R&D Spirits

Innovating the Future Backbone Network through IP + Optical Technology

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NTT Network Service Systems Laboratories is researching and developing "IP + optical" technology, which integrates IP (Internet protocol) and optical layers, as the core technology for innovating the future backbone network. How will IP + optical technology change the way that networks operate, and what will it mean for society? We put these questions to Senior Research Engineer Kohei Shiomoto, the leader of the IP Optical Networking Group.

Achieving advanced network operations through "IP + optical" technology

—Dr. Shiomoto, what is your current R&D theme?

The research group that I am currently leading is working on "IP + optical" network technology. Up to now, the optical network and IP (Internet protocol) network have been managed separately, but we are integrating them in the form of an IP + optical multilayer network (MLN), as shown in **Fig. 1**. The idea here is to introduce a server-based traffic engineering (TE) approach into a multilayer network consisting of IP and optical layers. In other words, the IP optical TE server controls both the IP and optical layers and optimizes all the network resources in both the IP and optical layers. This new network consists of client and server networks. The server network provides the optical layer except for electrical IP packet forwarding at border nodes. A core node of the server network is an optical transport node, which operates at ultrahigh speed by eliminating electrical processing of packets. Examples of core nodes include reconfigurable optical add/drop multiplexers (ROADMs) and optical cross connects (OXCs). The border and core nodes are controlled by a common control plane called gen-

- IP+optical MLN consists of border and core nodes.
  - Border node: IP router
  - Core node: optical transport node system (ROADM, OXC, etc.)
- Optical label switched path (OLSP) is used to carry traffic.
- Client network (e.g., IP/MPLS) network may be provided on top of MLN.

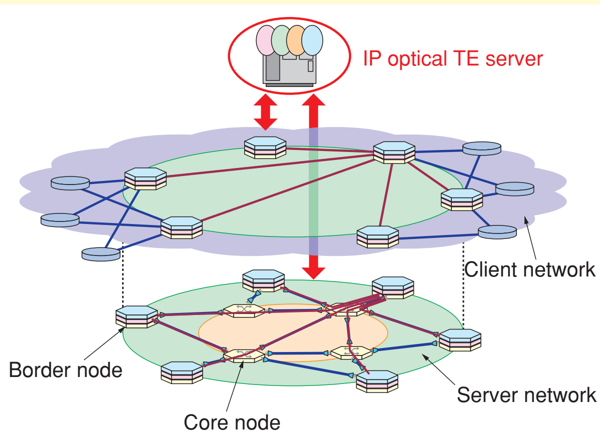

Fig. 1. IP optical multilayer network (MLN).

eralized multiprotocol label switching (GMPLS) in the server network. The client network is an IP network with or without MPLS, which provides various network services. Part of the client network is instantiated by using the resources provisioned in the server network. The IP optical TE server controls network resources in both the IP and optical layers so that the IP + optical MLN can be used as a common network for providing various client networks such as an IP/MPLS network. In short, the ultimate goal of our research is to innovate the future backbone network by introducing advanced and intelligent network operations offered by the IP optical TE server.

—What are the main technical features of this R&D work?

One would be constraint-based route computation. Routes must be computed to satisfy various constraints expressed as functions of cost, loss, delay, reliability, etc. Constraints could be complex and different for different networks. This task should be performed on a carrier-side server rather than at vendor-provided network nodes. Another feature is the ability to reconfigure the network topology dynamically, called virtual network topology (VNT) control (**Fig. 2**). Conventionally, a network topology is created in advance on the basis of traffic-demand forecasts. However, this makes it difficult to adapt to abrupt changes in traffic demand in the network. Such abrupt changes in traffic demand could be triggered by the unpredictable emergence of heavy traffic sources and by failures caused by unexpected natural disaster or network equipment malfunctions. In the system that we have developed, the network topology can be reconfigured as needed by creating and/or deleting optical paths.

