Interface Mapping Technology Using Semantic Information

Tatsuyuki Kimura†, *Makoto Nakatsuji, and Yoshihiro Otsuka*

Abstract

This article provides an overview of technologies that support fast, flexible inter-system cooperation and describes semantic information-based interface conversion technology. They will support the rapid development of new devices based on technological advances and cooperation between network operation systems (including diverse new service systems as well as legacy systems) and thus lead to the smooth provisioning of services.

1. Network changes and operational issues

With the widespread penetration of the Internet and broadband access in recent years, there has been a huge increase in the number and variety of new services. There has also been growing competition between services and service providers, and this is driving the ongoing trend to reduce the time from service conception to deployment to just a few months. At the same time, networks are becoming multilayered to support multiple types of switching (wavelength and SDH (synchronous digital hierarchy) layers in addition to the IP (Internet protocol) layer) and network throughputs and capacities are rising. The Internet is a vast conglomeration of countless networks and domains. It is very rare for one company to be able to single-handedly offer a service with widespread popular appeal, so it is important that companies can combine a number of service applications in order to create new value-added services that appeal to the public. In particular, now that we are approaching the ubiquitous era, we must prepare for networks that are used by a much larger number of entities to construct new services on an *ad hoc* basis. The basic challenges for the core network to ensure continued safe and secure operation of networks that are subject to constant change are to provide:

(1) multilayer network management technologies,
(2) multidomain network management technologies, and
(3) technologies for quickly establishing flexible cooperation between systems.

The management capabilities needed to support dynamic network evolution are shown in **Fig. 1**. Here, customers do not perform network operations. These are done only by the staff of other common carriers, maintenance persons, and planners (hereafter called operators).

2. Multilayer network management technologies

The rapid penetration of broadband communication into networks and the remarkable increase in throughputs and capacities of core networks have led to the deployment of new devices such as wavelength division multiplexing (WDM) systems and optical cross-connects (OXCs) that use photonic switching. This has driven research and development of generalized multiprotocol label switching (GMPLS), which supports multiple types of switching ranging from switching in the IP-layer to switching in the wavelength layer. To support these networks, it is essential to provide centralized management for i) various layer resources, ii) QoS (quality-of-service) classes, and iii) differentiation between paths that have been automatically configured by devices and paths that

† NTT Network Service Systems Laboratories
Musashino-shi, 180-8585 Japan
E-mail: kimura.tatsuyuki@lab.ntt.co.jp

