will use this

Table 2. Recall rates of event detection and reduction rates of data transfer using highly accurate AI models with two thresholds.

AI model	Recall rate of event detection	Reduction rate of transfer data	Elapsed time
Mask R-CNN 1	88.7%	55.0%	22 hours and 16 min.
Mask R-CNN 2	72.2%	65.7%	

knowledge and experience in the research and development of a space computing platform and develop more advanced AI inference techniques on the basis of event-driven data processing for space.

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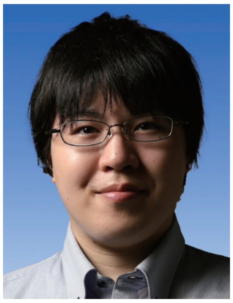

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Studies toward Practical Application of HAPS in the Space RAN

Yuki Hokazono, Yoshihisa Kishiyama, and Takahiro Asai

Abstract

The space radio access network is regarded as a communication infrastructure for the 5th-generation mobile communication system (5G) Evolution and 6G, and extreme coverage extension is being studied for use cases in all locations including air, sea, and space. For early implementation of extreme coverage extension, we are focusing on low-latency communication services using high-altitude platform stations (HAPSs). In this article, we present use cases and technical issues of wireless system technology with HAPSs and propose a three-dimensional-cell control technology for frequency sharing between a HAPS and terrestrial networks.

Keywords: HAPS, Space RAN, extreme coverage extension

1. Introduction

The space radio access network (Space RAN) is regarded as a communication infrastructure for the 5th-generation mobile communication system (5G) Evolution and 6G, and aims to achieve extreme coverage extension[*1] to all locations, including the sky, sea, and space, which have not been sufficiently covered by conventional mobile communication networks, using non-terrestrial networks (NTNs)[*2] based on geostationary (GEO) satellites, low Earth orbit (LEO) satellites, and high-altitude platform stations (HAPSs)[*3] [1].

For early implementation of extreme coverage extension, we are focusing on low-latency communication services using HAPSs [2]. HAPSs make it easy to extend communication-service coverage to a wider area; thus, making it possible to provide highly reliable communication in times of disaster, high-capacity communication for ships and aircraft, and communication services for distant islands and remote areas. Mobile carriers can improve the overall cost-effectiveness and energy efficiency of their mobile networks by combining HAPSs with an increase in the number of their terrestrial base stations to extend their service coverage.

This article describes the efforts toward the practical application of HAPSs in the Space RAN. Specifically, we present use cases and technical issues of wireless system technology with HAPSs and propose a three-dimensional (3D)-cell control technology for frequency sharing between a HAPS and terrestrial networks (TNs).

2. HAPS use cases and network configuration/control technologies

NTT DOCOMO is researching and developing communication methods and network architectures that can flexibly link 5G networks and other TNs with stratospheric HAPS networks [3]. In addition to providing flexible support for a wide range of future use cases as envisioned in 5G Evolution and 6G, this project is conducting studies aimed at the implementation

*1 Extreme coverage extension: To extend the area where base stations can communicate with mobile station terminals to all locations, including the sky, sea, and space, not covered by the current mobile communication system.

*2 NTN: Any network in which the communication area is not limited to the ground but extended to other locations such as the air, sea, and space through the use of non-terrestrial equipment such as satellites and HAPSs.

*3 HAPS: An airborne platform that is designed to operate in the stratosphere on board a vehicle such as a solar-powered aircraft or airship.

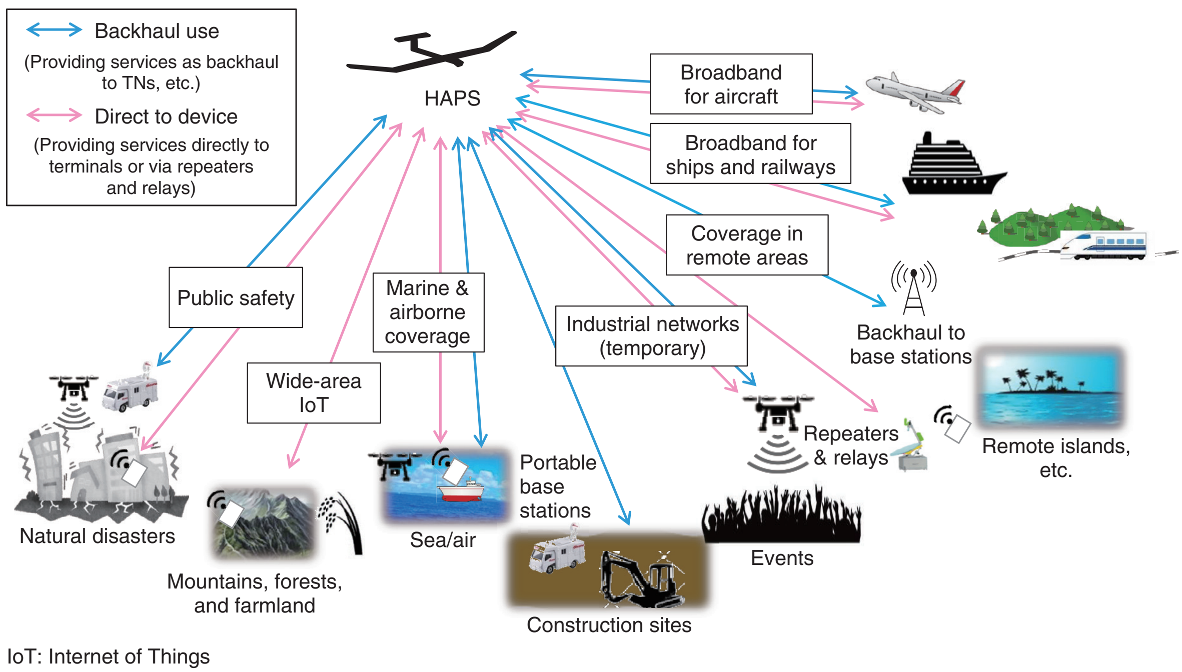

Fig. 1. Various use cases expected for HAPS.

of communication systems that use HAPSs in terms of development and operation costs.

2.1 HAPS use cases

As shown in **Fig. 1**, for the 5G Evolution and 6G era, it is expected that various use cases will involve using HAPSs to relay radio waves or emit radio waves as a base station. These use cases include fixed systems that provide services for backhaul[*4] applications and mobile systems that provide services to terminals either directly or via repeaters and relays. There is a need for flexible communication methods and systems that can support all use cases of fixed and mobile systems.

It is also necessary to flexibly control lines so that they can be adapted from normal business applications to public safety applications in the event of a disaster. Current disaster countermeasures are geared toward providing basic communication services such as voice calls and short message services, but it may also be necessary to consider use cases that require faster communication speeds, such as remote control of equipment at disaster sites, video transmission, and communication via drones. For disaster countermeasures, it will also be necessary to study network configurations and control technologies that assume the ability of a system to operate even if certain devices become unavailable.

2.2 Cooperative network configuration and control technology for HAPSs and TNs

2.2.1 Classification of HAPS-mounted stations

Regarding the network configuration and control technology used when implementing backhauls to 5G base stations via HAPSs, we are focusing on the categorization of HAPS-mounted stations. They can be roughly divided into two types: (1) relay stations, which receive signals from ground stations and relay them back to other ground stations after executing necessary processes such as frequency conversion, and (2) base stations, which are made by installing 5G network base-station equipment (or at least part of it) in a HAPS [4]. The relay type is effective when the number of onboard devices is relatively small and the size, weight, and power consumption of the HAPS-mounted station are strictly limited. The base-station type is formed by equipping a HAPS with an antenna device, together with many base-station functions. The more of these functions it includes, the greater the amount of control that can be executed within the

*4 Backhaul: In a mobile communication network, a backhaul is a fixed line that supports high-speed, high-capacity transmission of information between a large number of wireless base stations and the core network.

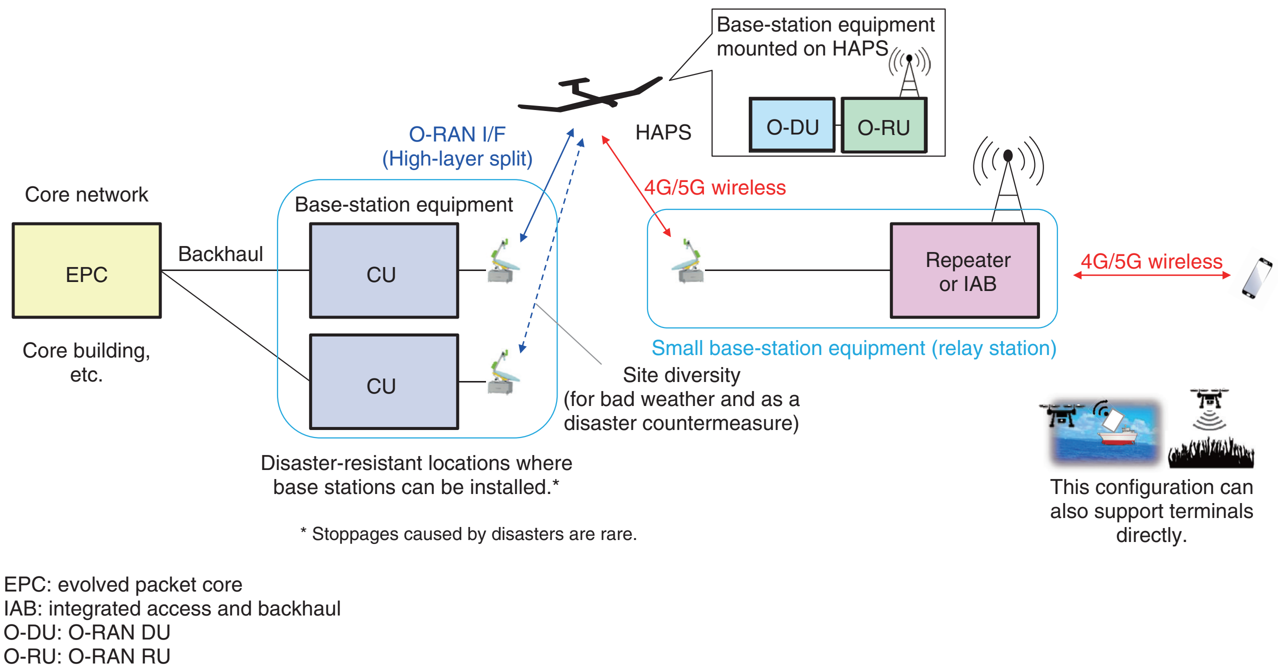

Fig. 2. Example of cooperative configuration when HAPS is used for backhaul.

