KDDI Research
Keio University
National Institute of Information and Communications Technology
OA Laboratory
Red Hat
UBiqube

iPOP2020 Showcase White Paper: "End-to-End Management of All Optical Disaggregated Network and Applications with Cloud Native Environment"

1 Introduction

Industries will be undergoing significant and radical evolution of 5th generation (5G) networks (NWs) for future "digital transformation" in the "With/After COVID-19" era. 5G requirements and specifications are designed as "cloud native" and "network slicing" and they become an important and mandatory feature to provide diverse services over Transport Networks (TNs).

In the iPOP2019 showcase, we demonstrated the network infrastructure and applications automation with TN slices over the cloud native 5G Core. We confirmed a possible scenario for the end to end 5G application driven systems automation and orchestration with an effective API based orchestration. In the iPOP2020 showcase, under the COVID-19 circumstance, iPOP2020 Interop Committee decided to execute the showcase via the multiple remote environments, and Cloud Native control and management planes helped to build the iPOP2020 showcase smoothly. We demonstrated the container based cloud native business applications and the infrastructure in the era of 5G and beyond. Network infrastructure was provided using All Optical Network (AON) and Private LTE/5G. Applications and infrastructure controls are implemented in a cloud-native environment to enable integrated automation platforms for the smart world.

2 Showcase Problems and Solutions

All Optical Network (AON): There is a continuous increase of bandwidth demand in communication networks. Recent R&D efforts have focused on large capacity transmission technology in future optical networks in order to support the increase of the bandwidth. Current optical networks are based on wavelength-division multiplexing (WDM) over single-mode fiber (SMF). Capacity limitation of WDM networks makes it difficult to cope with the future bandwidth demand because the maximum capacity of existing SMF has been predicted to be limited approximately 100 Tb/s. One of the possible solutions to this problem is to use an all-optical network (AON) empowered by space-division multiplexing (SDM) technology. This is expected to provide a long-term solution to the bandwidth bottleneck in an efficient manner.

Private LTE/5G: Current WiFi access is not suitable for in-door factory applications because of delay and jitter. To reduce the transmission delay and jitter, geo oriented private 5G (i.e. "local 5G") and private Long Term Evolution (LTE) become attractive solutions. To realize the local 5G and private LTE especially in the in-door environment, the precise clock synchronization is required among equipment such as base-stations (BSs), evolved packet cores (EPCs), and access points (APs). A key technology is a precision time protocol (PTP) enabled packet switching network. These local 5G/private LTE with PTP packet switching network become a solution of the low-delay and low-jitter factory applications.

Hybrid/Multi Cloud Environment and CNF: From the perspective of network control and management, current network systems have several weaknesses in terms of sustainability: decreasing number of repair staff and operational personnel, complex administration in operating the network system, and rapid service provisioning for unexpected demand increase. There are various types of networks such as TN, cellar network, data center network etc. One promising approach is Cloud Native network Function (CNF). CNF techniques enable us to implement the containerized network functions on general purpose hardware equipment and hybrid/multi-cloud environments.

AI based Resource Arbitration: Service function chaining (SFC) is a framework to deploy necessary network functions over network functions virtualization (NFV)/Telco Cloud infrastructure so that the virtual network can satisfy the application service requirements. These virtualized services are flexibly customized by software programs, and effective resource utilization or network management is an important issue.

Reliability Based Routing: Disaggregation of network equipment is attractive to realize an open network environment. However, from the view-point of the network operation, multi-vendor disaggregation equipment will make it difficult to realize a robust trustworthy network. Therefore, networks should be more reliable in the higher failure rate environment. There is a new concept which is combined with multi-path routing and failure prediction technology. The multi-path routing can provide a robust transport path with over transmission capacity provisioning. The failure prediction can guarantee the expected transmission capacity and lead optimal over provisioning capacity allocation to each member path.

