# Integrated Management of Networks and Information Processing for Future Networks

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**Abstract**

This article introduces two research initiatives in NTT Network Innovation Laboratories aimed at giving future networks functionalities that proactively facilitate novel information and communications technology services; namely, architectural design of deeply programmable networks and integrated management of networks and information processing. They will bring great value to society and people.

## 1. Introduction

This article introduces research on the fusion of novel network and information technologies being undertaken by NTT Network Innovation Laboratories. We aim to design a network infrastructure that fosters service creation of great value to society and people by effectively combining virtualized network resources and information technology (IT) equipment resources (NW/IT resources). The key concepts in this research are deeply programmable networks and integrated management of networks and information processing.

## 2. Structure of future networks

The logical structure of future networks that we are promoting is shown in **Fig. 1**. The networks consist of four layers. The lower three layers correspond to the flexible networks discussed in the first of these Feature Articles [1] on flexible networking technologies for future networks. Among them, we are paying special attention to two functional layers, namely, the ICT resource virtualization layer and the NW/IT integration layer (ICT: information and communications technologies). The bottom layer is a flexible ICT substrate composed of network and IT equipment, which is rapidly increasing in flexibility and becoming ready to be utilized as resources that can be composed through virtualization and abstraction.

The ICT resource virtualization layer virtualizes ICT resources and acts as a provider of the ICT resources to its upper-layer user and applications. The layer above is the NW/IT integration layer. The combination of networks and information processing has recently given rise to several valuable services, in areas such as information retrieval and social networking. We believe that the integration layer will play an important role in promoting the combination on the full scale in future networks.

An important viewpoint of future networks is that they bring a human-centric concept to ICT services. The seamless combination of NW/IT resources and processing lets users be unaware of NW/IT resource mechanisms and frees them from troublesome setup work; the situation and context of each user is handled by the layers so that users can enjoy rich services more readily, easily, and safely.

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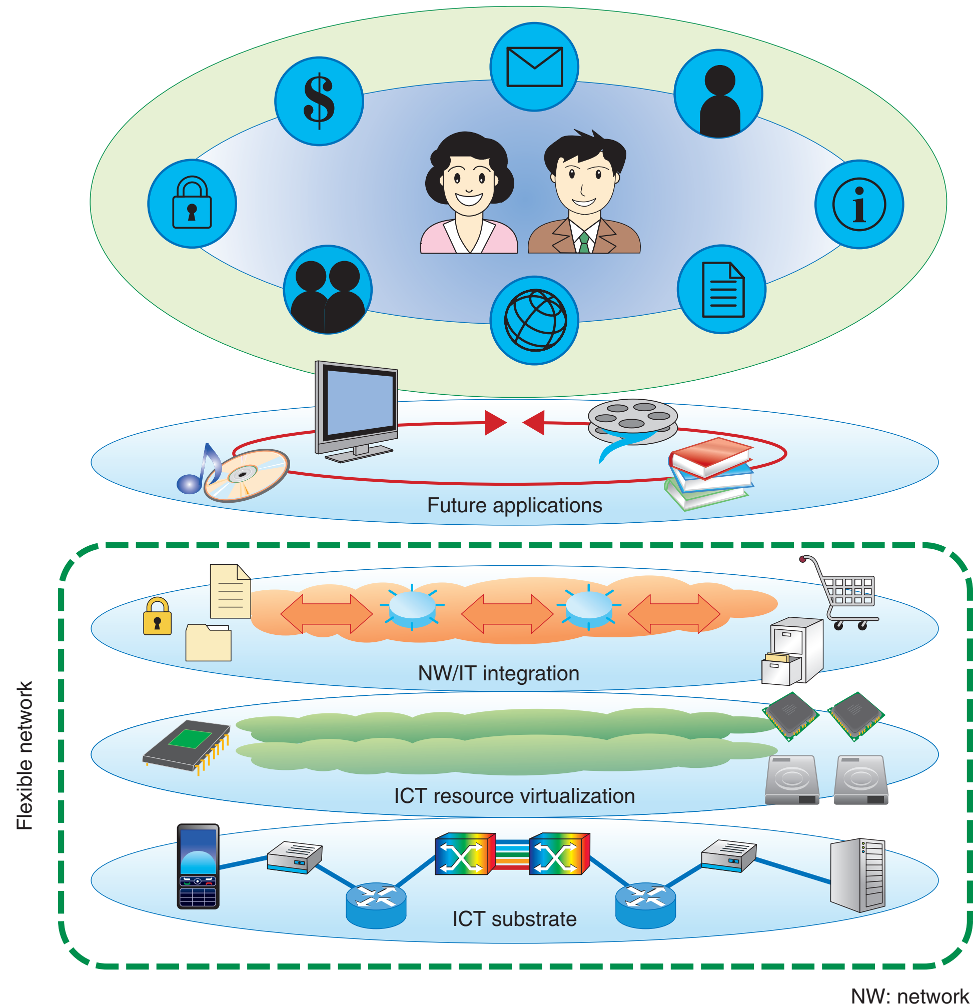


