# Virtualization Technology of Optical Access Networks for Efficient 5G/IoT Services

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The 5th generation mobile system (5G) will begin entering service in 2020 and full deployment is planned by 2025. Additionally, various sensors have been developed and a variety of IoT services is being studied. In the 5G/IoT era where these are combined, demands of communication service quality will diversify drawing attention to a network virtualization technology capable of simultaneously delivering multiple quality requirements on a single physical infrastructure, and it is expected that a wide variety of communication services will be provided to solve various social problems over the wired/wireless integrated network.

The eMBB[*1)], mMTC[*2)] and URLLC[*3)] services, which are expected to be realized in 5G, differ greatly in bandwidth, number of simultaneous connections and delay quality requirements. Therefore, when trying to satisfy the requirements with a single communication control, there is waste in the use of frequencies and the number of deployed equipment leading to soaring costs (delivery costs).

Under "The R&D on Wired-and-Wireless Converged Radio Access Network for Massive IoT Traffic for Radio Resource Enhancement" consigned from Japan's Ministry of Internal Affairs and Communications, OKI is conducting research and development on an optical access network (PON system) virtualization as a means to efficiently provide wide varieties of 5G/IoT services. This article introduces the virtualization technology of optical access networks, which will become part of the next generation communication infrastructure.

## Optical Access Network Virtualization

**Figure 1** shows the image of network virtualization. The optical access network, metro network, core network, edge server and cloud server hardware are abstracted with a SDN controller and NFV-MANO[*4)], which are being studied in network virtualization. Then, using the various abstracted virtual functions, the orchestrator constructs virtual networks with different requirements and provides them to the users. Various IoT services (automated driving, remote control, smart city, agricultural automation, ultra-reality, digital cinema, etc.) with different requirements can be realized on these virtual networks. In particular, OKI is involved in the research and development of optical access network virtualization.

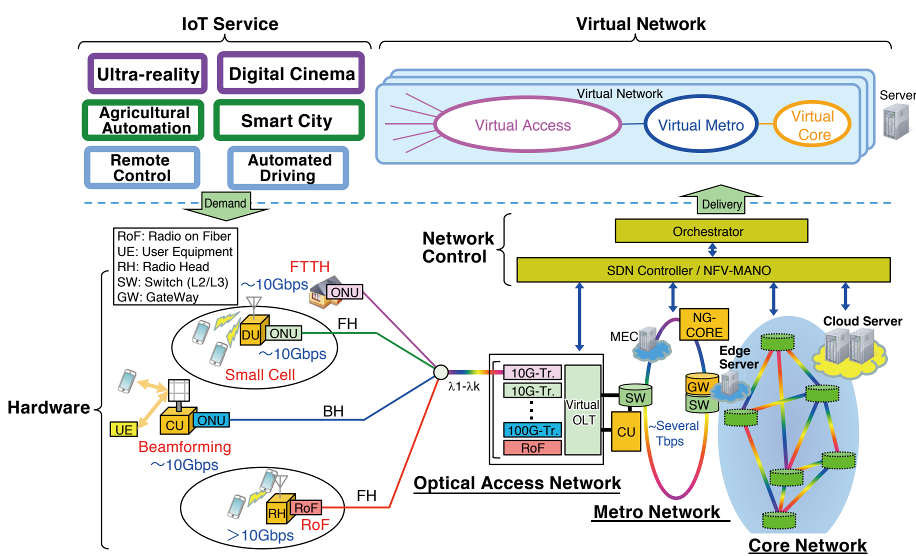


**Figure 1. Network Virtualization**

*1) eMBB (enhanced Massive Broadband) *2) mMTC (massive Machine Type Communication) *3) URLLC (Ultra-Reliable and Low Latency Communication)
*4) NFV-MANO (Network Function Virtualization - Management and Orchestration)

Future wireless systems will optimally distribute base station functions to the CU/DU[1] and be deployed in various locations, thus a flexibly changeable network infrastructure is required. **Figure 2** shows the CU/DU arrangements and the roles of the metro and access networks. The PON system can allocate lines as mobile backhaul (BH) or fronthaul (FH). The allocations can be changed to accommodate various wireless systems for example, in (1), BH between GW-CU is allocated to the metro network and FH between CU-DU is allocated to the PON, whereas in (2), BH between GW-CU is allocated to the metro network and PON while FH between CU-DU is point-to-point. The changes are realized by changing the wavelength and bandwidth between the OLT-ONU and allocating them as virtual resources.

