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FEATURE

Designing a Resilient World through Innovation

DIALOG

Panther OGATA Takahiro × INOUE Masugi

(NICT Resilient ICT Center)

Unshaken by disasters or disruptions!
Comedian Panther Ogata says "Thank you!!"
At the forefront of Resilient ICT

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Cover Photo

The sendai mediatheque is a multi-purpose cultural complex that combines the functions of a library, an art museum, and a media-arts center. It is supported by 13 truss columns and is known for its robustness, having kept damage to a minimum during the Great East Japan Earthquake. This time, we welcomed Panther Ogata into a glass-walled open space to discuss "NICT's Resilient ICT," which supports society.

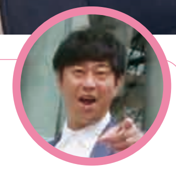
Upper Left Photo

The Resilient ICT Research Symposium is an annual event organized by the Resilient ICT Research Center to present its initiatives and results to date. Through lectures, exhibits, and demonstrations, the symposium introduces information technologies that not only support disaster-preparedness but also contribute to everyday social activities. It provides a forum for thinking about how enhanced resiliency can help build a sustainable society. Symposium details and contents (materials and videos) can be accessed via the QR code below.

Japanese Language site

Unshaken by disasters or disruptions! Comedian Panther Ogata says "Thank you!!" At the forefront of Resilient ICT

The Great East Japan Earthquake, which struck on March 11, 2011, caused devastating damage across a wide area, particularly the Tohoku region. Its impact is still vivid in our memories today. In the aftermath of the disaster, numerous tools leveraging NICT's technologies have been developed. One of the key research hubs behind these efforts is the Resilient ICT Research Center, located in Sendai.
For this feature, we welcome OGATA Takahiro from the comedy trio Panther, a Miyagi-born entertainer who personally experienced the terror of the earthquake, to the sendai mediatheque. Together, we explore the latest resilient information and communication technologies that NICT is developing.



Panther
OGATA Takahiro
〈right〉

Born in Higashi-Matsushima City, Miyagi Prefecture. In 2008, he formed the comedy trio Panther together with KAN Ryotaro and MUKAI Satoshi.
He has appeared on the NHK educational program "Warawanai Sugaku" (Math That Doesn' t Make You Laugh). He also stars in the local Sendai TV show "Sendai-shi Aoba-ku Kanooga Benriken," where he takes on physical challenges to bring smiles to the people of Miyagi.
Since January 2019, he has served as a Miyagi Kizuna Ambassador.

NICT
INOUE Masugi
〈left〉

Director General,
Resilient ICT Research Center,
Network Research Institute

After completing his doctoral program, he joined the Communications Research Laboratory (currently NICT) in 1997. He engaged in research and development of mobile networks and wired and wireless convergence technologies, as well as strategic planning and international collaboration projects. He has been in his current position since 2021.
Ph.D. (Engineering)

——Today, we are joined by Ogata-san from the comedy trio Panther, who is originally from Miyagi, for a discussion with INOUE Masugi, Director General of the NICT Resilient ICT Research Center.

Ogata-san, as a Miyagi Kizuna Ambassador, is it correct that you are involved in promoting Miyagi-produced foods and participating in prefectural events and publications such as Miyagi Kensei Dayori?

OGATA Yes. I've been serving as a Miyagi Kizuna Ambassador since January 2019, promoting famous products from Miyagi such as seaweed, beef tongue, sea pineapple, and *serinabe* (parsley hot pot). My hometown, Higashi-Matsushima City, is especially known for its high-quality seaweed. We're very proud of our *kenjo-nori*, the premium seaweed served to the Imperial Household.

——We can really feel your deep love for Miyagi. Now, Director General Inoue, could you introduce the Resilient ICT Research Center for us?

Resilient ICT Research Center

INOUE Random question, Ogata-san, but do you know what "resilient" means?

OGATA Huh? Where did that come from—sounds complicated.... Resi…? Resient? Resident? What is that?

INOUE It's a little unfamiliar and hard to understand, right? "Resilient" means, simply put, "flexible yet strong." An example would be the ability to recover quickly even after a disaster occurs. Flexible, but unbreakable—that kind of idea. The Japanese word would be "強靭性" (*kyojinsei*).

OGATA I see. So it's something like "recovering quickly from a disaster"? By the way, why is the center located in Tohoku?

INOUE During the 2011 Great East Japan Earthquake, the earthquake and tsunami caused phones and the internet to stop working, and people were unable to receive information. Because of that, it was decided that we need to develop a disaster-resilient communication system.

Tohoku was chosen as the location because it was determined that, based on the experiences and knowledge that Tohoku gained from the Great East Japan Earthquake, such research should be carried out in Tohoku itself. With support from Tohoku University, the Resilient ICT Research Center was established on the Katahira Campus in 2012.

OGATA I see. So there's a meaningful reason why it's located in Tohoku. What kind of research is being conducted there, then?

INOUE Well, before we get into the research itself, I have one question for you, Ogata-san. Do you have any image or idea of what "ICT" is?

OGATA ICT? I'm not really sure. I think it's some kind of computer-related term, but I'm the complete opposite of digital… I'm a comedian, so I'm always just like, "Waaah!" acting silly and over the top.

INOUE Even if you don't realize it, Ogata-san, you're already using ICT. The best example is the internet. The "I" in ICT stands for "information," the "C" stands for "communication," and the "T" stands for "technology," so ICT means information and communication technology.

It includes the technologies we use every day without even thinking about them, such as smartphones and computers. Our research aims to make ICT even more resilient and robust.

OGATA I see. So we've been relying on ICT without even realizing it.

The internet alone is amazing, but to hear that you're doing even more cutting-edge work—Miyagi is incredible! That makes me want to brag to people from other prefectures.

INOUE When you're using a smartphone, if the signal is weak, it can be hard to make a call or the audio may cut out, right? Isn't that really inconvenient?

OGATA Exactly! When it keeps cutting in and out, you can't understand what the other person is saying.

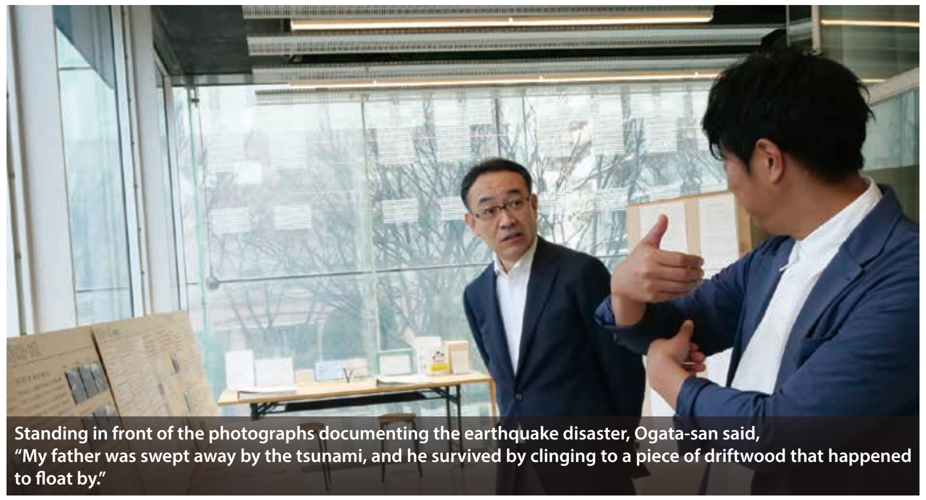
INOUE So we conduct research on wireless communication that is resistant to disruption even during disasters, when much of the network becomes fragmented.

