Venture Out of the Laboratory and Test Your Research Results in the Real World

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Overview

Future networks are expected to provide high-speed, large-capacity communications and enormous amount of computing resources that exceed the limits of the conventional network infrastructure. To meet these expectations, NTT is conducting research and development on the Innovative Optical and Wireless Network (IOWN), a future information-processing infrastructure that includes user's terminals. Yasushi Takatori, a senior distinguished researcher at NTT Access Network Service Systems Laboratories, is taking on the challenge of innovating wireless access toward the 6G (six-generation mobile communication system) era, which will be an essential component of IOWN. We asked him about his research activities and his attitude as a researcher.

Keywords: wireless access, Cradio®, extreme NaaS

Provide a natural and uninterrupted communication environment that does not force users to be aware of it

—Please tell us about your current research projects.

My current research is on using multiple wireless access systems to provide wireless access in the sixth-generation mobile communication system (6G) era, which will be an essential component of the Innovative Optical and Wireless Network (IOWN). In the field of wireless communications, the amount of communications via smartphones is increasing, and accompanying the development of the Internet of Things, a multitude of objects have become connected to the Internet. The types of wireless terminals and usage scenarios are also diversifying, as illustrated by remote control of autonomous vehicles and drones and exchange of ultra-high-definition images. Under these circumstances, the role played by wireless communications should increase dramatically in every aspect of our lives and that the amount of such communication will continue to grow. Such diversification of terminals and usage scenarios will require wireless networks to cover not only urban areas, where the population is concentrated, but also suburban areas, rural areas, and many other locations. It is also necessary to satisfy various requirements concerning wireless communication quality, which varies according to various usage scenarios.

