# O3 Project White Paper

Innovating Network Business
through SDN WAN Technologies

## O3 Project

**March 2015**

## O3 Project Members

## Preface

In 2013, the O3 (O-three) project(*1) was launched by NEC Corporation, Nippon Telegraph and Telephone Corporation, NTT Communications Corporation, Fujitsu Limited and Hitachi, Ltd. This world-first research and development (R&D) project seeks to make a variety of wide area network elements compatible with software-defined networking (SDN, *2), including platforms for comprehensively integrating and managing multiple types of wide area network infrastructure and applications. This initiative was also based on research consigned by the Ministry of Internal Affairs and Communications' Research and Development of Network Virtualization Technology, and has been promoted jointly by the five companies. In addition, this project aims to commercialize the results of research and development on network virtualization and to promote their global popularization and standardization. Disclosure of information related to the project has already begun online and through other outlets.

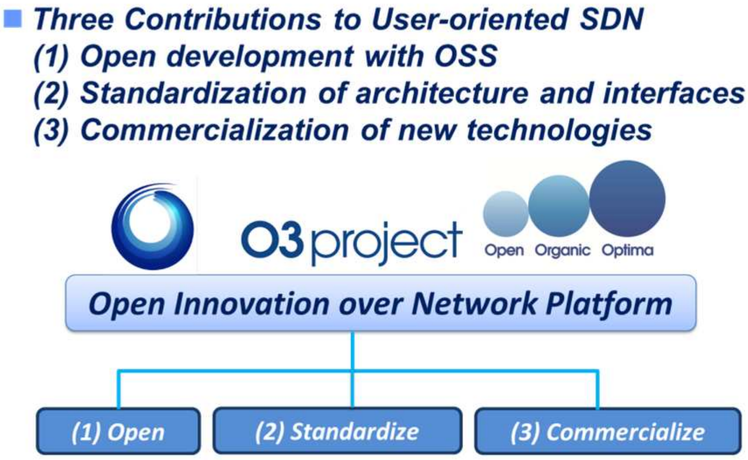


Fig. 1 Toward open user-oriented SDN

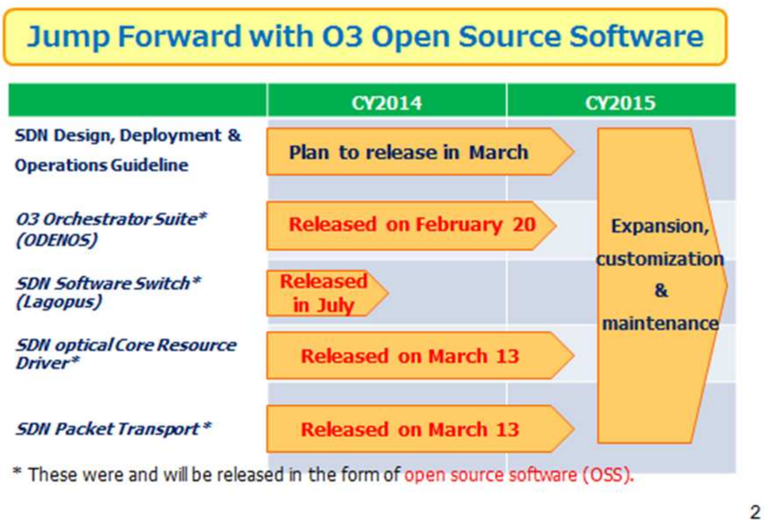


Fig. 2 Plan for disclosure of project results

Notes

*1: O3 stands for the overall concepts of this project: open, organic and optima.

*2: Software-Defined Networking (SDN) is a concept for controlling a network via software.

## 1. Background

With the expansion of cloud services, the number of applications using networks has also been increasing. Moreover, the widespread use of smartphones has also been accompanied by the rapid growth in the number of users, along with an expanding need for services. Responding to the speed of change in services, data centers (DCs) that provide cloud services face the challenge of reducing time to construct and change networks. To resolve this, there is a greater need for introducing software-defined networking (SDN) to networks within DCs and between DCs, since the SDN will make the construction and the changing of networks more flexible and faster, in addition to reducing the lead-time for providing DC services. It is expected that as corporate infrastructure to ensure business continuity is strengthened and globalized, collaboration will be needed between dispersed DCs and users around the world. As a result, there will be greater need for reducing the lead-time to provide services while assuring service quality for users across a wide area network, such as networks between DCs and between the DC and users. Application of SDN in wide area networks is therefore only expected to increase.