OGATA That's great! That would really help. It's just like my catchphrase: "Thank you!" (laughs)

INOUE Let's move onto another example. When there is a major disaster, not only the area that's directly affected but also a wider region can lose mobile and internet access. That's why we need technologies that can prevent large-scale network failures from happening in the first place.

Ogata-san, I'm sure you've also experienced moments when communication suddenly cut out and you panicked.

OGATA Yes, definitely! During the Great East Japan Earthquake, it was exactly like that. I couldn't get in touch with my family and relatives, and I seriously panicked.



Standing in front of the photographs documenting the earthquake disaster, Ogata-san said, "My father was swept away by the tsunami, and he survived by clinging to a piece of driftwood that happened to float by."

INOUE This can happen not only when mobile base stations collapse, but also when the optical-fiber lines along the ground are severed or when communication traffic becomes heavily concentrated. To prevent this, NICT is researching technologies that detect abnormalities in optical lines in advance and prevent failures from occurring.

OGATA Detecting things in advance like that is incredible.

INOUE Furthermore, we are also conducting research on technologies that allow response teams at disaster sites to keep sharing information even if communication networks become unstable and eventually fail completely.

Many people gather at large-scale disaster sites, including the Self-Defense Forces, police, and firefighters. In such situations, the very first thing needed is means of communication.

To enable all the people on site to work efficiently, it's essential to understand the situation on the ground and give accurate instructions. For that, the first thing they need is means of communication and the ability to exchange information.

At the Resilient ICT Research Center, we are developing technologies that can ensure reliable communication and information-sharing even during major disruptions such as earthquakes, so that we can save as many lives as possible.

Panther Ogata's Earthquake Experience

——Where were you during the Great East Japan Earthquake, Ogata-san?

OGATA I was in Tokyo at the time, but my hometown of Higashi-Matsushima was completely devastated, so I couldn't get through on the phone, and the only way I could know what was happening was by watching the news on TV. I couldn't get in touch with my family at all. I didn't even know where I was supposed to call. While all that was happening, I saw on the TV news that my parents' house was being swept away by the massive tsunami.

INOUE What!? Your family home, Ogata-san?

OGATA Yes, footage of it appeared on the news. At that moment, I thought, "Oh no, it's all over."

To be honest, I had prepared myself for the worst. My older sister had married and moved to Okayama, and every day she called me asking, "Do you think Mom and Dad are okay?" I told her, "You should prepare yourself…"

My father went through the horrifying experience of being swept away by the tsunami, but fortunately both of my parents survived. We didn't find that out until a week later, and even then, it wasn't from them directly—the news reached us through other people.

INOUE I'm glad to hear that.

OGATA I will never forget the anxiety I felt during that long period when I couldn't reach anyone. I never want to experience that feeling again. If communication had been working at that time and we had been able to contact each other properly, we would have been reassured much sooner. Maybe many more people could have been saved as well.

INOUE We usually never think twice about phone calls connecting, but when they suddenly don't, we panic, right? Even in places far from the disaster areas, like Tokyo, phone calls wouldn't go through, emails took days to arrive, and many people were unable to get home. In the affected areas, people must have been extremely anxious, not only because they couldn't confirm the safety of their family and friends, but also because, for a long time, they had no way of knowing what kind of damage was happening around them.

Ogata-san listens intently as he learns about "Resilient ICT" for the first time.

OGATA I remember that at that time, it wasn't just Tohoku. The whole country was in chaos. Even work-related communication was hard.

Resilient Wireless Communication

INOUE That's right. At that time, the entire country of Japan was in a difficult situation. So, at the Resilient ICT Research Center, we have been working on the research and development of technologies that work even in disasters, learning from the lessons of the Great East Japan Earthquake.

The first topic I'd like to introduce is resilient wireless communication. The smartphone you use, Ogata-san, communicates wirelessly using radio waves. Our research focuses on how to make that communication more robust and prevent it from being interrupted.

During the earthquake, there were massive communication failures, but even in everyday life, you've probably experienced your connection cutting out, haven't you?

OGATA When I'm on the Shinkansen, for example, the connection sometimes cuts out. During remote work, too, it's a real problem when the connection suddenly drops, isn't it?

INOUE What makes this especially difficult is that radio waves are invisible. If only we could know in advance when the signal is about to weaken, we could take action. That's why we have developed a way to measurement-based visualization of radio waves.

OGATA What!? You can see radio waves? That's unbelievable. That's the kind of technology you could win a Nobel Prize for, isn't it?

INOUE Not quite that remarkable (laughs).

OGATA That's brilliant. It sounds really interesting.

I imagine the researchers must get excited and really enjoy working on things like this. It's the kind of work you can only do if you have a strong sense of curiosity and an explorer's drive to understand how things work.

INOUE By visualizing the strength of radio waves, we can see where the "cliffs" in signal strength are.

OGATA What do you mean by a "cliff" in radio waves?

INOUE At disaster sites, many robots are deployed to carry out search-and-rescue operations. These robots coordinate with each other wirelessly, but inside damaged buildings that are about to collapse, there are places where the signal suddenly cuts off—what we call "radio-wave cliffs." In other words, beyond that point, the robots can no longer operate because communication is lost. By "visualizing" radio waves, we can identify these radio-wave cliffs in advance and ensure that the robots avoid approaching those zones during their activities.

OGATA I see—that's impressive. So this is what you mean by "visualizing" radio waves. With this, rescue operations can be carried out more safely.

Resilience of Optical Networks

INOUE That's right. Next, I'd like to introduce resilient optical network technologies. Ogata-san, you've heard the term "optical network" before, haven't you?

OGATA I've heard of it. An optical network is a high-speed network, isn't it?

INOUE Exactly! It's fast. Optical networks use optical fibers, which transmit light through cables. But if those fibers are severed during a disaster, it becomes a serious problem.

An enormous amount of data travels through optical fibers, so the impact on society is huge.

That's why NICT is researching technologies that can detect issues in optical lines in advance and prevent failures from happening.

OGATA Wow, I didn't know optical networks carry that much information.

Last year, there was that incident where a beverage company was hit by a cyberattack. Its computers were taken over and a massive amount of data was stolen. If security isn't solid, it can turn into a huge problem.

INOUE Exactly. We have to prepare for all kinds of threats, not only natural disasters. NICT also has a department that specializes in cybersecurity research.

OGATA That's good to hear! But that also means we live in a time when those kinds of measures have become necessary.

INOUE Yes. In addition to preventing communication from being cut off, we also have to think about safety and security.

OGATA It really is tough, isn't it?

SOCDA *

INOUE Next is the disaster-response chatbot, SOCDA.

OGATA What's a chatbot?

INOUE A chatbot is, simply put, like a "conversation robot" that replies instantly when you ask something on your smartphone or on the web.

When a disaster happens, staff at the local government office become extremely busy with many urgent tasks. When that happens, AI can communicate with residents through LINE on their behalf, collecting local disaster information, evacuation-shelter information, and more, and then visualizing that information on a map.

