Technology Reports

Virtualization Technology | NFV | SDN

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

Application of Virtualization Technology to Communications Networks

In the face of dramatic increases in data communications traffic and sudden changes in traffic characteristics brought on by the widespread adoption of smartphones, constructing and operating an always-connected network at a reasonable cost has become a common issue for many network operators. NTT DOCOMO has undertaken the development of an always-connected network that can reduce network CAPEX and OPEX by applying virtualization technology. This article describes issues and activities surrounding virtualization technology at NTT DOCOMO.

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1. Introduction

The volume of data communications traffic continues to increase due to the widespread adoption of smartphones, and the communication characteristics of always-on smartphones is making it difficult to predict traffic fluctuations. Under these conditions, constructing an always-connected network at a reasonable cost to achieve a reliable social infrastructure or prepare for a large-scale disaster has become a common issue for many network operators.

NTT DOCOMO aims to resolve this issue through Network Functions Virtualisation (NFV)*1 that applies virtualization technology to a carrier network. Virtualization technology in NFV logically integrates and divides hardware resources (CPUs, memory, and HDDs) to create a resource pool*2 irrespective of the physical hardware configuration thereby enabling all sorts of communications software to run on shared general-purpose hardware. With this technology, virtual hardware is configured within the resource pool and communications software is generated in the form of components on that virtual hardware. In addition, NTT DOCOMO also applies Software-Defined Networking (SDN)*3, a network technology having a correspondence with virtualization technology, to the communications software dynamically deployed on general-purpose hardware to ensure network reachability and secure necessary bandwidth.

During times of normal network operation, these technologies help to improve network usage efficiency, and

*1 **NFV:** Achieving a carrier network on general-purpose hardware through virtualization technology.

at the time of a disaster, they can automatically expand the capacity of network facilities and improve the ease of connection.

Furthermore, in contrast to the conventional method of constructing network facilities beforehand based on predicted levels of traffic, virtualization technology enables resources to be allocated in response to current traffic conditions. This results in network operations achieved by reasonable CAPital EXpenditure (CAPEX)*4 and OPerating EXpense (OPEX)*5.

In this article, we provide an overview of virtualization technology, present current issues facing network operators, and describe a solution based on the application of virtualization technology. We also describe elemental virtualization technologies and a new network issue associated with NFV.

2. What is Virtualization Technology?

In the past, communications software used by network operators to provide services could run only on dedicated hardware. This was because dedicated hardware optimized to the characteristics of that communications software was needed to satisfy carrier grade requirements such as high reliability and high performance. Virtualization technology, in contrast, enables communications software to be deployed on the virtual layer (hypervisor*6) installed on a unit of general-purpose hardware with the result that the software can operate irrespective of hardware characteristics.

Virtualization technology makes it possible to regard hardware resources (such as CPUs, memory, and HDDs) constrained by a physical configuration as a resource pool that bundles together a large amount of hardware (**Figure 1**). It enables hardware resources situated on any general-purpose hardware within the resource pool to be used as components in the configuring of a Virtual Machine (VM)*7. In this way, it is no longer a question of securing hardware resources on specific facilities since