Integrated Infrastructure Automation: The ever-growing amount of data is core to the digitalization of the current world. In the most up-to-date telecom infrastructure, for example, NFV/CNF has been deployed and provides a network function as a software running on commercial off-the-shelf (COTS). NFV provides a certain level of scalability and elasticity. Unfortunately, the NFV/CNF software is often locked in a vendor. Huge integrations and development efforts are needed to deploy the new network functions, which leads to slow delivery and inability of rapid creation of new network services. This will inevitably lead to an explosion in cost of operation and a greater dependency on expert staff, which are becoming increasingly difficult to find. To avoid and solve this problem, a holistic approach to integration and automation of the information technology (IT) and NW infrastructure is really important to enable the new digital services.

Programmable Open API: In addition to that, REST based Open Application Program Interfaces (APIs) will be needed in a range of scenarios, internally enabling service providers to transform their IT and operational agility and customer centricity, while externally delivering a practical approach to seamless end-to-end management of complex digital services.

3 Showcase Demonstrations

Figure-1 shows the iPOP2020 showcase demonstration architecture. Multi-cloud environments are deployed to realize the digital services platform with physical NW infrastructure. This architecture consists of four layers: 1) Business Cloud Applications, 2) Integrated Automation, 3) Network Service Applications, and 4) Programmable Interfaces.

1) Facial Recognition and Automatic Guided Vehicles are among business cloud applications examples.
2) Infrastructure automation is to provide domain and layer agnostic technologies integration and automation to the cloud native environment operations and management.
3) Reliability-based routing, Artificial Intelligence (AI) operations, and Network Demand Prediction are examples of Network Service Applications.
4) Open API is a key to flexibly creating network service applications and seamless operations and automation of the NW Infrastructure.

NW Infrastructure, which has been realized in a monolithic way (“vendor lock-in”), is now being disaggregated into components. Disaggregation extends the life of the system by replacing outdated components with new ones and enables a sustainable network system in an agile manner.

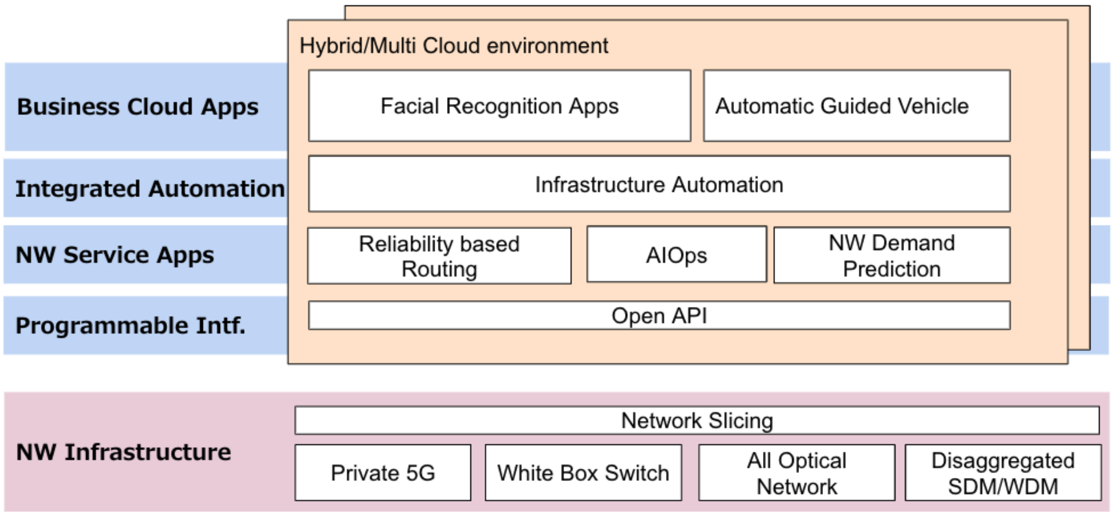

Figure-1 Showcase demonstration architecture

Experimental demonstration in this showcase is shown in Figure-2. We set up our demonstration mainly in five sites.

