R&D Spirits

Empirical Research and Development Using an Ultrahigh-speed Experimental Network

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The Service Innovation Project at NTT Service Integration Laboratories is constructing an experimental environment based on an ultrahigh-speed network in cooperation with outside organizations. We asked Hisao Uose, the supervisor of this project, why such an R&D environment is needed, what exactly is being done on this experimental network, and what new possibilities in information-communications could be expected from this work.

Contributing to Scientific Learning and Promoting Collaborative Research

—Please tell us something about the research now taking place in the Service Innovation Project.

If I were to sum it up in a few words, I would say that our research is focused on ultrahigh-speed network experiments. We are currently establishing various technologies in the transmission-speed region from several Gbit/s to several tens of Gbit/s, which is above the level of commercial networks. I would like to stress here that these experiments are not simply studies at the laboratory level—they are being conducted on an actual network spanning the Kanto district in Japan in cooperation with outside organizations, some of which are located overseas. For NTT Laboratories, this is a special kind of research style.

To be more specific, our research falls into two main categories. The first is the attempt to apply ultrahigh-speed communications technology to scientific research, in our case, radio astronomy where we make geodesic and astronomical observations using radio signals received from radio sources in space. The particular technique is called very long baseline interferometry (VLBI). With VLBI, to make detailed radio-wave observations, we combine signals obtained from multiple antennas installed at different locations far apart, typically a few hundreds of kilometers, and connected by a communication network. Here, the time difference of arriving radio waves is extremely important, and it is essential that data sent from these antennas is accurately time-stamped using an atomic clock placed at each antenna site. The image of the observed radio source is calculated with the time differences which can be derived by cross-correlating the radio signals received at each antenna sites. Also important here is the amount of data obtained for computation: the more data we obtain, the greater the sensitivity we achieve. In short, we construct and operate an ultrahigh-speed network as an essential part of ultrahigh-sensitivity, ultrahigh-resolution radio telescopes. This radio-astronomy research project named GALAXY has been going on for about ten years as a joint project with outside institutions such as the National Astronomical Observatory of Japan (NAOJ), Institute of Space and Astronautical Science (ISAS), and Communications Research Laboratory (CRL).

The second category is the construction and application of an experimental network called GEMnet (global enhanced multifunctional network) for use by NTT Laboratories. This work has been going on for several years now. To give you some background, most R&D at NTT Laboratories concerns telecommunications, but I think that a sufficient environment for testing R&D results in the field under actual con-

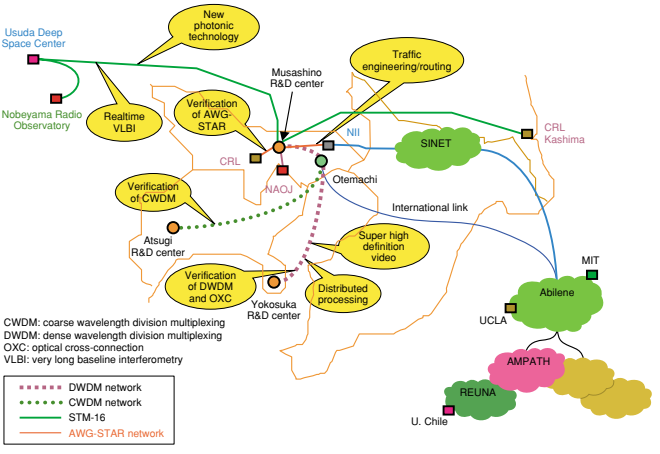


Fig. 1. GEMnet2 and its research topics.

ditions was not being provided. For this reason, we have been constructing an experimental network connecting the Musashino, Yokosuka, and Atsugi R&D centers of NTT as an R&D "test bed."

At present, we are operating our existing GALAXY network and GEMnet as one, united network (**Fig. 1**). In addition, this combined network, which we named GEMnet2, connects to other academic research networks including the Science Information Network (SINET) and Internet2. An important feature of GEMnet2 is that users include outside research organizations and universities. There are few examples in the world of a single private enterprise running a scientific network without public subsidies as we are doing here.

