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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Future networks

High-level technical characteristics of network softwarization for IMT-2020 – Part: SDN

Recommendation ITU-T Y.3151

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Recommendation ITU-T Y.3151

High-level technical characteristics of network softwarization for IMT-2020 – Part: SDN

Summary

With the advent of network slicing technology for IMT-2020, which is the most typical substantiation of the network softwarization approach, this Recommendation describes the technical aspects of the software-defined networking (SDN) part of network slice support, which assists in handling individual components of a network slice, and contains network infrastructure and its control/management (Recommendation ITU-T Y.3150). This Recommendation addresses the technical aspects of the SDN environment: architectural model, functionalities and interfaces. In particular, the high-level specifications of SDN control interfaces are treated based on a standard of SDN control of transport networks (Recommendation ITU-T G.7702).

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Control interface, network slice, network softwarization, SDN

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High-level technical characteristics of network softwarization for IMT-2020 – Part: SDN

1 Scope

This Recommendation addresses the technical aspects of the SDN environment for network slicing: an SDN architectural model, functionalities and interfaces. This Recommendation focuses especially on the SDN control interfaces of transport networks.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.7702] Recommendation ITU-T G.7702 (2018), *Architecture for SDN control of transport networks.*

[ITU-T Y.3100 C1] Recommendation ITU-T Y.3100 (2017) Corrigendum 1 (2018), *Terms and definitions for IMT-2020 network.*

[ITU-T Y.3150] Recommendation ITU-T Y.3150 (2018), *High-level technical characteristics of network softwarization for IMT-2020*.

[ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 management [ITU-T Y.3100 C1]: In the context of IMT-2020, the processes aiming at fulfilment, assurance, and billing of services, network functions, and resources in both physical and virtual infrastructure including compute, storage, and network resources.

3.1.2 network function [ITU-T Y.3100 C1]: In the context of IMT-2020, a processing function in a network.

NOTE 1 – Network functions include but are not limited to network node functionalities, e.g., session management, mobility management and transport functions, whose functional behaviour and interfaces are defined.

NOTE 2 – Network functions can be implemented on a dedicated hardware or as virtualized software functions.

NOTE 3 – Network functions are not regarded as resources, but rather any network functions can be instantiated using the resources.

3.1.3 network slice [ITU-T Y.3100 C1]: A logical network that provides specific network capabilities and network characteristics.

NOTE 1 – Network slices enable the creation of customized networks to provide flexible solutions for different market scenarios which have diverse requirements, with respect to functionalities, performance and resource allocation.

NOTE 2 – A network slice may have the ability to expose its capabilities.

NOTE 3 – The behaviour of a network slice is realized via network slice instance(s).

3.1.4 network slice blueprint [ITU-T Y.3100 C1]: A complete description of the structure, configuration and work flows for how to create and control a network slice instance during its life cycle.

NOTE – A network slice template can be used synonymously with a network slice blueprint.

3.1.5 network slice instance [ITU-T Y.3100 C1]: An instance of network slice, which is created based on network slice blueprint.

NOTE 1 – A network slice instance is composed of a set of managed run-time network functions, and physical/logical/virtual resources to run these network functions, forming a complete instantiated logical network to meet certain network characteristics required by the service instance(s).

NOTE 2 – A network slice instance may also be shared across multiple service instances provided by the network operator. A network slice instance may be composed of none, one or more sub-network slice instances which may be shared with another network slice instance.

3.1.6 network softwarization [ITU-T Y.3100 C1]: An overall approach for designing, implementing, deploying, managing and maintaining network equipment and/or network components by software programming.

NOTE – Network softwarization exploits the natures of software such as flexibility and rapidity all along the lifecycle of network equipment/components, for the sake of creating conditions enabling the re-design of network and services architectures, optimizing costs and processes, enabling self-management and bringing added values in network infrastructures.

3.1.7 orchestration [ITU-T Y.3100 C1]: In the context of IMT-2020, the processes aiming at the automated arrangement, coordination, instantiation and use of network functions and resources for both physical and virtual infrastructure by optimization criteria.

