Transforming Carrier Networks by Utilizing Network Functions Virtualization

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The rapid evolution of cloud technologies has led to efforts to commercialize network functions virtualization (NFV), which uses software applications running on virtualized resources instead of dedicated hardware to provide various network functions. Fujitsu's NFV operation management software—FUJITSU Network Virtuora OM and Virtuora RV—brings the advantages of virtualization to the telecommunication industry and thereby enable network operators to introduce new services by flexibly allocating resources and to meet fluctuations in traffic through simplified and efficient operation management. Fujitsu provides additional features that improve performance and enhance operability. They include a virtualized system test solution, a service chaining function for on-demand network service creation, and a distributed services platform as a key technology for the Internet of Things (IoT) platform for network operators. This paper outlines NFV, describes the challenges in its practical application, and explains how Fujitsu is working to meet the requirements for NFV to be introduced to carrier networks.

1. Introduction

The move toward network functions virtualization (NFV) has been accelerating in recent years in line with rapid advances in information and communications technology (ICT) and cloud technologies.[1] The idea behind NFV is to implement various types of network functions, which are traditionally provided by dedicated hardware, as software running on an OS that applies virtualization to general-purpose servers.

In January 2013, the European Telecommunications Standards Institute (ETSI) held the first NFV Industry Specification Group (ISG) plenary meeting. Since then, NFV has come to be recognized as a revolutionizing technology for the carrier network ecosystem not only by telecom carriers and telecommunications equipment vendors but also by ICT vendors. In short, activities toward adopting NFV have crossed traditional industry boundaries.

For example, the SDN & OpenFlow World Congress held in October 2014 included the presentation of 12 NFV proof of concept (PoC) cases from companies including Fujitsu in various industries. These presentations introduced various elemental technologies for achieving NFV and advanced approaches to system construction.[2]

Fujitsu is participating in ETSI and other NFV-related standardization bodies and open source communities while developing technologies through PoC activities toward the realization of NFV.

In this paper, we begin with an overview of NFV. We then describe issues to realize NFV, operations and management technologies as the main research and development area of NFV, and functions that are not included in the scope of ETSI specifications but are necessary for real networks operation. We also touch upon enhanced services using NFV and elemental technologies.

2. NFV overview

The end-to-end architecture specified by ETSI NFV ISG is shown in **Figure 1**. This architecture consists of three main sections.[3]

1) Virtualized network functions (VNFs)

Application software for achieving network functions operating on virtual resources

2) NFV infrastructure (NFVI)

Infrastructure providing necessary resources for executing VNFs including hardware and software to virtualize that hardware

3) NFV management and orchestration (MANO)

Operations and management system for managing physical/virtual resources and managing the lifecycle of a network service comprised of one or more VNFs

Various types of network services and solutions can be expected by operating a variety of VNFs on a common infrastructure consisting of MANO and NFVI.[4)]

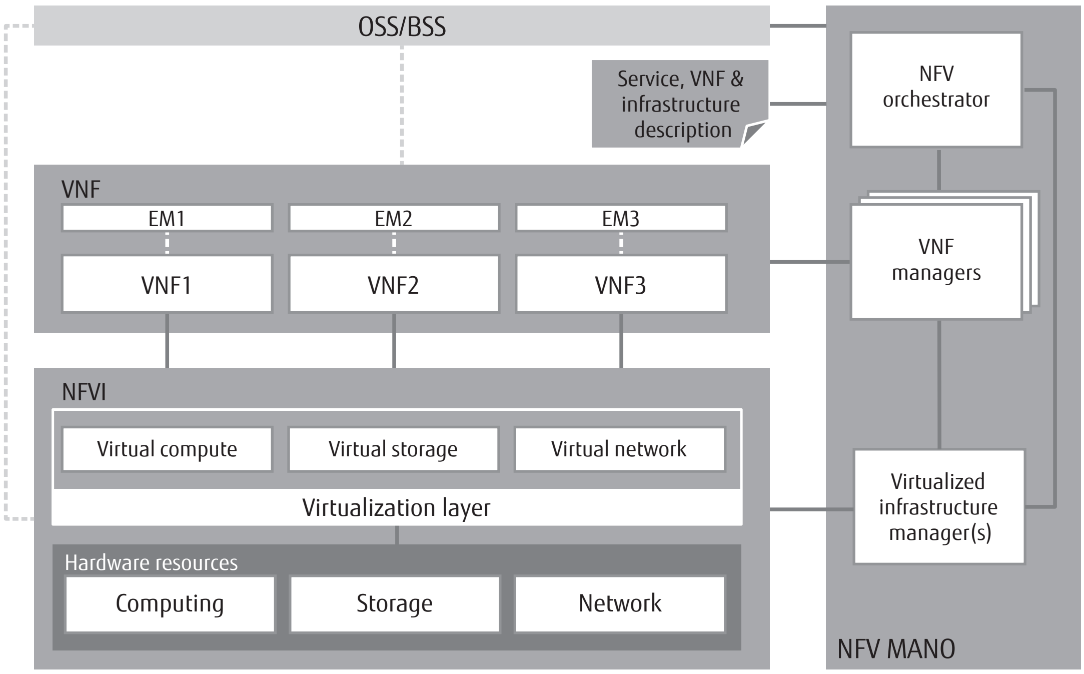
For example, a system that is flexible enough to deal with traffic fluctuations could be constructed by applying NFV to a mobile core network such as an evolved packet core (EPC) network or to the Internet protocol multimedia subsystem (IMS). Additionally, security equipment such as routers and firewalls could be virtualized and implemented on servers in a telecom central office by applying NFV to customer premises equipment (CPE). This approach should make maintenance operations more efficient. Furthermore, it should also increase revenue-generating opportunities through the introduction of new services because a network service comprised of multiple VNFs can be rapidly built in response to a user request.