—What are your specific objectives in performing these experiments?

There are two main objectives. The first is to contribute to scientific progress. Besides astronomy, data communications via an ultrahigh-speed network is also attracting attention in the field of physics. In high-energy physics, for example, organizations such as KEK (High Energy Accelerator Research Organization) in Tsukuba, Japan, and CERN (European Organization for Nuclear Research) are performing experiments where elementary particles are accelerated to nearly the speed of light and made to collide. The data generated by these experiments is needed by physicists around the world. Because the amount of data is huge, it is subjected to primary screening process, but in reality all of this raw data is needed for research. If we can provide a way to make all of this data readily available, perhaps it will lead to new scientific discoveries.

The second objective is to create a research environment within NTT Laboratories. In contrast to conventional telephone networks in which technology layers are clearly divided, research of internet-type networks in which various elemental technologies are closely connected requires cooperation among

researchers. Research at NTT Laboratories covers all areas of communications technologies from physical layer to applications layer, and the questions being asked now include what kinds of communications will be needed in the years to come and what technologies will be needed to support them. If we can create an environment where all of these technologies can be tested and discussed, I think we will be able to perform more efficient research. I also think an environment like this will help conceive new types of communication businesses.

—What are the main technical features of your experimental network?

First, it incorporates technologies developed by other groups at NTT Laboratories. For example, an AWG-STAR*1 device developed by the Optical Device Research Group at the Atsugi R&D Center connects CRL and NAOJ to the network by connecting optical signals in the form of a mesh. Similarly, the span between the Musashino and Yokosuka R&D centers use optical cross-connects developed by the NTT Network Innovation Laboratories. Finally, work like installing communications equipment and conducting transmission tests is actually handled by us (**Fig. 2**).

Second, of importance to network users, our experimental network has no "black-box" section even though it is an internet type. On commercial networks, users really have no idea which of the many providers in the world their transmissions may pass through. Even if that could be determined, what goes on inside those routers is a complete mystery and the range in which some sort of control can be performed is extremely limited. In short, it is not possible to estimate quality here and to determine how best to control traffic by using an ordinary network. Our network, however, is ideal for research of this type. It can acquire and process various types of data by linking with scientific networks, so it can be used to model and test the behavior of commercial networks for which black-box treatment cannot be helped.

Importance of International Cooperation in Establishing Research Environments

—Could you tell us about overseas and domestic trends in this field?

Overseas, the United States and Europe are making progress in this field. And during the time we have

*1 AWG-STAR: Product name for a full-mesh photonic network.

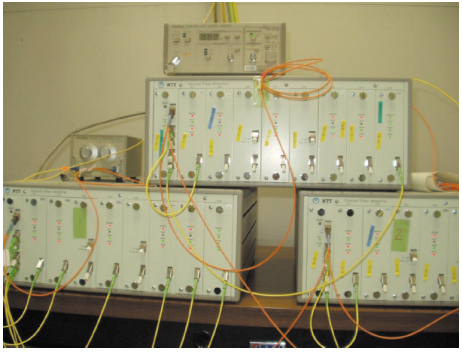


Fig. 2. Optical amplifiers for CWDM signals.

been involved in astronomical experiments, other groups have recently taken up similar research. Of great interest here are the efforts to create a database of observational data left idle for some time at individual astronomical observatories and to construct virtual observatories by connecting those observatories and databases by a network. This movement is especially strong in the United States and Europe and is also beginning in Japan. Furthermore, for future observations, a movement is taking shape in the United States to scan the entire sky and create a database of observations as a "digital sky survey" that does not require astronomers to actually peer through telescopes in various parts of the world.

—Are you involved in any international joint activities?