3.1.8 virtual network (VN) [b-ITU-T G.7701]: A designated subset of abstracted network resources.

NOTE – The network resources in the VN may be at different levels of abstraction and may correspondingly use identifiers from different name spaces.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
CMUD	Create, Monitor, Update and Delete
DBA	Dynamic Bandwidth Allocation
E2E	End to End
eMBB	Enhanced Mobile Broadband
EMS	Element Management System
FCAPS	Fault, Configuration, Accounting, Performance and Security
IMT-2020	International Mobile Telecommunications for 2020
ITS	Intelligent Transport System

MEC	Multi-access Edge Computing
NFV	Network Functions Virtualization
OLT	Optical Line Terminal
ONU	Optical Network Unit
OSS	Operations Support System
OTN	Optical Transport Network
PON	Passive Optical Network
ROADM	Reconfigurable Optical Add/Drop Multiplexer
RRH	Remote Radio Head
SDN	Software-Defined Networking
UE	User Equipment
URLLC	Ultra-Reliable and Low Latency Communication
VN	Virtual Network
vPON	Virtual PON
VR	Virtualized Resource
vROADM	Virtual ROADM
vSW	Virtual Switch

5 Conventions

None.

6 Overview of SDN for network slice support

Software-defined networking (SDN) provides abilities to programme automated behaviours in a network to coordinate the SDN-enabled networking hardware and software elements to support applications and services via application programming interfaces (APIs) [ITU-T Y.3300].

This clause addresses the outline of SDN for network slice support, which contains SDN-relevant functionalities for the creation, monitor, update and delete (CMUD) processes of network slice instances [ITU-T Y.3150].

6.1 High-level architectural model of network slice support

An IMT-2020 system for providing network slices can be modelled by three key functional entities as shown in Figure 6-1 [ITU-T Y.3150]. These are:

– Network slice customer/application: requests the creation/usage of network slices (instances) based on their service requirements.

– Network slice orchestration: manages network slices (instances) based on the requests.

– Network slice support: handles individual components of a network slice instance. The network slice support consists of network infrastructures and their management and control features. There are three kinds of network infrastructures in the network slice support: SDN part, network functions virtualization (NFV) part and other infrastructure part, which may include cloud computing resources.

This document focuses on functionalities of the SDN part in the network slice support.

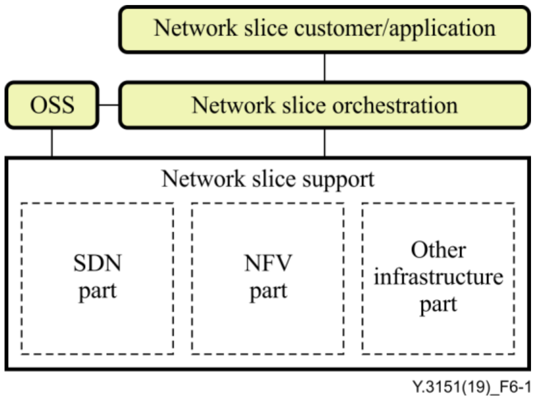

Figure 6-1 – High-level architectural model for network slice support

6.2 The SDN part in network slice support

The SDN of network slice support consists of an SDN controller and an SDN infrastructure.

Figure 6-2 illustrates SDN relevant functional blocks within the SDN part in Figure 6-1. Basic functional roles of the SDN controller and the SDN infrastructure are as follows:

– SDN controller: provides virtual networks (VNs) composed of various virtualized resources (VRs) and links according to requests of the network slice orchestration.

– SDN Infrastructure: provides various virtualized resources according to requests of the SDN controller.