3. NFV requirements

Several requirements must be fulfilled to apply NFV to a carrier network, and Fujitsu is working on them.

3.1 Multivendor support

In contrast to dedicated equipment and devices that have traditionally been provided by bundling hardware and software together, NFV is oriented to an ecosystem in which a variety of vendors supply hardware and the application software running on virtualized hardware. That is, different vendors provide hardware, a hypervisor, application software, and software for operating and managing hardware and software as products that are integrated into a single system. It is therefore important that servers, application software, and operations and management systems provided by different vendors interconnect and interoperate with each other and that they satisfy the service level agreements (SLAs) required of carrier



OSS: Operations support system
BSS: Business support system
EM: Element management

Based on figure in ETSI Network Functions Virtualisation (NFV), Architectural Framework[3)]

Figure 1
ETSI NFV end-to-end architecture.

networks. Moreover, they are usually required to coexist with existing systems.

Fujitsu has been developing products that support open interfaces in conformance with the ETSI architecture. It has also been conducting extensive interconnectivity tests with application software of other companies and providing solutions in support of a multivendor environment through integration.

3.2 Reliability guarantee

Service continuity and SLA guarantees are extremely important elements in constructing a carrier network. In NFV, application software and the operations and management system play a major role in constructing reliable network services using general-purpose servers. In this regard, the commonly used active/standby redundancy system suffers from low efficiency in terms of resource usage. In collaboration with other companies, Fujitsu has promoted the development of middleware and application software using that middleware to achieve N+1 redundancy while making efficient use of resources.[5] It is also providing a healing function that maintains a redundant configuration by linking with the operations and management system.

3.3 Performance guarantee

In making the transition from dedicated hardware to NFV based on general-purpose servers and software, it is essential that NFV be able to provide stable performance. To this end, Fujitsu supports technologies for achieving high-speed packet processing such as the data plane development kit (DPDK)[6] and single root I/O virtualization (SR-IOV).[7] Additionally, to achieve stable performance in applications, Fujitsu promotes operation testing and analysis when applying acceleration technologies to applications. It also supports the effective use of container technologies and hardware assist functions in the form of network interface cards (NICs) for reducing the overhead generated by virtualization processing. Moreover, from the viewpoint of effective resource usage, Fujitsu aims to achieve a VNF configuration that can be separately scaled on the C-Plane (control plane for message processing as in signaling) and U-Plane (user plane for packet processing) together with associated operations and management techniques.

4. NFV operations and management technologies

In this section, we first introduce the operation and management of an NFV system based on the specifications of ETSI NFV ISG. We then describe a virtual-operation inspection solution for checking that an NFV system is operating normally.

4.1 ETSI NFV operation and management

MANO as specified in the ETSI NFV architecture provides basic NFV operation and management functions. As shown in Figure 1, MANO consists of three sections that can be linked together to achieve basic operation and management processes.

1) NFV orchestrator (NFVO)

Performs lifecycle management (service generation and monitoring, action-taking in response to system events, service deletion, etc.) of network services consisting of multiple items of application software, and oversees the operation and management of the entire system.