However, as wide area networks support communications services across many types of networks, including optical networks and wireless networks, and as telecommunications carriers and service providers work on the design, construction and operations of services for each network, it is challenging to construct networks to meet a wide range of service requirements, including network performance, protocols and processing, and to start services promptly.

Moreover, existing wide area networks have network devices and operation management systems for each network type (layer), and operation management is conducted separately in each respective layer. Therefore, when a fault occurs in a lower layer, it is difficult for operation managers in upper layers to identify its location and quickly address it.

Similarly, since operation management is carried out separately in each respective layer, telecommunications carriers and service providers have difficulty in coordinating low-cost, high-performance resources throughout all of the layers in order to optimize service construction costs when they allocate network resources (network equipment, transmission routes, etc.) to services.

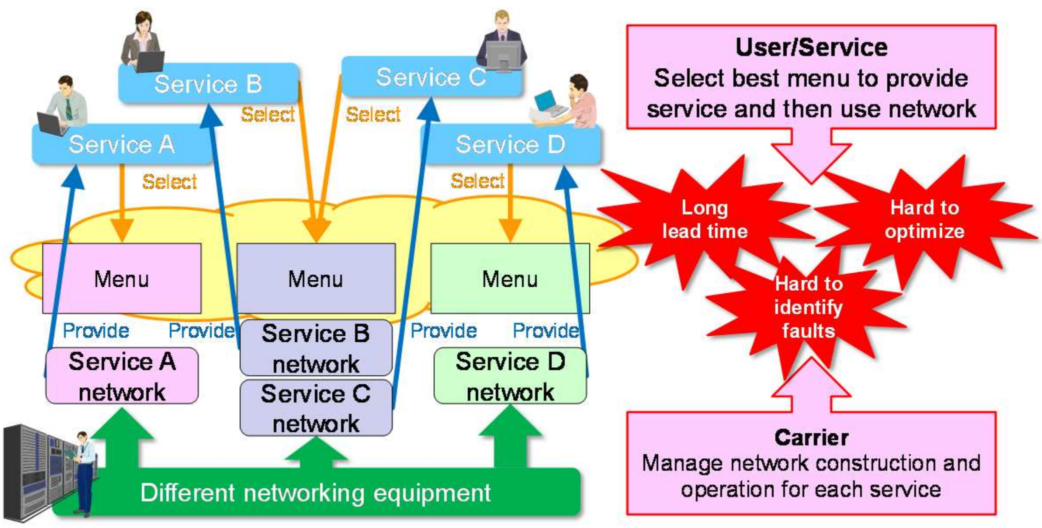


Fig. 3 Problems with traditional networks

 

In order to solve the above challenges, the O3 project aims to establish network virtualization technology that enables multiple telecommunications carriers and service providers who share network resources to design and construct networks and manage their operations freely to suit their needs. We aim to apply SDN technology to wide area networks to enable flexible and dynamic changes in network structure, configuration and settings as well as centralized control of network components (communications equipment, etc.) by software. Differences between networks configuring a wide area network must be absorbed by the SDN targeting the wide area network. This project addresses this problem by abstracting and expressing individual networks as object-oriented data models, and by expanding operator functions to process network objects according to user characteristics. This will realize a platform technology that enables flexible and dynamic network control and operation management, from finely-tuned networks for carriers to simple networks used by application providers.