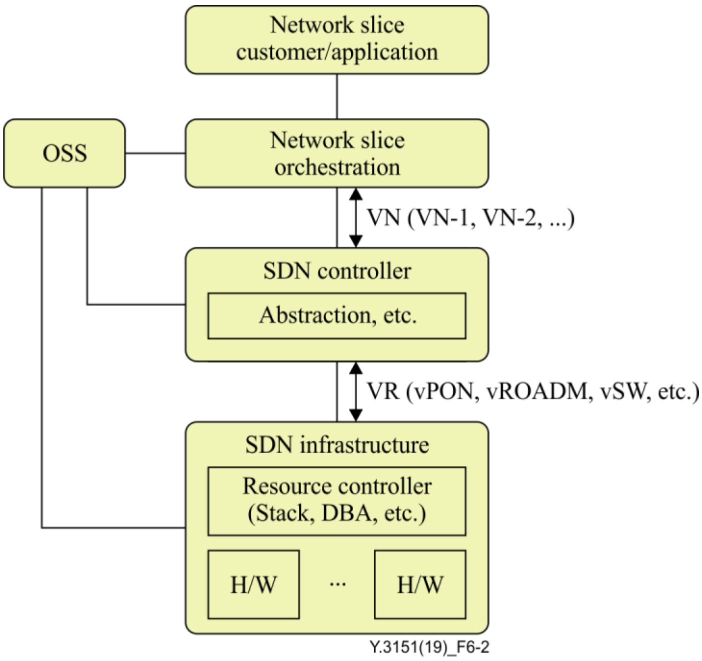

Figure 6-2 – General architectural model of SDN part

The SDN controller can open an interface that allows it to be exposed to clients including network slice orchestration and other management functions. The SDN controller presents a view of resources (i.e., a form of a VN) to its client(s) via the interface in a client context.

NOTE – For supporting network slicing in the transport network, [b-GSTR-TN5G] assumed that:

– Transport network management functions are implemented by the SDN controller.

– Transport networks will be presented as an independent set of VNs.

– The transport network is directly visible to clients including the management system and each VN instance may be viewed as a part or complete constituents of a network slice instance.
– A transport network VN instance supports each type of IMT-2020 services (e.g., URLLC, eMBB).
– Each transport network VN instance will provide a (logically) separate management interface.
– Transport network VN instances will not be aware of the end-to-end (E2E) slice instances because of the differences in granularity. Therefore, each transport network VN will support zero or more E2E slice instances.

The SDN controller has functions of resource abstraction for making a model of VNs; physical/abstracted resource conversion defining abstract elements, acquisition, setting and management of physical resource information; allocation and management of abstracted resource. In the case of the usage of hierarchical and segmented controllers, the orchestration function of the SDN controller supports multilevel control hierarchy, multi-layer control and multi-domain control [ITU-T G.7702].

The SDN infrastructure consists of a resource controller and network equipment. Examples of the network equipment are an optical line terminal (OLT), a reconfigurable add/drop multiplexer (ROADM), an L2 and/or L3 switch, a router etc.

The SDN infrastructure has functions supporting the monitoring and controlling of the network equipment.

A resource controller provides the usage of various VRs (e.g., virtual passive optical network (vPON), vROADM, vSW), and controls the VRs using subordinate network equipment groups. The resource controller provides information on VRs' states to the SDN controller.

As for the above-mentioned SDN functionalities, they can be implemented using existing SDN-related open source software.

NOTE – Candidates of standardized specifications on resource control interface are OpenFlow [b-ONF TS-025], NETCONF [b-RFC 6241]/YANG [b-RFC 6020], OVSDB [b-OVSDB] and OpenConfig [b-OpenConfig], etc.

Figure 6-3 shows the applicability of the usage of open source software for implementation of key SDN functionalities.