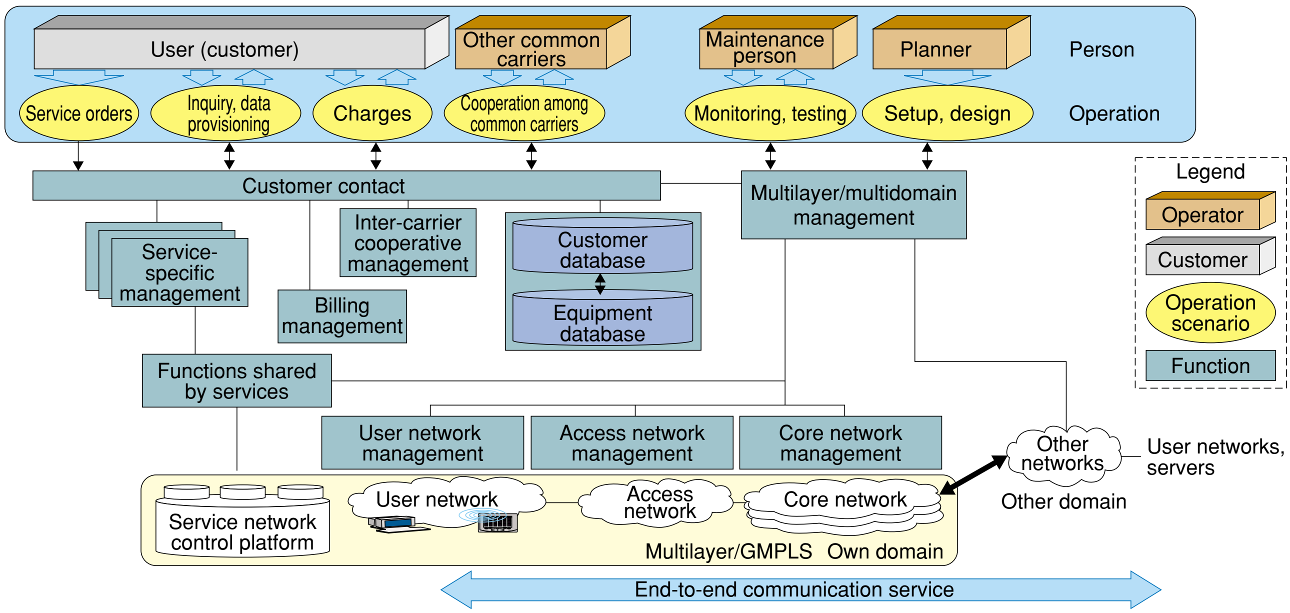


Fig. 1. Management capabilities needed to support dynamic network evolution.

have been set up by operators, as well as provide a rapid response to and recovery from failures.

NTT Network Service Systems Laboratories has studied two different approaches for meeting these needs: (i) technologies for managing links in each layer and other network resources and (ii) technologies for managing network resources so they can be provided in a way that is easy to exploit by services. These network management technologies are intended to make flexible models of the network for management in each layer. An implementation of these technologies is shown in **Fig. 2** as (i) a multilayer network management system [1] and (ii) service resource agents [2]. In future, these approaches will be integrated.

3. Multidomain network management technologies

In the Internet, paths cutting across different domains are set up by means of the standard protocol BGP-4 (border gateway protocol version 4). Nevertheless, problems occur on paths that traverse multiple domains (e.g., IP packets fail to arrive, routes are dropped, and Internet hijacking or webjacking occurs) because different domains have different operating policies. NTT Network Service Systems Laboratories has made significant progress in addressing these issues. Starting with a wide-area IP network monitoring and diagnosing method whose proof of concept was demonstrated by NTT Network Innovation Laboratories [3], it has developed not only a reliable commercial version of this technology but also a number of additional diagnostic functions including a hijack monitoring and routing information anomaly monitoring system.

4. Technologies for quickly establishing flexible cooperation between systems

4.1 Transition to inter-system cooperation technologies in the network operations domain

Since information is distributed between devices, servers, and other systems to be managed and the host service operations system in network operations, it is necessary for the interfaces to be converted. A number of approaches have been taken to implement this interface conversion at the protocol level, at the data level, and at other levels (**Table 1**).

When new services are made available, there are many instances where new devices or functions are introduced, and the network management system (NMS) must be modified as quickly as possible so that it can accommodate the new devices. To minimize the scale of upgrading, the most common approach is an architecture in which interface adapter modules for different devices can be readily added to the device interface part of the NMS, so devices can