By the way, enabling carriers to differentiate their services by server-based control implies the use of a standard interface between nodes and server (**Fig. 3**). We have been very active in standardization activities for this interface [1], [2]. I would like to describe these activities in more detail later, but let me say here that we have been submitting specifications to standardization bodies in cooperation with major carriers and vendors in the USA and Europe. My colleagues and I have written a book on GMPLS technologies [3] to evangelize these new technologies.

—How will this technology contribute to NTT and society?

Integrating what used to be separate layers opens up new possibilities in network services and has the potential to reduce network operation costs. The latter is especially important in terms of maintaining service quality. This relates to the much discussed "2007 problem," which refers to the expected shortfall in Japan's workforce as the generation that has been supporting society up to now enters retirement en masse. The world of information-communications is no exception, and the forecast calls for a rapid decrease in the number of engineers for network operations and maintenance. Our aim is to help solve

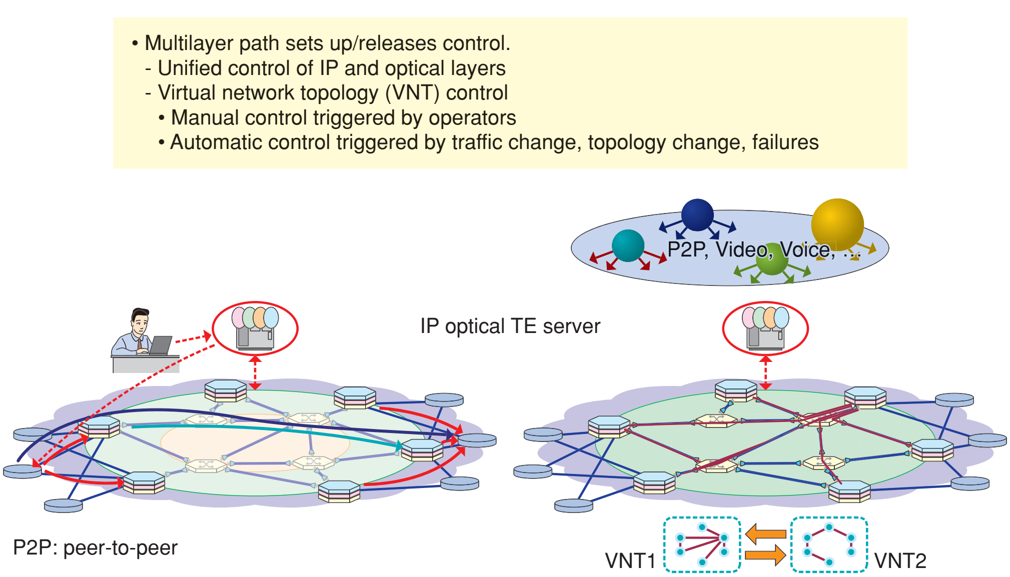

Fig. 2. IP optical multilayer traffic engineering.

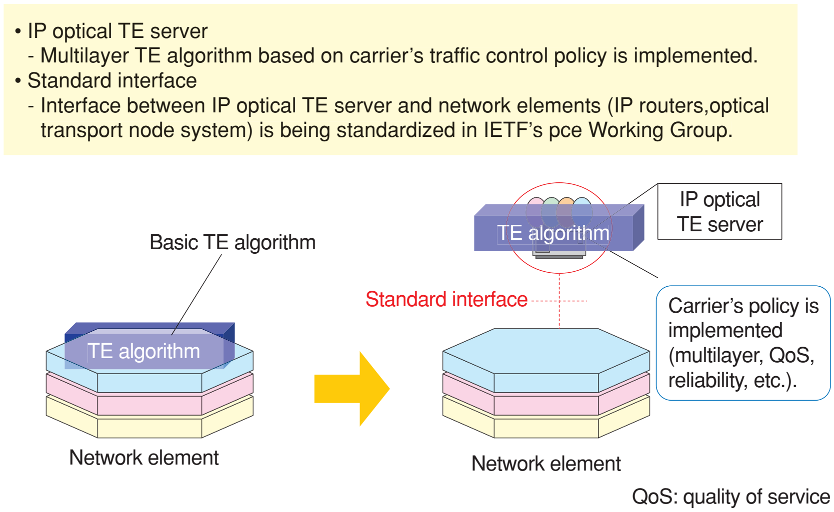

Fig. 3. Server-based approach.

this problem by integrating the network.