HAPS, making it possible to reduce the amount of feeder-link information. However, installing more functions results in a station that is larger, heavier, and consumes more power.

Implementing more base-station functions on the ground-network side has the advantages of lower development costs and ease of operation, but implementing these functions on the HAPS results in greater resilience to natural disasters. In terms of performance, a HAPS-mounted station should at least implement certain functions, such as beam control, when using millimeter waves. It is also necessary to comprehensively study a wide range of requirements to be considered when incorporating HAPS systems into a 5G network. These include the size, weight, and power consumption of HAPS-equipped stations, their development and operation costs, the ability of these HAPS platforms to be shared by backhaul use and direct-to-device communication systems, and their ability to cooperate with GEO/LEO satellites.

2.2.2 Examples of network configuration in conjunction with the 5G network

An example of a HAPS base station in a network configuration linked to the 5G network is shown in **Fig. 2**. The distributed unit (DU) and radio unit (RU) of the 5G base station are mounted on the HAPS in accordance with Open RAN (O-RAN) ALLIANCE specifications [5]. In this configuration, availability is ensured by installing a centralized unit (CU) at a disaster-resistant point on the ground. Information received by the HAPS from the CU in the feeder link is transmitted via 5G radio to a small terrestrial base-station device (relay station) in the service link, enabling the use of portable 5G base stations without having to use a wired backhaul. In this configuration, it is also possible to provide direct communication from the HAPS to 5G terminals without the need for intervening relay stations. As a further extension, site diversity*5 can be implemented using multiple CUs on the ground side to reduce the impact of bad weather and natural disasters, and mobility support*6 can be implemented by switching the communication target to a different HAPS when the terminal moves from one communication area to another.

Another promising configuration using a relay-type

*5 Site diversity: A technique for improving communication quality by switching between multiple ground stations when radio waves are highly attenuated due to rain or obstacles.

*6 Mobility support: Technology that allows communication to continue when a terminal moves across a communication area by switching it to a different base station before communication is interrupted.

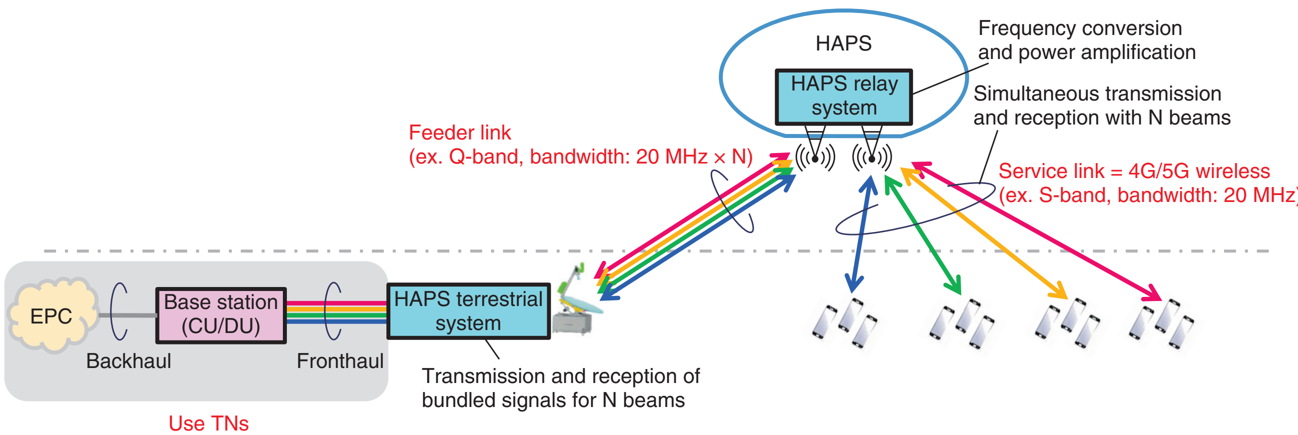

Fig. 3. Example of cooperative configuration when HAPS is used for direct access.

configuration where a 5G radio repeater is installed in a HAPS is shown in **Fig. 3**. In this configuration, the TN is used from the core network to the fronthaul*7, and the HAPS terrestrial system equipped with the RU function bundles and communicates signals for multiple beams. A broadband frequency, such as the Q-band, is used in the feeder link*8, and the HAPS relay system executes frequency conversion and power control. The HAPS can then establish service-link*9 communications using multiple beams at the same time. As the service link, certain frequency bands below 2.7 GHz already identified for International Mobile Telecommunications (IMT) should be used according to the specifications approved at the World Radiocommunication Conference 2019 (WRC-19) [6] and the agenda item for WRC-23 [7].

In addition to the configurations shown in Figs. 2 and 3, we consider other promising configurations in which a HAPS is used to carry a standalone*10 5G base station. For each configuration, it is necessary to conduct a comprehensive study that takes into account various attributes such as mobility support, site diversity technology, frequency-sharing technology*11, and HAPS installation requirements such as links with GEO/LEO satellites, the equipment weight, and power consumption.

3. 3D-cell control technology for frequency sharing between a HAPS and TNs

For mobile applications in which general user equipment (UE) communicates directly with HAPS base stations, the use of frequency bands below 2.7 GHz specified for IMT is being discussed as International Telecommunication Union (ITU) agenda item 1.4 at WRC-23 [8]. By sharing the same frequency between a HAPS and a TN, sets of UEs connected to the terrestrial IMT network can directly connect to the HAPS and conserve frequency resources. In this section, we present our proposed 3D-cell control technology that avoids interference between a HAPS and TNs. We also present a HAPS-performance evaluation in the 2-GHz band using the 6G system-level simulator developed as a stepping stone for actualizing HAPS technology.

3.1 Evaluation of interference avoidance in the 2-GHz band using 3D-cell control technology

3.1.1 3D-cell control technology

Our 3D-cell control technology suppresses the intersystem interference between a HAPS and TNs. As shown in **Fig. 4**, the HAPS suppresses the intersystem interference and achieves load balancing by

*7 Fronthaul: The line between the baseband processing unit of the base station and the wireless device, such as optical fiber.

*8 Feeder link: A communication path between a satellite or HAPS and a terrestrial base station (gateway) in an NTN communication system.

*9 Service link: A communication path between a satellite or HAPS and a terminal in an NTN communication system.

*10 Standalone: A deployment scenario using only New Radio (NR), in contrast with non-standalone operation which uses Long Term Evolution (LTE)-NR Dual Connectivity to coordinate existing LTE/LTE-Advanced and NR.

*11 Frequency-sharing technology: Technology that makes it possible to share frequencies by suppressing the interference effects that occur when two systems use the same frequency at the same location. In this article, we are mostly concerned with frequency sharing between HAPS systems and terrestrial mobile communication systems.

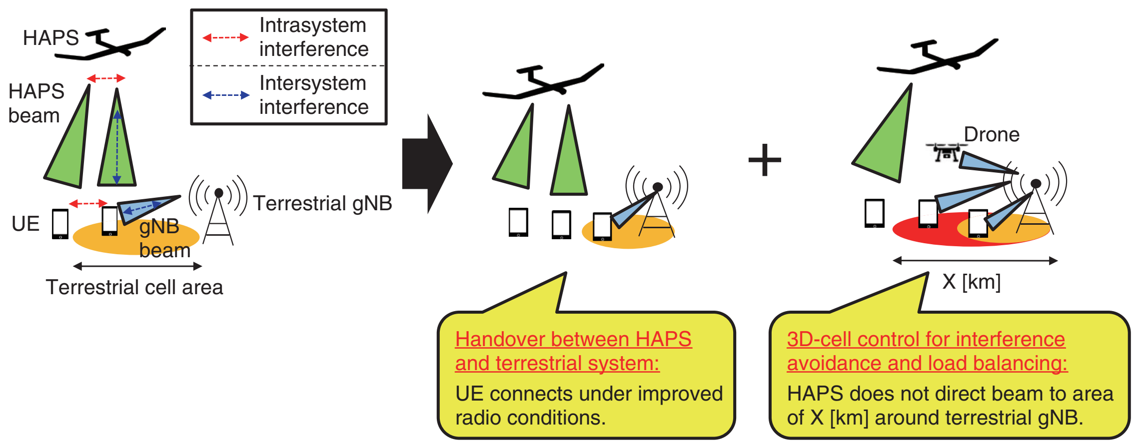

Fig. 4. Handover and 3D-cell control technology.

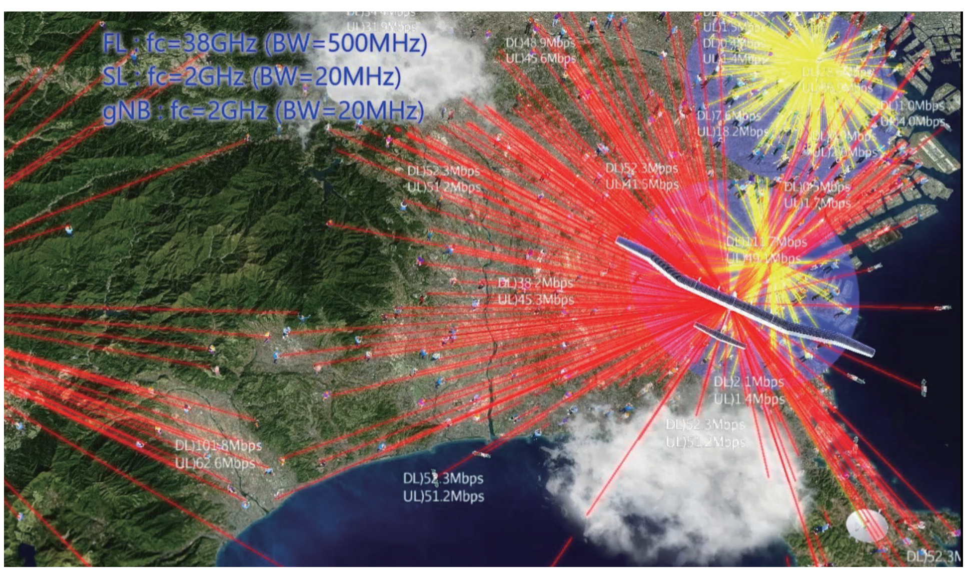

Fig. 5. HAPS simulator.

not directing the beam to the distance threshold X [km] around the terrestrial next-generation NodeB (gNB) (hereafter, X denotes gNB connection threshold).

