NFV ISG | OPNFV | NFV MANO

Technology Reports

Special Articles on Network Functions Virtualisation—Toward a Robust and Elastic Network—

Activities toward NFV Standardization

As a standardization organization established by ETSI with the aim of achieving NFV in communications services, NFV ISG has been the arena for lively discussions on NFV. This article begins by providing an overview of the NFV ISG organization and activities to date. It then describes NFV reference architecture for virtualizing network functions and for managing and orchestrating the operation of those functions. Finally, it describes interaction and coordination with other standardization organizations and open source communities as relevant activities to promote the use of NFV.

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1. Introduction

In November 2012, to find a common answer to the question "What is needed to virtualize telecom networks?", seven network operators selected the European Telecommunications Standards Institute (ETSI)*1 for establishing the Network Functions Virtualisation*2 Industry Specification Group (NFV ISG).

At the time of NFV ISG establishment, virtualization technology was already being used by IT service providers, so network operators likewise envisioned that virtualizing their networks could transform the cost structure of their business operations. A telecom network, however, differs from IT services in terms of large and complex Network Functions (NFs) that require high levels of performance and reliability and the need to interface with existing Operations Support System (OSS)*3 and Business Support System (BSS)*4. With this in mind, NFV ISG has been building a consensus on common requirements and NFV reference architecture within non-binding (informative) discussions as a prior step to studying concrete implementation methods. It then plans to broaden the scope of its activities to include formulation of binding (normative) specifications. NFV ISG has been growing and has come to include nearly 300 participating companies from around the world. NTT DOCOMO has been participating in NFV ISG since its very first meeting as a major contributor to NFV ISG architecture and specifications.

In this article, we summarize the history of NFV ISG and describe NFV

*1 **ETSI:** A European standardization organization concerned with telecommunications technology.

*2 **NFV:** Achieving a telecom network on general-purpose hardware through virtualization technology.

architecture whose standardization is now in progress. We also describe NFV ISG's interaction with other standardization organizations and open source communities as activities to promote the use of NFV.

2. NFV ISG

Led by network operators who actually procure and operate networking devices, NFV ISG aims to disseminate common NFV requirements to the entire Information and Communications Technology (ICT) industry with an emphasis on communications equipment vendors, standardization organizations, and open source communities. To this end, the organizational operation of NFV ISG has been designed to enhance collaboration and information dissemination among network operators. The NFV ISG organization is shown in **Figure 1**.

As of December 2015, NFV ISG consisted of a Technical Steering Committee (TSC) having the role of overall coordination and management, a Network Operator Council (NOC) serving as a liaison to network operators, and five Working Groups (WGs) each performing technology studies in a different field (see Phase 2 in Fig. 1).

The NOC is a key feature of NFV ISG that aims to enhance collaboration and information dissemination among network operators. It provides a forum for discussing needs and use cases with respect to strategic and priority issues of the operators. To date, 37 network operators, which make up nearly all of the major network operators in the world, have become NOC members.

NFV ISG holds a plenary meeting once a quarter. The first meeting held in January 2013 welcomed 150 participants from 57 organizations, which climbed to 219 participants and 295 registered organizations by the 13th plenary meeting held in February 2016.

NTT DOCOMO has been actively participating in NFV ISG since its launch by making proposals on use cases, architecture, etc. It has also contributed greatly to NFV ISG activities by holding posts such as NFV ISG vice chairman and TSC technical assistant manager.

NFV ISG activities are divided into Phase 1 that began in January 2013 and Phase 2 that began in December 2014. While Phase 1 focused on consensus building on NFV requirements and reference architecture (corresponding to stage 1 of NFV development), Phase 2 deals with the formulation of specifications for architecture and interfaces (stage 2).

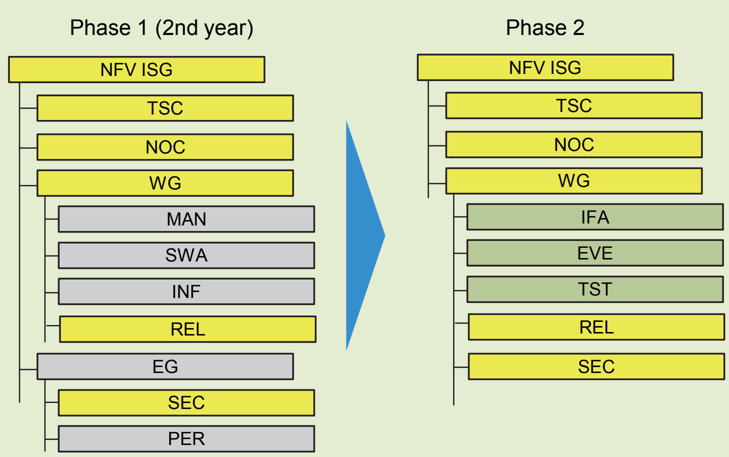

Figure 1 NFV ISG organization

*3 **OSS:** Operations support system of a network operator, responsible for system fault management, configuration management, charging management, performance management, and security management—all or in part—for smooth service operation.