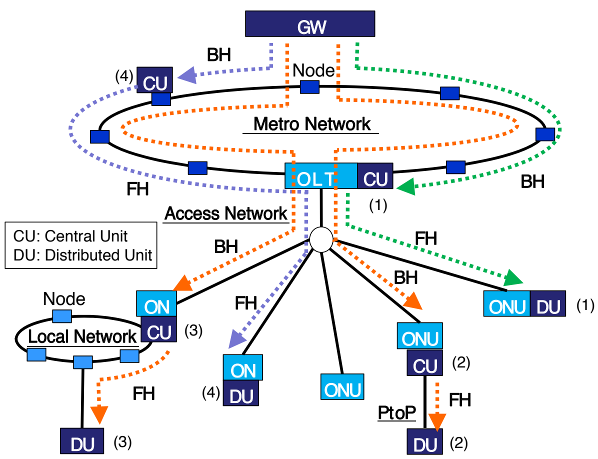


**Figure 2. Line Allocation in a PON System**

If eMBB, mMTC and URLLC services are provided with CU-DU connected in a conventional point-to-point configuration, a different frequency must be allocated for each different service to ensure network transmission capacity is not exceeded as shown in **Figure 3 (1)**, and the result is the waste of resources. The latest PON system (TWDM-PON) has DWA (Dynamic Wavelength Allocation)/DBA (Dynamic Bandwidth Allocation) functions, and by utilizing these functions, various traffics can be accommodated and aggregated as shown in **Figure 3 (2)**. During this time, if the peak rate is exceeded, traffic of services for which timing change is permitted will be shifted to achieve smoothing, and services are provided with minimum allocation of resources[2]. Details will be described in a latter section.

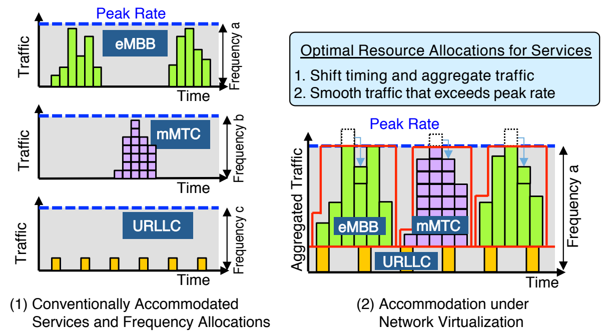


**Figure 3. Accommodated Services and Frequency Allocations**

## Development of Virtual OLT (vOLT)

As mentioned above, aggregation of traffic at the fronthaul (FH) is a problem, and development is being carried out with focus on virtualizing the optical access network. In the case of IoT service, the architecture for controlling the virtual network consists of an orchestrator, SDN controller and hardware. The orchestrator monitors and controls the resource (bandwidth) utilization efficiency and the communication service quality for each virtual network accommodating a service. The abstraction management/control unit (SDN controller) abstracts communication resources to the service request level and provides abstracted virtual link (vLink) and virtual node (vNode) so that the service user can use resources without being aware of the physical FH topology and communication resources. A virtual OLT (vOLT) and ONU are deployed between the CU-DU (FH). The vOLT controls the communication resources of the FH according to the instruction of the abstraction/management control unit and provides a virtual PON (vPON) from the subordinate OLT. Using an algorithm (bandwidth allocation control/management) that dynamically converts abstracted resources into physical resources within the vOLT and computing the bandwidth allocation for each virtual network, services with different requirements can be accommodated efficiently and service additions/changes can be made quickly as well.

The basic functional configuration of vOLT is shown in **Figure 4**. The figure consists of a concentrator SW, resource mapping unit, OSU (Optical Subscriber Unit), optical transceiver (Tr.) and optical wavelength multiplexer/demultiplexer unit. The OLT example in **Figure 4** is implemented with four OSUs. The resource mapping unit uses protocols such as Openflow and NETCONF to efficiently determine the virtual network's accommodation OSU according to the instruction from the host control device (orchestrator, SDN controller). If the OSUs are allocated with different wavelengths, the domain DWA (DDWA) operates in conjunction. A domain DBA (DDBA) function is built into each OSU, and virtual network bandwidth is allocated efficiently. The resource allocation control (resource mapping) and DBA, which are key technologies of vOLT, are described in detail[3] below.