3.1.2 Simulation conditions

We assumed a scenario in which the HAPS service link and terrestrial gNB link share the 2-GHz band, as shown in **Fig. 5**. The HAPS simulator was used to evaluate the interference avoidance of the 3D-cell control technology. **Table 1** lists the system-related parameters and **Table 2** lists the simulation parameters for each device. The layout of each device is shown in Fig. 5. As an initial evaluation, two Earth stations, two HAPSs, 500 UEs, and two terrestrial gNBs were placed in an area of approximately 60 × 114 km that includes Tokyo, Japan. The two terrestrial gNBs were placed near Tokyo, and UEs were randomly placed at a ratio based on population distribution.

3.1.3 Simulation results

The values of the cumulative distribution function (CDF) at 5, 50, and 95% for the throughput for all

Table 1. System-related parameters.

Parameter	Feeder link	Service link	gNB link
Frequency	38 GHz	2 GHz	
Bandwidth	500 MHz	20 MHz	
Atmospheric absorption loss	1 dB		
Path-loss model	Free space path loss		UMa path-loss model (TR 38.901 [9]) *Randomly applied at a ratio of NLOS:LOS = 9:1
Max. rank	2 *Circular polarization is assumed.		8

LOS: line of sight
NLOS: non LOS
UMa: urban macrocell

Table 2. Parameters for each device.

Device	Parameter	Value
UE	Quantity	500
	Peak gain	Tx: -3 dBi, Rx: 0 dBi
	Gain pattern	Omnidirectional
	Noise figure	3 dB
	Tx power to HAPS	Always 23 dBm
	Tx power to gNB	Max. value = 22 dBm *Accordance with distance to gNB [10]
HAPS	Quantity	2
	Altitude	20 km
	Peak gain	Service link: 24 dBi Feeder link: 30 dBi
	Antenna configuration	Parabolic dish Half-power angle of service link = 7.7° Half-power angle of feeder link = 2.5°
	Gain pattern	Bessel function pattern (TR 38.811 [11])
	Noise figure	3 dB
	Max. number of beams	50 or 500
	Tx power	Service link: 43 dBm/HAPS Feeder link: 34 dBm/HAPS
gNB	Quantity	2
	Peak gain	17 dBi
	Antenna configuration	Sector antenna
	Gain pattern	Compliant with ITU-R M.2101 [12]
	Down tilt	15°
	Antenna height	25 m
	Tx power	43 dBm/sector
	Noise figure	3 dB
Earth station	Quantity	2
	Position	Directly under HAPS
	Tx power	34 dBm
	Peak gain	50 dBi
	Gain pattern	Bessel function pattern (TR 38.811 [11])

ITU-R: ITU Radiocommunication Sector
Rx: receiver
Tx: transmitter

Table 3. Downlink throughput of HAPS-connected UEs.

Max. number of HAPS beams	X [km]	Throughput of HAPS-connected UEs (Mbit/s)		
		CDF 5%	CDF 50%	CDF 95%
50	0	4.4	18.4	171.3
	3	4.2	19.1	171.7
	9	9.5	39.5	222.0
500	0	9.0	44.6	203.5
	3	9.4	44.8	203.6
	9	19.0	70.0	249.9

Table 4. Downlink I/N of gNB-connected UEs.

Max. number of HAPS beams	X [km]	I/N of gNB-connected UEs (dB)		
		CDF 5%	CDF 50%	CDF 95%
50	0	16.9	19.4	22.9
	3	14.1	18.7	21.3
	9	6.8	13.2	17.8
500	0	12.9	18.2	19.8
	3	11.8	17.7	19.8
	9	6.8	13.0	18.0

UEs when X was changed are listed in **Table 3**. We confirmed that load balancing worked as X increased and the average throughput for all UEs improved in the downlink. If X increases to 9 km, the number of UEs with low received power of the desired wave increases, and the throughput deteriorates because even UEs at a point far from the terrestrial gNB are connected to it. When comparing the maximum number of HAPS beams, the throughput for all UEs was higher when the number of beams was 500 than when it was 50. This is because each HAPS-connected UE can select the optimal HAPS beam that yields the maximum gain.

The values of CDF at 5, 50, and 95% in the interference-to-noise ratio (I/N) of gNB-connected UEs when X was changed are listed in **Table 4**. The I/N decreased as X increased, so the interference avoidance effects could be confirmed. When comparing the maximum number of HAPS beams, the I/N in the downlink was higher when the number of beams was 50 than when it was 500. This is because the smaller the number of beams, the larger the transmission power per beam of a HAPS.

The same evaluation was conducted on the uplink, and load balancing and interference avoidance effects were confirmed as on the downlink. It is necessary to select an appropriate X considering that the coverage area of a HAPS decreases with the increase in X.

4. Conclusion

As part of our efforts to make HAPSs practical in the Space RAN, we presented use cases and technical issues with wireless system technology with HAPSs and proposed a 3D-cell control technology for frequency sharing between a HAPS and TNs.

NTT DOCOMO will continue developing NTN technology aimed at achieving extreme coverage extension and technology for HAPS networks and promoting demonstration experiments and standardization activities.

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Satellite Sensing Platform

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Abstract

This article introduces a 920-MHz Internet of Things (IoT) platform via a low Earth orbit (LEO) satellite using feeder-link multiple-input multiple-output (MIMO) technology. In this platform, the LEO satellite captures the IoT radio waves transmitted from terrestrial low-power wide-area terminals onboard then downlinks them to the base station when it passes over the station. Since the received signals are directly digitalized as wave data, the amount of data stored is huge. To downlink this huge amount of data within the limited period in which the moving LEO satellite passes over the base station, we propose applying MIMO technology to the downlink from the LEO satellite to the base station.

Keywords: satellite MIMO, satellite IoT, satellite blind beamforming

1. Introduction

Various Internet of Things (IoT) services are rapidly spreading worldwide [1]. Satellite communications is widely used in places a terrestrial network cannot cover, so it is an effective approach to provide IoT services to such areas. Several satellite IoT services accommodate IoT traffic using devices and frequencies provided by the satellite operators [2, 3]. However, the initial and running costs are so high that the number of users is currently small. To address the cost issues, we propose using terrestrial 920-MHz low-power wide-area (LPWA) terminals for satellite IoT systems. We aim to lower the cost of IoT services via satellite by using terrestrial LPWA terminals and shared unlicensed frequency bands.

2. Satellite sensing platform

2.1 Concept

Figure 1 shows the system configuration of our IoT platform [4]. The power-regulated terrestrial LPWA terminals can be used freely without a license in the 920-MHz frequency band. The radio waves emitted from the LPWA terminals are captured by a low Earth orbit (LEO) satellite. The captured waves are then digitalized and stored in the onboard memory. Finally, the stored data are downlinked to the base station. Demodulation is not carried out onboard, so our satellite IoT platform does not specify the communication protocol; it can correspond to any type of protocol. The stored data need to be downlinked in the limited time when the LEO satellite passes over the base station. Therefore, we propose applying multiple-input multiple-output (MIMO) technology to the feeder-link between the LEO satellite and base station. As Fig. 1 shows, the satellite MIMO technology executes spatial multiplexing transmission from a single satellite with multiple antennas to the base station connected with multiple remote antennas. The technical points and operational principles are introduced later.

2.2 Key technologies

(1) Satellite blind beamforming

Since many terrestrial LPWA terminals share the unlicensed 920-MHz band, onboard receiver (Rx) antennas receive both the desired satellite IoT signals and undesired interference emitted from a huge number of terrestrial LPWA terminals. Therefore, they need to extract the desired satellite IoT signals and suppress interference. To achieve this, several Rx antennas are implemented onboard and downlink the received signals they capture to the base station. The desired signal is then extracted offline while interference-cancellation software suppresses undesired

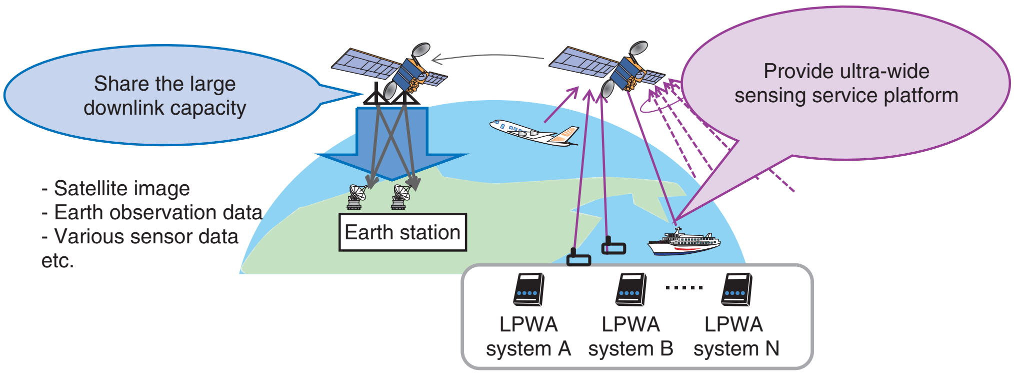


Fig. 1. Satellite sensing platform.

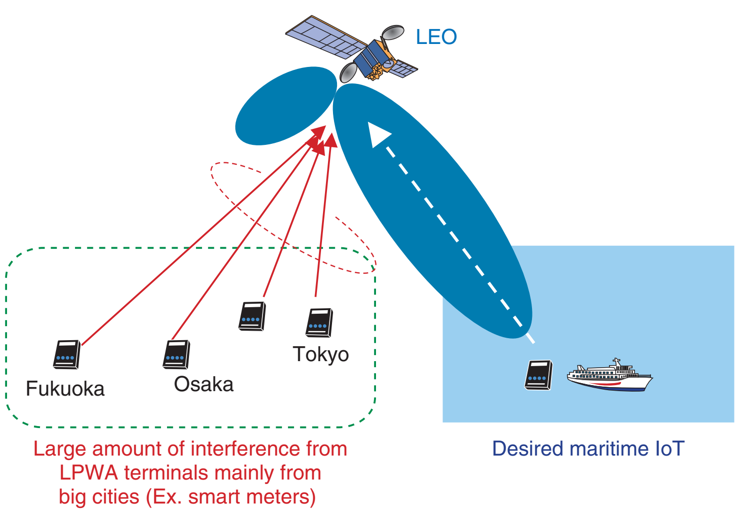


Fig. 2. Satellite blind beamforming.

signals [5]. **Figure 2** shows the concept of maximizing the power of a desired signal while suppressing the power of undesired signals. Multiple onboard antennas help channel the null directivity in the direction from which a large amount of undesired interference is emitted, simultaneously forming the peak directivity toward the desired LPWA terminal. This signal processing is carried out offline by using downlinked onboard wave data in the base station. This technique is called "satellite blind beamforming." Since demodulation is also carried out using software, our platform can flexibly accommodate any type of LPWA protocol by installing the appropriate demodulator.