Fig. 1. Structure of future network.

## 3. Virtualization and abstraction of NW/IT resources

It is of the utmost importance that the physical NW/IT resources, such as bandwidth and computing functions, are skillfully abstracted and virtualized and that unnecessary details about physical implementations are hidden in order to leave room for further improvement through the deployment of new technologies. Inventions in applied physics and materials engineering can produce more useful lower-layer devices that replace conventional ones; meanwhile, in the upper-layer, original applications come and go, resulting in ever increasing diversity in the usage of the infrastructure. Through resource abstraction and virtualization, we can retain room for further and continuous development to incorporate new technologies and accommodate new applications.

The concept of abstraction and virtualization has been a tradition in the telecommunications industry; notions of layering and interfaces, for example, are based on this concept. However, it is acquiring more importance nowadays because 1) the flexibility of resources is vastly increasing and 2) some techniques for combining various NW/IT resources are becoming mature; particular examples are cloud computing technologies and OpenFlow networking.

An example of the abstraction/virtualization of NW/IT resources is shown in **Fig. 2**. Suppose that a user wants to connect among multiple sites and some servers; a conventional way is to purchase several circuits that have a low level of abstraction such as conventional leased lines, combine them into a network, and connect to the server at one point. By

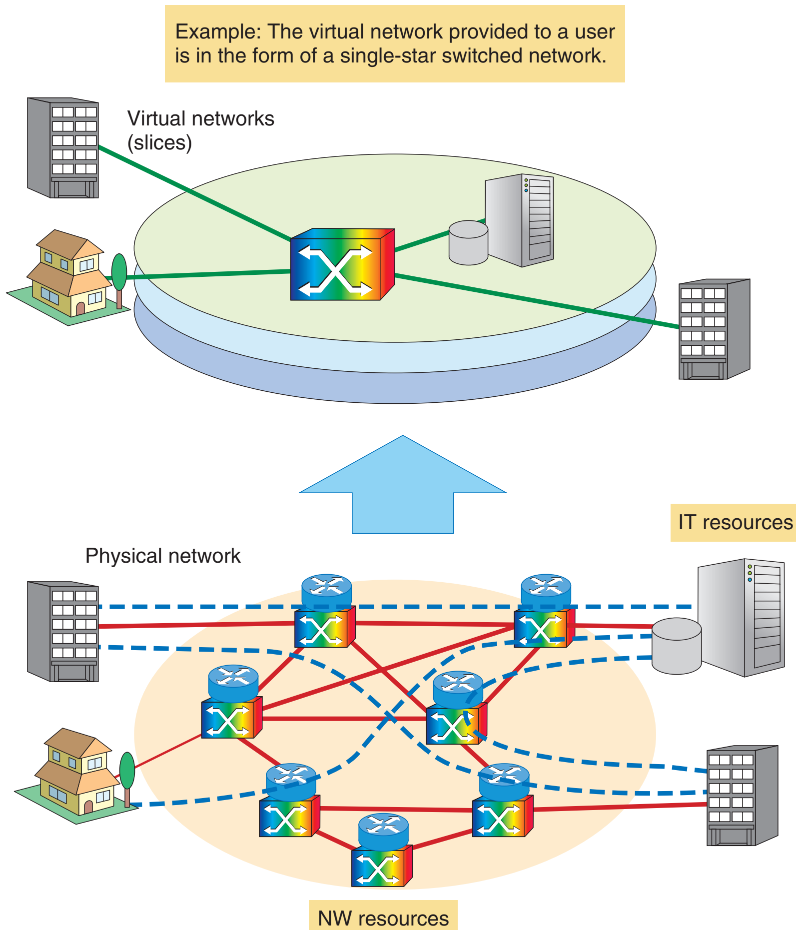


Fig. 2. Virtualization and abstraction of NW/IT resources.