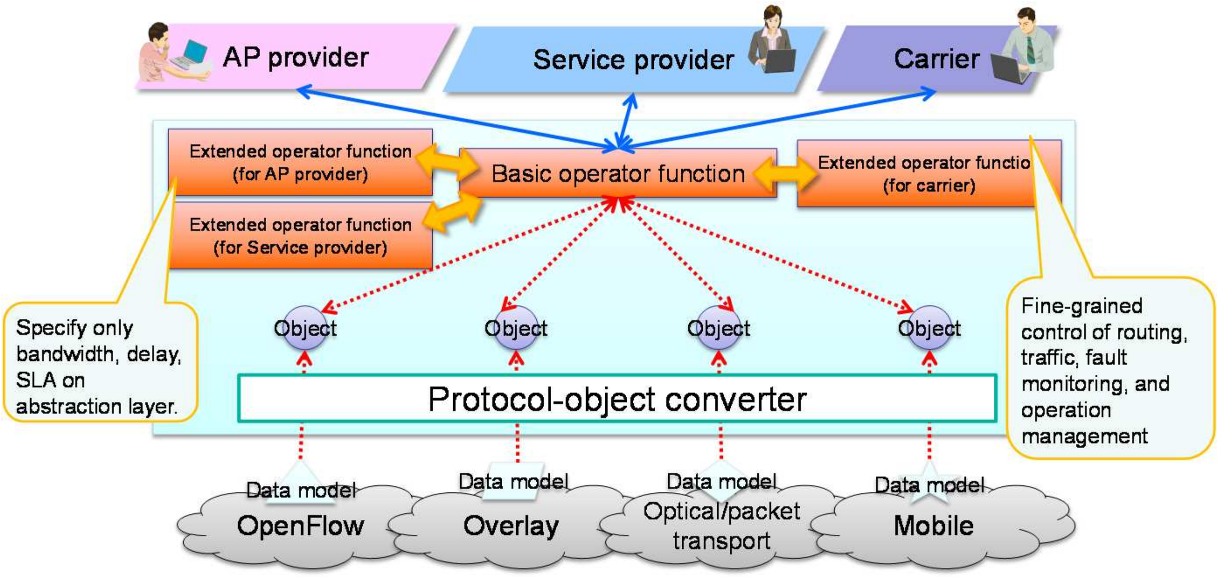


Fig. 4 Wide area network operation management implemented by SDN

This project has been promoting research & development in the following six areas, focusing on the creation of an integrated platform to control and operate network objects.

- Network management control platform
- SDN-enabled optical communication system
- SDN-enabled packet transport system
- SDN-enabled wireless communication system
- SDN-enabled software communication equipment
- Guidelines for SDN design, construction and operation

## 2. Network management control platform

Today's heterogeneous networks consist of multiple vendors and layers, ranging from networks in a DC to wide area networks. A platform that enables integrated control of multilayer networks will be effective in reducing operation costs and capital investment while improving resource utilization. Moreover, integrated control will further promote operation management efficiency by reducing service provision lead times and improving communication quality. Until now, implementing integrated network control involved determining the target layers and control methods and then constructing a system specific to those layers and methods. When target layers were subsequently added or control methods changed, the entire control system would often have to be modified. Developing an integrated control system that could handle evolving service demands therefore became very costly.

To solve this problem, we propose an integrated control platform that expresses the networks configuring a heterogeneous network as two abstracted data models: topology (the nodes, ports and links) and flow (end-to-end communication). Information specific to each network is handled as attributes of the abstracted models. With this platform, a driver abstracts the physical network and creates network objects pursuant to the aforementioned model. When the network objects are operated externally, this is detected by one of the drivers, which is then assigned control of the physical network. Moreover, by applying control operators such as Federator and Aggregator, network objects that are abstracted for a specific purpose can be obtained. By combining these control operators, control functionalities for a multilayer heterogeneous network can be readily implemented.