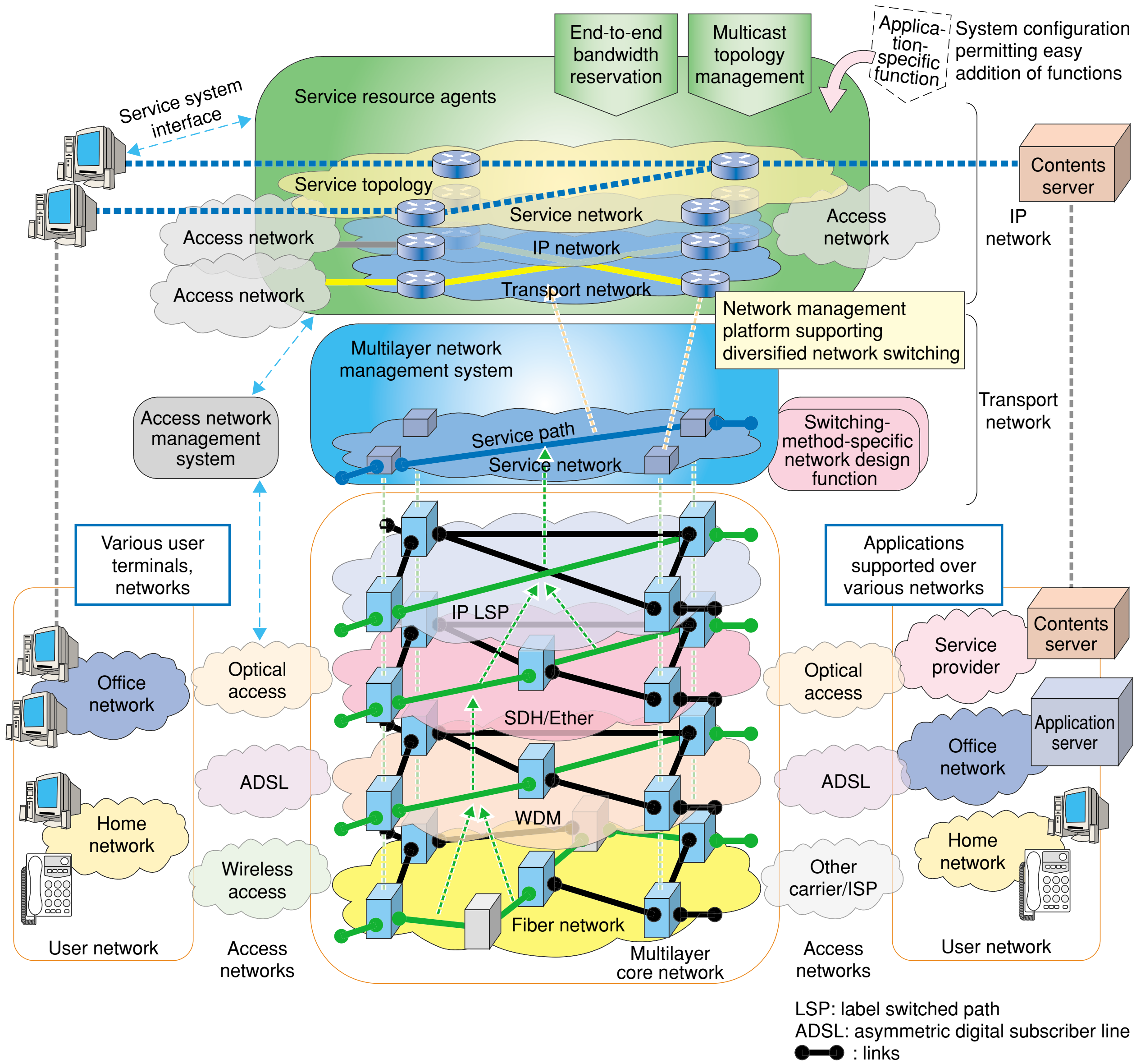


Fig. 2. Multilayer network resource management technologies.

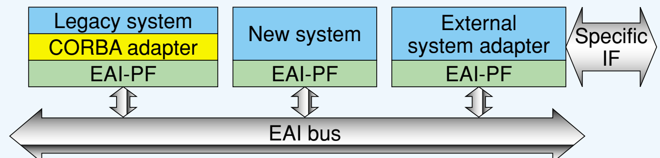
be added without altering the basic NMS itself. Nevertheless, while the scale of systems and the frequency with which new services are added varies, survey results reveal that close to 50% of an operator's work is spent on modifying these interface conversion functions. We can expect a growing number of network services to be developed ever more quickly in the years ahead, so the implementation of high-performance interface coordination functionality will become increasingly important.

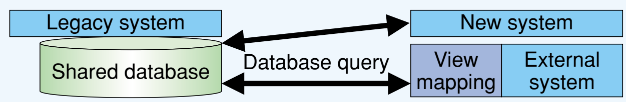
In addition to this subordinate system interface, we will also see a growing need for functionality to coordinate similar interfaces in higher-level service systems as the age of ubiquitous networking progresses. This higher-level interface coordination is essential to support coordination among various service applications (with various interface policies) and NMSs so that users can enjoy stress-free access to services.

4.2 Efforts to improve setup operation efficiency and minimize adapter development time

Most conventional network management systems incorporate device-specific interface adapters that are developed independently, so serious issues in terms

Table 1. Examples of inter-system cooperation technology in the operation domain.