1. SFC Platform Network in Koganei, Tokyo (NICT)
2. Trustworthy Multipath-based Routing network in Yagami, Kanagawa (Keio Univ.)
3. SDM optical network in Fujimino, Saitama (KDDI Research)

4. Private LTE in Shin Kawasaki, Kanagawa (Keio Univ.)
5. Integrated Infrastructure Automation in Grenoble, France (UBiqube)

We connected above site via Japan Gigabit Network (JGN, [JGN]), or IP virtual private network (VPN) over the Internet. In addition to this, several VPN networks are established between each site and showcase members' home/offices for making control planes.

[JGN] https://testbed.nict.go.jp/jgn/

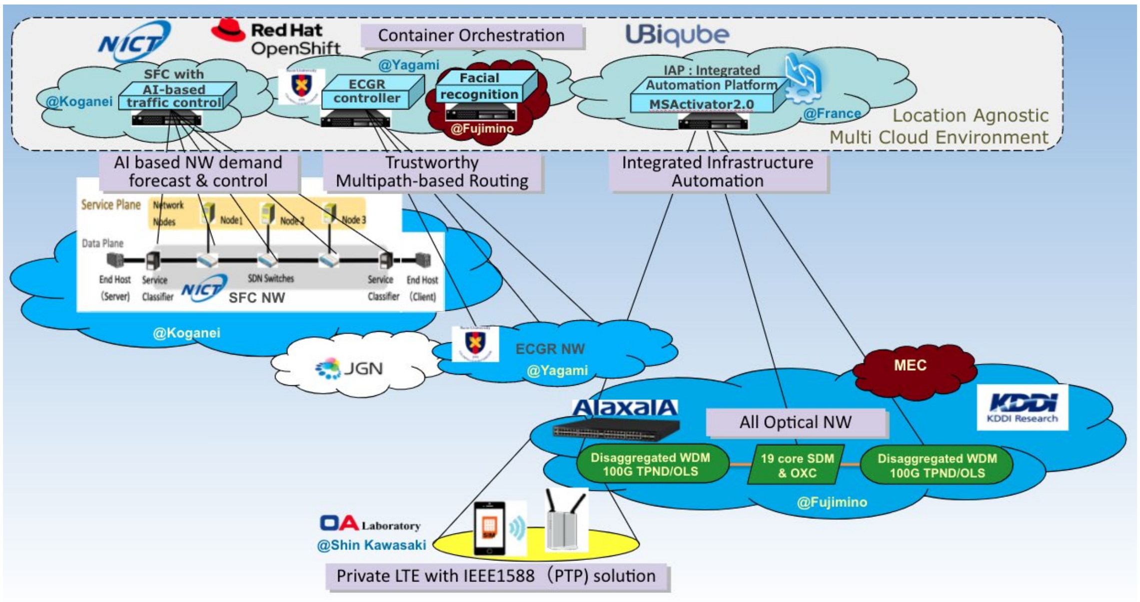

Figure-2 Showcase demonstration setup

The physical layer of the demonstration setup was a combination of high-capacity AON using SDM technology and WDM equipment (KDDI Research) with a packet switch equipment (Alaxala). The demonstrated AON setup consisted of three network domains: two conventional WDM network domains, and an SDM network domain. Each WDM network domain comprised reconfigurable optical add/drop multiplexers (ROADMs), a 40km-standard-SMF transmission line and an software defined networking (SDN) agent. In the transmitter and receiver sides, four transponders were connected to the WDM domain. Each transponder was equipped with a C-band tunable wavelength dual polarization quadrature phase shift keying (DP-QPSK) 100-Gb/s optical interface. The transponders were controlled by an Integrated Automation Platform(IAP) UBiqube) via open API (i.e. REST API). The SDM network domain comprised two optical switches (OXCs), a 11-km SDM transmission line (i.e. 19-core fiber) with a fan-in device, a fan-out device and an SDN agent. In this demonstration, the OXCs were used at the input of the fan-in device and the output of the fan-out device because a desired port of a ROADM in a WDM domain can be connected to a desired core of the SDM transmission line. The

IAP which was provided by UBiqube issued a request for provisioning paths across the optical network domains and the path provisioning was performed in the demonstration.