Our platform is based on the condition that signals of terrestrial 920-MHz LPWA terminals can be captured by the LEO satellite. Therefore, it needs to confirm that those received signals satisfy the required signal-to-noise ratio (SNR) for demodulation. Therefore, we investigate the coverage area of a satellite IoT terminal by calculating its link budget.

A dipole antenna is assumed for the LPWA terminal antenna. The transmitter (Tx) power is 20 mW, the same regulation as a typical terrestrial LPWA terminal. LoRa (long range radio) (spreading factor: 12, bandwidth: 125 kHz) is used as a protocol so that its required SNR is 6 dB. The antenna gain depends on how the dipole antenna is set. We set the boresight directivity of the dipole antenna to be vertical to the Earth.

We do not consider the undesired/unknown interference from other LPWA terminals for the fundamental

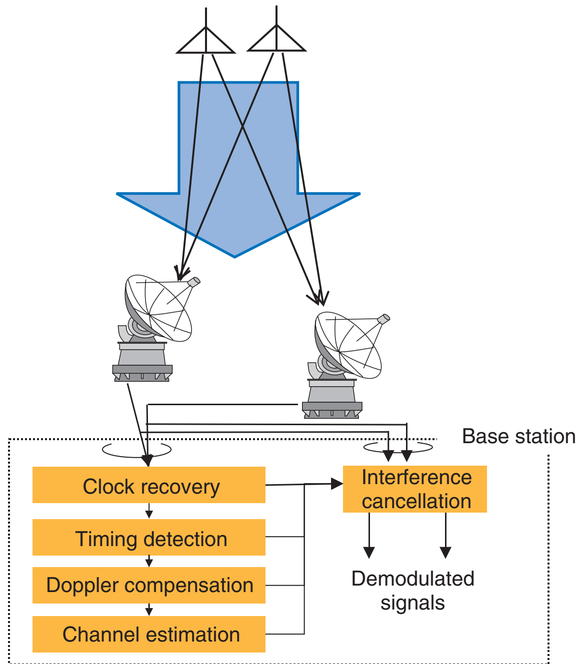


Fig. 3.   Satellite MIMO.

link-budget calculation. There are three onboard Rx antennas, each of which is a circular, patch-type antenna with a peak gain of 6.5 dBi, and the –3-dB-bandwidth is 80 degrees. Since we do not consider the undesired signals in this calculation, we apply maximal ratio combining to the three received signals. Under the above condition, the maximal radius of the service coverage area (SNR > 6 dB) is about 640 km.

(2) Satellite MIMO

Figure 3 shows the operational principle of satellite MIMO [6]. By using a control channel for multiple Tx antennas, the Doppler frequency is removed and symbol timing is detected in the Rx. The channel matrix is then estimated, which is used to cancel the MIMO interference.

The channel matrix and received SNR of LEO satellites are expected to change at each ground-antenna elevation angle and visible path. Because an LEO satellite moves around the Earth, it takes different positions when connecting to a ground station. The changes between the propagation distance, received SNR, and relationship between the Tx/Rx antenna positions are complicated for each visibility time and path. Therefore, the elements of the LEO-MIMO channel matrix must be analyzed at each visibility time to evaluate the capacity of the channel [7].

Figure 4 illustrates an example of the capacity enhancement using LEO-MIMO. Two antennas are mounted on the satellite with an interval of 70 cm and the interval between the two base stations is 70 km. For comparison, a conventional single-antenna satellite system, i.e., single input single output (SISO), is also being evaluated. The right side of Fig. 4 shows the capacity comparison while the LEO satellite is moving over Japan. The X axis shows time and Y axis shows capacity. The MIMO capacity is about double that of the SISO capacity. This means the MIMO technology can improve communications capacity corresponding to the number of antennas.

3. Satellite experiments

Experiments to confirm the practicality of a 920-MHz IoT platform via an LEO satellite using satellite MIMO technology are being considered. **Figure 5** shows an experimental configuration with a scale model. Three antennas are implemented on the satellite as onboard 920-MHz IoT Rxes. We will also conduct 3 × 3 MIMO experiments. On the basis of our experience, we plan to use the X band for MIMO experiments. For IoT experiments, our plan is to evaluate satellite IoT performance under various conditions, as shown in **Fig. 6**.

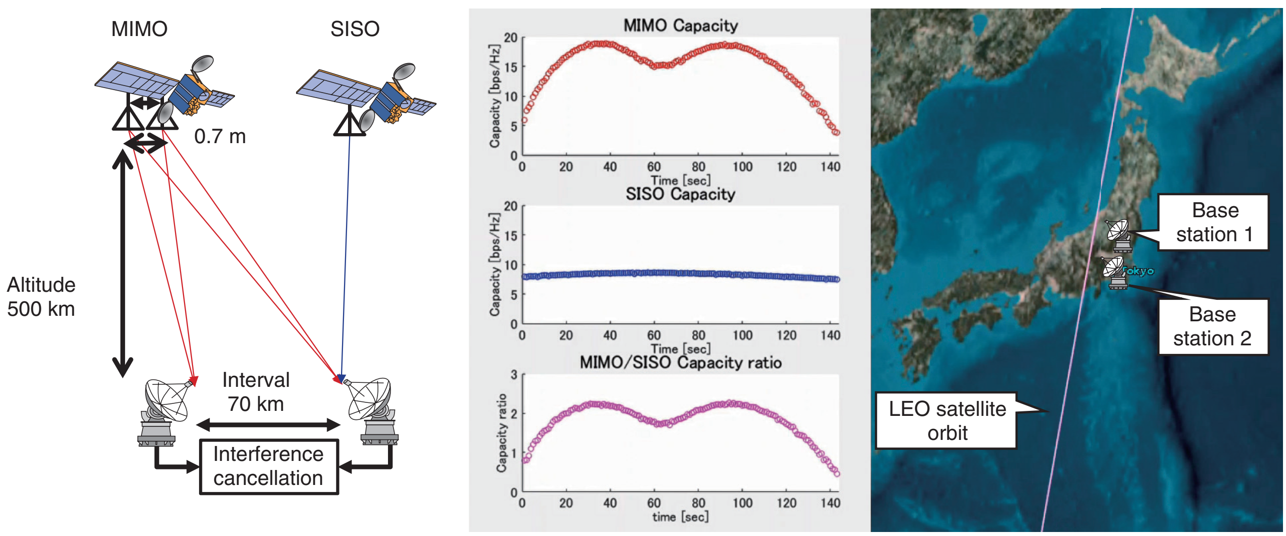
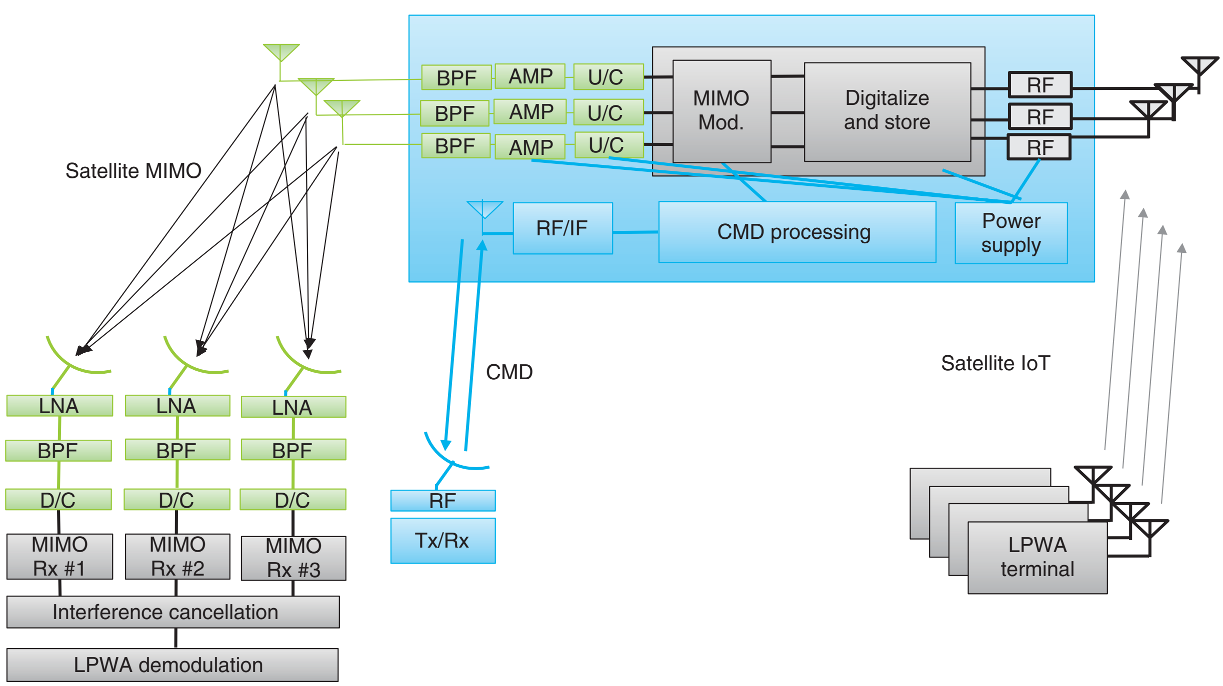


Fig. 4. Capacity enhancement using LEO-MIMO.



AMP: amplifier
BPF: band-pass filter
CMD: command signal
D/C: down converter
IF: intermediate frequency
LNA: low noise amplifier
RF: radio frequency
U/C: up converter

Fig. 5. Configuration of satellite experiments.