contrast, in the virtualized case, depicted in the upper half of Fig. 2, a single-star virtual topology is tailored and provided to the user, and the user does not have to be bothered by the actual physical layout (i.e., the layout in the physical layer). Computational resources can be prepared by the carrier so that the NW/IT resource combination gives good performance and they can be provided to the user as a seamless customized service. The main feature of NW/IT resource abstraction and virtualization is that it can offer multiple virtual networks simultaneously: each virtual network is called a slice.

## 4. Integration of networks and information processing

As a means of integrating networks and information processing, the concept of programmable high-performance networks is attracting attention. In this concept, in addition to communication functions, network nodes have information processing functions provided by central processing units (CPUs), memory, and storage. These various NW/IT resources in the nodes are flexibly combined to provide integrated services. NTT Network Innovation Laboratories has been promoting this concept through an industry-academia collaborative project with the University of Tokyo, NEC, Fujitsu, and Hitachi since 2008.

In this project, we are studying three components for programmable high-performance networks: virtual nodes, the access gateway, and a virtual network management system. The structure of the virtual node is shown in **Fig. 3**. It consists of a networking function block and a programmable processing block. The latter includes network processors to provide hardware-assisted high-performance processing and virtual machines to provide more flexible software-based processing using generic CPUs and memory.

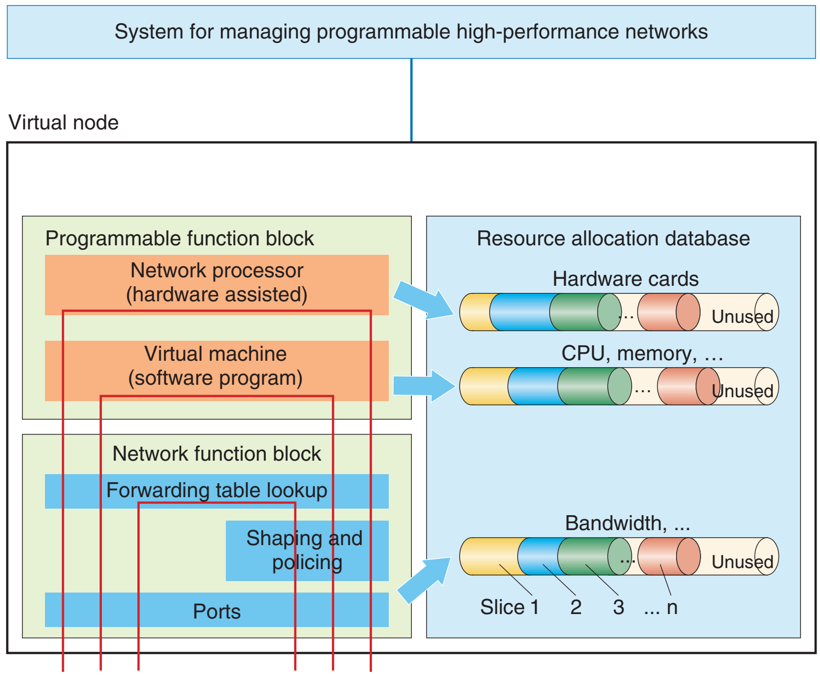


Fig. 3. Structure of virtual node.