The access network is assumed to be “Private 5G”, and this time we realized the access network with Private LTE /5G non-stand alone (NSA) technology. A key technology of the Private LTE is a PTP. A PTP enabled layer 2 switch is developed and applied to the showcase network. Global Positioning System (GPS) is used for root clock and the PTP enabled switch provides the low-delay and low-jitter network for EPC and APs. A Private LTE compatible smartphone is used to send an on-line video stream to the face recognition application which is on the Multi-access Edge Computing (MEC) server located in the KDDI Research Fujimino site.

We demonstrated a face recognition application in a distributed AI/Machine Learning (ML) system for realizing a “Smart City”. In addition, Expected Capacity Guaranteed Routing (ECGR) technology is applied and controlled to ensure high reliability of networks. The face recognition application is run on the MEC server in the KDDI Fujimino site and the source video stream is sent from the private LTE compatible smartphone in the Keio Univ.’s Shin Kawasaki site. The video stream is transported on the ECGR-based trustworthy network which is constructed in the Keio Unv.’s Yagami site. A multi-path routing is applied to the ECGR. In ECGR, a robust transport path is provided by over transmission capacity provisioning with failure prediction of all member paths. In the showcase demonstration, It has been presented that the application is unaffected in the event of a link failure.

We developed an AI-based SFC platform which enables network demand forecasting and control network resource and cpu resources for VNFs. These virtualized services are flexibly customized by software programs, and effective resource utilization or network management is an important issue.

Infrastructure Automation provides integration and automation for the Business applications and infrastructure operation & management. From services design to automated process implementation, integrated automation is exactly required to introduce the digital services to the market and can help an industry adapt to the technical complexity facing them. IAP (Integrated Automation Platform) provides a holistic approach to integrated automation of the IT, NW and Security infrastructure which is really important to enable the new digital services. The MSActivator (as an IAP) is running in the MEC at UBiqube Grenoble site and controls the AON equipment in the KDDI Fujimino site.
In this showcase demonstration, the control requests from Business Cloud Applications triggered the BPM (Business Process Management) workflow of MSActivator to automatically establish required wavelength paths where MSActivator

integrated AON infrastructure through REST API to control the OXC, Disaggregated WDM and 100G Transponders.

CNF techniques enable us to implement several types of containerized network functions on general purpose hardware equipment and hybrid/multi-cloud environments. In the showcase network, OpenShift is applied to the integrated container development and operation environment with Site Reliability Engineering. The ECGR controller located in the Keio Univ's Yagami site and the MEC server in the KDDI Fujimino site are run on the OpenShift.