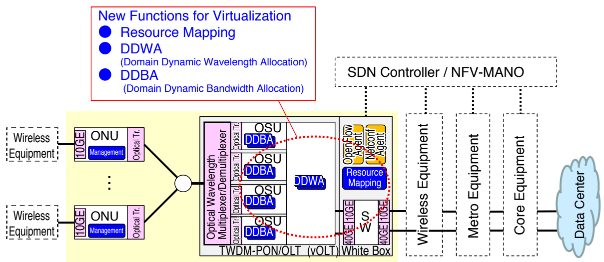


**Figure 4. Overview of vOLT Configuration**

The resource mapping function of the resource allocation control technology is a method of configuring vPON from multiple OSUs according to instructions from the SDN controller. The vPON is configured by combining two or more OSUs or extracting partial function from an OSU. **Figure 5** is an allocation example using a TWDM-PON. In a conventionally simple allocation (**Figure 5 (1)**), vPON is configured by allocating an OSU/wavelength to individual services. With resource mapping (**Figure 5 (2)**), free bandwidth and separation are calculated, and OSU resources are allocated to the vPON without any gaps. This way, the OSU can be made to sleep leading to the reduction of power consumption.

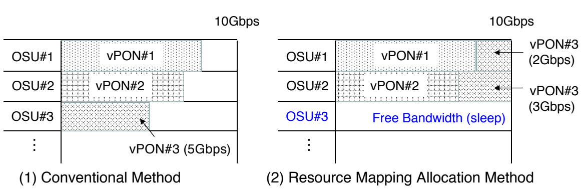


**Figure 5. Overview of Resource Allocation Control**

In domain DBA technology, DBA functions are allocated to each virtual network (domain) regardless of OSU and each DBA is driven. In a normal PON system, one OSU allocates bandwidth with one DBA. In the existing DBA (**Figure 6 (1)**), since the three different service VNW (Virtual Network) 1 to 3 are driven by the same DBA, the band variation of VNW1 affects VNW2/3. In the proposed method (**Figure 6 (2)**), because there is a DBA for each service and OSU, there is no effect on other services (VNWs), and therefore isolation of the virtual network is secured.

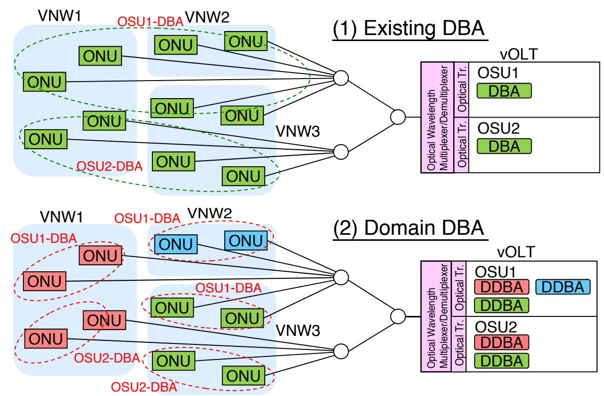


**Figure 6. Overview of Domain DBA Method**

In actual operation, it is required to operate according to the virtual network configuration decided by the resource mapping function and calculate the bandwidth allocation within the range of the configuration. Furthermore, in calculating the bandwidth allocation, the bandwidth allocation policy must be able to be set individually according to the required quality of the accommodated service. In order to satisfy these requirements, it is necessary to add the following functions to the conventional bandwidth allocation method.

(1) Set maximum bandwidth
(2) Individually set bandwidth allocation policy
(3) Increase frequency of bandwidth allocations

As shown in **Figure 7**, multiple virtual networks are virtually constructed on one OSU. In this case, the bandwidth of one OSU needs to be shared by the virtual networks. This requires a function to isolate the virtual networks over the bandwidth. Therefore, as shown in **Figure 7 (1)**, a maximum bandwidth is set for each virtual network, and a bandwidth allocation function is added so as not to exceed those bandwidths. As a result, the bandwidths are isolated, and multiple virtual networks can be constructed on one OSU.

In order to correspond individually to the quality of service accommodated by each virtual network, it is also necessary to set the bandwidth allocation policy individually. For example, as shown in **Figure 7 (2)**, virtual network #1 has fixed bandwidth allocation while virtual networks #2 and #3 have best effort (BE) bandwidth allocation. In order to configure the bandwidth allocation policy individually, it is necessary to add a function that performs bandwidth allocation calculation for each virtual network, that is, separately for each bandwidth allocation policy.