Virtual nodes provide their networking and processing resources to slices according to their demand under the supervision of the virtual network management system. The management system takes care of resource requests from users and resource usage in nodes, and it commands the nodes to allocate, adjust, and release appropriate resources according to the user's request for slice generation, modification, or deletion.

The project has developed prototypes of the virtual nodes, access gateway, and management system and has deployed them in the national networking testbed, JGN-X [2], for verification and demonstration. The prototypes are also actively utilized for studies of applications utilizing NW/IT resource combination.

We are also studying coarser-grained NW/IT resource integration. The aim is to establish techniques for coordinating IT servers and networks (rather than embedding server functions in networks). With the recent development of cloud computing, the flexibilities of IT resources such as servers, storage equipment, CPUs, and memory are ever increasing, so there are high expectations for sophisticated combinations of these NW/IT resources. NTT Network Innovation Laboratories has been studying this issue in another industry-government-academia project called VICTORIES (for Vertically Integrated Center for Technologies of Optical Routing toward Ideal Energy Savings) [3] with the National Institute of Advanced Industrial Science and Technology (AIST) and other companies. In that project, we have developed a resource management system that controls resource usages of contents servers and high-capacity optical path networks, and we successfully demonstrated its usability through experiments on ultrahigh-definition video distribution in August 2010. The experimental setup is shown in **Fig. 4**. Upon receiving a viewing request from a user, the management system searches for the necessary resources, i.e., traffic transmission capacity of video servers residing outside the network and bandwidth for the links that can provide a path between the server and the users (viewers). The management system determines a desirable combination of resources and allocates them for the video distribution session.

## 5. Integrated management of NW/IT resources

As described above, the management functionality is vital for an integrated service composed of network resources and computation resources. We are focusing especially on this among technologies for flexible networking.

The proposed architecture for integrated NW/IT

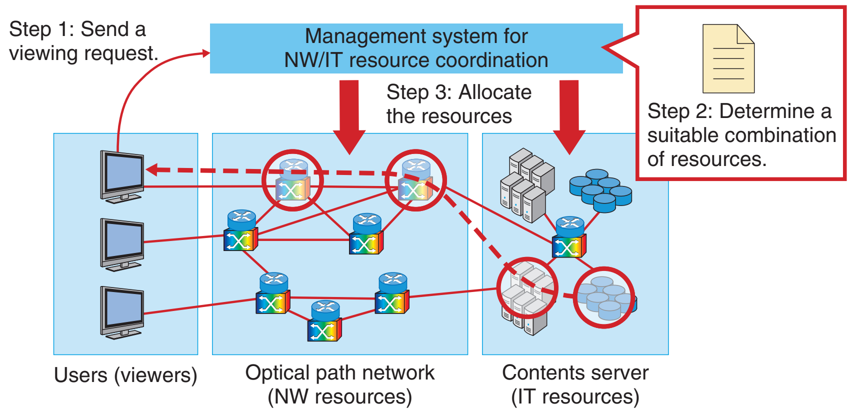


Fig. 4. Experimental setup of NW/IT resource coordination.