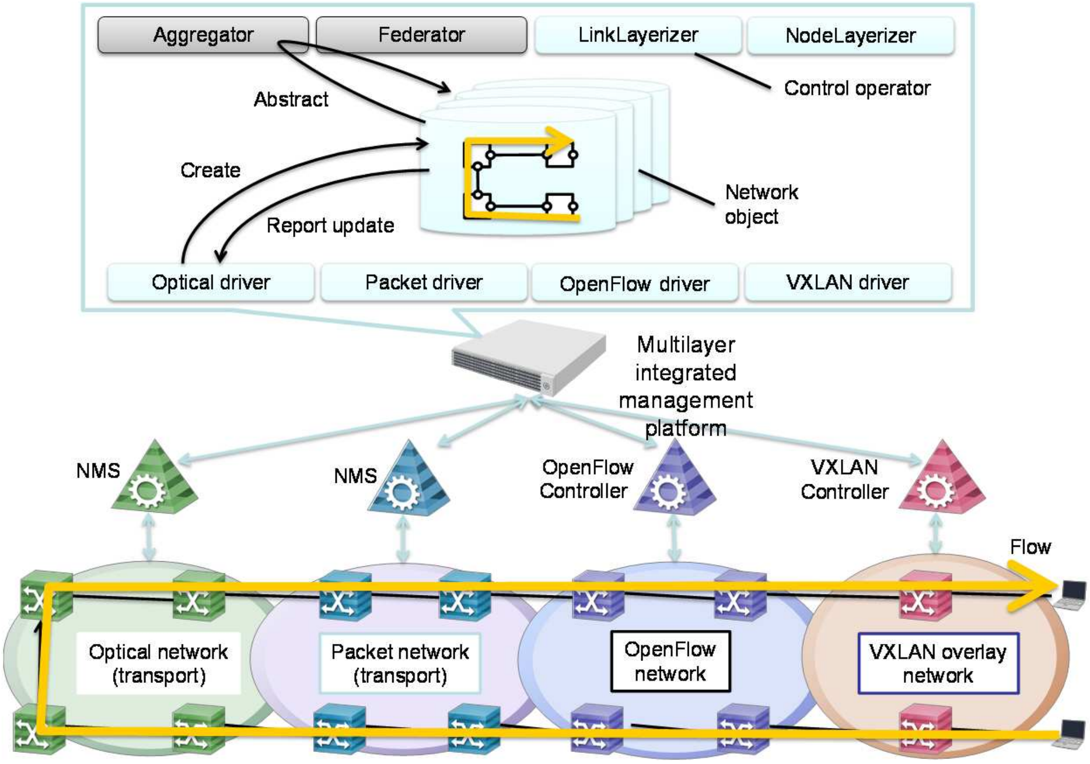


Fig. 5 Network management control platform

### 3. SDN-enabled optical communication system

The widespread use of high-performance terminals such as smartphones combined with the expansion of cloud services has caused communications applications to diversify. Moreover, as big data utilization and high-definition video streaming services such as 4K/8K have progressed, demand has grown for quality, high-bandwidth end-to-end network services that can be used on demand, whenever and as many times as the user likes. There is now pressure to enable bandwidth and communication paths to be changed quickly and flexibly even in optical networks. The SDN-enabled optical communication system being researched as part of this project aims to satisfy these demands by using an abstraction method to enable optical network resources (optical fibers, wavelengths, time slots, etc.) to be controlled by software. With this method, controllers perform centralized control of an entire multilayer network, including the optical layers, with full awareness of interlayer dependencies. This allows resources to be assigned automatically and efficiently.

By flexibly and automatically assigning and canceling resources such as wavelengths and time slots according to the signals entering the optical network from edge routers, etc., this system can enhance network scalability, allowing bandwidths to expand from 40 Gbps (mainstream in current wavelength multiplexers) to 400 Gbps, or even 1 Tbps, per wavelength. Bandwidths of 40 Gbps or 100 Gbps per wavelength can also be divided into approximately 1 Gbps per wavelength according to the service. In an end-to-end communication path consisting of multiple routers, edge routers can be connected directly, not via intermediate routers but via optical paths. This enables optical cut-through, thereby reducing transmission delays and improving communication quality.