Most of the scientific network experiments have involved international collaboration. For example, as part of the Japan-US-European project to construct a radio-telescope observatory in the Atacama Desert in the Andes, experiments are underway in cooperation with the University of Chile. This observatory, however, is located 5000 meters above sea level in the mountains, so people cannot stay there for an extended period of time without oxygen cylinders. For this reason, observatory buildings are to be built at a lower altitude several tens of kilometers from the telescope, making some means of communication indispensable. We consider, though, that it would be even more convenient if the telescope could be directly controlled from Japan and observational data could be collected remotely. To explore this idea, we extended the network from the NTT Musashino R&D Center to NAOJ's main campus in Mitaka, Tokyo, and made a connection from Musashino to Washington University via GEMnet and a connection from there to the University of Chile via Internet2, AMPATH[*2], and REUNA[*3]. In other words, we got data to flow in our direction by cooperating with scientific networks connected from Seattle onward and formed a path to Chile without incurring any more expense and labor than absolutely necessary.

There are other examples, by the way, of joint activities with overseas organizations. For the future, to promote internet-related research not just for our group but for NTT Laboratories as a whole, collaboration with the outside is essential, and because environments must be prepared for that purpose, I likewise place considerable importance on international cooperation.

Applying Ultrahigh-speed Communications to Scientific Fields

—How did you first become involved in ultrahigh-speed network experiments?

In 1993, the Multimedia Promotion Headquarters was created at NTT under the direct control of the president with the aim of providing novel services as can now be found on the Internet. Because I had been researching what communication networks of the future should be, I was called upon to provide support for this new group. The first project that I was involved with was multimedia joint trials performed in conjunction with outside organizations to determine what communication services to develop in addition to voice services and to find out how they might be used and what benefits they might provide. Here, we connected scientific information centers and universities by a 150-Mbit/s circuit and engaged in various kinds of research. These multimedia joint trials lasted only two to three years, but they enkindled in me a great interest in what could be possible with ultrahigh-speed networks. Consequently, in 1995, I became involved in radio-astronomy experiments using 2.4-Gbit/s communication lines (**Fig. 3**).

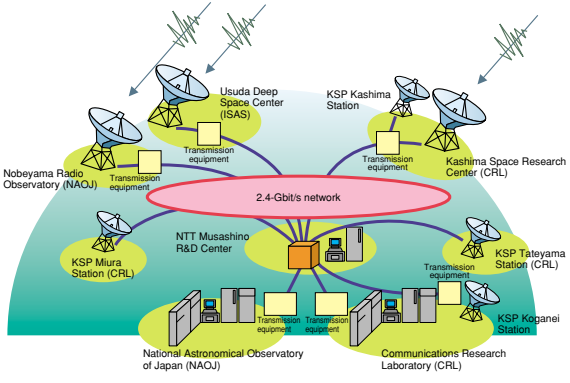
—What kinds of research have you been involved with up to now?

When I was a university student, my instructor was researching speaking-assistance tools for the hearing impaired, and I came to research speech recognition technology as part of this work. This involved developing equipment that could identify and classify vowels and consonants in real time so that sound could be represented visually. To perform this sort of classification, we used pattern recognition technology that combined various speech parameters such as pitch and frequency spectrum.

Pattern recognition is a kind of learning process, and I soon developed an interest in learning theory. After entering NTT Laboratories, I became involved with research of network control using learning theo-

*2 AMPATH: The AmericasPATH network. Using terrestrial and submarine optical-fiber networks, it interconnects the research and education (R&E) networks in South and Central America, the Caribbean and Mexico to US and non-US R&E networks via Internet2's Abilene network and the StarLight International Exchange Point. http://www.ampath.fiu.edu/about.htm

*3 REUNA: The National Research Network of Chile http://www.ampath.fiu.edu/news_REUNA_connects.htm



ISAS: institute of space and astronautical science

Fig. 3. The e-VLBI experimental network (GALAXY).

ry. For networks that were too complicated to model by conventional means, we would model their behavior by trying various combinations of conditions any number of times; that is to say, we would model using learning techniques. Then, based on the model achieved, we would investigate control methods. From then on, network control was a major aspect of my research, and that is still true today.

—Is there anything that attracts your interest as a future research theme?