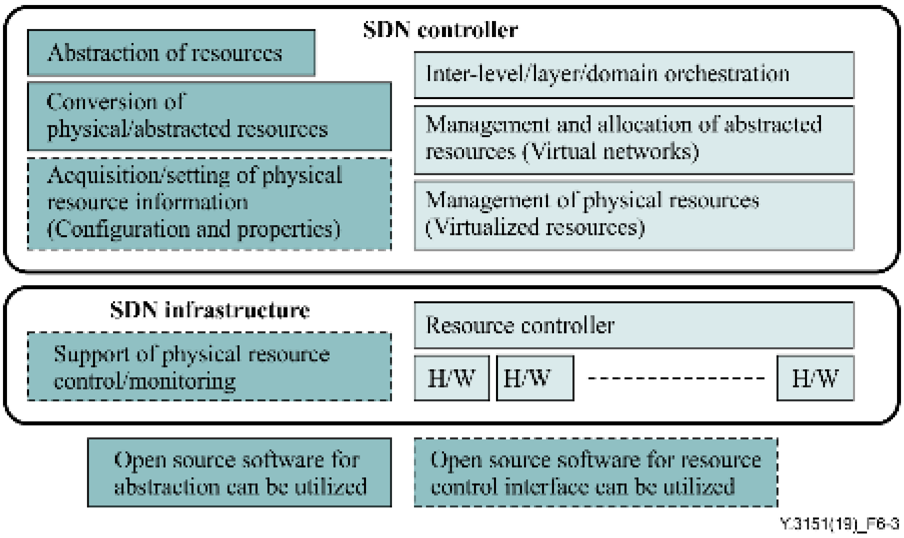

Figure 6-3 – Function elements of SDN for network slice support

6.3 Examples of applications using specific resource control

Examples of applications which need specific resource control functions are as follows:

– Time critical application: requests to fulfil specific requirements about latency of data communication;

– Power consumption critical application: requests to fulfil specific requirements of network power consumption.

NOTE 1 – Appendix I introduces examples of the applications.

NOTE 2 – Several issues on resource efficiency and/or processing time may occur in these applications that require dynamic control. As a solution to the issues, a resource control function handling abstracted resources should be located in the infrastructure layer.

6.4 Management function

Management aspects of the SDN controller are as follows:

– Management aspects for the SDN controller are described in [ITU-T G.7702].

– An element management system (EMS) needs to send and receive VR management signals for interactions with the OSS.

7 Control interfaces for network slicing

This clause describes specifications of control interfaces for CMUD of a network slice instance.

NOTE – Interfaces for fault, configuration, accounting, performance and security (FCAPS) management are out of the scope of this Recommendation.

7.1 Reference points

Reference points relevant to SDN are R1S and R2S in Figure 7-1:

– R1S: a control interface between network slice orchestration and an SDN controller.

– R2S: a control interface between the SDN controller and an SDN infrastructure.

R2S refers to and expands standardized specifications of [ITU-T G.7702], and R1S is specified in accordance with the specifications of R2S.

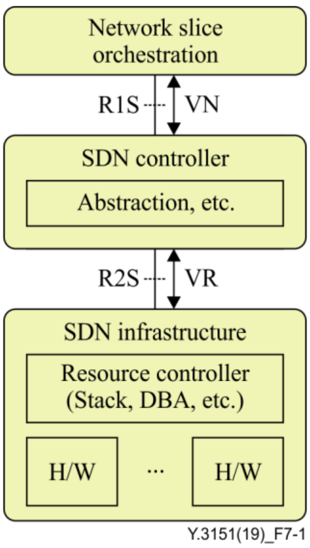

Figure 7-1 – Reference points of SDN for network slicing

7.2 Control interface between network slice orchestration and SDN controller

Parameters transmitted via R1S are used for CMUD of VNs (instances).

Request parameters, which are sent from a network slice orchestration to an SDN controller for slice orchestration for CMUD of VN instances, can be:

– network slice instance requirements (e.g., performance, security);
– service policy (e.g., resource allocation policy for URLLC, power saving).

Result parameters, which return from the SDN controller to the network slice orchestration, can be:

– VN information (e.g., topology, latency, capacity);
– VN status (e.g., failure alarm).

7.3 Control interface between SDN controller and SDN infrastructure

Parameters transmitted via R2S consists of general parameters based on specifications of [ITU-T G.7702] and expanded parameters for CMUD of VRs.