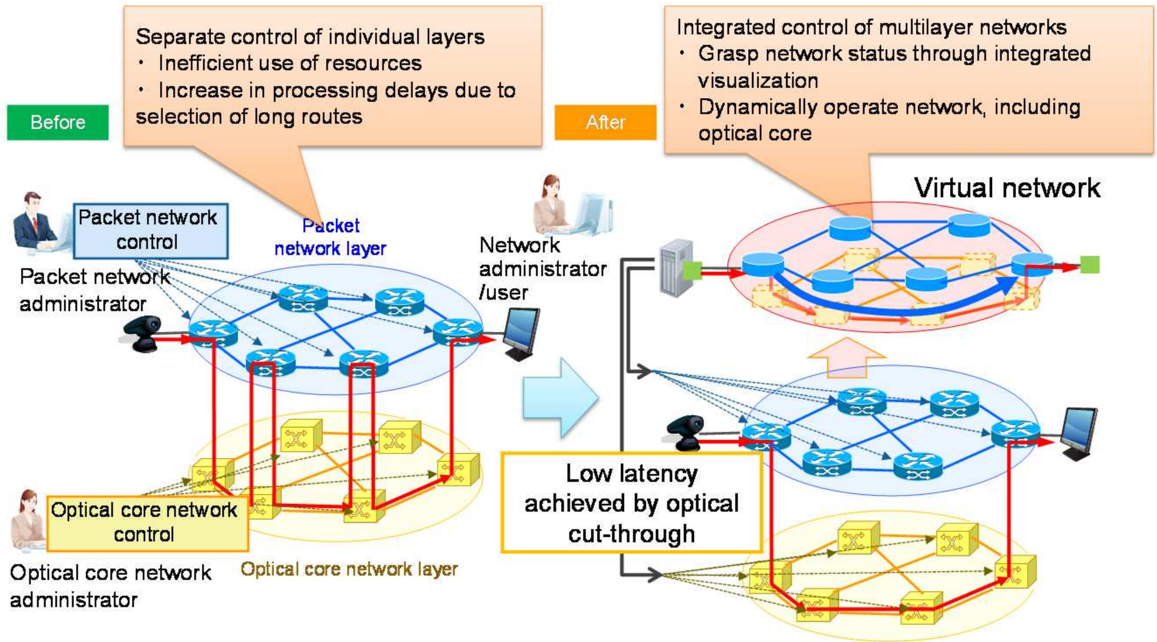


Fig. 6 Example of entire multilayer optimization by SDN (optical cut-through)

This SDN-enabled optical communication system achieves not local optimization within the optical layer but also optimization throughout all the layers, leading to improved network resource utilization efficiency. This system also enables flexible configuration changes in the optical layer and improves the efficiency of on-demand services.

## 4. SDN-enabled packet transport system

The packet transport system efficiently and reliably integrates the optical transport network that transfers large-capacity data with other networks such as the Internet and mobile networks. The packet transport system extracts the virtual network that satisfies the networking requirements of a specific service from the optical transport network and performs efficient and reliable operation management of network resources in coordination with optical transport. An SDN-enabled packet transport system will allow companies to optimize investment in and operation of networks that have independently been managed until now. This will lead to the creation of new value for the company as they become able to respond quickly and flexibly to variations in traffic and demands for service innovation.

We are currently developing a multilayer integrated management module to be used as a general-purpose scheme for implementing an SDN-enabled packet transport system. By adopting this scheme in carrier SDN systems, it will be possible to perform integrated control of the multi-vendor SDN controllers in each layer from the SDN application. Achieving this requires a standard interface between the SDN application and the multilayer integrated management module, deployment of SDN controller and multilayer integrated management module functions, and scalability of the multilayer integrated management module.