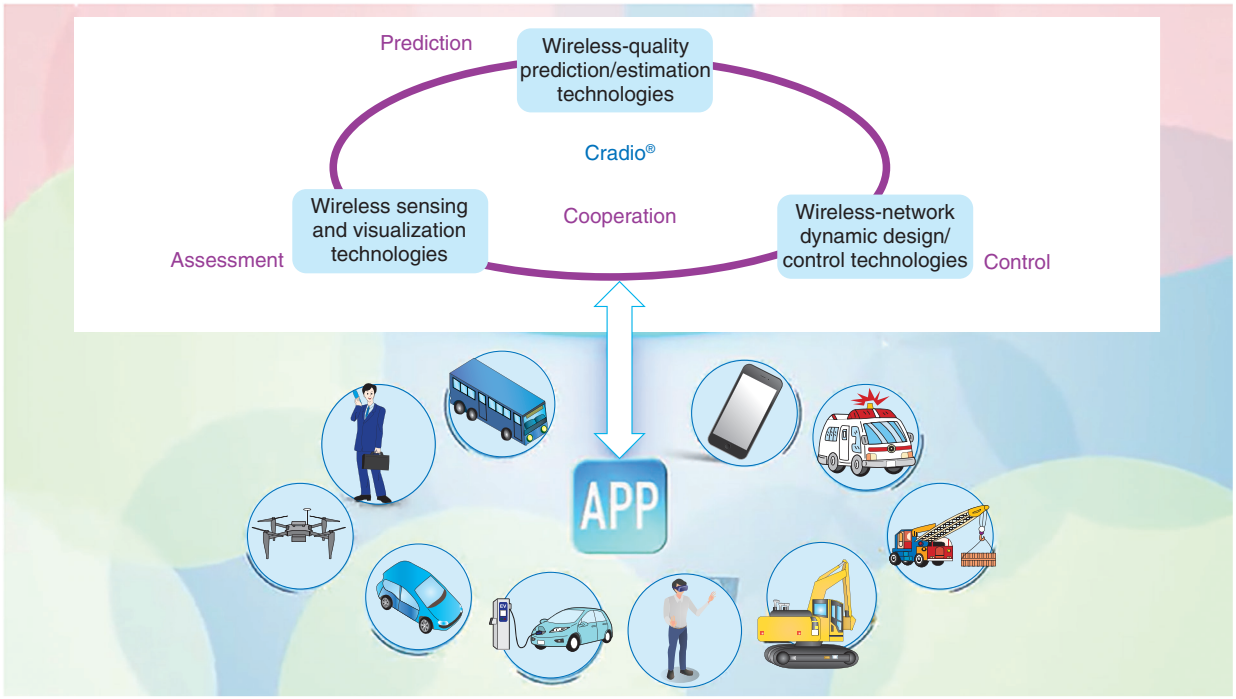


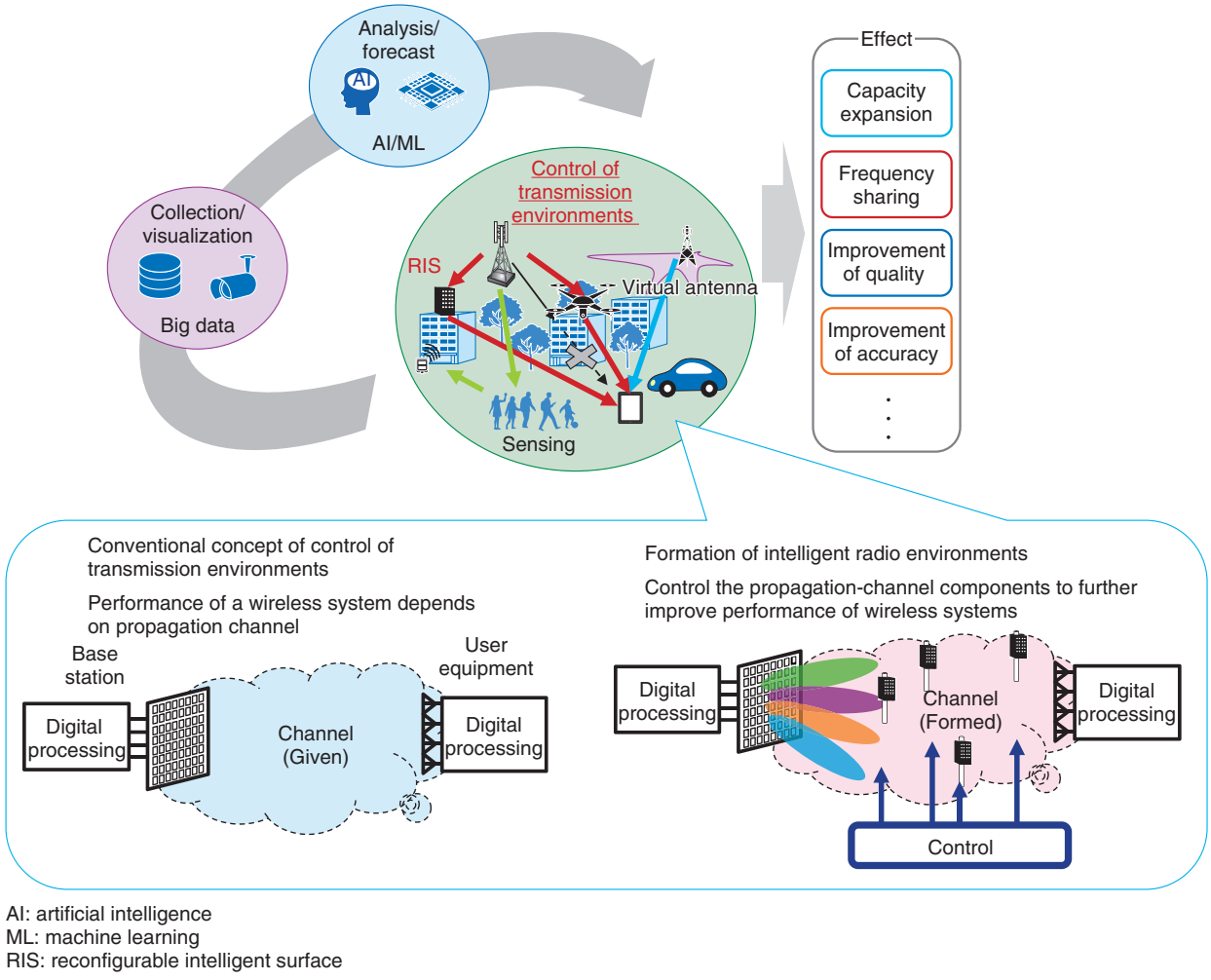
Fig. 1. Multi-radio Proactive Control Technologies (Cradio®) with various applications and social systems.