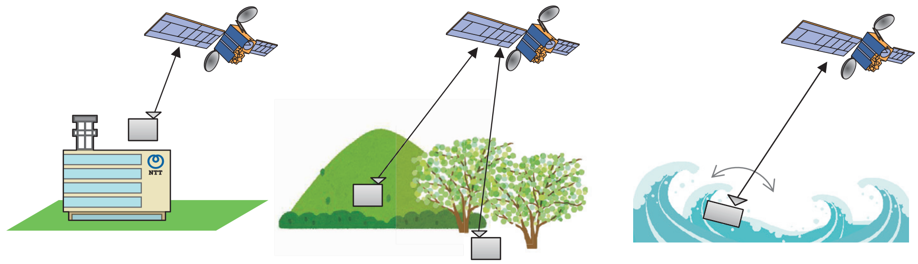


Fig. 6. Conditions for IoT experiments.

4. Summary

We proposed a 920-MHz IoT platform via a LEO satellite using feeder-link MIMO technology. We presented fundamental feasibility studies of the link budget calculation and estimation of MIMO channel capacity.

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Release of NTT Technology Report for Smart World 2022

Tomoyuki Kanekiyo, Daisuke Shirai, and Suzuyo Inoue

Abstract

NTT Research and Development Planning Department annually releases the NTT Technology Report for Smart World, which summarizes its vision for the Innovative Optical and Wireless Network (IOWN) launched in 2019 and technologies intended to make the world a better place for everyone. It has now published the 2022 edition. This article provides an overview and main updates of this new edition.

Keywords: technology, social trend, smart world

1. Innovation to create a sustainable society and regenerate the world

Humanity's constant technological innovations have created a prosperous world but have also caused various problems. To understand umwelts ("environments") beyond the limits of human cognition, we need new infrastructure that can process vast amounts of information. At NTT, we see the potential for breakthrough innovation in the field of optical technology and unveiled the concept of the Innovative Optical and Wireless Network (IOWN) in 2019. We have been making steady progress toward its implementation by 2030, and various pilot projects tailored to different contexts are underway. In this article, we introduce the foundational technologies needed to further advance toward the implementation of IOWN, as well as the efforts to introduce IOWN, which includes conducting field technology demonstrations in collaboration with many companies in Japan and abroad. These IOWN initiatives will enable us to innovate and regenerate the world.

2. Photonics-electronics convergence technology to implement IOWN, two social infrastructures, and five value domains created by IOWN

The implementation of IOWN is supported by photonics-electronics convergence technology, which enables more efficient operation by integrating light and electricity, and two social infrastructures, the All-Photonics Network (APN) and disaggregated computing, which can be built using this technology. With this technology and new infrastructures, IOWN is creating five representative value domains: next-generation data hubs, the 4D digital platform®, secure optical transport network, fifth-generation mobile communication network (5G) evolution/6G wireless technology, and the Space Integrated Computing Network. In NTT Technology Report for Smart World 2022, the photonics-electronics convergence technology, two social infrastructures, and five value domains are explained.

3. Photonics-electronics convergence technology

IOWN will achieve an ultra-high-capacity, ultra-high-speed, and energy-efficient communication infrastructure by introducing optical information transmission on smaller scales, between servers at datacenters, on circuit boards that connect computers to networks, and on chips and semiconductors inside them. To implement optical technology for shorter-distance communications, devices that manipulate light must be dramatically scaled down and made more economical and higher performing. To this end, we are working to establish photonics-electronics convergence technology that integrates light and electricity processing capabilities into a single device and enables more efficient operation. We will continue our research and development (R&D) efforts together with many partners following the roadmap that sets out five generations of photonics-electronics convergence technology to develop the ultimate ideal form and offer an innovative information and communication platform.

4. Two social infrastructures

4.1 All-Photonics Network

We are developing the APN as the "infrastructure of infrastructures" that will tie together various information and communication technology (ICT) infrastructures in the era of digital transformation/digital circulation. The APN will make it possible to construct a shared ultra-high-speed optical and wireless network that connects telecommunications hubs as well as user facilities and datacenters with end-to-end broadband optical networks and wireless access that anyone can use. In addition to the development of fundamental technologies, various technologies have been demonstrated to enable the APN. For example, in FY2021, we demonstrated Layer-1 communication-path delay-adjustment technology that revolutionizes gaming user experience, ultra-low-latency video-transmission technology for uncompressed 8K120p video, and optical transport network technology using next-generation highly secure cryptography.

4.2 Disaggregated computing

To make the most of infrastructures such as the APN, functions that have been handled by dedicated devices, such as routers and mobile base stations, need to be achieved through powerful computing hardware and software with low power consumption. The concept we have proposed to achieve this is disaggregated computing. The conventional premise in the computing field was to connect boxed computers through networks. Disaggregated computing will directly connect components, such as central processing units and memory, with optical connections, enabling us to treat racks and datacenters as single, large computers. By revolutionizing the physical configuration (hardware architecture), logical configuration (software architecture), and control methods, we will maximize the potential of light to achieve high-speed, low-power, and low-loss performance that far surpasses that of conventional computing.

5. Five value domains created by IOWN

5.1 Next-generation data hubs

With the spread of Internet of Things devices and development of communication networks, the amount of data circulating around the world continues to increase, and their use in various areas will increase with the development of artificial intelligence (AI) and other technologies. However, there are still challenges to overcome to achieve a society that can use data beyond the boundaries of industries and companies. For example, traditional storage and networks will be overwhelmed and difficult to manage. In addition, cross-industry data utilization is currently hindered by the lack of technical mechanisms to prevent secondary distribution or use for unintended purposes. To address these issues, we are engaged in the R&D on next-generation data hubs composed of three technologies: virtual data lake, data broker, and data sandbox, which will accelerate the utilization of data in society.

5.2 4D digital platform®

The 4D digital platform® is an infrastructure that collects a variety of sensing data on people, objects, and things in real time, matching and integrating the four-dimensional (4D) information of latitude, longitude, altitude, and timestamp with high accuracy, and enabling data fusion and future prediction with various industrial infrastructures. By integrating a mobile mapping system and other advanced 3D spatial information with existing map data, as well as using Smart Satellite Selection™, which improves positioning and time synchronization accuracy in urban areas, we will be able to collect highly accurate location and time data. This is then combined with AI to achieve advanced future predictions. The 4D digital platform® provides value through optimization of road traffic and other urban assets, maintenance of social infrastructure, and a more fine-grained understanding of the natural environment.

5.3 Secure optical transport network

We are conducting R&D on secure optical transport networks that can protect networks against attacks involving extremely advanced computers such as quantum computers. The key to making this possible is the use of quantum technology and countermeasures against new attackers at the architectural design level. For the former, we are developing two types of key cryptography and delivery mechanisms: quantum key distribution and post-quantum cryptography-based key distribution. For countermeasures against new attackers, we may add security without interfering with the low latency of IOWN and the APN by implementing encryption at lower layers.

5.4 5G evolution/6G wireless technology

We believe that six conditions must be met to achieve 6G by 2030: ultra-high-speed and high-capacity communication, significant coverage expansion, ultra-multi-connection and sensing, ultra-low power consumption and low cost, and ultra-low-latency and ultra-reliable communications. However, the expansion of usage areas and the increasing complexity of user needs make it difficult to provide a network optimal for all individuals. To address this issue, we are developing Cradio®, a set of multi-radio proactive control technologies that enable people to enjoy a more natural communication environment. We are currently conducting a series of demonstration tests of automatic driving and remote monitoring and control of agricultural machinery between fields, aiming for practical application by 2030.

5.5 Space Integrated Computing Network

The Space Integrated Computing Network, which we are currently envisioning, will create an independent, decarbonized, and self-sustainable infrastructure in space, unaffected by the Earth's environment. Through space sensing, space datacenters, and space radio access networks, we will integrate multiple orbits including high-altitude platform stations in the stratosphere and satellites in low and geostationary orbits and connect them to the ground via an optical wireless communication network, creating a completely new ICT infrastructure.

6. A worldwide IOWN network

NTT cannot achieve IOWN alone. This new information infrastructure can only be actualized through co-creation with many partners, including companies around the world. The IOWN Global Forum (IOWN GF) is growing beyond national borders, revealing the shape of future co-creation. After beginning to recruit members in March 2020, 93 organizations have joined IOWN GF as of March 2022. Unlike traditional international organizations, the high frequency of discussions has resulted in the release of a white paper in April 2020, use case interim reports (February and June 2021), a technology outlook report (April 2021), and Use Case Release 1 (October 2021), as well as six reference documents that were released in December 2021 in accordance with IOWN's technology development roadmap. We will work with IOWN GF members on proofs of concept and technical studies based on the published documents.

7. Conclusion

NTT Research and Development Planning Department will continue to release a summary of technology trends and the activities of NTT R&D. NTT Technology Report for Smart World 2022 can be downloaded from NTT R&D's website [1].

Reference

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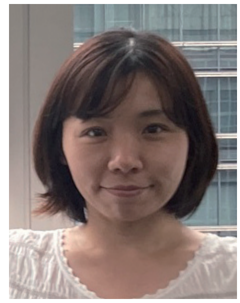

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New ITU-T Study Group 5 Structure and Deliberations

Yuichiro Okugawa, Minako Hara, and Kazuhiro Takaya

Abstract

The NTT Group is participating in the international standardization activities in the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group (SG) 5 to protect telecommunication facilities from electromagnetic interference and lightning surges, assess the impact of information and communication technologies on climate change, address the issue of a circular economy that enables sustainable development, and contribute to improving the reliability of telecommunication services and reducing the environmental impact of its business activities. In this article, we introduce the study structure of ITU-T SG5 for the new study period (2022–2024), which has finally started due to the COVID-19 pandemic, as well as the latest discussion trends at the first meeting held in June 2022.

Keywords: ITU-T SG5, electromagnetic compatibility, climate change

1. Overview of the study structure of ITU-T Study Group 5 and the first meeting for the new study period (2022–2024)

The new study period (2022–2024) started one year later than the originally planned due to the COVID-19 pandemic, and a new study structure was established in the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group (SG) 5 (**Fig. 1**). Compared with the previous study period, the old Working Party (WP) 1, which mainly discussed electromagnetic compatibility (EMC) and electromagnetic exposure, was continued as the new WP1, while the old WP2, which mainly discussed eco-efficiency, e-waste, circular economy, and sustainable information and communication technology (ICT) networks, was renamed as the new WP2. The new WP3 is mainly concerned with climate-change adaptation and mitigation, and net zero emissions.