7.3.1 General parameters

General parameters defined in [ITU-T G.7702] are as follows:

– identifiers in the client/server context (e.g., connection identifiers);
– requests for the operation of VN instances;

  NOTE 1 – These are supported in client contexts.

– transport network connection parameters (e.g., end points, capacity, network layer, latency, cost);
– notification subscription(s);

  NOTE 2– A transport resource (e.g., a link) may be requested to subscribe to a type of notification regarding that resource (e.g., alarm).

– success/failure;

  NOTE 3 – The results of requesting parameters from the SDN infrastructure.

– operational state.

  NOTE 4 – The operational state gives the information about the real capability of a resource to provide or not provide service [b-ITU-T M.3701].

7.3.2 Expanded parameters

Expanded request parameters, which are sent from an SDN controller to an SDN infrastructure for getting information of the SDN infrastructure, can be:

– request of a type of network function (e.g., router, Ethernet switch, firewall, optical transport network (OTN) switch, PON);
– the number of access network equipment when an access network is controlled by the SDN controller;
– service policy such as capacity allocation (e.g., guarantee, best effort, fairness);

  NOTE – A combination of values of these parameters are expected to be used. For example, the SDN controller offers allocation policies (e.g., best effort, fairness) to the SDN infrastructure. The SDN infrastructure allocates bandwidth while considering these policies.

Expanded result parameters, which returns from the SDN infrastructure to the SDN controller, can be:

– A type of network function;
– VR information (e.g., latency, capacity).

8 Security considerations

The security and reliability of SDN networks remains a high priority. This Recommendation focuses particularly on interfaces of an SDN controller. Therefore, the access control of its interfaces (e.g., authorization, authentication and security policy management) is the key to confront security threats.

In addition, the SDN controller is responsible for the creation of a connection. This includes creating both a working connection and a protection connection, or providing connection specific configuration information for a protection scheme [ITU-T G.7702].

For general security treatment in IP-based networks, relevant security requirements are also identified by clauses 7 and 8 of [b-ITU-T Y.2701].

Appendix I

Examples of critical applications

(This appendix does not form an integral part of this Recommendation.)

I.1 Introduction of critical applications

A time critical application and a power consumption critical application are introduced in this appendix.

I.1.1 Time critical applications

For control of devices and/or systems in process automation, factory automation, intelligent transport system (ITS) and train control, specific requirements on latency of data communication (including URLLC) may be requested. Figure I.1 shows an image of a time critical application.

Ovals A, B, C and D in Figure I.1 are network slices which include UEs, access nodes, servers or multi-access edge computing (MEC). Servers in the figure mainly deal with transactions for non-URLLC applications and deliver and aggregate relevant information. On the other hand, the MEC mainly supports URLLC applications and treats their data transmission. The non-URLLC means an application category in which ultra-low latency is not requested but a certain level of latency and processing time is requested. For example, "xx ms" on straight arrows in the figure shows the transfer latency time, and "yy ms" on curved arrows shows the transaction time. As also shown in the figure, an access node conducts real-time resource allocation by grasping both the status and quantity of resource for the applications in order to meet the requirements of the transfer latency time in each network slice. The access node also decides which route of a data flow is appropriate (i.e., a data flow to servers or to the MEC).