Furthermore, by replacing the traditional telephone network that we have been using for about 100 years with an IP + optical network, we should be able to do things never even thought of in the past. The communications network, which is now becoming a true social infrastructure, will not merely affect the way we communicate. It is, of course, expected to give birth to new business models and advance education and medical care, but it should also help establish government countermeasures to natural disasters by making the network even more robust. I believe that we are going to face hard-to-manage changes in traffic demand as those new services emerge.

—What problems are you currently facing?

Though we have a good outlook for the future in terms of technology, a big problem for us now is how we can successfully introduce new technology in real business situations. This is very difficult to do in general, and especially difficult in the case of backbone network technology. People often believe that new technology is risky until it has been proven to be safe after considerable practical use. They are naturally afraid of it and therefore reluctant to introduce it. To overcome such misgivings we need to prove that the new technology is safe by using it in real business situations. It is a kind of chicken-and-egg problem in which the question of which comes first is continuously being argued. The infrastructure and applications should not be treated as a chicken-and-egg problem. Rather, they should be developed in a mutually cooperative way. They should also be discussed not just in terms of R&D, but also in terms of technology management. We need to find innovators and/or early adoptors for the new technology we have developed. In order to meet innovators and potential early adopters, we need a watering hole where people with different business backgrounds get together. In nature, all kinds of animals gather together to drink from the same watering hole. It is this kind of facility that I believe we should also create for the world of technology. I have been working on IP + optical technology extensively from the technical viewpoint. But I think that we need to work more extensively from the viewpoint of technology management. I think we must serve as a contact point between the infrastructure and applications by creating a mechanism for incubating and promoting services that make full use of IP + optical technology.

—How do you think IP + optical technology will develop from here on?

I believe that technologies like GMPLS that are treated as future core technologies must still undergo some improvements taking into account actual operating scenarios. At this stage, nobody can tell how these technologies will look like at the time of implementation, but I think that the need to increase the speed, capacity, and reliability of the network will continue to be demanded from here on. For this reason, I believe that IP + optical technology will become all the more important in the years to come and that it will become a core technology for high-capacity, high-speed networks within a matter of years.

Working to deploy and spread IP + optical technology through academic and international standardization activities

—What is the worldwide trend in this research?

Academic research in this field is quite active in the USA, but testbeds are being constructed and actual GMPLS operations are being performed in Japan and Europe. Discussions are also progressing at the Internet Engineering Task Force (IETF), an international standardization conference, with participation by leading carriers such as NTT, AT&T, and France Telecom and global vendors such as Nortel, Cisco, and Juniper. And last year, NTT hosted the International Conference on IP + Optical Network (iPOP), an international gathering that promotes IP + optical network technology. This conference does not simply hold discussions on technology—it also provides a forum for carriers and vendors to perform interconnectivity experiments and public demonstrations. In this sense, it also has the important role of a showcase for technology and is attracting much attention as a contact point between academia and industry. The iPOP conference has so far been held twice in Tokyo. It is hoped that iPOP will come to function as the watering hole for IP + optical network technology.

The iPOP is mainly organized by a Japanese organization called the Photonic Internet Laboratory (PIL) [2]. This consortium was formed by NTT and leading Japanese information-equipment makers to promote international standards for IP + optical network technology originating in Japan.

—How is NTT perceived in this field on the world stage?

My feeling is that NTT, with many technological achievements in the field, is highly regarded. For example, Layer-1 VPN (virtual private network), which is now a common term in standardization activities, was originally NTT technology. NTT strongly influenced the inauguration of two of the IETF's working groups, l1vpn (layer 1 VPNs) and pce (path computation element). I served as a co-chair on iPOP's Technical Program Committee to make iPOP a big success. Conference participants from many countries gave NTT high marks for driving the latest trends in IP + optical network technology.

—Are you now involved in any collaborative projects with other companies or research institutions?