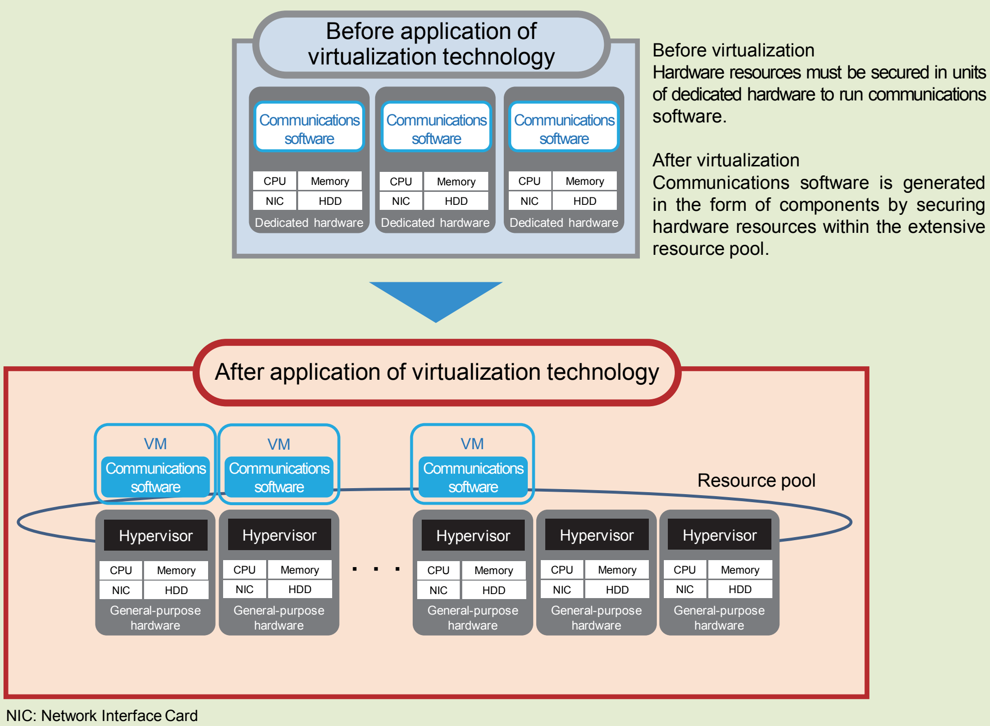

Figure 1 Resource pool

*2 **Resource pool:** The bundling of many units of hardware to form a set of resources (CPUs, memory, HDDs, etc.) held by each piece of hardware. Various types of virtual machines can be created from a resource pool.

*3 **SDN:** Generic name for technology that enables centralized control of communications devices through software.

*4 **CAPEX:** Amount of money expended for hardware and hardware installation.

*5 **OPEX:** Amount of money expended for maintaining and operating facilities.

*6 **Hypervisor:** A control program for creating and running virtual machines—a type of virtualization technology.

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

they can now be secured from a resource pool, which improves the usage efficiency of facilities. This is why virtualization technology has been attracting attention in recent years as a solution to issues currently faced by network operators.

NTT DOCOMO is making it possible to achieve "easy connection at times of congestion," "improved reliability," and "early provision of services," at a reasonable cost by applying virtualization technology to communications networks.

3. Issues Facing Network Operators

One mission of a network operator is to provide a sense of reassurance in the form of an "always connected" and "always usable" communications network that serves as a social infrastructure. However, there are four issues that need to be addressed to instill confidence in users.

(1) Connection control at times of congestion

When a disaster or other unexpected event causes a massive number of calls to be attempted all at once, the possibility exists that data communications traffic exceeding facility capacity will flow into the network. At this time, some of that traffic will have to be discarded before capacity overload occurs. This is because, if network facilities should reach the point of a system halt due to congestion, services would be disabled for at least several hours, which would simply magnify the problem. In short, there is no other way in such a situation but to choose the action that would minimize the impact on services.

(2) Risk at times of equipment failure

Systems are given a redundant configuration so that services can continue unimpeded even if some equipment experiences problems or failures. However, in the interval between the occurrence of such problems or failures and the replacement of the faulty equipment, redundancy is lost. Thus, if another failure should occur before that equipment has been completely replaced, service continuity becomes difficult.

(3) Difficulty of prompt facility support

The provision of new services or the addition of facilities in response to increasing traffic demand requires the development of new dedicated hardware and planning, procurement, installation, etc. toward the deployment of new facilities. These measures require time to execute, which makes prompt facility support difficult.

(4) Increase in facility/operation costs

The high price of dedicated hardware for running communications software, which is used by a network operator to provide services, increases CAPEX. Additionally, the need for maintenance personnel to replace faulty equipment to restore redundancy as soon as possible drives up OPEX.

4. Solution: Apply Virtualization Technology to Communications Networks

The benefits of introducing virtualization technology to carrier networks are described below for each of the issues described above.