OGATA The AI answers the questions? That's fantastic. There's no way the staff at the local government office could handle inquiries from tens of thousands of residents on their own.

But, can AI really give accurate answers? There's so much incorrect information and misinformation on the internet.

INOUE Don't worry. SOCDA has a function that helps reduce misinformation by filtering and organizing reported information. SOCDA has already been adopted by over one hundred local governments across Japan.

OGATA So it can even tell you where the evacuation centers are? That's really helpful.

NerveNet

INOUE Next, I'd like to introduce NerveNet. The name NerveNet comes from the English word "nerve," referring to the nervous system. It's a network in which many small base stations are installed in advance, and each base station is connected wirelessly in a mesh-like structure, almost like a biological nervous system.

This network uses a technology called multi-hop wireless networks.

Like a bucket brigade, each base station passes information on to the next one, allowing the data to eventually reach all base stations.

This type of network maintains communication and makes it easier to obtain information even during disasters, so local governments install and use it in advance, before any emergency occurs.

In addition, each NerveNet base station has a built-in battery, allowing it to operate for about three days even without external power.

This system is currently being deployed by three local governments.

OGATA It's excellent that the battery lasts for three whole days. That's definitely a feature we'd want it to have.

INOUE Another important point is that this system is based on the concept of "phase-free design."

OGATA What? Hold on a second. You said it so casually, but what exactly is "phase-free design"?

Experiencing what it feels like to carry the information-relay device currently being developed for disaster-response agencies.


I see — because it's phase free and usable in everyday life, it becomes useful during disasters as well.

INOUE "Phase free" refers to the idea that the things we use in our daily lives can also be useful just as they are during disasters. In other words, they can be used both in everyday life and in emergencies. Camping gear is a good example of something that's phase free—you use it for camping normally, and you can also use it in an emergency.

OGATA I see. It's great to be able to use things we normally use in disasters as well. If someone suddenly told us to use something we're not familiar with, we'd have no idea what to do.

Disaster Detection Technology Using Video Analysis

INOUE That's right. Being phase free is an important point.

Well then, let's move onto the next topic. The next technology, disaster detection technology using video analysis, is a system that detects disasters from camera footage.

OGATA You can detect disasters just from video footage? That's fantastic!

INOUE For example, AI can detect smoke or flames from fires that occur during an earthquake. Smoke is wispy and doesn't have a clear shape. Volcanic plumes are also hard to distinguish from clouds. But the system can automatically identify them. This makes it possible to immediately know where a disaster is happening.

OGATA To monitor disasters, humans would have to keep watching the cameras all the time, but you can't have a huge number of people glued to the screens 24 hours a day.

INOUE Exactly. This system can also detect the heights of ocean waves crashing against coastal seawalls. When waves hit the seawall, they create spray, and just like smoke, spray has no fixed shape, making it difficult to identify. We are currently testing this technology on the coast of Toyama, and it has been receiving very positive evaluations.

OGATA That's outstanding—Waves change shape every single time. And it can still recognize them!


"So you use sounds inaudible to humans to detect distant tsunamis early?" Ogata-san said, showing great interest.

Infrasound

INOUE That's right! This research lets us detect subtle differences. The last technology I'd like to introduce is infrasound, which makes use of sound. "Infrasound" refers to sounds generated when powerful natural phenomena, such as earthquakes, tsunamis, and volcanic eruptions, exert force on the atmosphere. These sounds are inaudible to the human ear.

OGATA It can detect sounds we can't even hear? That's awesome!

INOUE It's not exactly sound as we normally think of it. It's actually a change in pressure (air pressure). Using this, we can contribute to earlier estimation of tsunami arrival times. You might remember the powerful underwater volcanic eruption in Tonga in January 2022. At the time, we had sensors installed to detect tsunami-generated infrasound. When we later analyzed the data, we found that it had captured very strong infrasound signals. From these data, we can determine the expected arrival time of a tsunami much earlier.

OGATA With tsunamis, you absolutely want to know as early as possible. Even 5 minutes or 10 minutes can matter a lot.

A Big "Thank You!!" from Ogata-san

——Because even that amount of time could help save many lives.

So, Ogata-san, what are your thoughts on the NICT technologies you've seen so far?

OGATA I was truly amazed by these incredible technologies. I had no idea that NICT was conducting such remarkable research in my home prefecture of Miyagi, with the aim of saving people from disasters.

This is more than research—it's a real contribution to society. I'm deeply moved!

For those of us who went through the Great East Japan Earthquake, it's something we deeply appreciate. And since we don't know what the future holds for the world or the planet, I hope you will continue your research and keep helping people with these remarkable technologies. Please keep helping people around the world. I'll keep promoting your work as much as I can, so I'm counting on you.

INOUE We will also do our part, working day and night with the goal of making the world more resilient. And we will continue to pursue research that can truly make a difference.

OGATA To all the researchers, staff members, and partner organizations of NICT, "Thank you!!"

This interview was conducted at the sendai mediatheque.

＊ SOCDA：SOCial-dynamics observation and victims support Dialogue Agent platform for disaster management

Rapid Disaster Detection and Uninterrupted Connectivity:
Advancing Safety through AI and Communication Technologies

TAKIZAWA Kenichi
Director of Sustainable ICT System Laboratory, Resilient ICT Research Center, Network Research Institute
After completing a doctoral program, Dr. TAKIZAWA joined NICT (formerly Communications Research Laboratory) in 2003, where he has been engaged in research and development on various wireless communication applications. Current position since 2021. Ph.D. (Engineering)