2) VNF managers (VNFMs)

Perform lifecycle management of individual items of application software, and initiate actions such as auto scale-out as needed.

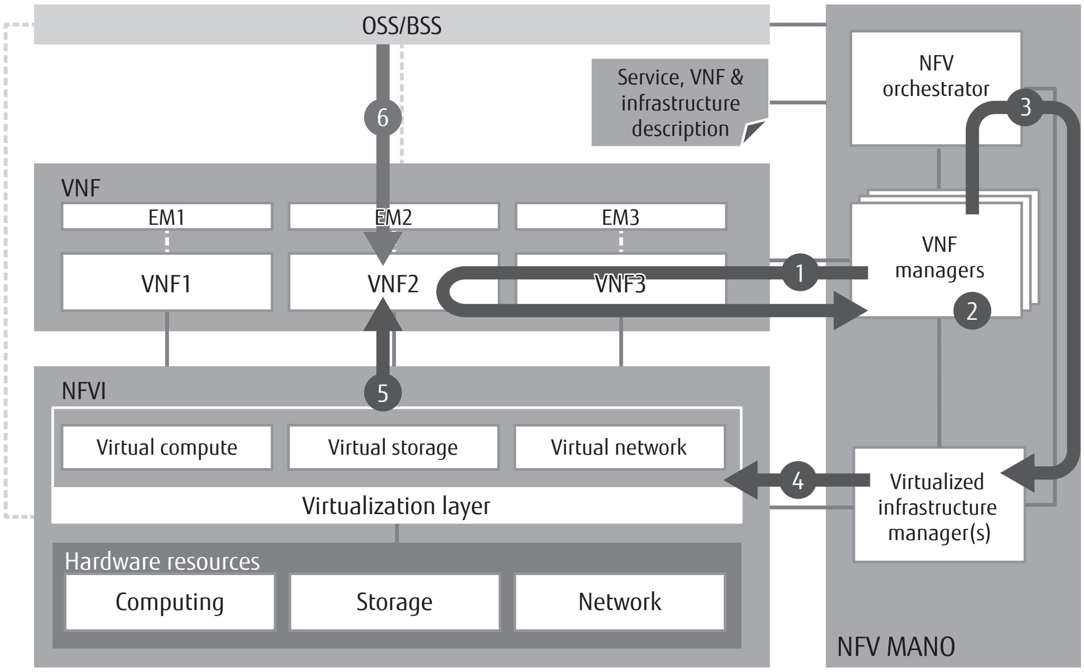
3) Virtualized infrastructure manager (VIM)

Performs operation and management of physical/virtual resources (servers, networks, storage) typically through the use of OpenStack software.

An example of an auto scale-out operation to avoid congestion and degradation of user quality of experience (QoE) by establishing an additional VNF and distributing the load is shown in **Figure 2**. The auto scale-out procedure consists of six steps.

1) Collect information on VNF performance
2) Detect congestion and determine need for sending resource-allocation request
3) Send resource-allocation request to VIM via NFVO
4) Instruct hypervisor to allocate virtual resources
5) Deploy virtual resources
6) Set VNF parameters

However, the functions prescribed in the MANO specifications[8] released in November 2014 are insufficient on their own to implement and operate virtual network services on a carrier network at a level of reliability and operability equivalent to or better than that of existing networks. This makes it necessary to



Based on figure in ETSI Network Functions Virtualisation (NFV), Architectural Framework[3)]

Figure 2
Example of auto scale-out operation.

provide those functions that are lacking and to systematize operational know-how.

To meet this need, Fujitsu has announced FUJITSU Network Virtuora OM and Virtuora RV as software products providing MANO functions for telecom carriers.[9)] Virtuora OM provides Orchestrator and VNFM functions while Virtuora RV provides VIM and other NFVI virtualization functions in collaboration with OpenStack. Together, Virtuora OM and RV supplement the basic functions specified by ETSI NFV ISG with functions necessary for the maintenance and operation of a carrier network such as MANO redundancy, easy installation of a virtualization infrastructure, and mapping of physical and logical resources.

4.2 Virtual-operation inspection solution

Since NFV constitutes a multivendor environment, it is essential at the time of a fault that the cause of the problem be isolated and analyzed. However, in the case of virtualized entities, fault analytics is more difficult than in conventional systems, so some sort of troubleshooting mechanism covering the entire system is needed. Fujitsu offers a solution in the form of a mechanism that inspects the health of the system at each level from the virtualization infrastructure to applications in conjunction with MANO functions.