<table>
<tr><th>Cooperation level</th><th>Approach</th><th>Technology highlights</th></tr>
<tr><td rowspan="3">Protocol level</td><td>The sharing of inter-system interfaces enables the use of only standardized communication protocols.</td><td rowspan="3">Example of protocol transformation using an EAI tool


Even if protocols are standardized, distributed data must be processed in a separated transformation.
Preconditions
- Data definitions between cooperating systems must be uniformly determined and required transformations must be simple.
- Shared platform products must be supported.
- There must be few connections to new systems that do not observe shared data definitions.</td></tr>
<tr><td>For the part of the inter-system interface needed for cooperation, the communication protocol is designed to match the unique protocol part.</td></tr>
<tr><td>A far more efficient inter-system interface can be implemented using a commercial EAI tool to connect separate systems over a system path with a shared protocol than using separate transformations.</td></tr>
<tr><td rowspan="4">Data level</td><td>Standard database based on shared schema
Information link through common database</td><td rowspan="3">

Because the data schema is unified in a shared database, applications may be easy to design. The database shall be tuned for connecting systems.
Preconditions
- The platform is mainly used to refer to data from other systems.
- It is better to use a common database management system (DBMS) product.</td></tr>
<tr><td>The part of the existing database that is targeted is treated as a shared schema; limited distribution information is shared.</td></tr>
<tr><td>Only specified systems closely cooperate by using a shared database.</td></tr>
<tr><td>Messages are coordinated only for specified information; internal database expressions are kept just as databases for separate systems.</td><td>• Database is not shared.
• Technologies used when cooperating and combining at the protocol level.</td></tr>
<tr><td>Other level</td><td>User interfaces for each system through on-screen integration on a Web browser.</td><td>• It is highly effective at reducing the number of terminals.
• Because the system could become unusable for different types and versions of browsers, design guidelines have been prepared and different systems must observe the guidelines.</td></tr>
</table>

PF: platform IF: interface EAI: enterprise application interface

of development cost and flexibility arise when interface specifications are changed. We have recently seen the emergence of products using scripts to act as interface adapters and NMSs using prepared application programming interfaces (APIs), but these are confined to the level of simply reproducing device operations based on device information that is collected and recorded. With the goal of simplifying the development of interface adapters, NTT Network Service Systems Laboratories has been working on two fundamental technologies:

(1) Interface blending/diagnosis technology

This technology is a new attempt to automatically generate scripts for interface adapters using the general-purpose script language EXPECT. Using a diagnostic script based on an existing adapter script, devices to be added to the network are examined, diagnosed, and then prepared on-the-fly for the device based on the results of the script. This technology markedly improves the efficiency of setup operations and reduces the time needed to develop adapters, thus enabling new functional capabilities to be added or devices to be upgraded quickly and flexibly. Details of its two aspects are given in the next article of this Special Feature [4].

(2) IP service setup control technology

A system using this technology creates setup sequences tailored to the systems targeted for management using a general-purpose script language. This greatly simplifies the work of setting up services and permits flexible addition and modification of management objects.

4.3 Flexible interface technology using metadata

As the ubiquitous information society evolves, all sorts of new devices and services will be connected to the network in a wide variety of different ways. To enable us to take advantage of these advanced net-