4.1 Connecting at Times of Congestion

In the past, data communications traffic would have to be discarded to prevent a capacity overload in network facilities. From here on, however, it will be possible to apply a method called "scaling" (see section 5.2). In this method, the inflow of traffic large enough to exceed facility capacity will trigger the automatic installation of communications software on general-purpose hardware on which no such software is currently running. This will have the effect of increasing facility capacity in a short period of time. As a result, traffic that in the past would have to be discarded out of necessity can now be processed normally making for ease of connection.

4.2 Improving Reliability of Communications Services

In a conventional network, the occurrence of an equipment failure meant that equipment redundancy would be lost until replacement of that unit by maintenance personnel in the field was completed. Now, at the time of equipment failure, a method called "healing" (see section 5.3) will enable redundancy to be restored promptly by automatically moving communications software to good hardware. This approach minimizes the risk of a service shutdown thereby improving reliability.

4.3 Early Provision of Services

Adding new equipment took a relatively long time in the past. In the future network, the shared use of inexpensive general-purpose hardware will enable a variety of communications software to be executed. Specifically, to facilitate the launching of new services and addition of new functions and to deal with growing demand, a method called "instantiation" (see section 5.4) will enable communications software to be promptly deployed on general-purpose hardware facilities deployed beforehand (**Figure 2**). This is a great advantage for operators who wish to develop and roll out new services promptly or scale down or withdraw services.

4.4 Cost-efficient Network Facilities and Operations

Thanks to technological advances in recent years, it has become possible to lower costs through a transition from dedicated hardware to general-purpose hardware and to reduce the amount of required facilities through effective utilization of hardware resources. As a result, excess facilities can be greatly reduced compared to conventional systems and CAPEX can be lowered. In addition, equipment redundancy lost at the time of an equipment failure can be restored by the healing method. There is therefore no obstacle to service continuity, which means that the replacement of faulty units can be carried out in batch at a later date thereby reducing OPEX as well.

5. NFV Elemental Technologies

5.1 Differences with Ordinary Virtualization Technologies

In an IT world in which Web services are now mainstream, cloud*8 operation based on server virtualization is a sensible approach. In the world of communications, however, communications software often takes on a structure that requires complex coordination within a software group to provide services. Appropriate startup procedures and con-

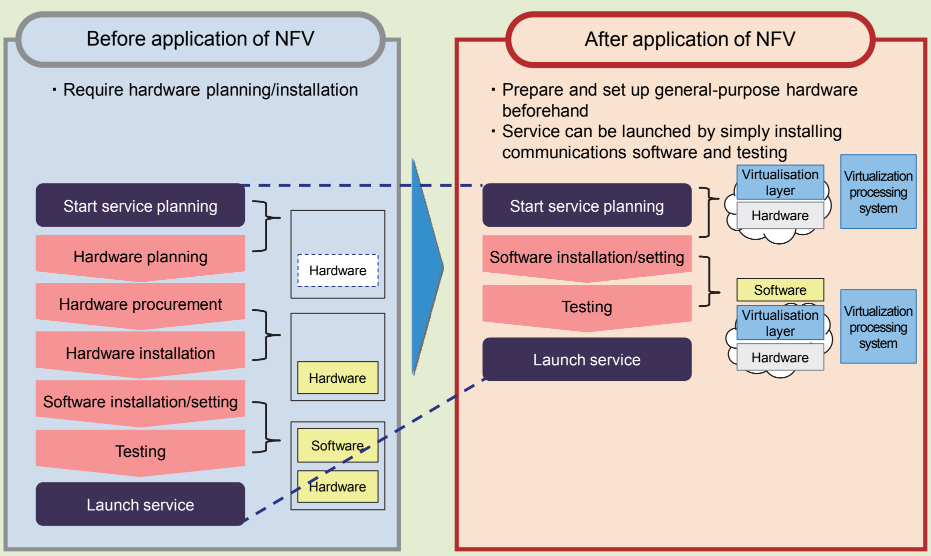

Figure 2 Early provision of services

*8 **Cloud:** A format and mechanism for providing services over the network. Server resources can be allocated according to demand making for high scalability.

trol are needed in accordance with the software structure and high reliability is required.