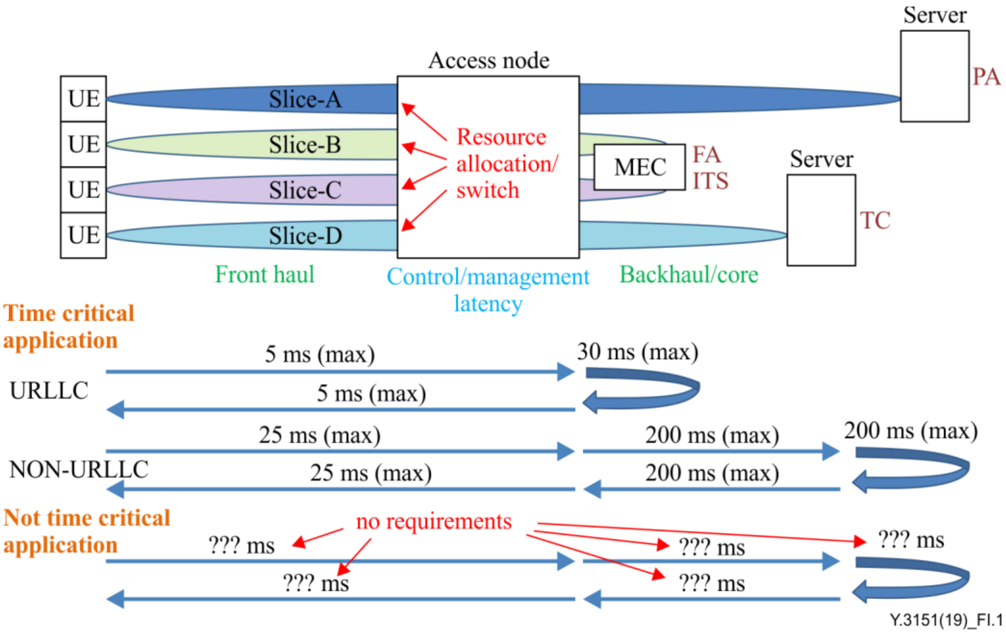

Figure I.1 – An image of a time critical application

I.1.2 Power consumption critical applications

Mobile communication networks are requested to meet requirements on network power consumption in total. Figure I.2 illustrates an image of a power consumption critical application.

A network slice consists of UEs, front-haul networks, access nodes, backhaul networks and servers. Servers in the figure conduct data delivery to or data aggregate form UEs, and treat relevant information processing.

When UEs move to different hexagons a, b and c, which mean mobile cells, along red arrows, required power consumption is changed based on the movement. Grayed ovals 'Slice-X' also show the image of change of a network slice according to the move.

For optimizing power consumption, it is necessary to figure out the number of UEs and resource states in each mobile cell and to carry out real-time resource allocation. An access node plays roles in the scheduling and controlling of relevant resource allocation processes.

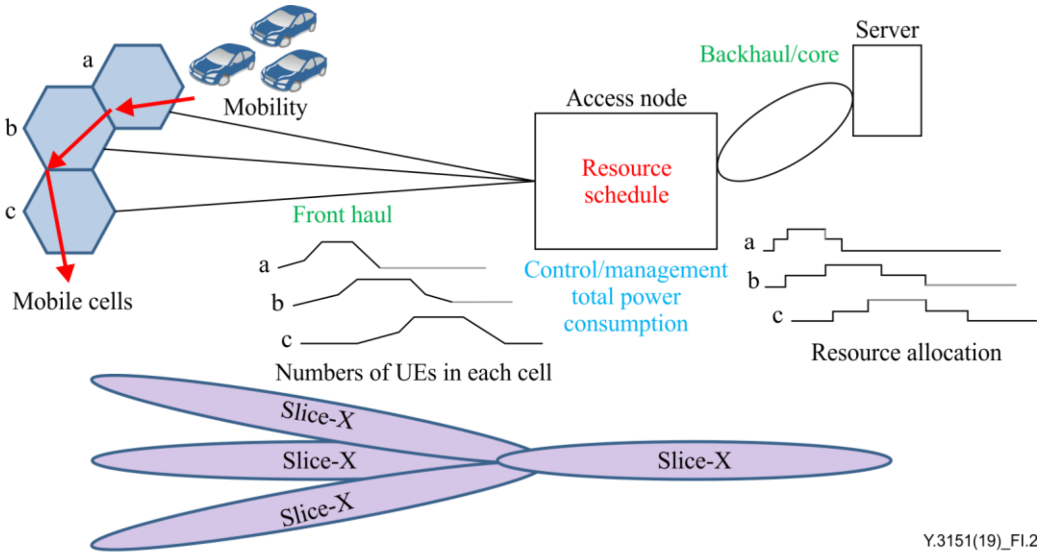

Figure I.2 – An image of a power consumption critical application

I.2 An example of time critical application

This clause introduces a time critical application in an optical access system (e.g., passive optical network (PON)). Generally, the PON requests high-speed processing functions such as dynamic bandwidth allocation (DBA).