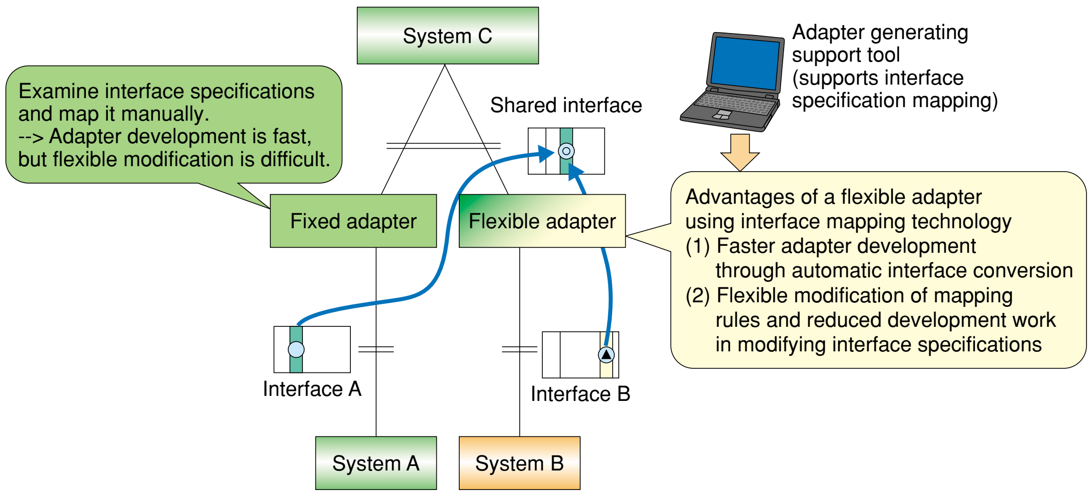


Fig. 3. Comparison of adapters.

work resources, a new inter-service coordination system is needed that permits these services and other resources to be quickly and flexibly integrated into network operations.

Currently, WebService is the leading software system with an interface to support system-to-system interaction between service systems over a network. It supports the dynamic exchange of messages based on interface definitions written in Web Services Description Language (WSDL), an XML-formatted language used to describe Web service capabilities (XML: extensible markup language). But even if WebService can read values, in order to utilize messages stored in non-standard information, it must be able to not only determine the format but also decipher the meaning represented by the information elements. The method proposed for adding this kind of semantic information to messages is metadata, and the system is a Semantic Web service [5], [6]. Since the keywords entered for the metadata can be freely selected, a range of different expressions can be chosen. For example, as keywords to describe a network fault, one might choose “fault status”, “interface failure”, or some other similar expression. While human engineers typically use many different expressions to describe a fault, the lexicon must be standardized to make it machine processable. Finally, it is necessary to decide whether to impose standard interface rules or give each service system a separate changeable dictionary.

The Semantic Web deals with semantic information elements endowed with metadata within a structural framework known as an ontology. It uses an XML-formatted language called Web Ontology Language (OWL) to describe these elements [7]. An ontology represents the relationship between one concept and another concept, so it can represent the structure that “interface failure” is an equivalent concept to “fault”.

Different kinds of adapters are compared in **Fig. 3**. Up to now, interfaces between two systems were always converted using fixed adapters. This involved examining the interface specifications and performing the mapping manually. Consequently, modification of specifications was extremely time consuming and inflexible. This led NTT Network Service Systems Laboratories to focus on semantic information and propose a novel approach based on flexible adapters in which API information rules written in interface specifications are represented as ontologies and interface mapping technology is used in an interface coordination function [8].

The basic principle of interface mapping technology is shown in **Fig. 4**. The System A interface is divided into the message format and semantic information. Each of these is converted to an ontology and the mappings are stored. The same is done for System B. Then the similarity of semantic information is calculated and automatically mapped from System B to System A.

Since functions are similar in the operations domain even if the systems are different, affinities are found through the semantic information mapping. Considering that there are also attribute names with practically no semantic content such as “bit #8”, a sub-tree topology above the ontology can be grasped as a characteristic, and the resemblance can be used