4 Detailed Technologies in the Showcase Network

4.1 All Optical Network: SDM and disaggregated WDM (KDDI Research)

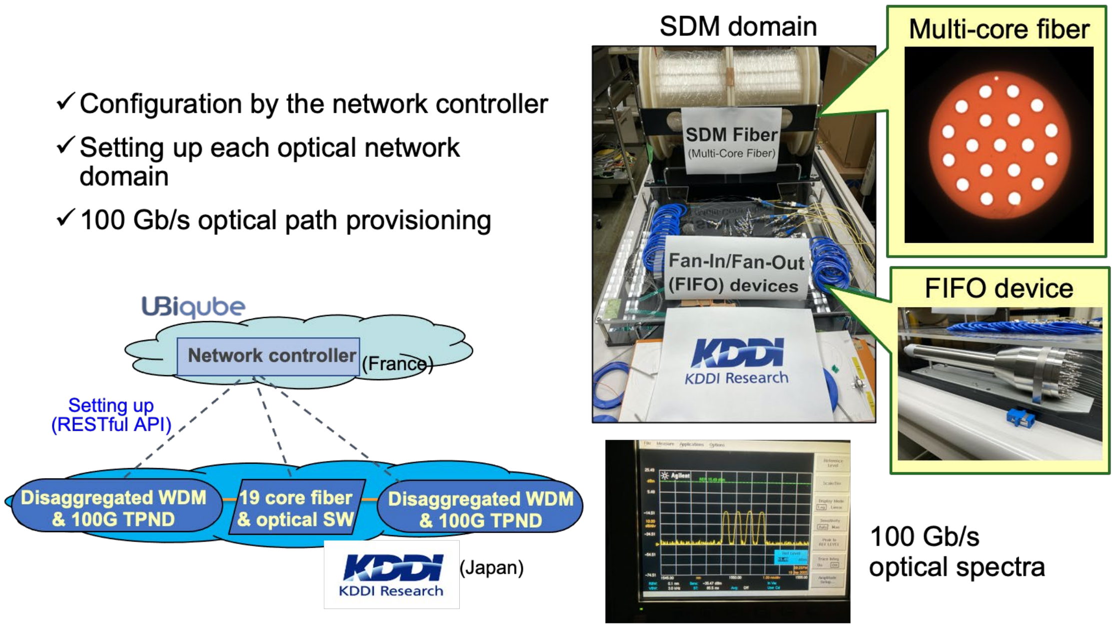

Figure-3　AON demonstration setup

The demonstration setup consisted of three network domains: two conventional WDM network domains, and an SDM network domain. The SDM network domain comprised two optical switches, a 11-km SDM transmission line (i.e. 19-core fiber : Ref [1]) with a fan-in device, a fan-out device. A network controller which was provided by UBiqube issued a request for provisioning paths across the optical network domains and the path provisioning was performed in the demonstration.

4.2 OpenShift: Container Platform orchestration (Red Hat)

As shown in Figure-4, when multi-clouds (Kubernetes clusters in this case) are distributed in different data centers and possibly different geographies, one needs a method for directing traffic towards each instance. For this scenario, a global load balancer will be a good solution. It would be ideal, obviously, if the configuration that we have showcased could be automated. With this in mind, we intend to create a Kubernetes Operator* to automate the configuration of the DNS server that acts as a global load balancer. Based on that, each container control plane function and container management plane ments for this showcase.

*https://github.com/redhat-cop/global-load-balancer-operator

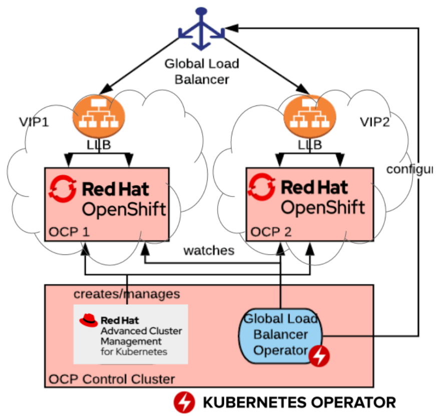

Figure-4
Example for Multi Cluster management and Multi Cluster connection

4.3 OpenMSActivator: Integrated Automation Platform (UBiqube)

UBiqube is the leader in integrated automation platform (IAP) technologies. Multi-domain and multi-vendor integration for infrastructure automation is the essence of the MSActivator™ framework. MSActivator is the cloud native and uses highly abstracted device and function modeling to eliminate the integration penalty associated with distributed infrastructures and provides a smooth journey to digital infrastructure automation, such as software-defined data center (SDDC), software-defined wide area network (SD-WAN)/universal customer premise equipment (uCPE), Hybrid Cloud Orchestration, 5G/Edge Computing, Security Automation, Smart City Infrastructure and so on.<https://ubiqube.com/>

Figure-5 MSActivator the Integrated Automation Platform

4.4 Private LTE (sXGP) over PTP flow through the FPGA based Layer-2 switch solution (OA Laboratory)

OA Laboratory provides Private LTE (i.e. shared eXtended Global Platform (sXGP)) equipment (e.g. EPC, PTP enabled Layer 2 switch, sXGP APs, and sXGP smartphones). We are working with sXGP over PTP flow through the field programmable gate array (FPGA) based Layer-2 switch solution, looking toward the future global private 5G network application. In the lab., we are still doing experiment, validation and verification related showcase demonstration.