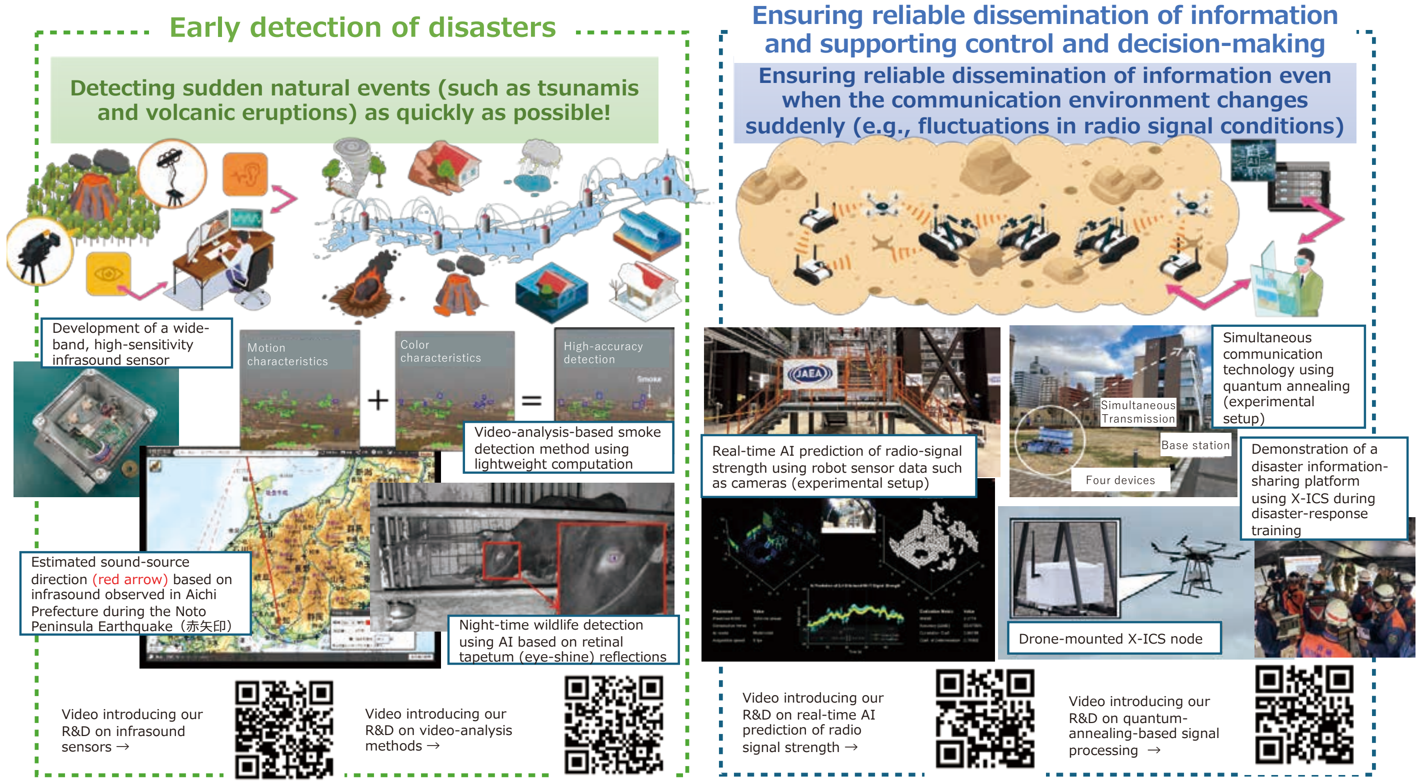
Japan faces a high risk of disasters such as earthquakes, heavy rainfall, and volcanic eruptions, so it is essential to establish robust and resilient information and communication technologies that can limit the spread of the damage. The Sustainable ICT Systems Laboratory is engaged in the research and development of technologies for the early detection of disasters using artificial intelligence (AI), technologies for reducing the risk of communication outages, and platforms for sharing disaster-related information.

Background

Looking back over the past two decades, many disasters and accidents have occurred in Japan, affecting our daily lives. These include the 2011 Great East Japan Earthquake and the subsequent tsunami and nuclear power plant accident, the 2014 Mount Ontake eruption, frequent flooding of rivers and landslides due to heavy rainfall in recent years, and even infrastructure-related accidents involving aging sewer pipes, tunnels, and other facilities.

Japan faces a wide range of natural hazards, including earthquakes, tsunamis, volcanic eruptions, typhoons, heavy rainfall, and heavy snowfall, while being home to many critical and aging infrastructure systems and densely populated urban areas. As a result, Japan is considered one of the countries with the highest disaster risk in the world. At the same time, there is strong public demand for highly reliable and safe social infrastructure, and information and communication technology (ICT) is playing an increasingly important role in meeting these expectations.

One factor that can worsen the impact of disasters is the problem of information delivery. When information fails to reach people, arrives too late, or is not trusted, individuals may be unable to take appropriate evacuation actions, increasing the potential for harm. Examples include situations in which a tsunami cannot be detected in time, people are unable to secure adequate evacuation time due to delayed information, or unreliable information fails to prompt people to act.



ICT can contribute to addressing these challenges in three main areas:

1. ICT for supporting the early detection of disasters (sensing),
2. ICT for reliably delivering information and data (communications), and
3. ICT for supporting situational awareness and decision-making based on information and data (sharing and analysis).

The Sustainable ICT Systems Laboratory is advancing research and development in these areas. We recognize that user perspectives are crucial for developing technologies that reduce disaster impacts, and we therefore place great importance on engaging with users from the early stages of research and development through to validation and field testing, thereby ensuring a smooth path to social implementation.

Early Detection of Disasters — Sensors and Edge AI—

One approach to achieving the early detection of disasters is the utilization of infrasound. Infrasound refers to extremely low frequency sound waves that are inaudible to the human ear and are generated by large-scale natural events such as earthquakes, tsunamis, and volcanic eruptions. By observing infrasound at multiple locations, it is possible to estimate the position of the source of the sound, i.e., the location of the volcanic eruption or sea-level change. Because infrasound travels faster than a tsunami, it may enable the detection of tsunamis occurring far offshore before they arrive, allowing evacuation actions to be taken in advance. We have also developed new sensors that are inexpensive, compact, and low-power, while still providing sensitivity and bandwidth comparable to conventional high-cost sensors. Through observations of infrasound generated during events such as the Noto Peninsula Earthquake and eruptions of Sakurajima, we are advancing the verification of sound-source localization methods.

In addition, we are working on disaster detection through AI-based video analysis. We have developed a smoke-detection method based on commercially available network cameras that can be implemented on small processors, such as camera-equipped microcontrollers. We are also working on its application to the early detection of wildfires and suspicious fires. Furthermore, taking advantage of the fact that animal eyes appear to shine at night, we are also researching technology that detects wildlife using infrared cameras and AI analysis. All of these are lightweight AI technologies that can be processed on-site (at the edge) rather than in the cloud, enabling both rapid detection and low power consumption.

Ensuring Reliable Dissemination of Information and Supporting Control and Decision-making — Resilient Communications and Data Sharing—

To ensure the reliable dissemination of information during disasters, wireless communications capable of simultaneous wide-area broadcasting are essential. However, radio waves are easily affected by buildings and terrain, causing communication quality to vary greatly by location and creating the risk of interruptions. This risk is particularly critical when robots perform tasks in areas inaccessible to humans, such as inspections inside sewer pipes or emergency response in industrial plants, because a loss of control communications could lead to secondary accidents. To address this challenge, we are researching technology that uses AI to predict changes in radio signal strength in real time based on data from cameras mounted on the robot, which enables communication to be maintained without interruption. Using a mock-up facility for Unit 1 at the Fukushima Daiichi Nuclear Power Plant, we successfully demonstrated a system that predicts Wi-Fi communication quality several seconds ahead and incorporates the prediction in robot control.

Furthermore, we are advancing research and development on "resilient communications" that reduce the risk of communication outages, such as the simultaneous use of multiple access points, the extension of communication range through ultra-low-latency relaying, and technologies that enable simultaneous communication with numerous devices while having limited frequency resources. These efforts have been reflected in the international 5G-Advanced standard, and we have also conducted demonstrations in a private 5G environment.

At the same time, during large-scale disasters, the communication methods available in the affected areas may become limited. Even under such conditions, it is essential that disaster response organizations such as fire departments, police, and the Self-Defense Forces are able to share information, as this is critical for situational awareness and decision-making during disasters. To address this need, we have developed X-ICS, a Cross-Agency Information and Communication System that enables information-sharing using multiple communication methods (mobile phones, Wi-Fi, satellite communications, etc.). We are actively promoting its use in large-scale disaster response drills.

Future Prospects

The technologies introduced in this article are, in the end, only component technologies. To truly address the societal challenge of reducing disaster impact, these technologies must be further developed into systems that can be operated as services or institutional frameworks. This can only be achieved through collaboration among many stakeholders, not only within NICT but also with ministries, companies, universities, research institutions, local governments, and even members of the community. Let's work together across the border to build a more disaster-resilient society.