The first meeting was held from June 21 to July 1, 2022, in Geneva, Switzerland, in a hybrid online format. There were 164 participants, 12 of whom were from Japan (all online), and a total of 97 contributions (including 6 from Japan). At the Opening Plenary, WP chairs and rapporteurs for the new study period were nominated and approved, then each subject was discussed. The results of the deliberations are introduced in the next section, and a summary of the deliberations can be found on the ITU-T website (https://www.itu.int/en/ITU-T/studygroups/2022-2024/05/Pages/exec-sum-202207.aspx).

2. Results of WP1 discussion

2.1 Question 1

Question 1 is studying the requirements for protection of telecommunication systems against lightning strikes, grounding, and power system disturbances, countermeasures against soft errors in telecommunication equipment caused by particle radiation, and protection methods against attacks by high-power electromagnetic waves. At this meeting, NTT proposed the second draft of K.87 "Guide for the application of electromagnetic security requirements – Overview," and the revision was agreed upon in the final draft incorporating the opinions of IEC (International Electrotechnical Commission) experts expressed during the meeting. The 1st draft of K.lp "Using data of lightning positioning system for

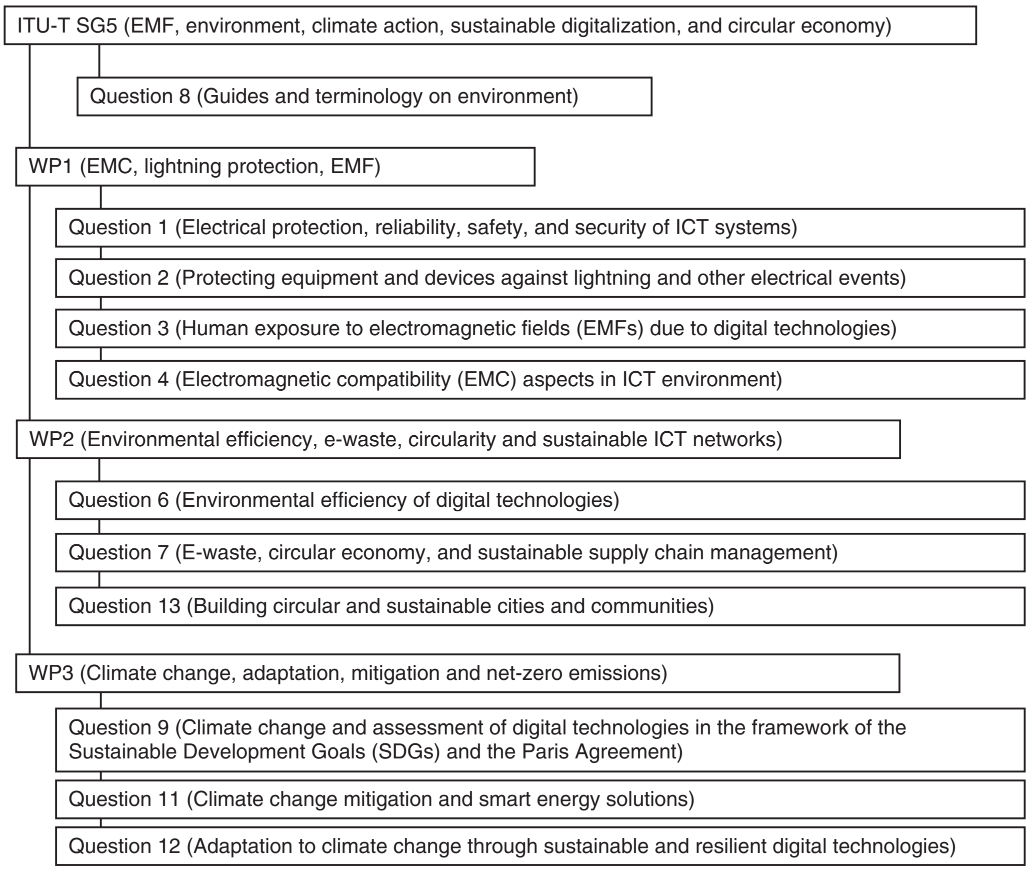

Fig. 1. Study structure of ITU-T SG5 in the new study period (2022–2024).

network protection" was proposed by China, and after discussion, it was decided to revise some parts of the chapter structure, add NTT as an editor, and continue the discussion in the next meeting.

2.2 Question 2

Question 2 is studying the requirements for protection of telecommunication systems against overvoltages and overcurrents and protecting devices. At this meeting, NTT proposed to revise some exceptions in the test application of K.21 "Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents," and the revision was agreed after discussion. NTT also proposed to add the test items added to K.20 "Resistibility of telecommunication equipment installed in a telecommunication centre to overvoltages and overcurrents" at the May 2021 meeting to K.Supplement 24 "ITU-T K.20 – Rationale for setting resistibility requirements of telecommunication equipment installed in a telecommunication centre against lightning." After discussion, the revision was agreed.

2.3 Question 3

Question 3 is studying the estimation procedure, calculation method, and measurement method of electromagnetic field (EMF) intensity around antennas of cellular phones and wireless systems to protect human exposure to EMF. In this meeting, Korea proposed the 2nd draft of K.Supplement WPT "EMF strength inside and outside of electric vehicle using wireless power transfer (WPT)" on the basis of the results of EMF measurement and numerical analysis inside and outside of dynamic and electric vehicles using WPT technology. After discussion, it was agreed to publish as K.Supplement 29. For K.Supplement 16 "Electromagnetic field compliance assessments for 5G wireless networks," the GSM Association proposed the addition of a map showing the measurement results of radio-frequency exposure from fifth-generation mobile communications system (5G) base stations, and Japan proposed the update of the description of international standards related to 5G, which were agreed after deliberation.

2.4 Question 4

Question 4 is studying EMC standards for new telecommunication equipment, telecommunication services, and wireless systems. At this meeting, NTT proposed and discussed a revised draft of K.123 "Electromagnetic compatibility requirements for electrical equipment in telecommunication facilities," which removes power equipment from the scope, and K.power_emc "Electromagnetic compatibility requirements for power equipment in telecommunication facilities." Both drafts had been continued for discussion due to disagreement on the disturbance rules below 150 kHz, but as a result of discussion with new contributions, it was agreed to revise the drafts and establish new Recommendations. As for K.76 "EMC requirements for telecommunication network equipment (9 kHz–150 kHz)," the emission provisions considering power-line communication protection, which is under discussion by CISPR (International Special Committee on Radio Interference), were added as provisional limits, and the title of the Recommendation was changed to "EMC requirements for DC power ports of telecommunication network equipment in the frequency range below 150 kHz." The revision was agreed after the discussion.

3. Results of WP2 discussion

3.1 Question 6

Question 6 is defining eco-efficiency and requirements for digital and new advanced technologies and developing Recommendations on technical solutions, indicators, key performance indicators (KPIs), and related measurements.

At this meeting, L.1318, L.1333, and L.1390 were consented. L.1318 defines the Q-factor (quality factor), a metric applicable to measuring and improving the energy efficiency of integrated circuits in ICT. L.1333 defines the greenhouse gas (GHG) emissions from energy use in networks. L.1333 defines a KPI called Network Carbon Intensity Energy (NCIe) to evaluate GHG emissions from energy use in networks and study ways to reduce emissions and discusses the correlation between carbon intensity indicators and energy efficiency indicators. L.1390 provides principles for power saving in 5G radio access network devices and best practices for using and controlling power-saving technologies using artificial intelligence (AI). Two new work items were also approved for consideration.

3.2 Question 7

Question 7 is developing Recommendations on the concept of the circular economy, environmental requirements for digital technologies based on improved supply chain management, and eco-rating programs for products, networks, and services.

At this meeting, L.1034 and L.1040 were consented and L.Supplement 47 was agreed. L.1034 provides guidance to raise awareness of the health and environmental impact of counterfeit ICT products, particularly in developing countries. L.1040 provides guidance on the environmental impact of e-waste, including that of self-driving cars. L.Supplement 47, proposed by NTT and NEC, provides a case study on the provision of Internet services using Single Pair Ethernet cables and provides a resource-saving example of chiplet design introduced by Orange for central processing unit/graphics processing unit manufacturing, to show how resource saving can be promoted in factories, buildings, and homes. Three new work items were also approved for consideration.

3.3 Question 13

Question 13 develops Recommendations on requirements for the use and operation of digital technologies (AI, 5G, etc.) and the application of circular-society thinking in cities and communities, technical specifications, effective frameworks, guidance in applying circular-society thinking to assets in cities, and indicators and KPIs needed to establish a baseline scenario for circular cities and communities.

At this meeting, L.1604, L.1610, and L.1620 were consented, L.Supplement 51 and L.Supplement 50 were agreed. L.1604 focuses on the bioeconomy, which covers both sustainability and circularity, and includes the definition and role of the bioeconomy in cities. L.1610 provides urban science methods to analyze and solve urban sustainability problems. L.1620 provides an implementation framework for circular cities to evaluate and prioritize improvement actions to support and facilitate actions to improve urban circularity. L.Supplement 51 presents examples of successful implementation of urban scientific methods in accordance with L.1610. L.Supplement 50 provides 17 case studies on the deployment of circular cities according to L.1620.

4. Results of WP3 discussion

4.1 Question 9

Question 9 develops Recommendations on how to use environmental impact assessment methods, including methods and guidance for assessing the sustainability impact of digital technologies, including ICT, AI, 5G, and others; consideration of the importance of climate change and biodiversity issues; and assessment from an environmental, social, and governance (ESG) perspective.

At this meeting, L.1480 and L.1481 were consented. L.1480 provides a methodology to assess the impact of using ICT solutions on GHG emissions, including a quantitative assessment of the second-order effects of ICT solutions. L.1481 provides examples of ICT solutions related to GHG emission reductions to facilitate the ITU's work towards the Connect 2030 target considering Sustainable Development Goal 13 (climate change), the Paris Agreement, and the Glasgow Climate Agreement. Seven new work items were also approved for consideration.

4.2 Question 11

Question 11 develops Recommendations on standards, frameworks, and requirements and conditions that facilitate real-time energy service and control solutions for more effective and efficient energy management using ICT and digital technologies, as well as energy management improvements aimed at increasing energy efficiency and reducing carbon dioxide emissions.