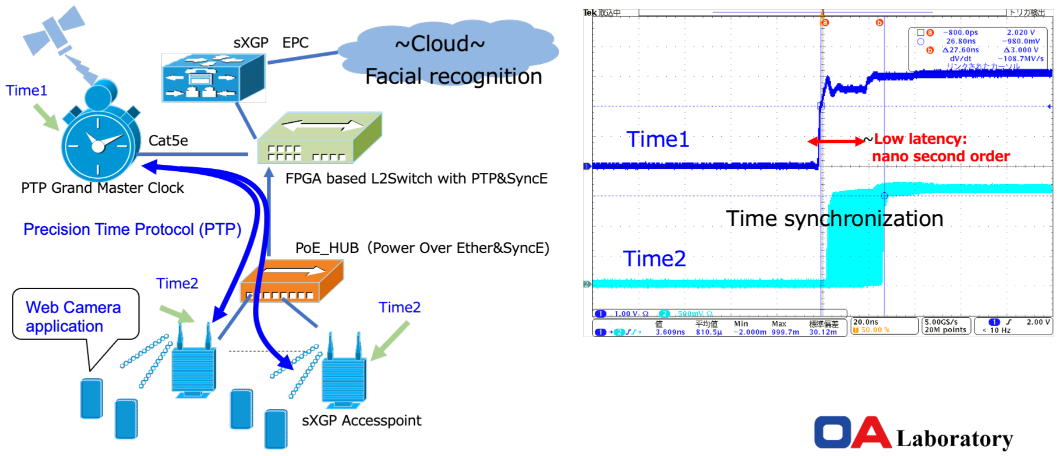

Figure-6 sXGP set up in the iPOP2020 demonstration and time synchronization result in the lab test.

4.5 ECGR: New Trustworthy Multipath-based Routing Concept over WhiteBox Routers (Keio Univ.)

Keio University provides a trustworthy multipath network introducing ECGR and facial recognition application for cache based human tracking service with edge servers. ECGR selects paths and allocates bandwidth based on the network links' failure probability and the tracking service enables real-time identification without high performance machines. The multipath network accommodates video streaming traffic of the camera from Shin Kawasaki site and traffic from NICT site via JGN. In this demonstration, a single link failure caused lower frame rate and an increase in time to identify the person. However, the other available paths succeeded to keep the application running.