There also remain technical challenges, such as developing AI systems that remain robust even in unforeseen situations and improving detection and prediction accuracy through simulations using digital twins. NICT will continue its research and development efforts to establish information and communication technologies that protect society from disasters and other threats well into the future.

*Some of the research outcomes introduced here were conducted as part of the Cabinet Office's Council for Science, Technology and Innovation Strategic Innovation Promotion Program (SIP) Phase 3, "Development of a Resilient Smart Network System" (implementing agency: National Research Institute for Earth Science and Disaster Resilience), as well as the Ministry of Internal Affairs and Communications' Strategic Information and Communications R&D Promotion Program (SCOPE), Advanced Radio Usage Promotion Type, "Research and development of ultra-massive simultaneous connectivity technology using quantum annealing for interference suppression among terminal devices (project number: JP235003004)."

Resilience Enhancement Strategy via Cooperation between Optical Networks

AWAJI Yoshinari

Director of Robust Optical Network Laboratory,
Resilient ICT Research Center, Network Research Institute

After completing a doctoral program, Dr. AWAJI joined the Communications Research Laboratory (CRL, now NICT) in 1996. Conducts research on optical networks. Ph.D. (Engineering).

HIROTA Yusuke

Senior Researcher,
same affiliation as above.

After completing a doctoral program, Dr. HIROTA served as an Assistant Professor at the Osaka University Graduate School in 2008 and joined NICT in 2017. Conducts research on optical networks. Ph.D. (Information Science).

XU Sugang

Research Manager,
same affiliation as above.

After completing a doctoral program, Dr. XU served as a Research Associate at the Waseda University Global Information and Telecommunication Institute in 2002, before joining NICT in 2005. Conducts research on optical networks. Ph.D. (Engineering).

In modern society, where networks and the cloud serve as indispensable lifelines, rapid responses to large-scale network congestion and failures, as well as early recovery after disasters, are essential. However, current restoration procedures and the ICT technologies supporting them cannot fully meet these demands, leaving a significant gap during restoration phases. Recognizing this issue, we are advancing research and development to enhance the resiliency of optical networks. Our work goes beyond conventional restoration procedures confined to single-domain networks and leverages cross-domain coordination strategies spanning networks, testbeds, and operators.

Background

The current optical fiber networks create high-capacity communication environments by adjusting various communication devices to transmit optical signals. However, disturbances such as natural disasters, deterioration of equipment, configuration errors, and vibrations can alter the quality of transmission (QoT) of optical signals, leading to various network failures such as momentary interruptions and link disruptions. Therefore, mechanisms that can prevent failures from occurring at different levels of the network from multiple perspectives and across multiple layers are essential.

That is why, in addition to technologies for failure detection, prediction, and impact mitigation within a single optical network, we are contributing to enhancement of resilient networks by interconnecting and integrating surviving resources across heterogeneous transport networks. Furthermore, through appropriate coordination between communication and computing infrastructures, we are advancing initiatives to handle large-scale network congestion during normal operations and promote early recovery after failures and disasters.

Collection and Utilization of Emulated Failure Information for Detecting Early Signs of Optical Network Failures

Within a single optical network, detection of failures as early as possible is essential. "Detection" may sound simple, but it actually involves not only determining whether a failure has occurred, but also identifying the type of failure, its location, and the extent of its impact—all based on the limited information available at the moment of occurrence. It is also important to detect early signs of potential failures and take action before their effects come to the surface.

We have therefore developed a method for detecting early signs of optical network failures based on physical-layer optical signal information (Figure 1). More specifically, using commercially deployed optical network equipment, we emulated various failure scenarios, such as QoT degradation that does not reach the surface at the service level due to error correction, and collected labeled data (e.g., optical power level, optical signal-to-noise ratio, etc.) for machine learning training, through which we developed algorithms to predict latent failures. Furthermore, based on these prediction results, we conducted proof-of-concept experiments, such as transmission path switching procedures to maintain the service. Moreover, to promote the development of machine learning models in related research areas, we have made a part of the collected failure data publicly available. This type of data sharing is of significant interest internationally, and, as an initiative to actively share data across national borders and accelerate research and development, we are also working on data sharing and policy design for an international optical-network testbed using the Dataspace concept, which enhances the data sharing between various institutes (Figure 2).

Research and Development on Open Networking Technologies

In the event of large-scale failures or disasters, communications can be restored more quickly if surviving resources across multilayer, heterogeneous transport networks are interconnected and utilized in an integrated manner, rather than waiting for each individual network to be recovered. To this end, we are conducting research and development on open networks. As part of these efforts, we have designed modeling and control and management methods that support interconnection, integrated use, and recovery of increasingly diverse optical devices. We have also developed impact assessment methods for failures spanning multi-domain optical networks, while confidential information is kept mutually hidden between the parties. At the packet layer, we have carried out research and development on protocol conversion modules for interconnecting heterogeneous transport networks and conducted a proof-of-concept demonstrating cooperative restoration across operators (Figure 3).

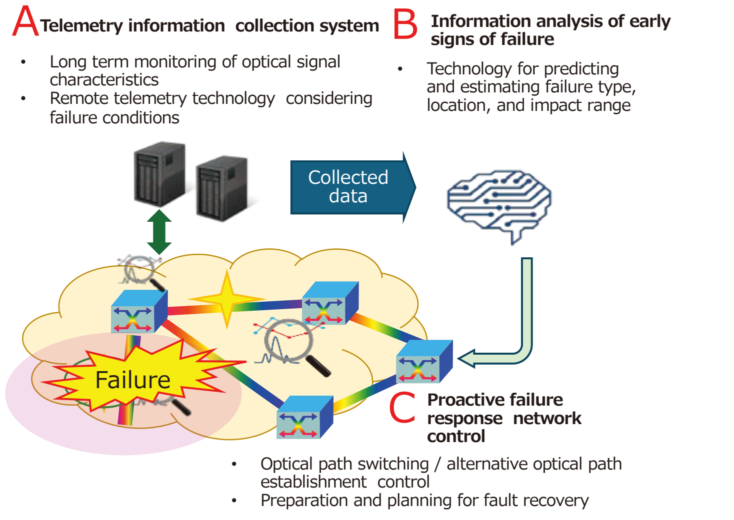


Figure 1 Telemetry data collection, failure analysis and prediction, and proactive mitigation

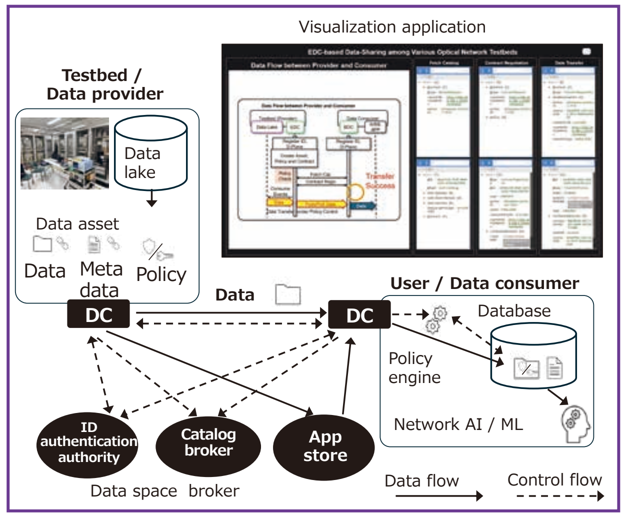


Figure 2 International optical network testbed data sharing

Research and Development on Resilience Enhancement of Network-Cloud Ecosystem

When establishing or coordinating a network-cloud ecosystem, it is essential to enable dynamic and efficient information sharing, supply-demand matching, and the development of cooperative restoration strategies between the supply of communication resources within the communication infrastructure and the demand for connectivity in inter-cloud environments. In cross-operator collaboration, safeguarding each party's confidential information (trade secrets) is critically important. As part of our efforts, we have conducted research and development on modeling the interconnection of communication and computing infrastructures, and we have proposed cross-carrier and cloud-carrier cooperative restoration strategies. The results of numerical evaluation show a significant effect, indicating that, compared with conventional standalone recovery, which typically takes several days or even weeks, collaboration among carriers increases the amount of communication services that can be restored immediately after a disaster ("day 0" of the recovery time) by 78%, while cloud-carrier cooperation increases the amount of cloud services that can be restored immediately by 97% (Figure 4).