At this meeting, L.1230 and L.1240 were consented and L.Supplement 48 was agreed. L.1230 specifies the power-supply-system configuration with 10 kVAC input and up to 400 VDC, general requirements for output voltage, safety, and EMC, and the architecture of power-monitoring systems. L.1240 specifies a power-supply system of telecommunication center buildings, safe system operation, and evaluation framework of a power-supply system applicable to energy conservation evaluation, classification of telecommunication center buildings, and methods for evaluating reliability. L.Supplenent 48 specifies power-management methods using AI and the digital twin computing technology in telecommunication center buildings and datacenter infrastructure. Four new work items were also approved for consideration.

4.3 Question 12

Question 12 develops Recommendations for improving the efficiency of power and air conditioning systems, supporting the development of energy-efficient ICT architectures with power systems up to 400 VDC, as well as early warning systems for climate change-induced events, applications in smart agriculture, micro-smart grids, and building optimization.

At this meeting, L.Supplement 49 was agreed, which presents an overview of Recommendations and technical standards on the impact of ICT on climate-change adaptation in other sectors, as well as on strengthening the resilience of ICT networks against natural disasters. Four new work items were also approved for consideration.

5. Future development

This article introduced the latest deliberation trends in ITU-T SG5. We will continue to promote timely standardization activities in response to changes in the environment surrounding telecommunications infrastructure and services and contribute to improving the quality and reliability of telecommunications services and reducing environmental impact.

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The Occurrence of Mold in Telecommunication Equipment and Facilities and Its Impacts on Material Degradation

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Abstract

This article provides two case studies of the occurrence of mold in telecommunication equipment and facilities and its impacts on the materials of the equipment and facilities. This is the seventy-third article in a series on telecommunication technologies.

Keywords: mold, SEM, EDS, rDNA-sequence analysis

1. Introduction

Telecommunication equipment and facilities are composed of various materials, including metals, concrete, and plastics, which degrade with prolonged use. The rate of degradation of those materials depends on the environment in which they are installed. Consequently, some equipment and facilities may degrade at a significantly higher rate than others and may subsequently fail or cause accidents. As shown in **Fig. 1**, the degradation progresses due to many factors in the environment in which the equipment or facility is installed [1]. It is known that natural and climatic phenomena cause the degradation. For example, particles of sea salt cause corrosion to metallic materials called “salt damage” and ultraviolet rays contained in sunlight cause damage to organic materials. On the other hand, organisms have been reported to cause unique failures. For example, cicadas, rats, etc. have been reported to damage aerial communication facilities and cause failures [2]. We have also received inquiries from the field about mold growth and the possibility of its impacts on material degradation depending on the environment surrounding telecommunication equipment and facilities. In this article, two case studies investigating the occurrence of mold in telecommunication equipment and facilities and its impacts on the materials of the equipment and facilities are presented.

2. Characteristics of mold and their impacts on telecommunication equipment and facilities

Mold can be found in people’s homes and even suspended in the air; in other words, it can be found everywhere—indoors and outdoors. It is also important to note that some molds are known to pose a health hazard to the human body. Mold grows when spores implant in various environments and grow into mold while absorbing nutrients and moisture through the tips of their fungal filaments. After a while, more spores are dispersed from the mold and spread through the air. Mold growth primarily requires nutrition, the right temperature, and moisture (humidity) [3]. The temperature range in which mold can grow is 0 to 40°C, in which the optimum growth temperature

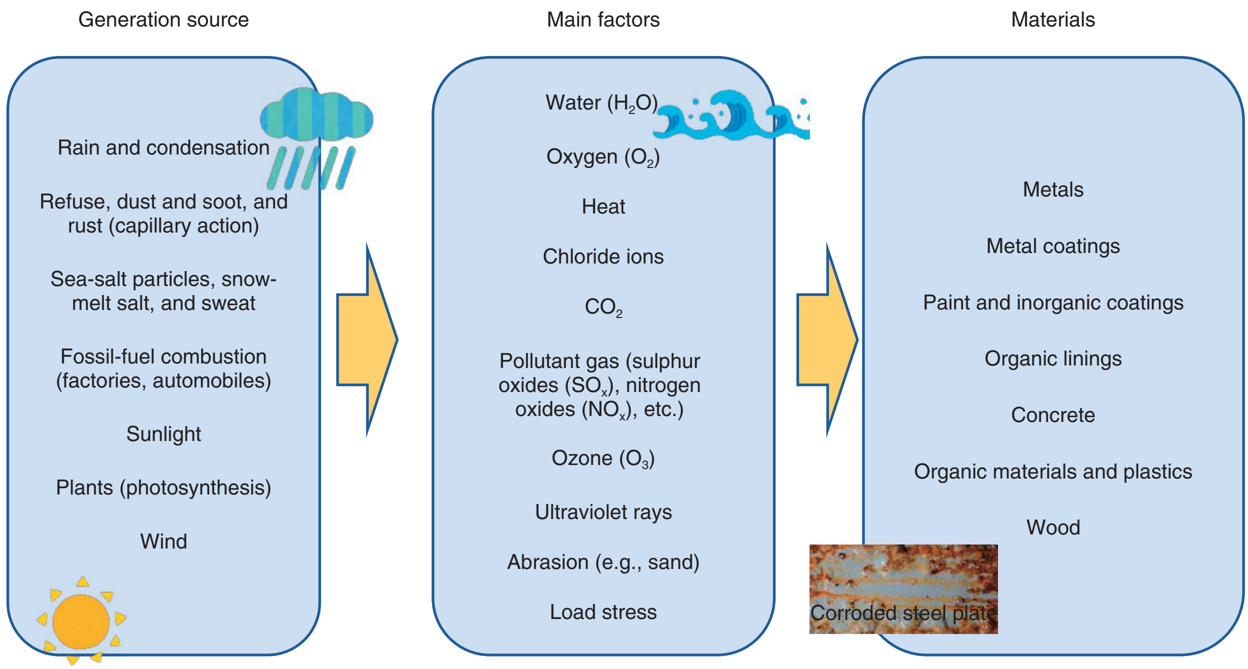


Fig. 1. Major factors affecting degradation of materials in air.

is 25 to 28°C. Moisture is also essential for mold growth. A decrease in moisture content causes a decrease in the growth rate of mold and eventual cessation of growth. To maintain a mold-free environment, relative humidity of the environment in question must be kept below 60% constantly regardless of temperature changes [4].

Metal corrosion also proceeds when oxygen and moisture (humidity) coexist as major factors (Fig. 1). If the environmental temperature increases, the reaction rate of such corrosion increases and may accelerate degradation of materials. The fact that mold is generated and continues to grow without dying suggests that the humidity of the environment in which the telecommunication equipment is installed is maintained at a consistently high level. In other words, maintaining a mold-free environment effectively prevents material degradation.

This article presents two case studies on mold growth: one concerning the walls of an outdoor telecommunication box (Section 3), and the other concerning the machine room of a telecommunication center building (Section 4).

3. Investigation of foreign matter on the walls of an outdoor telecommunication box

3.1 Circumstances of foreign-matter generation

The first case study concerned the walls of an outdoor telecommunication box. We received reports of black adhering substances on some of the walls of an outdoor telecommunication box and peeling paint in some of the areas where the adhering substances are present. The condition of the wall surfaces of the telecommunication box in question is shown in **Fig. 2**. The local maintenance personnel requested the Technical Assistance and Support Center (TASC), NTT EAST to investigate and identify any foreign matter adhering to the walls and determine its impact on the paint peeling.

3.2 On-site environmental investigation and analysis of foreign matter

To identify adhering substances of foreign matter on walls of the telecommunication box, we conducted (1) a visual inspection and (2) observation and analysis of adhering substances. We also conducted (3) an adhesion test of wall paint to determine the degradation of the exterior-wall paint.

(1) Visual inspection

Visual inspection revealed adhering substances on

Fig. 2. Appearance of outdoor telecommunication box. Left: side with poor sunlight; right: side with good sunlight.

Fig. 3. Adhering substances and peeling paint on the wall.

Fig. 4. Adhering substances on the walls. Top: optical-microscope image; bottom: SEM image.

the exterior wall of the outdoor telecommunication box. We observed no adhering substances on the walls of the box that received plentiful sunlight due to the location of the facility; to the contrary, we observed adhering substances on the walls that received poor sunlight. We also observed peeling paint on the wall surfaces where the adhering substances were observed (**Fig. 3**). In contrast, we observed no significant peeling of the paint on the walls without adhering substances of foreign matter.

(2) Observation and analysis of adhering substances

We observed the adhering substances on the walls using optical microscopy and scanning-electron-microscope energy-dispersive X-ray spectroscopy (SEM-EDS) (**Fig. 4**).

The results of the EDS analysis indicate that the adhering substances were mainly composed of carbon and oxygen, i.e., organic matter. The environment surrounding the outdoor telecommunication box in question, which is located in a mountainous area, suggests that the adhering substances also contain organic matter such as moss and dust. However, the shape, size, color, and other characteristics of the spores observed in the SEM and optical-microscope images—as well as the fact that the adhering substances were observed mainly in the shade—confirmed that the adhering substances on the walls were molds.

(3) Adhesion test of wall paint

A paint layer with adhesion strength meeting the standard prevents oxygen and moisture from penetrating the wall surface and protects the steel materials composing the facility from corrosion. We therefore used the prescribed method to measure the overall adhesion strength of the paint on the walls of the outdoor telecommunication box. When we compared the adhesion strength of the paint on the walls with the adhering substances with that of the paint on the walls without the adhering substances, we found no difference in the adhesion strengths. We also confirmed areas of the walls of the entire telecommunication box in which the adhesion strength of the paint was below standard.