I am interested in what can be achieved when applying ultrahigh-speed communications to scientific fields. Grid computing is one example. Although NTT is a communication network operator, I believe that, in the days ahead, it must devote some effort to processing in addition to carrying data. At that time, a distributed processing architecture will become a necessity. Consider a scheme that lets a large number of personal computers at different locations exchange huge amounts of data over a network to perform a single task. While such a scheme is very interesting from the viewpoint of network control, it might also be useful from a business viewpoint as an application that increases demand for traffic. I have also talked about my desire to try correlation processing in radio telescopes. Besides these themes, there are a great many topics related to ultrahigh-speed networks that I am interested in. As an individual, however, there is only so much that I can do, and if I did pursue a new research theme, it would probably be in the form of joint research with other experts in the field.

Toward Even Higher Speeds to Meet the Expectations of Scientific Fields

—How have your past activities been received?

I was very pleased that there was considerable interest within NTT Laboratories in my experiments. There were even researchers who offered their own experimental results for me to use. Some examples of this generosity are the AWG-STAR device and the cross-connects that I mentioned earlier. In this regard, I look forward to more contributions like this so that we can gather various types of research on the test bed and do interesting things that could not be done

before.

But, while experiencing this response, I suddenly realized that it's people who connect networks. Of course, it's actually machines that connect the hardware, but what makes that possible is the way that people interconnect. If people have no desire to extend a helping hand to each other, there is no way that good networks can be built. I have been blessed with many wonderful partners to whom I am very grateful.

—What directions do you think your research will take from here?

For the moment, we must make this research more meaningful for NTT Laboratories as a whole. Our first priority is to complete the Atsugi-Yokosuka-Musashino connection and provide an environment in which everyone can experiment freely. This means, in turn, that we must make connections with both domestic and international scientific networks and establish an environment conducive to joint research with the outside. At any rate, I would like to create a site where, in addition to physical research, researchers can exchange ideas, perhaps in the form of periodic symposiums.

Later, I would like to work on increasing the performance of our experimental network by about 100 times. If this can be accomplished, we should be able to do things that are dramatically different from what we can do now. In 1995, when I began radio-astronomy experiments, a transmission speed of 2.4 Gbit/s was quite spectacular. Now, it is becoming the norm. With this in mind, I feel that we will not be able to engage in cutting-edge research unless we aim for transmission speeds on the order of several hundred Gbit/s.

—Based on the variety of outside activities that you have experienced, how do you feel NTT Laboratories is evaluated and what do you think is expected of them?

That depends greatly on the field. Wherever telecommunications carriers gather, NTT Laboratories receives top praise with no complaints. Within internet-related fields, however, NTT Laboratories is not really well known. This may be because NTT Laboratories had not been greatly involved with international communications in the past. In the world of scientific networks with which I have become associated, however, we do have some recognition. Our realtime VLBI experiments in radio astronomy got their start when a radio-astronomy working group was established for Internet2. No doubt there were great expectations here for partners to conduct research and experiments.

—What kind of place is NTT Laboratories for you?

My present work is not something that I was instructed to do by my superiors. I requested and perhaps even pleaded for it until they agreed to let me proceed. What this shows is that I have quite a bit of freedom here at NTT Laboratories. I have been given the opportunity to pursue a project that not only benefits NTT but also contributes to the advancement of science and technology throughout the world. For this, I am immensely grateful. At the same time, the severe economic climate in recent years has required us to justify continuing this research, which does not have immediate business benefits, and this is becoming increasingly difficult. I am therefore always thinking how our research might benefit NTT business in the years to come. I do believe, though, that I will repay NTT Laboratories for the freedom granted me by completing "an environment" where NTT researchers can gather through an autonomous mechanism.

Interviewee profile

■ Career highlights

1978 B.E. in electrical engineering from Kumamoto University, Kumamoto, Japan
1980 M.E. in electrical engineering from Kumamoto University
1980 Joined NTT Laboratories, Tokyo, Japan.
1994-1998 Guest associate professor at the National Center for Science Information Systems (NACSIS)
1999-2000 Guest professor at NACSIS
1998- Currently in charge of the ultrahigh-speed application experiments and the high-performance network testbed at the NTT Service Integration Laboratories.