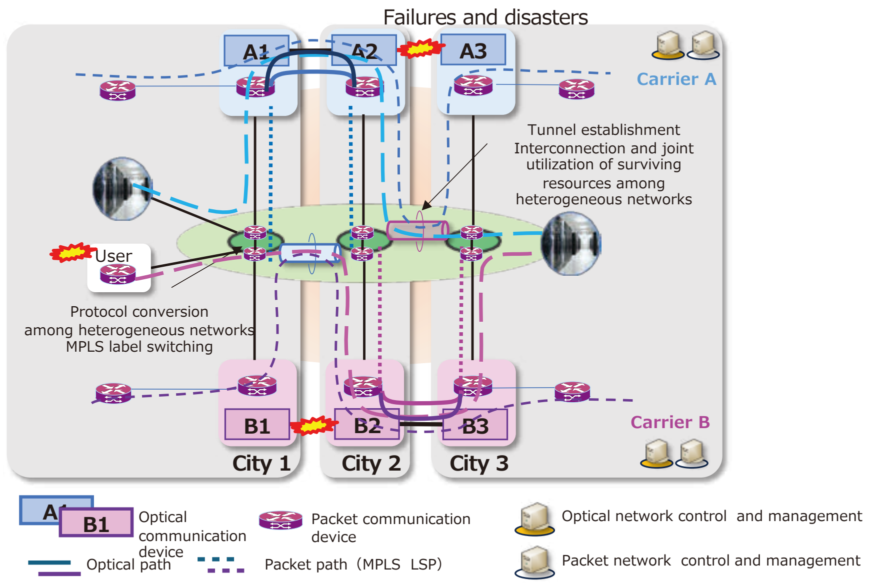


Figure 3 PoC for cooperative restoration across heterogeneous operators and multi-layer heterogeneous transport networks

Furthermore, to promote cooperation among operators, we developed a collaboration promotion platform based on Hyperledger Fabric (an open-source software that implements blockchain) and conducted a proof-of-concept of cooperative restoration planning among carriers and cloud service providers.

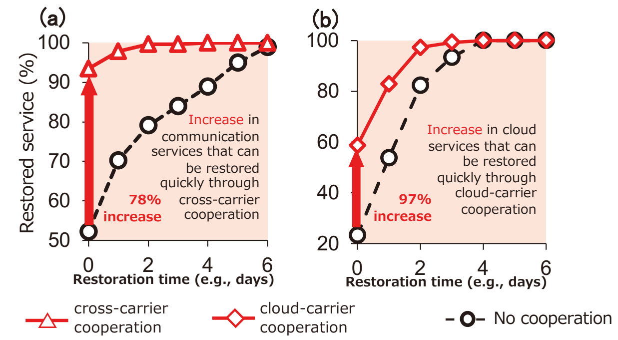


Figure 4 Evaluation of cooperative restoration models for medium-scale disasters

Future Prospects

Advances in AI and machine learning continue to be made. There are a wide range of such technologies related to optical network control, operation, and management. In the future, multiple AI systems will support optical networks.

Considering the future development of AI for optical networks, data used for training is essential. By enabling the sharing of data and restoration strategies not only among operators but also more broadly, we aim to significantly enhance the resiliency of optical networks against disasters and failures.

From Tohoku (Japan) to the World: Activities and Case Studies on Social Implementation of Research Achievements

Toward Resilient Networks to Support Digital Transformation (DX)

TANAKA Kenji

Director of Planning and Collaboration Promotion Office, Resilient ICT Research Center, Network Research Institute / Innovation Producer, Tohoku ICT Collaboration Core Regional/Industry-Academia Collaboration Promotion Office, Strategic Program Produce Office, Social Innovation Unit

Dr. TANAKA joined CRL, currently NICT, in 1989. I have been engaged in activities to promote the social implementation of research outcomes from the Resilient ICT Research Center since 2023. Ph.D. (Engineering)

The Resilient ICT Research Center carries out research and development that contributes to improving resilience both in Japan and abroad, including ICT that is resilient to disasters and failures and is useful in such times. It is made up of three units. One of them is the Sustainable ICT Systems Laboratory, which conducts research on ICT that can function even in severe environments such as large-scale disaster sites or the decommissioning of nuclear power stations, where human access and communication are difficult, as well as on technologies for measuring the natural environment. Meanwhile, the Robust Optical Network Laboratory conducts research on technologies for predicting and detecting failures and restoring functionality in the optical network systems of telecommunications operators. The Planning and Collaboration Promotion Office works to deploy the results of our research in society. Here, we introduce several of these efforts and examples of implementation.[*1]

Background

The vulnerabilities of information and communication systems, which are vital social infrastructure, were exposed during the Great East Japan Earthquake. To realize resilient (strong and flexible) information and communication systems, the Resilient ICT Research Center was established in April 2012 on the campus of Tohoku University with the university's cooperation. Since then, we have been working in collaboration with relevant organizations in Japan and abroad on research and development, demonstration experiments, and the social implementation of research outcomes (Figure 1).

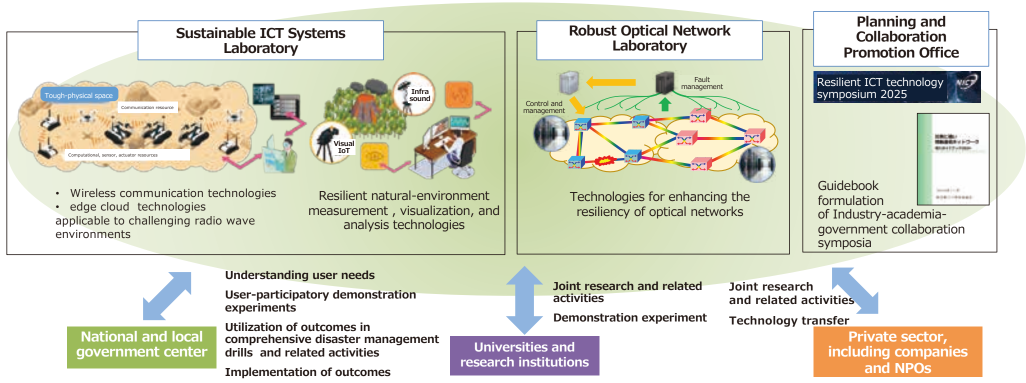


Figure 1　System for promoting the Resilient ICT Research Center's work

Social Implementation Efforts

Research aimed at realizing disaster-resilient ICT plays an extremely important role in protecting human lives and property during disasters, as well as in supporting recovery and reconstruction after a disaster. Based on this idea, the Resilient ICT Regional Cooperation Committee was established in May 2012, bringing together the Ministry of Internal Affairs and Communications, NICT, Tohoku University, and representatives from private companies and universities engaged in resilient ICT research. The purpose of this committee is to promote cooperation and collaboration among these parties to enable the maximum utilization of these research outcomes in society. In November 2024, the committee formulated the Guidelines for the Introduction of Disaster-Resilient Information and Communication Networks, which are guidelines on implementing ICT that supports disaster response and the continuation of routine operations by local governments even in the event of large-scale disasters. The content will be updated and new topics will be incorporated in a revised edition to be completed by the end of FY2025 (Figure 2).