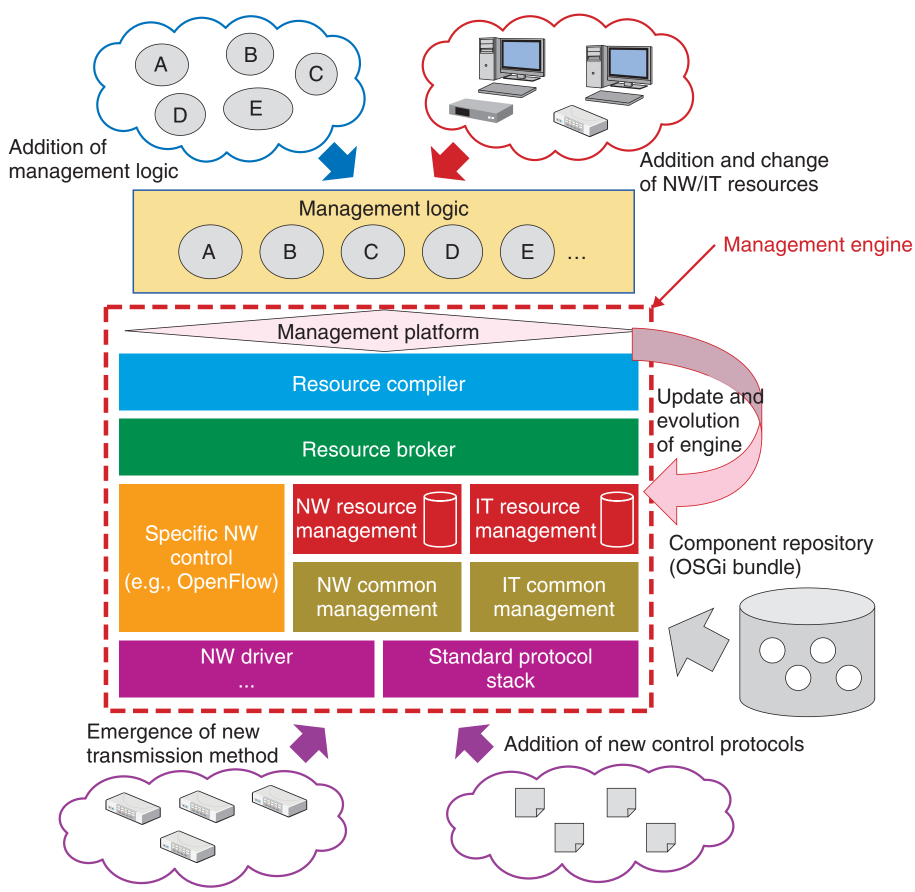


Fig. 5. Management Engine, an architecture for integrated NW/IT resource management.

resource management is shown in **Fig. 5**. Called the Management Engine, it is designed in a hierarchical manner with the upper layer being the most abstract while the lowest layer is the least abstract to provide an interface with physical equipment.

The management logic is a platform that allows network users (including service providers of various kinds such as Internet service providers and application service providers) to describe their requests to network operators in a highly abstract manner. By defining new management logic, it is easy and straightforward to add an operation policy, change an existing one, or combine new NW/IT resources. A service request is issued by management logic, which is translated in the management engine's resource compiler. The resource broker, working in association with the network resource manager and IT resource manager, searches for and determines the optimal combination of various resources that fulfills the service request. If the network includes a subdomain with specific control interfaces and protocols, such as an OpenFlow subdomain, these interfaces are utilized by the resource broker. The resource broker issues requests for the selected resources, which are translated by network drivers and a standard protocol stack into appropriate sequences of commands for corresponding equipment, so that the equipment is set up to accommodate the service. In addition to the resource management, common management modules for NW/IT resources in the engine will offer functions for failure management, performance management, etc. The engine is being implemented using the OSGi [4] framework, which is a modular software component platform and an international standard promoted by NTT and other companies, so that it can swiftly and flexibly deal with new protocols in various layers and the rapid emergence of novel transmission methods and equipment.

## 6. Concluding remarks

The integration of networks and information processing in future networks is expected to lead to a rich set of novel valuable services. We will continue our research on NW/IT resource abstraction & virtualization and the component-oriented management engine toward a flexible management engine that can be extended in line with innovations in networking and information technologies.

## References

[1] A. Hiramatsu and R. Kawamura, "Flexible Networking Technologies for Future Networks," NTT Technical Review, Vol. 10, No. 8, 2012. https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201208fa1.html
[2] JGN-X. http://www.jgn.nict.go.jp/english/index.html
[3] VICTORIES. http://www.aist-victories.org/en/
[4] OSGi Alliance. http://www.osgi.org/

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He received the B.E. degree in electronics engineering from Gunma University in 1987. In 1987, he joined NTT Electrical Communication Laboratories, where he engaged in research on a programmable transport system. Since 1998, he has been developing carrier network operation systems. Since 2003, he has been developing a digital television relay network operation system. His current research interests are network virtualization and network management technologies for future networks. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

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