In this regard, the following describes elemental technologies using typical use cases. A more detailed description of architecture and workflow is provided by another special article in this issue [1].

5.2 Scaling

As described above, improving ease of connection at times of congestion can be achieved by a technique called "scaling." Scaling means increasing or decreasing communications software and VMs according to hardware and VM load conditions to optimize processing power. Specifically, adding VMs to improve processing power is called a "scale-out" operation and deleting VMs to cut back on processing power is called a "scale-in" operation.

In addition, both "auto-scaling" and "manual scaling" are possible. In the former, the system automatically executes scaling, while in the latter, maintenance personnel judge the need for scaling and do so if needed in cases that automatic execution by the system is difficult. An example of auto-scaling is shown in **Figure 3**.

Today, at the dawn of NFV, there is a need for both auto-scaling and manual scaling. In the future, though, expanding the scope of auto-scaling will enable more rapid scaling in response to greater amounts of communications traffic.

5.3 Healing

Next, improving the reliability of communications services can be achieved by a technique called "healing." In the event of a hardware or VM failure, this technique moves the VM to (or recreates the VM on) good hardware thereby restoring the communications software to a normal state.

Similar to scaling, healing comes in two types: "auto-healing" in which the system detects a hardware or VM failure and automatically executes a healing process, and "manual healing" in which maintenance personnel judge the need for scaling and do so if needed in cases that automatic execution by the

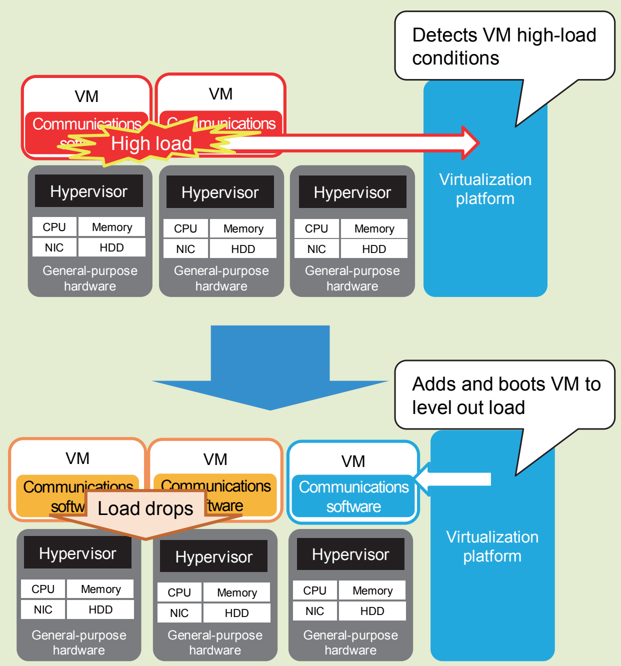

Figure 3 Scaling operation (auto-scaling)

system is difficult. An example of auto-healing is shown in **Figure 4**.

At present, there is a need for both auto-healing and manual healing, but the aim going forward is to improve reliability even further by expanding the scope of auto-healing.

5.4 Instantiation

Finally, early provision of services can be achieved by a technique called "instantiation." This technique prepares a VM on general-purpose hardware and launches communications software on that VM. Once the resources needed by the communications software based on resource usage conditions have been secured from the resource pool made up of many units of general-purpose hardware, the communications software is launched on the most optimal deployment destination.

An example of instantiation is shown in **Figure 5**.

6. NFV and New Network Issue

The ability to launch and move communications software on and to general-purpose hardware through NFV has many advantages. At the same time, dynamically moving communications software having particular communications requirements among general-purpose hardware units raises a new issue. That is, network devices (switches, routers, etc.) connected to such general-purpose hardware must track this movement of communications software.