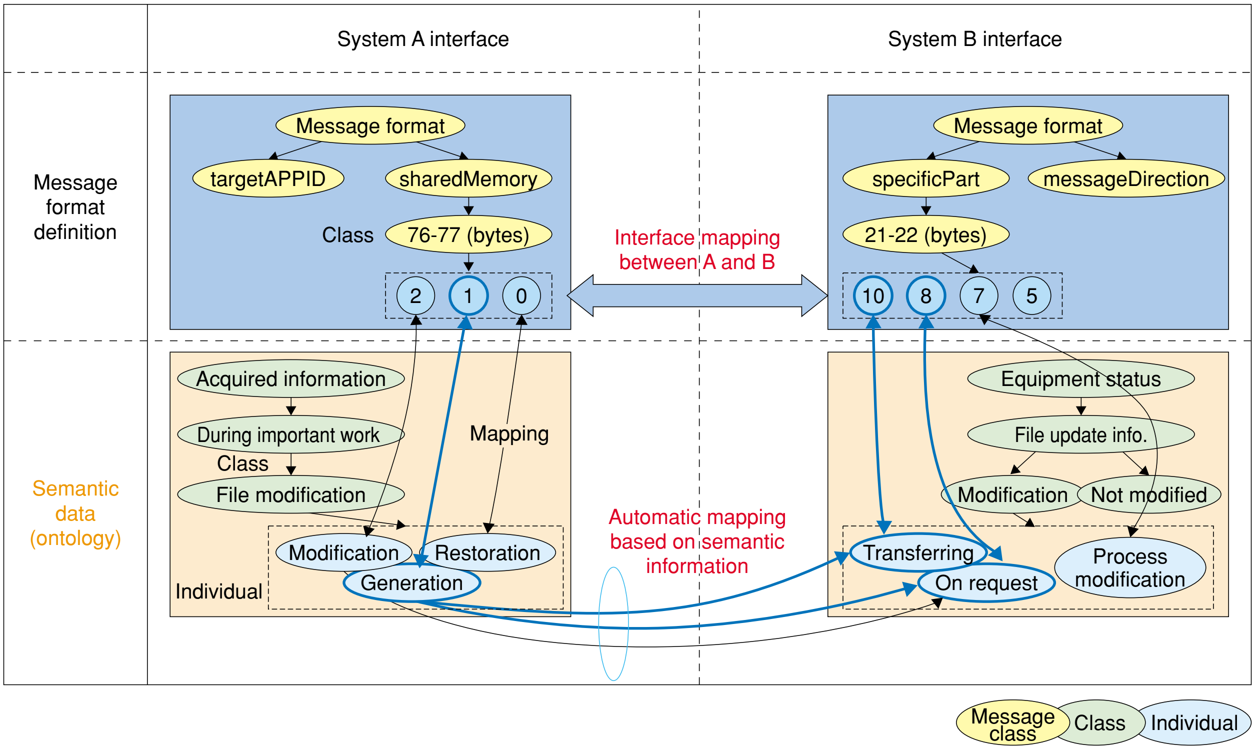


Fig. 4. Basic principle of interface mapping technology.

to further enhance the accuracy of the mapping.

We built a prototype implementation of the interface mapping technology described above and evaluated its performance in creating 15 kinds of interfaces between subordinate systems in a commercial operation system. The interfaces between systems consisted of some 25,000 attributes. However, using this interface mapping technology, we could narrow this number down to 468 sets of candidates though a similarity calculation based on simple inter-class mapping. We expect to achieve even better mapping accuracy using a topology-based similarity calculation through the reuse of past mapping results. This should dramatically reduce the work involved in designing an adapter for interface conversion.

5. Future issues

Automatic generation from UML (unified modeling language) has been proposed as an ontology creation method, but there are still issues to be resolved such as expansion of the range of objects using the data mapping technology. It also shows promise as a basic technology that can retrieve conditional search results of applications. Building on the promising results achieved so far, we are now researching and developing an interface conversion technology between network operation systems and applications by combining the interface diagnosis and preparation technology with a management application platform.

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Tatsuyuki Kimura

Senior Research Engineer, Software Service Group, Network Software Service Project, NTT Network Service Systems Laboratories.

He received the B.E. degree in mechanical engineering from Keio University, Tokyo in 1990. He joined NTT in 1990. Since then, he has mainly been engaged in research on transmission network management. He is currently working on the modeling of network management functions and multi-layered network management systems. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan.

Makoto Nakatsuji

Researcher, Software Service Group, Network Software Service Project, NTT Network Service Systems Laboratories.

He received the M.S. degree in system science from Kyoto University, Kyoto in 2003. He joined NTT in 2003. Since then, he has mainly been engaged in research on flexible interface technology. He is currently working on semantic modeling and mapping of inter-system interfaces. He is a member of IEICE and the Database Society of Japan.

Yoshihiro Otsuka

Senior Research Engineer, Supervisor, Software Service Group, Network Software Service Project, NTT Network Service Systems Laboratories.

He received the M.E. degree in physical electronics from Tokyo Institute of Technology, Tokyo in 1985. He joined NTT in 1985. Since then, he has mainly been engaged in research on broadband switching systems and network management systems. He is currently working on the modeling of network management functions and multi-layered network management systems. He is a member of IEICE.