*4 **BSS:** Business support system of a network operator used for customer management, order management, etc.

2.1 Phase 1

1) Four Basic Documents

In the first year of its existence, NFV ISG published four basic documents (NFV use cases, architectural framework, terminology, and requirements) as Group Specifications (GSs) to serve as guidelines for standardization organizations and the market. These documents are summarized below.

(1) NFV use cases [1]: This document summarizes NFV application fields as a basis for studying requirements and architecture.

(2) NFV architectural framework [2]: This document summarizes high-level logical architecture and design concepts toward NFV standardization. It defines the architectural functional blocks and the reference points*5 connecting these blocks with the aim of achieving interoperability among multi-vendor products.

(3) NFV terminology [3]: This document defines terminology used by NFV ISG. A uniform set of terms is essential to achieving a common understanding of new technical concepts in NFV.

(4) NFV requirements [4]: This document summarizes high-level requirements toward the commercial use of NFV.

The public release of these documents helped the industry to rapidly develop a common understanding of NFV as proposed by NFV ISG.

2) NFV PoC

Another feature of NFV ISG is its Proof of Concept (PoC)*6 initiative in which network operators and vendors cooperate in developing PoCs to demonstrate the feasibility of concepts presented in the four basic documents. The NFV PoC framework works as a guide for creating an interoperable NFV ecosystem*7 and disseminates the results of joint PoCs to demonstrate the feasibility of NFV ISG-based solution to the world.

3) Expansion of the Basic Documents

In the second year of Phase 1, four WGs and two Expert Groups (EGs) were established and 16 GSs were published expanding upon the results of the four basic documents. These GSs are summarized below.

(1) NFV Management and Orchestration (MANO) [5]: This document elaborates the NFV Architecture Framework, creates associated specifications to address management and orchestration tasks specific to virtualization, and defines new operations for NFV. The contents developed by NFV MANO constitute the most important result of NFV ISG. Almost all Work Items (WIs) involved in normative standardization in Phase 2 are concerned with formulating specifications for the functional blocks and reference points defined in NFV MANO.

(2) Virtual network functions architecture [6]: This document defines the software architecture of individual network functions known as Virtualised Network Functions (VNFs).

(3) Infrastructure [7] – [12]: These documents define requirements and interfaces for the infrastructure where the VNFs are hosted and executed.

These documents are informative in nature; normative specifications are formulated in Phase 2.

2.2 Phase 2

In ETSI, an ISG is generally active for a maximum of two years. However, while Phase 1 discussions confirmed that interoperability based on open specifications is essential for the expansion and proliferation of NFV, it was generally understood that no standardization organization existed that could appropriately discuss NFV standards that involve many new technical concepts. It was therefore decided to extend the NFV ISG lifecycle for another two years. Phase 2 discussions then commenced toward the formulation of normative specifications by NFV ISG itself.

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*5 **Reference points:** A conceptual point at the conjunction of two functional blocks defined in a specification.

*6 **PoC:** A relatively simple demonstration of the significance or feasibility of a new concept or idea.

*7 **Ecosystem:** A mutually beneficial interdependency in which multiple enterprises collaborate within a certain field or for business purposes making use of each other's technologies and resources while involving even consumers and society. An ecosystem gives structure to a process flow ranging from R&D to sales, advertising, and consumption.

As shown in Fig. 1, Phase 2 consists of five WGs: InterFaces and Architecture (IFA), EVolution and Ecosystem (EVE), TeSTing, experimentation, and open source (TST), RELiability, availability, and assurance (REL), and SECurity (SEC). These are summarized below.

(1) IFA WG: Based on the results of Phase 1, this WG formulates architecture and interface (stage 2) specifications. In contrast to other WGs, the deliverables of this WG include normative specifications. Additionally, for the next step following stage 2, this WG cooperates with other standardization organizations and open source communities in formulating detailed technical specifications sufficient for product implementation (stage 3) and in developing open source software.