As I have explained, we are now promoting the idea that node equipment should be standardized and that server-based technology should be the means of differentiating a carrier's services. For this reason, we will strengthen the cooperation and ties with vendors and other carriers. We are also collaborating with academia in leading-edge technologies.

In pursuit of highly original technology that can make far-reaching contributions to society

—Dr. Shiomoto, what was your motivation for entering NTT Laboratories?

In graduate school, I majored in information engineering and evaluated the performance of ATM (asynchronous transfer mode) switches and token-ring LANs (local area networks). I was therefore specializing in the field of communications from the very start, and it was only natural that I would see NTT, the dominant institution in network research in Japan, as the place to work. In 1989, when I entered the company, ATM was regarded as the way to go for the coming era of multimedia communications, and ATM research was quite active at NTT. I also had a very strong interest in ATM, and I very much wanted to continue ATM research here at NTT.

—Could you give us a brief history of your R&D activities to date?

I was first assigned to the ATM-switching-node research group, where I was involved in the development of ATM switching system architecture designs. Our research team successfully developed the world's first ATM switching system. This assignment was exactly what I wanted, and from 1989 to 1995, I was engaged in R&D of ATM traffic control and ATM switching systems, my specialty. During that period, I become involved in all of the processes related to ATM switches, from the study of specifications to their development, testing, and implementation. Those switches came to be deployed in important NTT networks and academic networks.

Then, in 1996, I joined Washington University in St. Louis, Missouri, as a visiting researcher for one year. At that time, the trend in network research was "IP over ATM," and the problem was to find ways of controlling IP traffic on an ATM network. As part of this trend, I also researched IP with ATM at the core, and eventually I came to the realization that network control would come to be performed by IP. On returning to Japan, I immediately advised my superior of my desire to take up IP research even though our research group still devoted itself to ATM technology. As you may easily imagine, it is very difficult to change the R&D strategy in a big company like NTT. But I never gave up my desire to change it. I discussed with him over and over again until I was finally able to begin IP research, though on my own. That was in 1997. Then, after about a year of preparations, I developed an IP + ATM-node system based on ATM switches. It was just around that time that a rapid shift toward IP began to take place around the world, and NTT R&D also began the conversion to IP. My R&D work likewise expanded to include IP routers and multi-service network nodes, and I worked on those IP themes until 2001. During that time, my R&D target shifted to IP + optical technology, and here I am now.

—Looking back, is there any one incident that you would regard as a turning point?

Yes. During the time that I was in the USA, I participated in a workshop on IP over ATM. There was much heated discussion on the IP-over-ATM scheme, and one researcher in particular stated that “everything can be done by IP, so ATM is not really necessary.” That was Stephen Deering, who has made a name for himself in IP multicast research. At first, I had no idea what he was talking about, but on doing some self study, I came to understand that this approach could help increase network capacity significantly, and I gradually learned how such an IP system could be achieved. While ATM is capable of very detailed control, IP has plenty of horsepower. In terms of pure research, ATM is a very interesting subject, but when it comes to high-speed and large-capacity systems, which the world demands, I’ve come to think that IP is the better choice. That, I would say, was my turning point. Since winning the battle against ATM, IP has become sophisticated with help from MPLS technology. This is a typical example of how technology evolves. The technical viewpoint is not the only important one; the business viewpoint also matters.

—What has been your goal throughout your R&D activities?

More than anything else, I want to be useful to society. And I want to create things that never existed before. I want to come up with technology that people describe as “this is something new,” or technology that no one has even thought of before, and then provide that technology to the world by incorporating it into the communications infrastructure. It is with this feeling that I undertake R&D. Of course, one way of pursuing R&D is to concentrate on only those things that you find interesting without regard to trends or needs in society. I, myself, however, feel that the meaning of R&D work is to create things that not only possess originality but that are also useful to people in society. This is why I entered NTT. From here on as well, with a perspective that I could have only at NTT, I would like to do work that has great social impact beyond what is possible from the viewpoint of a single company.

Aiming for better application of R&D results as a contact point between infrastructure and services

—What direction would you personally like to take from here on?