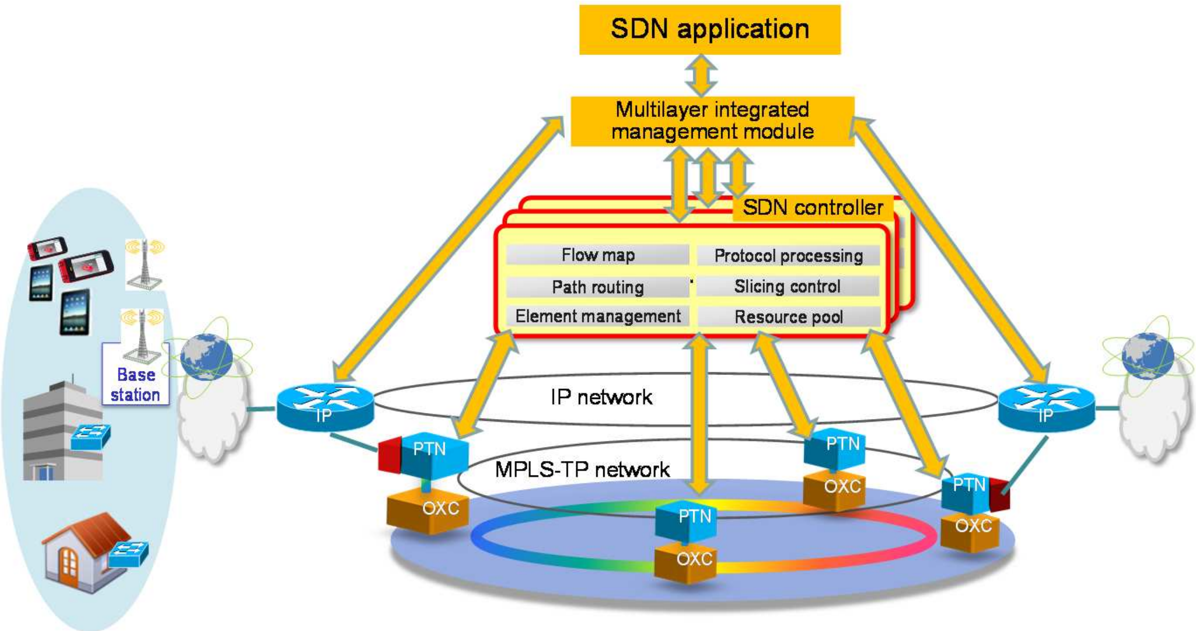


Fig. 7 Overview of SDN-enabled packet transport system

An important feature of next-generation networks will be the ability to leverage IP networking technologies to fuse the transport layer with IP networks such as the Internet, VPNs, and mobile networks. A means of fusing packet-based transport technologies that enable centralized control using SDN with distributed control IP networking will be indispensable in achieving this. We are therefore developing technologies to enable coordination between the SDN-enabled packet transport system and IP networks.

## 5. SDN-enabled wireless communication system

An SDN-enabled wireless communication system is also indispensable to the introduction of network virtualization into a wide area network. Achieving this system will require both traffic control technology to enable coordination among mobile networks and technology to enable virtualization of wireless networks.

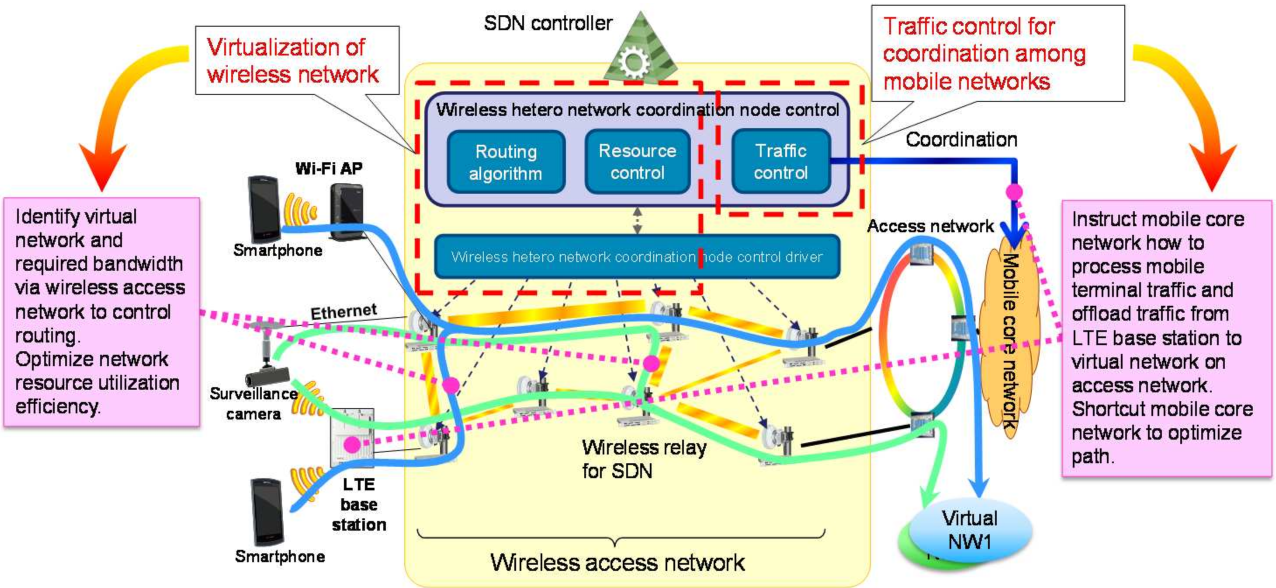


Fig. 8 Illustration of SDN-enabled wireless communication system

### 5.1 Traffic control for coordination among mobile networks

Conventional 3GPP mobile networks such as LTE enable data to be transferred while terminal users are on the move by creating a tunnel between the gateway in the mobile core network and the LTE base station. Because all traffic passes through the gateway in the mobile core network, even when terminals are communicating with each other, network resources in the mobile network have not been able to be used effectively.