(2) EVE WG: This WG studies new NFV use cases and the feasibility of new NFV-related technologies. It defines, for example, methods of applying Software Defined Networking (SDN) to NFV.

(3) TST WG: To ensure the interoperability of multi-vendor products based on NFV specifications, this WG maintains and expands the PoC framework of Phase 1 and performs interoperability tests.

REL WG and SEC WG are carried over from Phase 1 (although SEC has been moved from EG to WG) as discussions continue on NFV reliability and security.

3. NFV Reference Architecture

NFV ISG proposes the reference architecture shown in **Figure 2** with the aim of achieving a multi-vendor environment consisting of interoperable NFV-compliant products. This architecture defines the functional blocks making up NFV and the reference points between those functional blocks. The NFV architecture document [2], one of the basic documents delivered in Phase 1, defined the framework of this architecture and presented a detailed study on

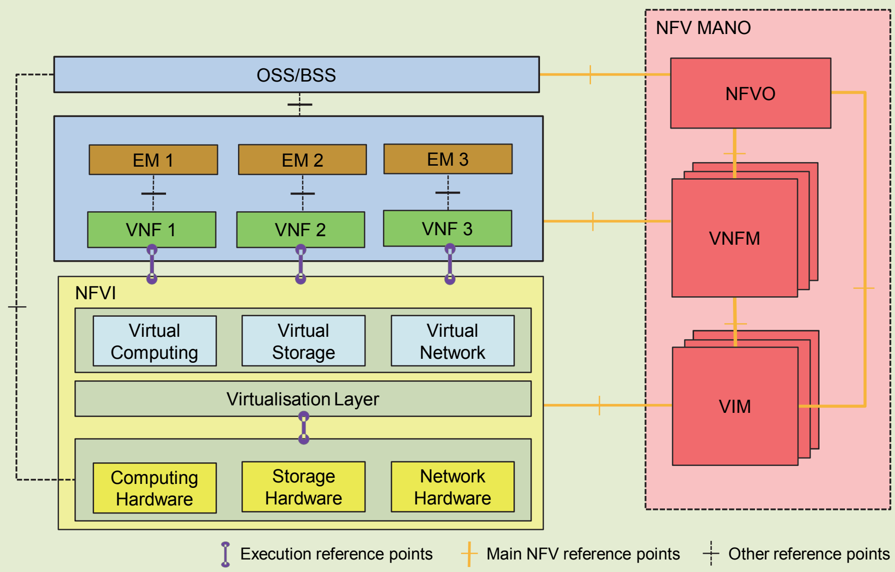

Figure 2 NFV reference architecture

NFV MANO, the functional block performing management and orchestration. In Phase 2, the IFA WG is mainly formulating stage 2 specifications on the reference point interfaces between these functional blocks.

3.1 Functional Blocks

The main functional blocks of the NFV reference architecture are VNFs, NFV Infrastructure (NFVI), and NFV MANO as described below.

1) VNFs

VNFs are the virtualized implementation of the NFs seen in a communication network. In conventional systems, NFs run on dedicated hardware equipment. However, VNFs are independent of the hardware as virtualization decouples the VNF software from the underlying hardware. A specific example of a VNF is a virtualized mobility management function or a virtualized packet processing gateway in an Evolved Packet Core (EPC)*8 mobile system. Such EPC VNFs realize a virtualized vEPC.

Although any virtualized network function implementation can be considered as VNF, there are significant differences in complexity between IT VNFs and telecom VNFs. Most VNFs in IT services can be deployed in a single Virtual Machine (VM)*9. In contrast, most telecom VNFs require multiple VMs and their interconnections. A large scale telecom VNF may consist of several hundred VMs.

2) NFVI

NFVI is the infrastructure for hosting and executing the VNFs. It consists of physical hardware resources such as computing, storage, and network devices as well as software called the "Virtualisation Layer" [2]. The Virtualisation Layer virtualizes these physical resources thereby providing virtual resources in the form of virtual computing, virtual storage, and virtual network to the VNFs. A VNF is configured on these resources.

Using virtualization technology to decouple the VNFs from the physical resources in NFVI enables an operator to build its infrastructure by using general-purpose products. It also enables the VNFs to be flexibly deployed without having to worry about the actual location of that hardware.