Creating an advanced infrastructure will not, in itself, give birth to new things. And, of course, the reverse is also true. I believe one’s attention must be turned to both the infrastructure and services if one is to make contributions to society through communications technology. Accordingly, while continuing to promote R&D in the IP + optical MLN, I would like to channel much of my energy into creating a forum where network researchers and application developers can gather freely and hold open discussions.

And as another future direction, I would like to pursue development work from a wider perspective. In the development process, it is often found that a certain technology, if available, would make a great difference, but alas, for one reason or another, it cannot be obtained. This is more of a problem of methodology than creativity. But it should be possible to minimize this problem if good advice on development methods and appropriate technology-related information were to be provided and if industry and academia were to collaborate and produce results in an appropriate way. The picture I’m painting here is of development consulting, which I am very interested in. Making use of my extensive experience in development work and in the administration of international conferences, I think it would be very interesting to become a catalyst for the matchmaking of technologies.

—What is your ultimate dream as an engineer?

My first and foremost desire is to contribute to society through the R&D of communications technologies. This may sound rather simplistic, but I would like to be involved in creating communication services that people are happy to use and really find necessary.

—What is it like working at NTT Laboratories for you personally?

NTT is a leading carrier in the world, and the quality and size of its R&D program are world-class. Though it is a private enterprise, its influence on society is great, and the technologies researched and developed there are used by NTT communication businesses to bring genuine changes to the world of communications in Japan. Being a part of this endeavor gives me a great feeling of worth. There are also many excellent researchers at NTT Laboratories, and the range of research fields is extensive, which makes it very easy for me to obtain information from outside my field of specialty. Being able to carry on my research in such an environment is something that I value greatly and appreciate very much.

—Dr. Shiomoto, what would you say to young researchers?

More than anything else, I would say "have conviction." From what I have seen in recent years, young researchers need a more confident and independent attitude. Young researchers should not be reluctant to voice different opinions even against their superiors. In order to maintain creativity, we must continue to have active discussion. We need more debate to find the truth. A former superior of mine once told me that "If someone presents a particular idea, be sure to suggest modifications or alternatives. Even if you also believe that the original idea is right, you should still play the devil's advocate. It is only in this way that the truth can come out." Perhaps that is an extreme example, but I also favor this kind of interplay in discussions. Of course, I'm not saying that it's good to take an opposing stance no matter what the issue. The important thing here is that one has the confidence to challenge other opinions if necessary. Otherwise, new and novel things will not be created. By all means, have conviction as a researcher and be ready to refute the opinions of even your superiors.

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Interviewee profile

■ Career highlights

Kohei Shiomoto received the B.E., M.E., and Ph.D. degrees in information and computer sciences from Osaka University, Osaka, in 1987, 1989, and 1998, respectively. He joined NTT in April 1989 and engaged in R&D of ATM traffic control and ATM switching system architecture design. From August 1996 to September 1997, he was engaged in research on high-speed networking as a Visiting Scholar at Washington University in St. Louis, MO, USA. From September 1997 to June 2001, he was directing architecture design for the high-speed IP/MPLS label switching router research project at NTT Network Service Systems Laboratories. Since July 2001, he has been engaged in the research fields of photonic IP router design and routing algorithms and in GMPLS routing and signaling standardization, first at NTT Network Innovation Laboratories and then at NTT Network Service Systems Laboratories. He is active in GMPLS standardization in IETF. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan, IEEE, and the Association for Computing Machinery. He was the Secretary for International Relations of the Communications Society of IEICE from June 2003 to May 2005. He was the Vice Chair of Information Services of the IEEE ComSoc Asia Pacific Board from January 2004 to December 2005. He has been involved in the organization of several international conferences including HPSR 2002, WTC 2002, HPSR 2004, WTC 2004, MPLS 2004, iPOP 2005, MPLS 2005, iPOP 2006, and MPLS 2006. He received the Young Engineer Award from IEICE in 1995. He received the Switching System Research Award from IEICE in 1995 and 2000. He was one of the authors of "GMPLS Technologies: Broadband Backbone Networks and Systems".