In conventional systems, communications software and dedicated hardware operate in an integrated manner. Thus, once the accommodating relationship between the hardware and network devices has been decided, settings (such as Virtual LAN (VLAN)*9 trunk port*10 settings) based on the communications requirements of that communications software can be registered beforehand in the network devices. However, in NFV, there is absolutely no knowledge as to what type of communications software will be launched at the point in time that the accommo-

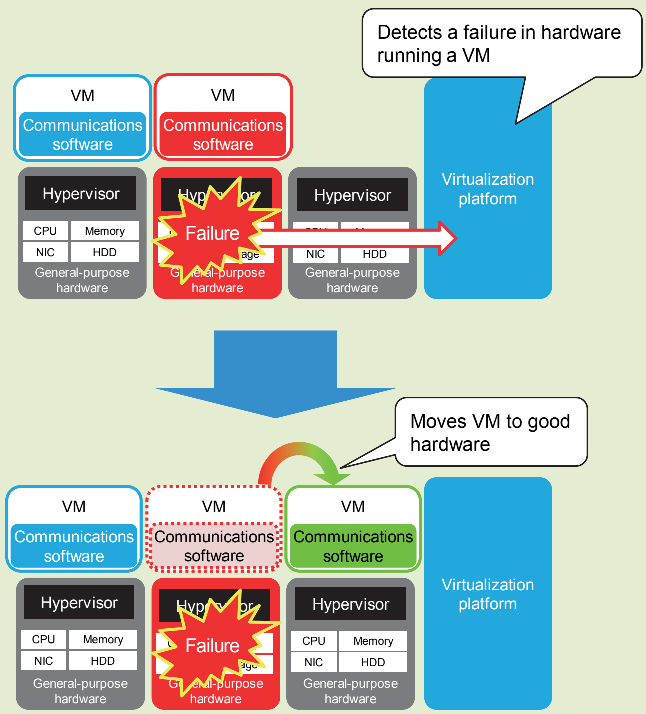

Figure 4 Healing operation (auto-healing)

*9 **VLAN:** Technology enabling the creation of a logical network irrespective of the physical connection layout. Since communications software connects to various networks, VLAN can be used to separate those networks appropriately.

*10 **Trunk port:** A port that belongs to multiple VLANs. The values of the VLANs to which the port belongs to must be set.

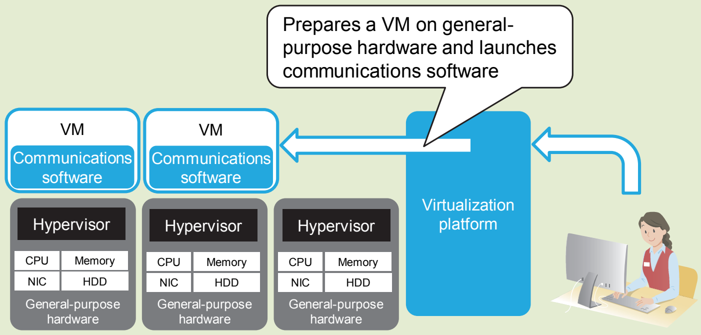

Figure 5 Instantiation

dating relationship with hardware is determined. There is therefore a need for a means of dynamically registering settings tied to the launching and movement of communications software.

NTT DOCOMO is introducing NFV combined with SDN to solve this issue. Another special article in this issue describes SDN [2].

7. Conclusion

In this article, we provided an overview of virtualization technology, described current issues faced by network operators, presented a solution based on the application of virtualization technology, described elemental virtualization technologies, and discussed a new issue generated by the introduction of NFV.

The application of virtualization technology makes it possible to both improve connectivity in the communications network—a key social infrastructure—and reduce CAPEX/OPEX, which has heretofore been difficult to achieve. At present, discussions are being held on standardizing inter-system interface specifications for NFV, which applies virtualization technology to carrier networks. NTT DOCOMO has contributed to dramatic advances in this field by promoting proactive standardization activities and taking up the challenge of developing NFV under a multivendor product configuration. It has also become a world leader in introducing NFV and associated SDN network technology in its communications network.

Through a variety of development activities including the integration of multivendor products and resource design taking reliability and ease of operation into account, NTT DOCOMO launched commercial services using NFV technology in March 2016.

Going forward, NTT DOCOMO plans to apply the results of its world-leading activities in combining multivendor products to making further contributions to the development of NFV.

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