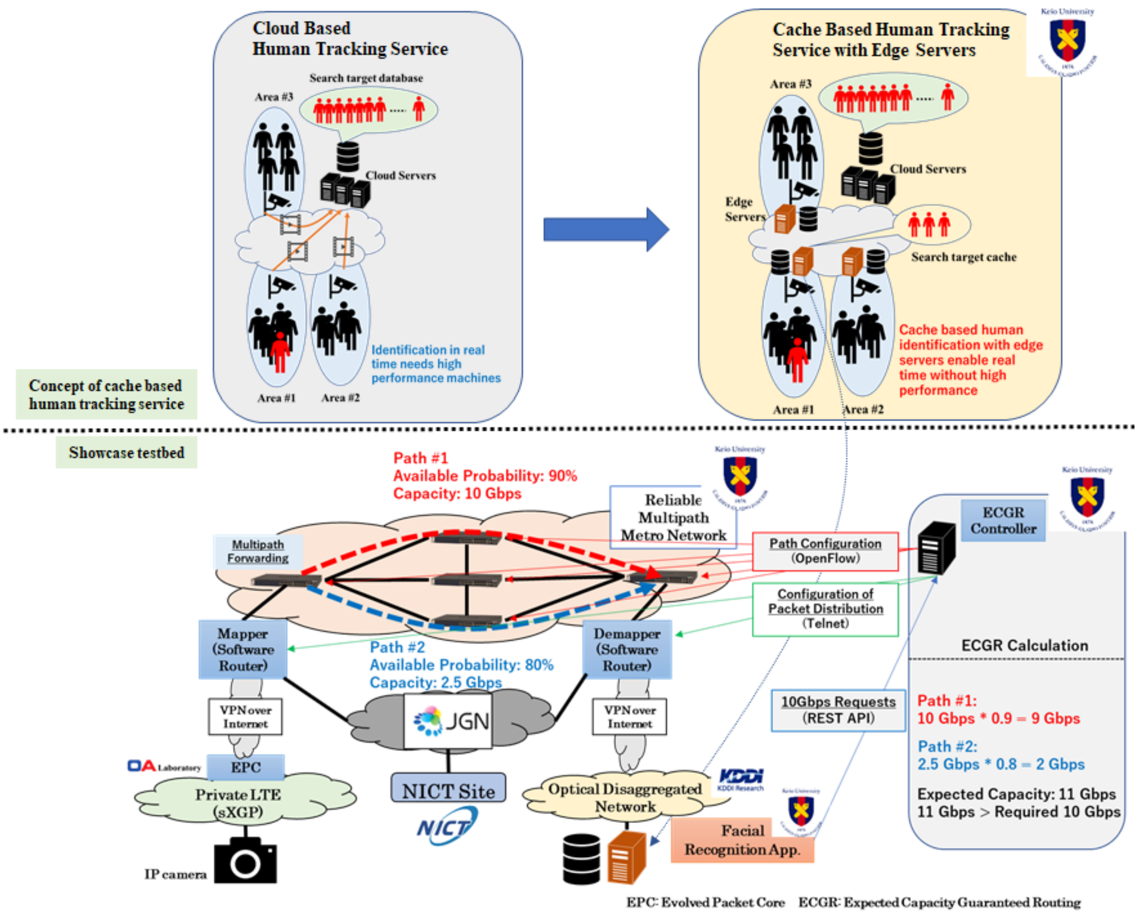

Figure-7 Concept of the cache based human tracking service with MEC and iPOP 2020 demonstration structure for the face recognition over ECGR network and AI-based traffic precision and resource arbitration for SFC by NICT.

4.6 AI-based Traffic Precision and Resource Arbitration for Service Function Chaining Platform (NICT)

SFC is a framework to deploy necessary network functions over NFV infrastructure so that the virtual network can satisfy the application service requirements. We have made an SFC platform which is compliant with the SFC architecture specified in RFC 7665 [2] and network service header in RFC 8300 [3]. We developed and experimentally demonstrated the SFC platform with AI-based resource arbitration mechanism as a proof of concept (PoC). Figure 8 shows our SFC platform and the experimental demonstration. More detailed information about our autonomic resource arbitration is reported in Refs. [4, 5].