Against that backdrop, I am taking on the challenge of developing a wireless access network that offers new value with the following key phrases in mind: "achieving continuous connection," "sharing experiences," and "expanding into unexplored areas." 5G features high speed, large capacity, low latency, and simultaneous connection of many terminals. Looking toward IOWN and 6G, however, it will be necessary not only to improve the performance of each feature but also skillfully combine these features. Therefore, we are developing elemental technologies for extreme network as a service (NaaS) to deliver wireless access that satisfies individual *extreme* service requirements in a flexible manner whenever and wherever needed. One group of such elemental technologies for proactively controlling wireless access by assessing various wireless conditions is called Multi-radio Proactive Control Technologies or Cradio® (**Fig. 1**).

—You are attempting to create a communication environment in which people do not have to be aware of the wireless network. What exactly are you working on?

As one of the components of IOWN, Cradio is a group of wireless technologies that will provide users with a natural and uninterrupted communication environment without making them aware of the wireless network. It consists of the following three areas of technologies: (i) wireless sensing and visualization technologies are tasked with *assessment*, namely, collecting and visualizing wireless status and visualizing real-world status through means such as wireless sensing; (ii) wireless-quality prediction/estimation technologies are tasked with *prediction*, namely, predicting and estimating wireless communication quality that changes moment by moment; (iii) wireless-network dynamic design/control technologies are tasked with *control*, namely, designing physical locations of movable base stations, deriving optimal wireless parameters, and dynamically controlling network parameters, resources, etc. according to the environment and requirements. By developing the three areas of technologies and coordinating them in real time, we aim to satisfy user requests and control the momentarily changing wireless conditions to provide a natural communication environment that does not force the user to be aware of the wireless network.

To maximize the potential of wireless communications, we are also researching intelligent radio environment formation technology for controlling the



AI: artificial intelligence
ML: machine learning
RIS: reconfigurable intelligent surface

Fig. 2. Formation of intelligent radio environments.

environment in which radio waves propagate (**Fig. 2**), aiming at a paradigm shift from a *given propagation channel* to a *formed propagation channel* by controlling the propagation-channel components to achieve a fast and stable connection.

Up until now, we have considered that the environment is given to us and we had to build a communication system optimized for that given environment; however, we changed such perspective and started researching and developing various technologies for creating the environment ourselves. For example, when a typical reflector receives light or radio waves from a certain direction, it reflects the light or radio waves in a certain direction. However, using a recently developed reflector that can arbitrarily change the direction of reflection, we conducted an experiment to change the reflection environment.

We have used Cradio to drive autonomous farm machinery on a farm road in Iwamizawa City, Hokkaido. As the autonomous farm machinery runs across multiple wireless networks such as 5G, artificial intelligence predicts fluctuations in communication quality and automatically switches to an appropriate network before the communication quality degrades. Thus, we demonstrated stable and automatic driving of the machinery without interrupting the remote monitoring of the machinery. In coordination with NTT's Cooperative Infrastructure Platform, Cradio overcomes the differences in Internet Protocol addresses and communication schemes, thus provides connectivity independent of the particular access network. In this manner, users can use applications as usual without having to be aware of the network.