This mechanism makes use of virtualized inspection applications to construct a virtualized inspection environment on a commercial network without the need for preparing special test facilities. It enables on-demand operation checking and problem troubleshooting. With this solution, the user can safely and reliably deploy new services and functions on a commercial network.

The basic idea behind the virtual-operation inspection solution when targeting an NFV system is shown in **Figure 3**. This solution provides three types of inspection functions.

1) Inter-host connection inspection

Deploys inspection applications on all physical servers to check for communication between physical servers and confirm server connectivity

2) Inter-VM connection inspection (VM: virtual machine)

Performs a connection inspection between an inspection application and a VNF targeted for inspection to check connectivity of the virtual network

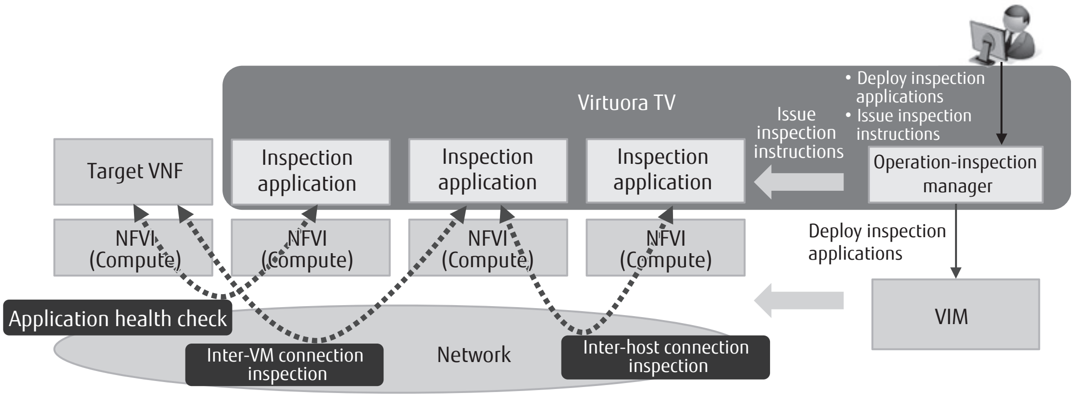


Figure 3
Virtual-operation inspection solution.

3) Application health check

Deploys an inspection application against a VNF targeted for inspection and issues a test call (C-Plane/U-Plane) to check the state and operation of that VNF

5. Service enhancement and elemental technologies

NFV virtualizes existing systems such as the mobile core network to enhance flexibility, achieve efficient use of resources, and automate operations. It also serves as an infrastructure technology that can facilitate the creation of new services and the enhancement of existing services.

In this section, we first describe an advanced on-demand application provision service that leverages the capability of NFV to flexibly deploy various types of application software. We then introduce an Internet of Things (IoT) infrastructure for providing IoT services.

5.1 On-demand application provision service

Services in which a user selects desired application functions (firewalls and other types of security functions, router functions, etc.) and the telecom carrier provides those functions on its cloud servers are expected to increase in the years to come. To provide such services, it is essential that multiple items of application software be provided while keeping initial deployment costs down. This is one business area in which the superior features of NFV technology can be put to use. That is, the capability of NFV to flexibly and quickly introduce a variety of applications on the same server platform can be exploited to achieve "service chaining" in which a number of applications are combined on demand.[4] One specific method for achieving service chaining is routing control using the network service header (NSH)[10] specified by the Internet Engineering Task Force (IETF), but this requires network devices and application software to support NSH. Taking this into account, Fujitsu has implemented a method in Virtuora OM that can achieve service chaining without having to upgrade devices in the existing network.

The service chaining method in Virtuora OM has a function for generating and distributing routing information in accordance with the address processing methods of different types of application software. Specifically, this function generates routing information in accordance with the characteristics of applications that pass IP packets such as firewalls and applications that change IP-packet addresses such as Web proxies. This enables service chaining of a variety of virtual applications.

The service chaining method is illustrated in **Figure 4**.