3) NFV MANO

NFV MANO manages each of the three elements newly introduced in telecom networks by NFV: (1) NFVI, (2) VNFs, and (3) network services in the form of virtual networks realized by interconnecting a set of VNFs. Furthermore, NFV Architecture [2] allows the connection of NFV MANO with OSS/BSS, which makes it possible to operate NFV in the current operation environments of network operators.

3.2 NFV MANO Functional Blocks

NFV MANO is divided into three functional blocks as described below.

1) Virtualised Infrastructure Manager (VIM)

VIM is the overall manager of an NFVI. It manages the physical computing, physical storage, and physical network resources in NFVI and provides virtual resources based on upper-level requests from VNF Manager (VNFM) and NFV Orchestrator (NFVO).

2) VNF Manager (VNFM)

VNFM is a functional block that controls a VNF that may be complex and large in scale. It is responsible for VNF operations such as instantiation, termination, scaling, and healing, known as VNF lifecycle management events. In addition, the management of Fault, Configuration, Accounting, Performance and Security (FCAPS)*10 specific to a VNF is carried out by an Element Manager (EM)*11 found in legacy implementations.

3) NFV Orchestrator (NFVO)

NFVO performs two main functions as described below.

- First, as a function related to virtual resources, NFVO uniformly manages virtual resources on multiple NFVIs that are being managed by respective VIMs. For example, it monitors the capacity of each NFVI through their respective VIMs. NFVO is the manager that has a complete view of the whole virtualized network spanning multiple NFVIs and

*8 **EPC:** A communications system that accommodates a variety of radio access technologies including LTE and that provides customer authentication, mobility management for uninterrupted data communications while moving, etc.

*9 **VM:** A computer created in a virtual manner by software.

*10 **FCAPS:** Refers to fault, configuration, accounting, performance, and security as management and monitoring items in a network.

*11 **EM:** A functional block that manages and monitors FCAPS with respect to individual network equipment.

VIMs. For VNF instantiation, a VNFM will issue a request to the NFVO, which will then select an appropriate VIM based on location requirements or resource availability.

- Second, regarding network services, NFVO can configure a network service by establishing connections among VNFs and existing non-virtualized physical network functions, and it can control the lifecycle of that service.

3.3 Basic Process Flow

To give an example of a typical process in NFV reference architecture, **Figures 3** and **4** show the process flow for requesting the creation of a new network service from OSS/BSS to NFVO.

At first, a VNF package that contains the information on VNF structure and configuration, software images of VMs, etc. is uploaded from OSS/BSS to NFVO/VNFM as shown by step (1) in Fig. 3. This uploaded VNF package is shared with the corresponding VNFMs (step (2)).

Next, OSS/BSS instructs NFVO to create the network service as shown by step (1) in Fig. 4. NFVO now selects the VNFs that will make up the net-