Accumulate experiments, measurements, and evaluations while confirming those results in the real world

—You were able to achieve results by changing the conventional perspective and approach, right?

Yes, we got that idea from a chat within our team. A technology can be *environment-dependent*; that is, one technology may produce good results in a certain environment but not the same results in another environment. We wondered if we had been bound by that notion and willfully set limits based on it. Therefore, we decided to overcome those limits by applying different ideas more freely, controlling the environment for ourselves, and changing our perspectives.

This shift in thinking has also been influenced by technological advances. In the past, only one type of wireless system existed in one area; however, various types now co-exist. As technology progresses, we'll likely end up with an environment in which many wireless systems overlap each other. When I pondered this situation, I thought that rather than looking at optimizing each system on a one-by-one basis, we should conduct research and development (R&D) assuming an environment in which multiple wireless systems overlap.

I'm thankful that great expectations are being placed on our R&D concerning wireless technology. This heightened expectation from society is echoed in the motivation of our researchers. People from various industries are interested in exchanging opinions on this topic. This type of stimulation can trigger new ideas and lead our R&D in the right direction. However, the more active the discussion, the more issues will arise. Although we are sequentially addressing the issues that have arisen, new issues may come up, and it will take some time to address them all. Nevertheless, we are determined to patiently repeat experiments and accumulate knowledge bit by bit. These experiments are low profile and physically demanding; however, they will provide us with unique data that no one else in the world has seen. Being able to create new technologies based on those data is rewarding.

—You conduct experiments not only in the laboratory but also in the actual field, as in the case of Iwamizawa City.

One of the interesting aspects of research activities is to actually go out into the field and conduct experiments and measurements. It is important to conduct experiments, measurements, and evaluation while confirming those results in the real world. When we consider what type of wireless environment is needed for use of better services in real life, the place for research activities is not the laboratory. Merely saying, "We have achieved various results in the laboratory." does not mean that the results are real. To be useful in the real world and meet the expectations of users, it is important to get out of the laboratory and verify our research results in the real world.

These experiments would not be possible without the collaboration of people who are facing problems, so it is very important to have an opportunity to conduct experiments in the field. In addition to conducting the experiment in Iwamizawa City, we have recently collaborated with people who are having trouble detecting damage caused by birds and other animals. The cost of the damage to crops caused by wild birds and animals is about 20 billion yen per year, of which about 80% is accounted for by wild boars and deer. Such damage also leads to secondary damage, such as loss of motivation to farm and abandonment of cultivation, which is becoming a serious social problem in Japan. As a countermeasure to such damage caused by birds and animals, we have been researching sensing technology using radio waves for detecting intrusions by animals.

The request from our collaborators was for a technology to remotely check what the sensors installed in the cages detected. When a sensor detects something, an administrator or other person is sent to check the cage; however, the person sent to check should depend on whether a wild boar, deer, or other animal is captured in the cage. Since the current system does not detect what is in the cage, the person sent to the site to check the content of the cage often finds captured birds and other animals that are not their responsibility, so another person—who is responsible for those animals—is sent to the site. Sending images wirelessly from the mountains where the cages are installed is a very difficult task because of many obstacles. However, we were able to carry out an experiment because that task matched a technology we were researching and developing.

Responding to requests from the fishing industry, we also experimented with transmitting images taken by underwater drones to the coast to obtain information on the types of fish caught in offshore nets and the condition of the nets. It is valuable experience to be able to see how well our technologies can perform in such real environments. When we asked people

with actual problems to collaborate in experiments, the fact that they said, "Let's give it a try." indicates that they have high expectations for our research and technology. Being recognized in the real world in this way is rewarding for us.

Don't set limits, aim to break through them

—What do you keep in mind when you are looking for a research theme?