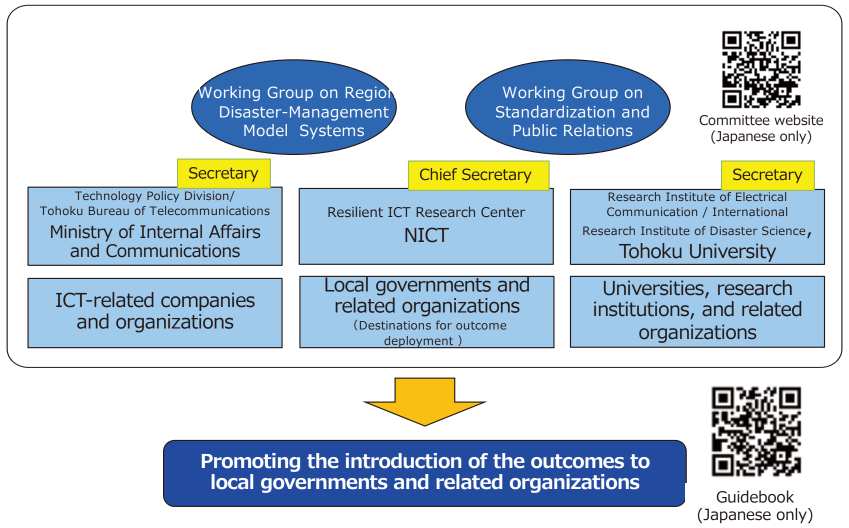


Figure 2　Structure and objectives of the Resilient ICT Regional Cooperation Committee

Examples of Implementation

The SOCDA[*2] Chatbot for Disaster-management

In collaboration with private companies and with support from the Second Phase of Cross-ministerial Strategic Innovation Promotion Program (SIP), we applied technologies related to our disaster-information analyzer system (DISAANA) and disaster-summarizer system (D-SUMM), both developed at NICT, conducted research and development on the SOCDA chatbot for disaster-management, which supports individual citizens in evacuation and assists disaster-response agencies in decision-making, and carried out demonstration experiments. Subsequently, in November 2021, the AI Bosai Council released the AI Disaster-Management System. This is a LINE account through which the AI-enabled disaster-management chatbot SOCDA autonomously engages in dialogue with large numbers of disaster victims via LINE on behalf of human operators to support disaster-information collection and analysis and provide evacuation assistance. In Kobe City, operation of the system began in December 2024 under the name "Kobe City Disaster Information Bulletin" on LINE. In addition, independent commercial services developed using SOCDA have been launched, and they have been adopted by 120 municipalities.

Regional Digital Infrastructure NerveNet[*3]

NerveNet is a regional digital infrastructure that is phase-free (usable both in normal times for free public Wi-Fi and tourist information services and during disasters for evacuation-shelter operations) and also contributes to well-being. It has been introduced in three local governments in Japan and two overseas as a municipally operated information infrastructure. In Shirahama Town, Nishimuro County, Wakayama Prefecture, deployment began in FY2022, and 33 base stations have been installed throughout the town. In addition, an LGWAN connection was launched at the town's Tokyo office, enabling administrative operations to be conducted there in the same manner as at Shirahama Town Hall. In Nobeoka City, Miyazaki Prefecture, deployment began in FY2023, and 52 base stations are scheduled to be installed by the end of FY2025 (Figure 3). In Sarabetsu Village, Hokkaido, deployment also began in FY2023, and ten base stations are scheduled to be installed by FY2025.

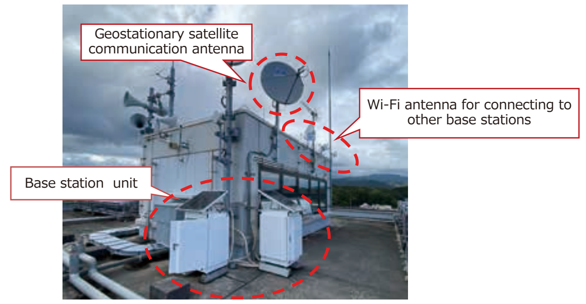


Figure 3　NerveNet base station on the rooftop of Nobeoka City Hall

Furthermore, three base stations have been installed in Dullu Municipality in Nepal, and ten in Gampola City in Sri Lanka, all of which are operated by local stakeholders.

Die-Hard Network (DHN)

The Die-Hard Network is a network concept that layers various communication methods to ensure that the flow of information is never interrupted under any circumstances. It is a "distributed authentication technology combined with fast initial link setup (FILS)" that enables edge nodes to synchronize and share information through high-speed, authenticated device-to-device connections, even in areas where communication has been disrupted. It was first introduced in Konan City, Kochi Prefecture in FY2021 as a "Disaster Prevention Information, Communication and Management System." By the end of fiscal year 2022, the system was composed of approximately 100 communication devices and enabled cross-departmental information sharing by linking 13 disaster-response operations. In addition, in FY2021, it was also adopted for the "Disaster Response Operation System" of the Kochi City Fire Department.

Figure 4　Off-grid power system-based observation equipment and volcano disaster management drill

High-resolution volcanic monitoring independent of commercial power sources

At Mt. Io in Kirishima, which straddles the prefectures of Kagoshima and Miyazaki, we have installed a Visual IoT system characterized by low power consumption that enables long-term observation using a self-contained power supply (solar cells and batteries) even in locations without commercial power. We are currently conducting continuous observations that have lasted for more than three years and five months. The video images are provided to Miyazaki Prefecture and to the cities of Ebino and Kobayashi, in the same prefecture, which are affected by this volcano, and the images are being considered for use in both disaster prevention and tourism. In Ebino City, volcanic disaster-prevention drills using these images have also been conducted (Figure 4).

Future Prospects

To contribute to the development and operation of resilient information and communication networks capable of responding to increasingly severe natural disasters, we will continue to promote research and development and the social implementation of the resulting outcomes in collaboration with universities, companies, local governments, and other relevant organizations in Japan and abroad.

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Autopoiesis Edge Cloud (AEC): Self-Organizing Resilient ICT Systems for Disaster Response and Beyond-5G Networks

Cheikh Saliou Mbacke Babou

Researcher
Sustainable ICT System Laboratory, Resilient ICT Research Center, Network Research Institute
Ph.D. (Computer Scienece), member of IEEE

Biography

2017-2018
2019-2021 Special research Student at NAIST
2021 Received the Ph.D. from Cheikh Anta Diop University (UCAD) , Senegal
2021 Joined NICT

(Member, IEEE)

AWARDS

2018 Best Paper Award International Conference on Edge Computing (EDGE2018)

Q&As

Q What is good about being a researcher.