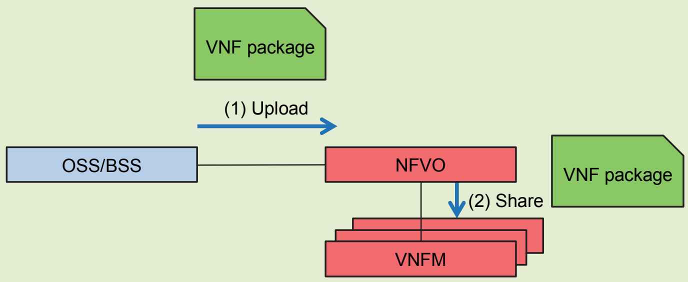

Figure 3　VNF package upload

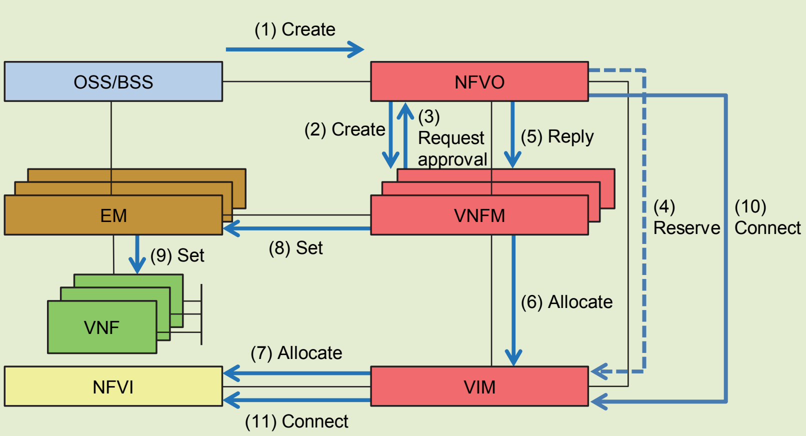

Figure 4　Flow of network service creation

work service and the VNFMs to manage those VNFs, and instructs the selected VNFMs to create those VNFs (step (2)). At this time, VNFMs estimate the virtual resources needed to create the specified VNFs. The VNFMs present the NFVO the list of estimated virtual resources and requests approval for allocating those virtual resources (step (3)). The NFVO judges whether the requested virtual resources are available in the VIMs and replies to the VNFMs accordingly (step (5)). Here, the NFVO can request the VIMs to reserve those virtual resources (step (4)) to ensure that the VNFMs are guaranteed to use the requested virtual resources during the VNF instantiations.

Now, based on the reply from the NFVO, the VNFMs request the VIMs to allocate the virtual resources as shown by steps (6) and (7) in Fig. 4. This allocation can be requested to the VIMs directly from the VNFMs or via the NFVO. Next, the VNFMs coordinate with the respective EMs to make the necessary VNF configuration (steps (8) and (9)) thereby completing the instantiation of the VNFs. Finally, the NFVO interconnects the VNFs (steps (10) and (11)) completing creation of the requested network service.

4. Activities for Promoting the Use of NFV

NFV ISG has been actively interacting with other standardization organizations and open source communities in their respective fields. In particular, collaborating with open source communities reflects a new approach since the conventional approach of developing de jure standards*12 can result in a lengthy commercializing period because of the time needed for consensus building among participating institutions. The IT world, in fact, has incorporated open source solutions for some time and has a proven record in promulgating new technologies in a relatively short period of time.

NFV ISG has therefore been fostering ties with other standardization organizations such as Third Generation Partnership Project System Aspects-5 (3GPP SA5)*13, TeleManagement (TM) Forum*14, Next Generation Mobile Networks (NGMN)*15 [13], and Open Networking Foundation (ONF)*16 [14], and with open source communities including OpenStack*17 [15], OpenDaylight*18 [16], and Open Platform for NFV (OPNFV) [17]. It has also been concluding Liaison Statements*19 and Memorandum of Understanding (MoU)*20 agreements with these parties. These activities are enabling prompt launching of services using NFV-related open source software. Ensuring interoperability in this way based on uniform standards and their implementation should facilitate the creation of an effective NFV ecosystem.

4.1 OPNFV

Today, in the field of cloud computing, open source software (such as OpenStack, OpenDaylight) is becoming mainstream. However, a number of functional differences exist between such open source software and NFV ISG's NFV reference architecture and specification, preventing multi-vendor interoperability.

To solve these differences and guarantee interoperability, OPNFV was established in October 2014 to develop a NFV reference platform that integrates NFVI and VIM. NTT DOCOMO is a founding member, and at present, 19 platinum members consisting of network operators (including NTT DOCOMO) and IT companies, and 42 silver members are participating in OPNFV. Work is progressing on the creation of a NFV reference platform that uses existing open source software such as OpenStack, OpenDaylight, Open vSwitch*21 [18], and Kernel-based Virtual Machine (KVM)*22. OPNFV plans to issue two releases a year of its NFV reference platform. The first release called Arno was released in June 2015, and the second release called Brahmaputra was released in March 2016.

OPNFV artifacts are published through an Apache® Version 2.0 license*23. All decisions in OPNFV are reached by voting making for rapid consensus building and all meetings and documents are made public. Anyone can participate in OPNFV.

OPNFV promotes new feature de-

*12 **De jure standard:** A standard formulated by a public institution such as a standardization organization.

*13 **3GPP SA5:** 3GPP is a standardization organization concerned with mobile communications systems. SA5 is a working group discussing OSS/BSS relevant topics in 3GPP.

*14 **TM Forum:** A non-profit organization studying industry standards for the management of telecom networks.

*15 **NGMN:** An organization that formulates visions and roadmaps for next-generation mobile communications networks. It is composed of vendors and operators including NTT DOCOMO.

*16 **ONF:** A non-profit organization promoting SDN-related standardization activities. OpenFlow is a standard protocol formulated by ONF.