5.2 IoT infrastructure

In the future, as all kinds of sensors and terminals are connected to networks, there will be a need for a network infrastructure that can cope with diverse traffic characteristics and fluctuations in traffic volume. In other words, networks will have to respond to changes in the received requests. This will require an IoT infrastructure that can flexibly construct a system on servers

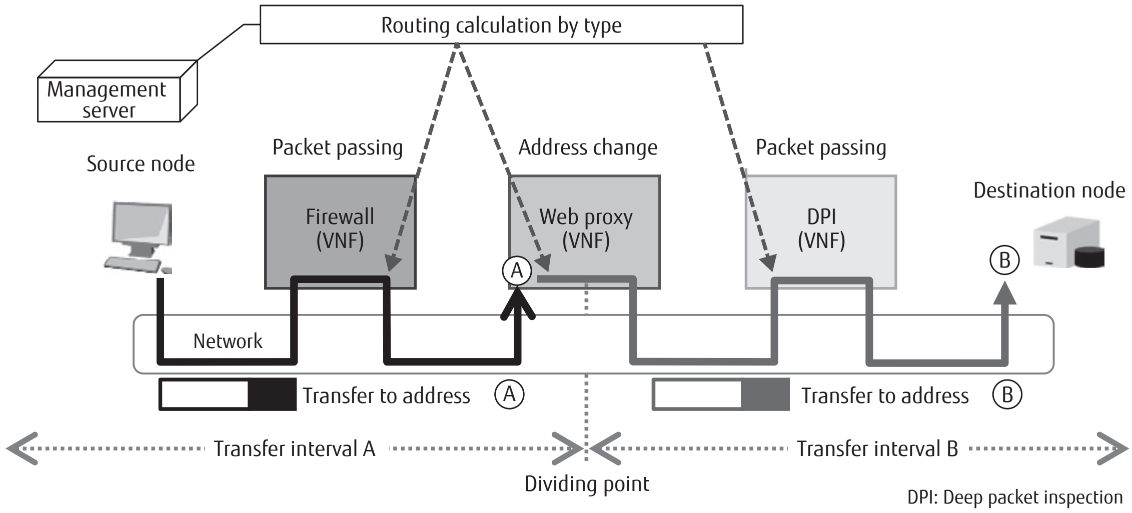


Figure 4
Service chaining method.

deployed across a telecom carrier's wide area network in line with the service requirements of the application software that processes the data generated by sensors. In this way, by performing data processing with distributed applications that are deployed on intermediate servers near the data sources or elsewhere within the carrier's wide area network, traffic volumes can be decreased and real-time processing of data can be achieved. Fujitsu has developed a distributed service platform as a major element of an IoT infrastructure, as shown in **Figure 5**.[11]

In addition, Fujitsu plans to link this distributed service platform, which automates system construction and operation, with MANO functions in line with changes in service requirements. It also plans to link it with the mission critical technology (load distribution, overload control, etc.) that it has developed over the years in the construction of large-scale networks for telecom carriers with the aim of achieving a robust and scalable IoT infrastructure that can have a transformative effect on society.

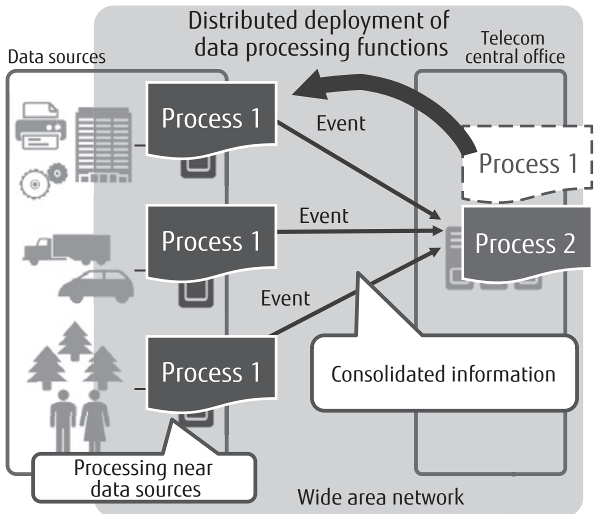


Figure 5
Provision of distributed service infrastructure.

6. Conclusion

This paper described Fujitsu's approach to transforming carrier networks using NFV. The Virtuora OM/RV software offered by Fujitsu for managing NFV provides telecom carriers with a foundation for enjoying the benefits of virtualization as already provided in the cloud environment. Going forward, Fujitsu will continue working to simplify operations and management and to make it more efficient through extensive automation with the aim of achieving even higher levels of system reliability. It will also promote activities toward the construction of a new communications services infrastructure especially for the IoT era. Fujitsu aims to become a leader in researching and developing new network construction technologies such as NFV.

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