Figure I.3 shows an example of a time critical application when a PON applies to an SDN infrastructure.

A resource controller gets total bandwidth and the number of optical network units (ONUs) which connect to optical line terminal (OLT) hardware, and conveys virtualized resources (vPON) information to an SDN controller. For example, in a case where the bit rate of PON 1 is 10 Gbps and number of users are 12, the bit rate of PON 2 is 8 Gbps and number of users are 8, vPON information which is conveyed to the SDN controller is that total bit rate is 18 Gbps and total number of users is 20. The SDN controller conveys a service policy (e.g., guarantee, best effort and delay) and requests to construct vPON to the resource controller. For example, vPON1 is 6 Gbps and 3 users, and vPON2 is 4 Gbps and 5 users. The resource controller constructs vPON in according with the instructions of the SDN controller and replies completion as a kind of vPON information to the SDN controller. The SDN controller abstracts vPON information as virtual network (VN) information and conveys the information to a network slice orchestration. The network slice orchestration constructs a network slice instance based on the VN information. The resource controller controls the OLT hardware in order to allow it to complete bandwidth allocation of ONUs in the DBA cycle time.

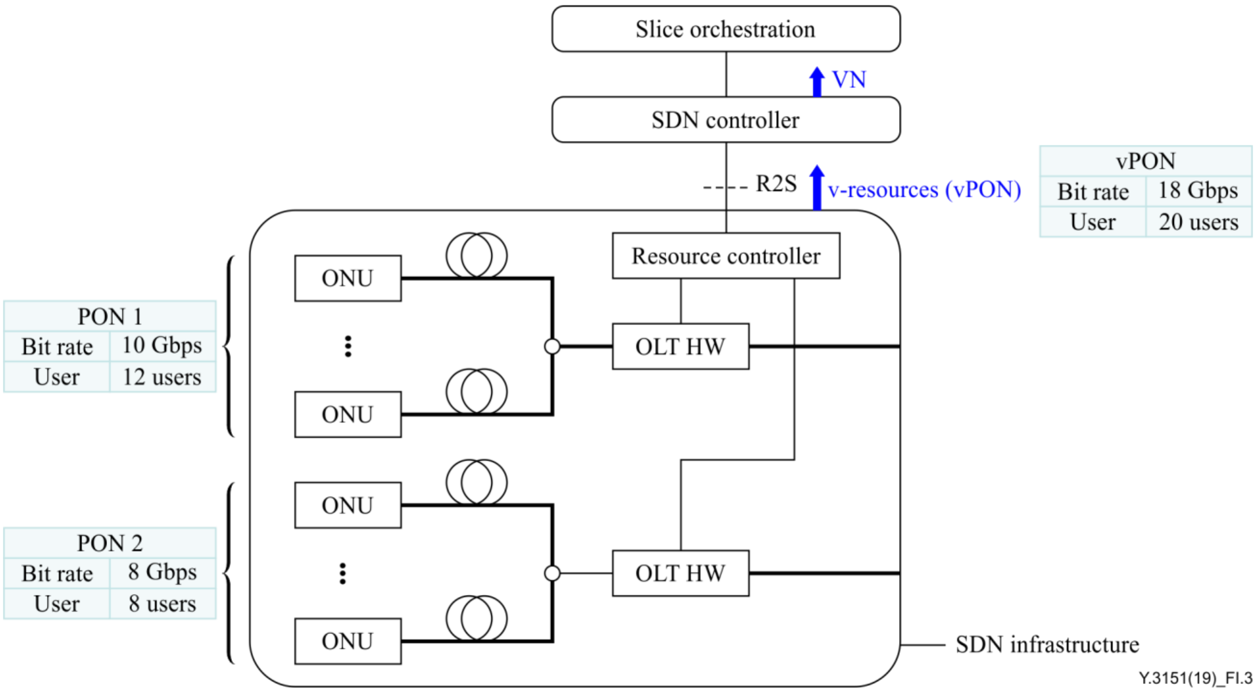

Figure I.3 – An example of a time critical application for PON

I.3 An example of power consumption critical application