3.3 Considerations and countermeasures

The results of the above-described investigation confirmed the presence of mold in the adhered organic matter. Since we found areas with paint below the standard adhesive strength on the telecommunication

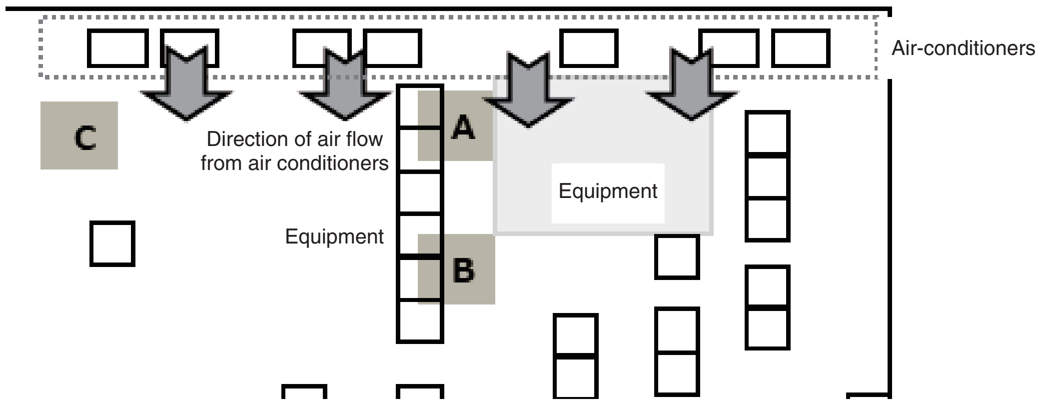


Fig. 5. Layout of equipment in machine room.

box, regardless of the presence or absence of the adhering substances, we concluded that mold was not the direct cause of the decrease in adhesive strength of the paint. However, we presumed that the adherence of foreign matter such as mold created a high-humidity state, which further accelerated degradation such as the observed peeling of paint.

Mold like this and other adhering substances on walls can result in degradation of paint being overlooked and accelerate such degradation. It should thus be cleaned and removed from the walls of outdoor telecommunication boxes during inspection. When degradation is observed, such as a decrease in adhesion strength of the paint or peeling of paint, repairs such as repainting are necessary.

4. Investigation of foreign matter in the double floor of the machine room of a telecommunication center building

4.1 Circumstances of foreign-matter generation

The second case study concerned a machine room of a telecommunication center building. A white foreign matter adhering to cables was founded in the double-layer floor of the machine room of a telecommunication center building. The layout of the equipment in the machine room is shown in **Fig. 5**.

White foreign matter was observed at locations A and B in the figure, but not at location C. The local maintenance personnel asked TASC to investigate this white foreign matter and determine if it was mold and what impacts it had on the equipment in the double floor and people's health.

4.2 On-site environmental investigation and analysis of foreign matter

(1) Visual inspection

We inspected the detailed state of the foreign matter. As shown in **Fig. 6**, the foreign matter was found adhering to cables, the underside of the double-layer floor, and duct openings at locations A and B in the machine room. Upon checking around the inside of the equipment, we also found the foreign matter at the points at which the cables housed inside the equipment were installed above the floor.

(2) Measurement of temperature and humidity

To investigate the cause of foreign matter occurring only in certain parts of the machine room, we installed temperature and humidity data loggers over a long period. We then investigated whether differences in temperature and humidity exist in the areas where the foreign matter was observed and the areas where not observed. The temperature and relative-humidity ranges for the measurement period (late April to early May) are listed in **Table 1**.

Compared with locations where no foreign matter was observed (location C in Fig. 5), the locations where foreign matter was observed (locations A and B) were found to be in a low-temperature, high-humidity environment.

(3) Observation and analysis of foreign matter

Component analysis and morphological observation of the collected foreign matter using SEM-EDS revealed that it was composed of about 50% carbon by weight, which indicates that organic matter was the main component, although magnesium, an inorganic element, was also detected at about 7% by weight. The magnesium is thought to be derived from magnesium hydroxide, which is a flame retardant

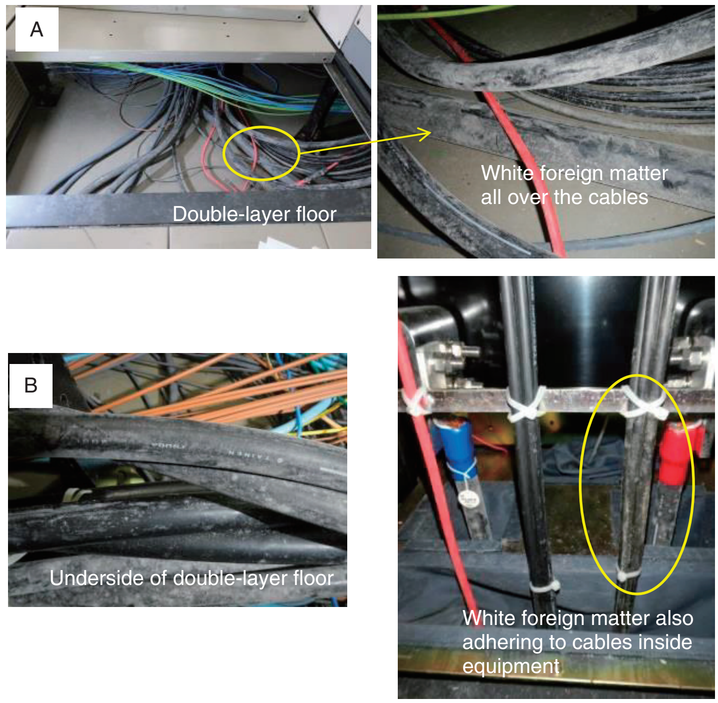


Fig. 6. Condition of facilities.

Table 1. Results of measuring temperature and humidity. (Range of measured values during the measurement period).

Measurement point (Fig. 5)	Temperature (°C)	Relative humidity (%)
A	17–20	40–78
B	19–21	37–69
C	25–27	23–47

contained in the outer sheath of the cables. Magnesium hydroxide is known to be harmless, non-toxic, and non-corrosive, so it is not expected to affect the human body or cables. Precipitation of magnesium from the surface of the cables is only trace amounts, and it has little impact on the flame resistance and electrical properties of the cables; therefore, continued use of the cables with magnesium precipitation should pose no problems.

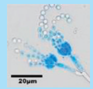
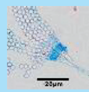
(4) Mold culture test and analysis

Considering the results of the above investigation and given that organic matter was the main component of the foreign matter, we assumed that the foreign matter was mold. Since the foreign matter was generated in the machine room, we had concerns about its impact on the human body. Accordingly, by collecting and culturing the foreign matter taken from the site, we conducted detailed analyses of the foreign matter by morphological observation, microbiological examination, and rDNA-sequence analysis to determine the fungal genus and species. The results of the analyses showed that the foreign matter was mainly blue mold (Penicillium) and black mold (Cladosporium), which commonly occur in living environments (**Table 2**). Both of these bacterial strains have been reported to have a low risk in regard to the human body.

4.3 Considerations and countermeasures

The main component of the foreign matter was mold, and the cause of growth of the mold was the high-humidity environment; therefore, to prevent mold growth, the relative humidity of the machine room must be kept constantly below 60% [3]. The presence of moldy and non-moldy areas in the same machine room also indicates that temperature and humidity are unevenly distributed in the room. Although the mold identified in this investigation is harmless to humans, the presence of a mold-prone environment in some parts of the machine room may cause condensation or other problems that may affect

Table 2. Results of culture test, analysis of molds and risks to human health.

Name of bacterium		Risk
Penicillium corylophilum (blue mold)		No significant health hazards to humans have been reported.
Cladosporium cladosporioides (black mold)		In rare cases, it has been identified as a cause of corneal mycosis and mycobacteria in the lungs, but the risk to healthy humans is extremely low.
Penicillium chrysogenum (blue mold)		PR-toxin, roquefortin C, and secalonic acid are fungal toxins known to be produced by this species, but they are not considered pathogenic.
Arthrinium kogelbergense		Currently no reports of pathogenicity

the equipment in the room.

Under those circumstances, two countermeasures to prevent recurrence of mold outbreaks are necessary: (1) remove the mold with ethanol-containing paper towels or other means; (2) check whether the current statuses of the outside-air inflow and the temperature and humidity distributions in the machine room are properly controlled, identify the cause of high humidity, and implement improvements to the air-conditioning system.

5. Concluding remarks

To protect telecommunication equipment and facilities from degradation due to adhesion of naturally occurring foreign matter, such as mold, it is necessary to regularly inspect outdoor equipment and facilities and check for the presence of foreign matter. If foreign matter is found, it should be removed by cleaning or other means. As for indoor equipment and facilities, for example, in a machine room, it is necessary to prevent the generation of foreign matter by appropriately controlling temperature and humidity of the room.

TASC will continue to engage in technical cooperation to solve problems in the field, such as degradation of equipment and facilities caused by natural phenomena and natural organisms and microorganisms, to contribute to improving the quality and reliability of telecommunication services.

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External Awards

IEICE Electronics Express (ELEX) Best Paper Award

Winners: Hiroyuki Uzawa, NTT Device Innovation Center; Shuhei Yoshida, NTT Device Innovation Center; Yuukou Iinuma, NTT Device Innovation Center; Saki Hatta, NTT Device Innovation Center; Daisuke Kobayashi, NTT Device Innovation Center; Yuya Omori, NTT Device Innovation Center; Ken Nakamura, NTT Device Innovation Center; Shuichi Takada, ArchiTek Corporation; Hassan Toorabally, ArchiTek Corporation; Kimikazu Sano, NTT Device Innovation Center
Date: September 6, 2022
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For "High-definition Object Detection Technology Based on AI Inference Scheme and Its Implementation."
Published as: H. Uzawa, S. Yoshida, Y. Iinuma, S. Hatta, D. Kobayashi, Y. Omori, K. Nakamura, S. Takada, H. Toorabally, and K. Sano, "High-definition Object Detection Technology Based on AI Inference Scheme and Its Implementation," IEICE ELEX, Vol. 18, No. 22, p. 20210323, 2021.

Young Scientist Presentation Award

Winner: Fumihide Kobayashi, NTT Device Technology Laboratories
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Organization: The Japan Society of Applied Physics (JSAP)

For "Co-optimized Metalens and Reconstruction Network for Compressive Spectral Imaging."
Published as: F. Kobayashi, M. Miyata, Y. Sogabe, and T. Hashimoto, "Co-optimized Metalens and Reconstruction Network for Compressive Spectral Imaging," The 69th JSAP Spring Meeting, 23p-D315-2, Mar. 2022.

Young Researcher Encouragement Award

Winner: Ko Natori, NTT Network Innovation Center
Date: October 6, 2022
Organization: IEICE Technical Committee on Network Systems

For "Proposal of C-state Control Method in Frame Forwarding System for vRAN Traffic."
Published as: K. Natori, K. Fujimoto, and A. Shiraga, "Proposal of C-state Control Method in Frame Forwarding System for vRAN Traffic," IEICE Tech. Rep., Vol. 122, No. 198, NS2022-92, pp. 70–75, Oct. 2022.