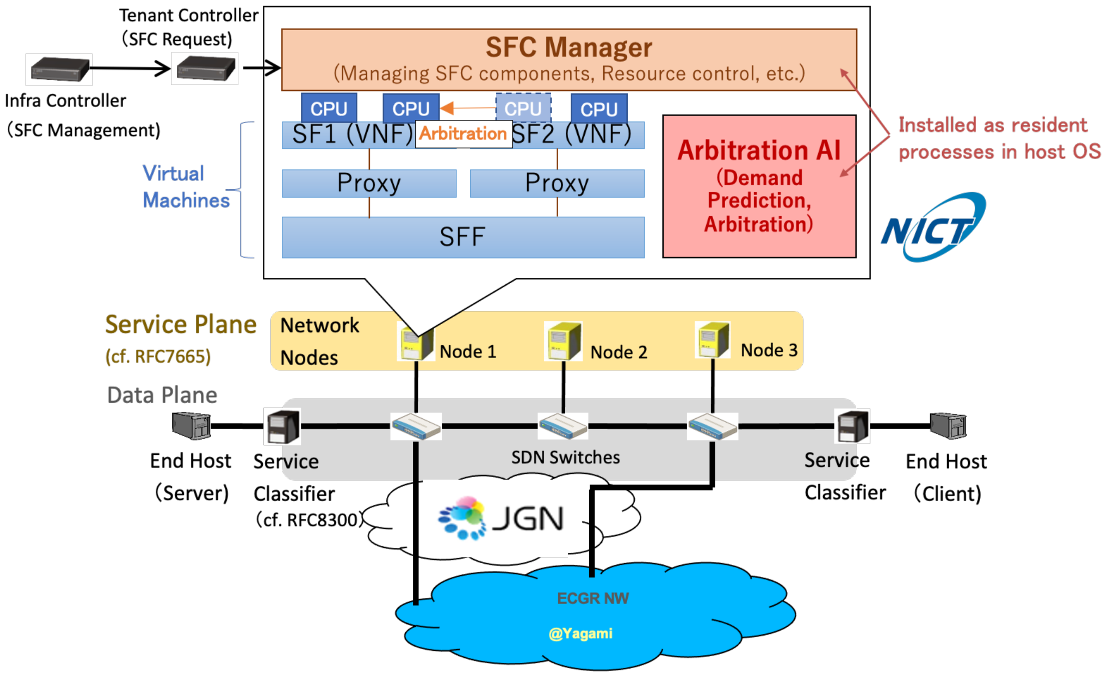

Figure-8 AI system and resource manager in SFC platform and its experimental setup.

References

[1] D. Soma, et al., “10.16 Peta-bit/s Dense SDM/WDM transmission over Low-DMD 6-Mode 19-Core Fibre across C+L Band,” ECOC2017.

[2] IETF RFC 7665, "Service Function Chaining (SFC) Architecture," Oct. 2015.

[3] IETF RFC 8300, "Network Service Header (NSH)," Jan. 2018.

[4] T. Hirayama et al., "Regressor Relearning Architecture Adapting to Traffic Trend Changes in NFV Platforms," IEEE NetSoft, July 2020.

[5] T. Hirayama and V.P. Kafle, "Relearning Architecture for Autonomic Resource Arbitration in SFC Platform," iPOP, Sept. 2020.

Acknowledgements

These demonstrations have been supported by the Research Promotion Council of Kei-han-na Info-Communication Open Laboratory.

We thank Alaxala Networks Corp. for providing router equipment.

Keio Univ. part is supported by TB-0285/JGN-A20003 and the R&D of innovative optical network technologies for supporting new social infrastructure project (JMPI00316) funded by the Ministry of Internal Affairs and Communications (MIC) Japan.

KDDI Research part is partially supported by "Massive Parallel and Sliced Optical Network", NICT, JAPAN.

We thank Prof. Satoru Okamoto for providing his continuous support.

<< iPOP2020 Information >> <https://www.pilab.jp/ipop2020/>

Date: September 10-11, 2020

Virtual, Web conference

<< Trademarks >>

Abbreviations:

AI	Artificial Intelligence
AON	All Optical Network
AP	Access Point
API	Application Programmable Interface
APPs	Applications
CNF	Cloud Native network Function
COTS	Commercial Off-The-Shelf
DNS	Domain Name Server
DP-QPSK	Dual Polarization Differential Quadrature Phase Shift Keying
ECGR	Expected Capacity Guaranteed Routing
EPC	Evolved Packet Core
FIFO	Fan-In, Fan-out
FPGA	Field Programmable Gate Array
GPS	Global Positioning System
IAP	Integrated Automation Platform
IT	Information Technologies
LTE	Long Term Evolution
MEC	Multi-access Edge Computing
NFV	Network Functions Virtualization
NSA	Non-Stand Alone
NW	Network
Ops	Operations
OXC	Optical Cross-connect Switch
PTP	Precision Time Protocol
ROADM	Reconfigurable Optical Add/Drop Multiplexer
SD-WAN	Software Defined Wide Area Network
SDDC	Software Defined Data Center
SDM	Space DIvision Multiplex
SDN	Software Defined Networking
SFC	Service Functions Chaining

SMF	Single Mode Fiber
sXGP	Shared eXtended Global Platform
TN	Transport Network
uCPE	Universal Customer Premises Equipment
VNF	Virtual Network Function
VPN	Virtual Private Network
WDM	Wavelength Division Multiplex

Edited by iPOP2020 Interop Committee (Issue 1 on 25 November, 2020):

Interop Co-Chairs: Kohei Shiomoto, Tokyo City University, Japan
Yusuke Hirota, NICT, Japan
Vice Chairs: Hyde Sugiyama, Red Hat, Japan
Shinya Nakamura, UBiqube, Japan
Advisor: Noboru Yoshikane, KDDI Research, Japan