Figure I.4 shows an example of a power consumption critical application. A resource controller gets user information which connects to switch hardware, and conveys virtual switch (vSW) information to an SDN controller. The SDN controller requests the resource controller to construct vSW. The resource controller constructs vSW in according with the instructions of the SDN controller and conveys completion as a kind of vSW information to the SDN controller. The SDN controller abstracts vSW information as VN information and conveys the information to a network slice orchestration. The network slice orchestration constructs network slice instances based on the VN information. In case that users move from remote radio head (RRH)1-RRH4 to RRH4-RRH7, the resource controller sleeps RRH1-3 and makes RRH5-RRH7 wake up.

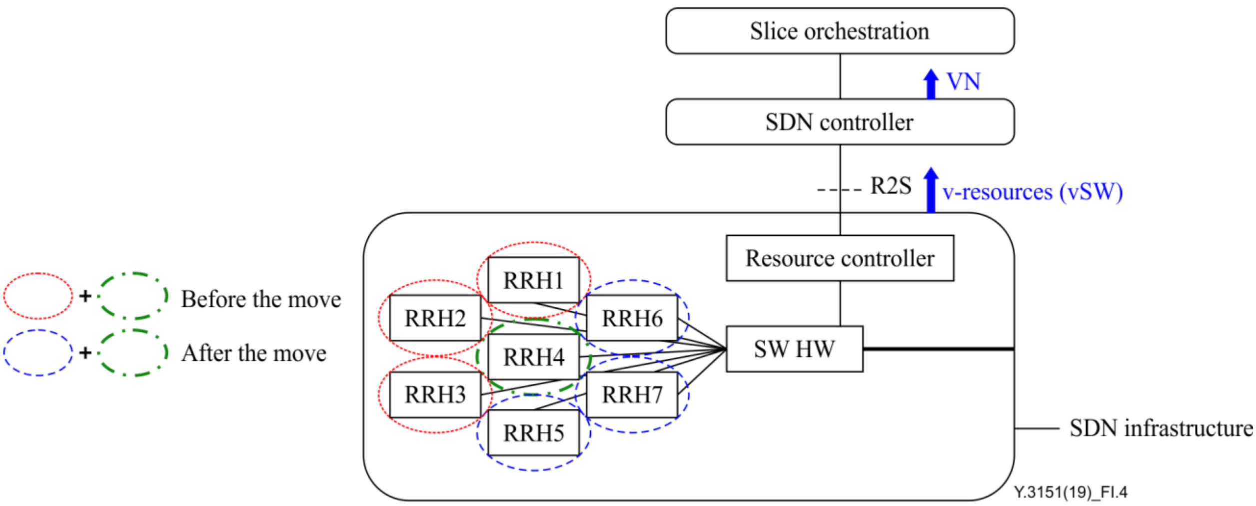

Figure I.4 – An example of a power consumption critical application for RRHs

Appendix II

Examples of existing SDN-based open source software

(This appendix does not form an integral part of this Recommendation.)

Several organizations provide open source software for i) abstraction functions and ii) resource control interfaces. In this appendix, OpenDayLight and Ryu are introduced as representative examples.

1) Abstraction functions:

   a) OpenDayLight [b-OpenDayLight]

   NW service: Topology/NW status/switch management

   Abstraction: L2 switch, group based policy, virtual tenant network, etc.

   b) Ryu [b-Ryu]

   Library: NW topology detection, Packet generation and analyze, etc.

2) Resource control interfaces:

   OpenFlow, OVSD, Netconf/YANG, OpenConfig, etc.

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[b-Ryu] http://osrg.github.io/ryu/

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