Furthermore, as shown in **Figure 7 (3)**, when multiple virtual networks are constructed on one ONU, a function of allocating bandwidths a multiple of times is required in order to calculate one bandwidth allocation. For this, a function is added that enables the ONU to possess multiple logical links to the virtual networks belonging to it. As a result, bandwidth allocation calculation of each virtual network can be performed for the number of logical links.

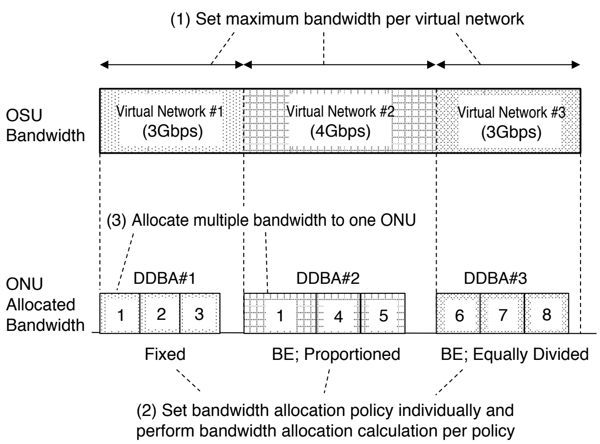


**Figure 7. Example Configuration for Domain DBA**

Currently, basic functions of main signal continuity and wavelength switching operation are being confirmed to verify the resource mapping function and DDBA operation. **Photo 1** shows a vOLT prototype equipped with basic functions. The prototype conforms to the NG-PON2 international standards of the ITU-T[*5)]/SG15[*6)].

**Photo 1. vOLT Prototype**

## International Standardization Efforts

The architecture for controlling and managing virtual networks is currently under deliberation in the international standard organization ITU-T/SG13[*7)]. The objective of international standardization is to standardize the interface between the SDN controller and the vOLT, which is important for controlling the resource allocation and domain DBA functions to be implemented in the vOLT, thereby promoting the spread of vOLT products and develop a network business to realize 5G/IoT services.

OKI has participated in FG IMT-2020 from 2015 extracting network virtualization subjects and since 2017, has been making proposal contributions for virtualization architecture at SG13. In November 2017, OKI's basic architecture proposal was accepted as Y.3150 (**Figure 8 (1)**). Continuing, OKI is proposing a detailed architecture of Y.Netsoft-SSSDN (tentative name) incorporating contents under development, and its standardization is headed towards reaching a consensus in 2019 (**Fig. 8 (2)**). ◆◆

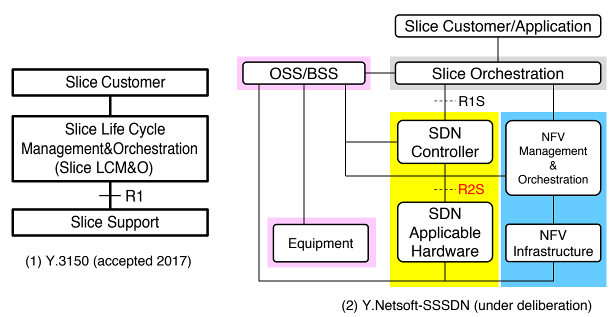


**Figure 8. International Standardization Architecture**

## References


1) 3GPP Release15, http://www.3gpp.org/release-15
2) Akihiro Nakao, et al., "Virtualization Technology to Improve Frequency Utilization Efficiency in 5G/IoT Access Network," IEICE General Conference, B-8-50, 2018
3) Hiroyuki Saitou, et al., "Architecture for Flexible/Dynamic Control of MFH/MBH to Providing IoT services," IEICE Technical R, CS2018-50, 2018
4) ITU-T, https://www.itu.int/en/ITU-T


*5) ITU-T (International Telecommunication Union Telecommunication standardization sector)　*6) SG15 (Study Group 15)　*7) SG13 (Study Group 13)

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## TIPS 【Glossary】

**OpenFlow**
Communication protocol enabling access to the forwarding plane of the switch or router on a network. Network devices can be centrally managed by one control equipment, and flow table performs the complicated transfer control.

**NETCONF: Network Configuration Protocol**
One of the RPC-based communication protocols for configuring network devices. Defines transfer data using YANG model (models configuration and state data) and controls network devices.

**FG IMT-2020**
**(Focus Group on International Mobile Telecommunications-2020)**
Focused discussions held from 2015 to 2016 in ITU-T/SG 13 to analyze existing standards of wired networks and identify areas of focus for the realization of future mobile networks.