To solve this problem, the SDN controller must be able to coordinate with the mobile network to perform efficient traffic control as an alternative to simple tunneling. Through this coordination, the SDN controller can obtain traffic information from the mobile network, including the Access Point Name (APN), Tunnel Endpoint Identifier (TEID) and QoS Class Identifier (QCI), and traffic can be offloaded to a virtual network by the OpenFlow switch (OFS) adjacent to the LTE base station. The SDN controller can directly control routes of the offloaded traffic and send data traffic down the optimal route. This means that traffic can bypass the gateway in the mobile core network, preventing the occurrence of a traffic overhead due to tunneling. Also, because the SDN controller can control the offloaded traffic based on the APN information relevant to the IP address space, the controller can be used even in environments where IP address space collisions occur.

## 5.2 Virtualization of wireless networks

In a physical network consisting of multiple wireless relays (known as a wireless network), the frequency band used is often vulnerable to environmental changes such as weather and wavelength interference. Wireless networks are also affected by link band fluctuation, depending on the external environment. Configuring a virtual network on this kind of wireless network requires technologies that will enable wireless network band characteristics to be changed flexibly in response to environmental variations and routes to be configured according to the application of the virtual network, and network resource management technologies to enable the dynamic allocation of resources.

To realize these technologies and enable flexible and efficient control, priority levels are added to each virtual network and routes are configured and resources allocated taking the stability of each band, not just the current band, into consideration. This is done for each link configuring the wireless network. For example, fixed bands that are less affected by environmental variations are allocated to virtual networks through which high-priority traffic is flowing (such as VoIP) to provide a stable communication environment. At the same time, bands more seriously affected by environmental variations are allocated as required to virtual networks through which low-priority traffic is flowing (such as the Internet).

The first effort to realize wireless network virtualization was the modeling of a wireless link on a wireless transport network for the purpose of managing a wireless network on the integrated control platform described in section 2. Modeling a wireless link based on the five parameters of current link band, estimated rate, maximum rate, minimum rate and availability enables control that makes allowances for wireless link band fluctuation. Using this model to, for example, specify a transmission rate equal to or greater than the available rate as the estimated rate allows the transmission rate to be managed so that bandwidth is guaranteed based on available rate.

## 6. SDN-enabled software communication equipment

With the advent of Network Functions Virtualization (NFV), communications equipment that was previously hardware based is virtualized and controlled by software. In NFV environments, software-based switches managed by SDN can be used to interconnect multiple network functions. To achieve this kind of SDN-enabled software switch, we have adopted a two-level hierarchical structure that includes an agent layer and a data plane layer. We have been working on improving the performance so that the agent layer can provide flexible and controllable driver technology, while the data plane layer can achieve 10 Gbps traffic transfer and accommodate one million flows. Our policy is to use common components for network functions wherever possible and combine these components to implement a SDN software switch to which functions and modules can be flexibly added. Our driver technology is compliant with OpenFlow 1.3 and we have evaluated its functionality based on the Conformance Test Specification for OpenFlow Switch Specification and the Ryu Certification. We have confirmed a high conformance rate with specifications including control of the MPLS, PBB, and other protocols used in wide area networks. Also, by using state-of-the-art multi-core CPUs and high-speed I/O processing, we have seen considerable improvements in performance in our goal to achieve an architecture that is capable of executing high-speed packet processing on a general-purpose server.