It is important not to set limits. When I hear someone say, "This is the most significant characteristic," I would think, "Something is wrong," and seek an approach to break the deadlock. This way of thinking came from my experience at Aalborg University in Denmark, where I studied for a year (2004 to 2005). After quoting Guglielmo Marconi's words, "It is dangerous to put limits on wireless," my supervisor asked me what limits I was thinking of overcoming in regard to future wireless technology. This question made me more determined to push the envelope, and I began to examine whether a goal is high enough or how unconventional it is when setting my research themes.

When IOWN becomes a reality, a world in which everything is interlinked will come. In this era of R&D, it is necessary to incorporate not only wireless technology but also a variety of other elements into the R&D process. This idea of incorporating R&D and perspectives from other fields has been important for a long time; however, it will become even more important in the future, and I think we should aim to adopt that idea.

If we consider only wireless technology, we tend to pursue R&D for evaluating communication quality and speed and determining how to improve it. Instead, it is important to verify those parameters in the actual environment, while keeping in mind how the user's experience and services can be improved, and create technology that works in conjunction with a real society. I also believe that we need to think of products and services that are not only easy to use from the viewpoint of the users but also easy to develop from that of the people who develop them.

Imagining the R&D world as a sphere, I think there are two approaches to R&D: one is to look at the surface of the sphere as a whole, and the other is to push toward the center of the sphere and hone one's expertise. I believe that since the sphere has only one center, the closer we get to the center by pursuing our specialties, the more our sense of commonality grows, no matter which field we pursue, and the more we can understand each other at essential points. I want to pursue R&D that pushes toward the center of the sphere.

—Do you have any words of encouragement for younger researchers?

I believe that age does not determine one's seniors and juniors in regard to research activities and hope that researchers will work hard together and improve each other's skills. When I talk to young researchers, I sometimes find it a bit of shame that although they all have very good sense and come up with the best idea very quickly, they tend to dismiss ideas that are a bit strange or didn't work out. I think it is also important to try out ideas that "might not work" with the mindset that what didn't work out this time will lead to a success down the road. The time you spend thinking about something is unique to you, and that experience in itself is an asset that you can use for your next R&D topic.

Also, don't lock your ideas away; instead, create new technologies by knocking those ideas against other ideas. I want to work with young researchers on these activities. Of course, sometimes we get stuck, and it can be difficult to make decisions about what to discard from research that has not been successful and whether to continue a research topic. In such a case, if you have the sense of "I like it" or "It's interesting" even though your judgment with logic tells you otherwise, you don't have to throw it away.

I have been with NTT for more than 26 years, and when I joined the company, there were times when our R&D on wireless technology did not bear fruit. However, when many researchers envisioned the future of devices and networks, the last-mile access network was always wireless, and I have been pursuing research believing that the time of wireless technology would come. In light of the growing interest in wireless technology, I am glad that I have been researching it for all these years.

R&D does not produce results in one or two years, so keep a long-term perspective and be persistent. I am sure that one day you will be glad you did.

■ **Interviewee profile**
Yasushi Takatori

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He received a B.E. and M.E. in electrical and communication engineering from Tohoku University, Miyagi, in 1993 and 1995. He received a Ph.D. in wireless communication engineering from Aalborg University, Denmark, in 2005. He joined NTT in 1995 and has served as a secretary of Institute of Electrical and Electronics Engineers (IEEE) Japan Council Awards Committee and a vice chairman of the Wireless LAN system development project in the Association of Radio Industries and Businesses (ARIB). He was a visiting researcher at the Center for TeleInFrastructure (CTIF), Aalborg University from 2004 to 2005. He served as a co-chair of COEX Adhoc in IEEE 802.11ac from 2009 to 2010. His current research interests include future wireless access systems for IOWN. He received the Best Paper Awards from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2011, 2016, and 2020. He was honored with the IEICE KIYASU Award in 2016. He received the Radio Achievement Award from ARIB in 2020 and the IEEE Standards Association's Outstanding Contribution Appreciation Award for the development of IEEE 802.11ac-2013 in 2014. He is a senior member of IEICE and a member of IEEE.