*17 **OpenStack:** Cloud-infrastructure software that uses server virtualization technology to run multiple virtual servers on a single physical server. It can allocate virtual servers to different cloud services used by the users. OpenStack is open source software.

velopment in the upstream communities (e.g. OpenStack, OpenDaylight). This reduces code maintenance tasks in OPNFV as the upstream communities can maintain the codes by themselves. Apart from integration of the reference platform, OPNFV also performs gap analysis between standard specifications and open source software and formulates new requirements based on such gaps. Interested parties can then take these requirements for implementation in the respective upstream communities. NTT DOCOMO also leads two projects in OPNFV that formulate two distinct requirements for OpenStack. Brief description of the two projects are given below.

1) Doctor Project [19]

This project aims to achieve fast fault notification from VIM to VNFM to ensure high service availability in telecom nodes. The fault detection and notification requirements are quite stringent for telecom nodes compared to an ordinary IT node. At the time of OPNFV establishment, the time interval from fault detection to notification was on the order of several minutes in OpenStack. This would be a major issue in the event of a fault in a telecom network if fault detection and consequent notification took that long.

The Doctor project proposed and implemented a northbound interface from OpenStack which can notify a VNFM about fault events on computing resources. It also significantly reduced the notification latency in OpenStack. These features have already been deployed and released in OpenStack Liberty release*24. Specifications for remaining development items for computing resource faults have already been submitted to the OpenStack community. They are expected to be developed and integrated in the OpenStack Mitaka release*25.

2) Promise Project [20]

This project aims to add a resource reservation function to OpenStack in the form of a plug-in as a case study. Once interoperability between this plug-in software module and OpenStack has been achieved, the next step will be to develop the resource reservation function within OpenStack. Completed Promise features have been released in the OPNFV Brahmaputra release.

4.2 Other Open Source Communities

Similar to OPNFV, many other open source communities are being established to achieve the NFV reference architecture defined by NFV ISG. These include Open Source MANO for developing NFV MANO [21], and Open Baton and others for developing NFVO [22], all of which reflect steady progress in the implementation and adoption of NFV through open source initiatives.

5. Conclusion

This article reviewed the history of NFV ISG, described NFV architecture now under a normative specification process, and explained how NFV ISG is interacting and coordinating with other standardization organizations and open source communities to promote the use of NFV.

The telecommunications industry has high expectations for the results obtained through NFV ISG activities, and NFV-related implementations are moving forward through open source projects and commercial systems. These initiatives will help clarify areas in need of technical improvement in the NFV reference architecture. A well-coordinated implementation-to-standardization cycle is important for the fast adoption of NFV in the ICT industry.

NTT DOCOMO participated in the following two collaborative R&D projects funded by the Ministry of Internal Affairs and Communications (MIC). The experimental results from these projects have been reported to MIC and used in standardization discussions at NFV ISG.

- FY2012 “Experimental challenges for dynamic virtualized networking resource control over an evolved mobile core network - a new approach to reduce massive traffic congestion after a devastating disaster” in collaboration with Tohoku University, NEC Corporation, Hitachi Solutions East Japan, Ltd., and Fujitsu Limited.

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*18 **OpenDaylight:** Software that provides functions for externally controlling network equipment based on the SDN concept. OpenDaylight is open source software.

*19 **Liaison Statement:** A statement that is exchanged when a standardization organization collaborates or exchanges information with another institution.

*20 **MoU:** A statement that summarizes an agreement between two organizations.

*21 **Open vSwitch:** Software that creates virtual switches for connecting virtual machines in a virtualization environment. Open vSwitch is open source software.

*22 **KVM:** Software for achieving virtualization. KVM is open source software.

*23 **Apache® Version 2.0 license:** A license format used in open source software.

*24 **Liberty release:** The 12th release of OpenStack open source software used for managing a cloud environment. Released on October 15, 2015.

*25 **Mitaka release:** The 13th release of OpenStack open source software used for managing a cloud environment. Released on April 7, 2016.

- FY2013 "Research and development of network conversion of communication processing functions in large-scale communication congestion" in collaboration with The University of Tokyo, Tohoku University, NEC Solution Innovators, Ltd., NEC Corporation, and Fujitsu Limited.

In addition to the above, NTT DOCOMO successfully deployed NFV technology in its commercial EPC network in March 2016 using multi-vendor equipment based on NFV ISG specifications. The knowledge obtained by this commercial deployment will be fed back to standardization activities as part of NTT DOCOMO's ongoing contributions to NFV ISG.

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