A The opportunity to solve real-world challenges, especially in disaster-prone areas. Seeing my edge computing research deployed in actual disaster response scenarios and helping communities build resilient ICT systems is incredibly fulfilling. Collaborating with international teams and bridging technology gaps between developed and developing countries makes the work meaningful.

Q What advice would you like to pass on to people aspiring to be researchers?

A Stay curious and persistent. Research requires patience: my PhD took years of collaboration between Cheikh Anta Diop University (UCAD) in Senegal and the Nara Institute of Technology (NAIST). Don't hesitate to seek out international collaborations and always link your theoretical work to practical applications. Focus on issues that matter to your community and the world.

Q What are you currently interested in outside of your research?

A I mentor students at various universities in Senegal and on Cisco's CCNA online platform. I enjoy sharing my knowledge of telecommunications and systems, cybersecurity, AI, and network engineering.

My research focuses on developing autonomous and resilient edge computing systems for tough environments, particularly disaster-affected areas. The Autopoiesis Edge Cloud (AEC) concept I proposed creates self-organizing networks and services that can operate independently when traditional infrastructure fails during earthquakes, tsunamis, or other disasters (as well as during human interventions).

The AEC system integrates Artificial Intelligence (AI), Software-Defined Networking (SDN), and Network Function Virtualization (NFV) to enable dynamic resource management and intelligent clustering at the network edge. This architecture allows edge nodes to automatically merge, and split based on real-time conditions, optimizing performance while maintaining service continuity. By bringing computation closer to data sources, we achieve ultra-low latency, which is critical for emergency response applications.

My work on the HEC-NerveNet architecture demonstrates how edge computing can support Beyond-5G networks by distributing intelligence across hierarchical edge layers. This approach significantly reduces latency compared to traditional cloud-centric models while improving quality of service through intelligent load balancing.

I've also developed AI-driven automation systems for optimal edge cluster network management, enabling networks to self-configure and self-heal without human intervention. This is particularly crucial in disaster scenarios where communication infrastructure is damaged, and technical support is unavailable.

Recent work focuses on resilient communication systems for disaster response, including: the portable SIP4D system enabling information sharing among disaster response agencies in network-disconnected environments, semi-narrowband ad-hoc wireless communication systems (SNB-AWCS) utilizing VHF frequencies for reliable disaster communications, and intelligent clustering and merging algorithms for autopoiesis edge cloud architectures, incorporating AI-driven automation for optimal edge cluster network management in beyond-5G networks. Through international collaborations between NICT Japan and institutions in Senegal, I'm working to deploy these technologies for smart agriculture, e-Education (e-Learning), and rural connectivity in developing countries, demonstrating how cutting-edge research can address real-world challenges in resource-constrained environments.

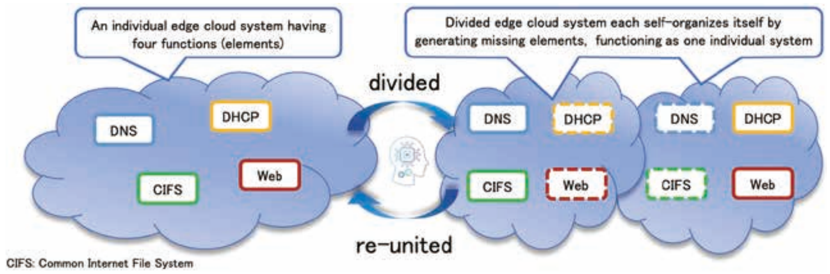

Figure 1 Overview of AI-Based Autopoiesis Edge Cloud (AEC)

NICT Bridges High School Students and Companies: Students from Tokyo Metropolitan Tama High School of Science and Technology Visit Niterra!

Public Relations Department

In November 2025, students from Tokyo Metropolitan Tama High School of Science and Technology (located in Koganei City, Tokyo, and designated as a Super Science High School (SSH)) visited Niterra Co., Ltd., a comprehensive ceramics manufacturer headquartered in Komaki City, Aichi. This visit came about after NICT Auditor Dr. DOI was intrigued by the school's poster presentation titled "Testing High-Strength Materials that Mimic the Nacre Layer of Abalone" at the NICT Open House 2025 and decided to offer the students an opportunity to broaden their learning by visiting Niterra's research and development site, where she serves as an outside director. The visit began with a message from Mr. ITO Shingo, Head of Niterra's Scientific Research Laboratory: "Japan has no natural resources. That is why we must change society through research and development. I hope today's visit will inspire your future research." The students then enjoyed a packed schedule of site tours and lectures.

Tour of the Oxygen Sensor Factory

Students visited the oxygen sensor factory as well as sites where spark plugs and ceramic bearing balls are analyzed. During the tour, they asked many questions, such as:
"How does a ceramic oxygen sensor work?"
"What is its temperature resistance?"
"Are racing spark plugs different from those used in regular cars?"

Students earnestly trying to absorb as much as they could

Introduction to Simulation Technology

Ms. ITO, who is in her third year at the company, shared practical examples of simulations that are essential for product development. The students, who actually use simulations in their high school, raised several specific questions such as:
"What kind of software do you use?"
"When do errors occur?"

Listening intently to the importance of simulation

Overviews of Researchers' Research

Dr. TSUJII, in her 10th year at the company, and Mr. ARAKAWA, in his 9th year, provided overviews of their research on technologies utilizing ultrasound (such as applications for acoustic devices). Despite the highly specialized content, the students were seen diligently taking notes.

Tour of the Research & Development and Analysis Center

Traditionally, sintering of ceramics required high temperatures and long processing times, but the students visited the development site for a new technology called cold sintering process (CSP), which makes this possible at low temperatures and in a short time. The students showed great interest in this new technology and asked many questions such as:
"What is the difference in strength compared to ceramics made by conventional methods?"
"Can it produce large items?"
"What are its applications?"

Hydrogen Forest: Visit to SUISO no MORI Hub

The students also visited the department that supports startups in the hydrogen and circular-carbon fields. They learned about ongoing initiatives and had the opportunity to see a hydrogen engine currently under development.

An experience that might one day contribute to the creation of a unicorn company that changes the world

After the visit, students shared their impressions:
"It wasn't my specialty, but they explained everything so clearly that it sparked my interest."
"It provided useful insights for my simulation-based research presentation."
"The CSP technology that eliminates wasted heat energy is amazing!"
"I was surprised to learn that ceramic materials are used not only in blades but also in cars and pharmaceuticals."
"I'm glad I got to see the process of making ceramic oxygen sensors."
There was a sense that the students were determined to use their learnings to take the next step, with one commenting, "This might be useful for my own research project (development of new materials using diatomaceous earth)!"
This visit provided a valuable opportunity for the students to experience cutting-edge Japanese "monozukuri" (manufacturing), from manufacturing sites to research and development, and even startup support. Mr. TAKAHASHI Ryou, the supervising teacher from the high school, commented, "We would definitely like to have opportunities like this in the coming years as well." It was an inspiring day for high school students aspiring to become future researchers and engineers.
We extend our sincere gratitude to the Management of Technology Division of Niterra, as well as everyone at the Komaki Plant for their efforts in making this visit possible.

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