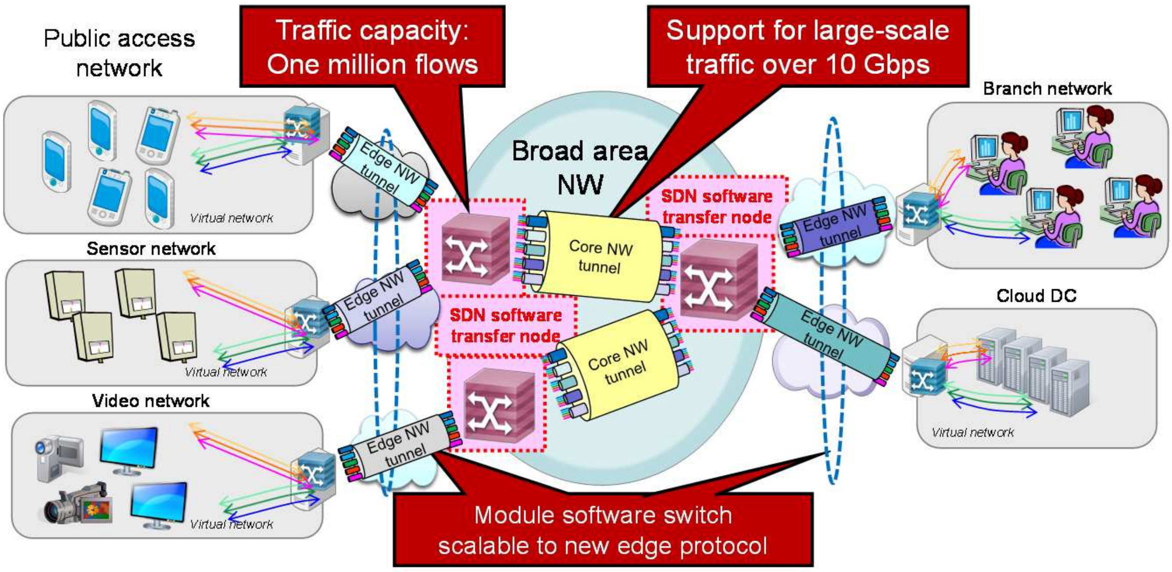


Fig. 9 Illustration of SDN-enabled software switch usage

We evaluated the performance assuming the use of a gateway connecting a DC and WAN, an MPLS router, and an Ethernet switch, and verified a data transfer performance higher than the targeted 10 Gbps (20 Gbps was achieved with the use of two links) and a one-million flow capacity.

## 7. Guidelines for SDN design, construction and operation

SDN is a technology that allows network communication devices to be controlled by software. Users can easily apply SDN technology to construct their own software-based networks, even without specialist knowledge of networks. However, SDN is used in many different applications and for many different purposes. It is therefore difficult to know in advance how the application of SDN to an existing network will affect the performance, quality, scalability or operation of that network, making it imperative to establish a method for evaluating SDN.

As part of the O3 Project, we are developing a set of guidelines to help users efficiently implement SDN. These guidelines are based on preconditions, utilization methods, and usage issues that we have identified based on objective evaluations made from the viewpoint of applying SDN to public networks. Specifically, we aim to develop guidelines that differ from existing network guidelines by containing know-how specific to designing, constructing and operating SDN-based networks. These guidelines aim to help users design and operate SDN-based networks that provide a balanced cost performance by delivering a range of operability improvements such as shortening the time between network construction and service launch, increasing the number of users who can use the network, and improving the utilization rate of network resources (number of traffic flows, etc.). In preparation, we are currently constructing a testbed environment to evaluate SDN nodes from the viewpoint of design, construction and operation, as well to verify the items that should be in the guidelines. This testbed environment is being used to evaluate SDN nodes and SDN controllers developed by O3 Project members at each site.

These evaluation results will be reflected in the guidelines. We have also developed a conformance test tool to verify that SDN node response messages comply with the OpenFlow (a communications protocol used between SDN controllers and the SDN nodes) specifications defined by the Open Networking Foundation (ONF). Upon verifying each OpenFlow 1.3-compliant OFS by using this tool, we found that the correct message response rate differed depending on the OFS implementation. This result will also be reflected in the guidelines.

Once we have completed the guidelines, we will present them to industry standards bodies with a view to having them published in the form of a white paper or other document.

## 8. Conclusion

Practical applications of the technologies being developed by the O3 project will enable carriers to quickly and flexibly design, construct and modify wide area networks in response to demand from service providers. Service providers will also be able to launch and discontinue services much more quickly, and general users will be able to use provided services "on demand." Companies, also, will be able to build optimal networks instantly and utilize services simply by applying specialized software to meet their application needs, from utilizing big data and transmitting high-quality broadcasts, to operating a global corporate intranet.

In addition to publishing some of the outcomes of our work in the O3 project as open-source software (OSS), we also plan to enhance the quality of the platform technologies we have developed, and broaden our global network by presenting proposals to promote international standardization.

Website: http://www.o3project.org/en/