Virtualization Platform | Communications APL | Hypervisor

Technology Reports

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

Practical Implementation of Virtualization Platform in NTT DOCOMO Network

NFV ISG's proposal of operating communications APLs on the cloud has triggered lively discussions throughout the world. These discussions have uncovered issues that must be resolved to achieve NFV including (1) degradation of APL processing performance due to resource sharing, (2) the need for techniques to maintain fault resilience in applications running on the cloud, and (3) the complexity of troubleshooting on the physical and virtual layers at the time of a fault. This article describes a virtualization platform that NTT DOCOMO has implemented to resolve these issues.

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1. Introduction

NTT DOCOMO has been promoting the development of a virtualization platform based on the architectural framework standardized in the Network Functions Virtualisation (NFV)*1 Industry Specification Group (ISG). There are a number of items that must be considered toward the practical implementation of such a platform based on the characteristics of the network operator. These include the (1) design and operation of a resource pool, (2) requirements for operating a communications APpLication (APL)*2 in a cloud environment*3, and (3) change in the network-construction and maintenance/operation formats used by the network operator. The network operator must decide on what course of action to take with respect to these matters based on its own policies and plans, as discussed below.

(1) The design and operation of a resource pool depends on the facilities possessed by the network operator and its approach to communications APL reliability, so the network operator itself must design the resource pool.

(2) As a critical type of software providing communications services to users, degradation in the performance and quality of a communications APL is directly related to a drop in the quality of user services. The performance, quality, and reliability [1] demanded of communications APLs running in a cloud environment must therefore be maintained.

(3) Virtualization means the addi-

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

tion of a virtualisation layer, so the maintenance of communications APLs as in fault troubleshooting is likely to become increasingly complicated. Maintenance operations must be made more efficient to deal with this added complexity.

Based on the needs and requirements described above, NTT DOCOMO clarified the issues to be targeted and took measures to resolve them. Thanks to these efforts, it completed the practical implementation of a virtualization platform and launched a commercial service based on this platform in March 2016.

In this article, we first clarify the issues and requirements surrounding the operation of communications APLs in a cloud environment with the aim of making the most of what virtualization can offer. We then describe the practical implementation of a virtualization platform that applies measures for resolving and satisfying those issues and requirements. Here, we assume that virtualization can be achieved without changing the software structure of communications APLs so that the cost of their development can be reduced.

2. Issues Surrounding Communications APLs in a Cloud Environment

To make effective use of the benefits that virtualization can provide, certain issues need to be recognized and resolved. These issues are discussed below.

2.1 Resource Sharing (Issues 1 and 2)

In general, virtualization makes it possible for multiple applications to share virtual resources. This makes resource usage more efficient, which is a benefit to users. In addition, virtualizing physical resources such as computers, networks, and storage through the use of a Hypervisor*4 enables the creation of virtual computers, virtual networks, and virtual storage so that physical resources can be hidden from applications. In other words, running a communications APL on virtualized equipment called a Virtual Machine (VM)*5 eliminates the need to worry about the physical configuration of equipment and makes development work such as OS upgrading unnecessary when a physical server reaches its End Of Life (EOL)*6.

A conceptual diagram of arranging communications APLs on a resource pool is shown in **Figure 1**.

In the past, the arrangement and de-

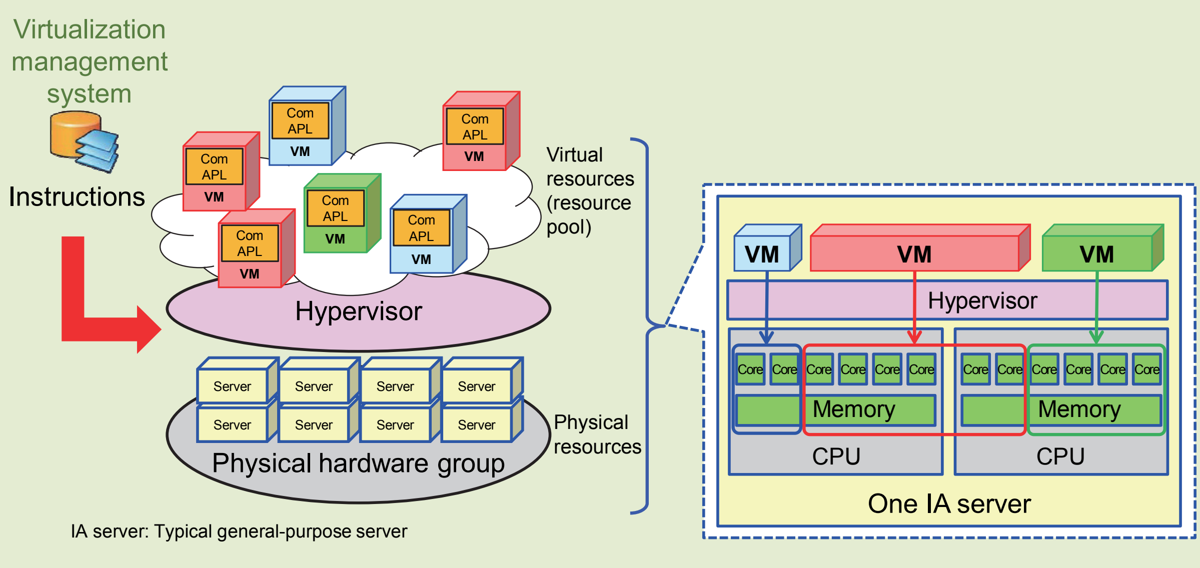

Figure 1 Arrangement of communications APLs on a resource pool

*2 **Communications APL:** Refers to the functional components making up a necessary function in the provision of telecommunications services. Specifically, it means an application that runs on telecommunications equipment such as switches, transmission equipment, and radio equipment.

*3 **Cloud environment:** A virtualization platform such as VMware and OpenStack for achieving virtualization.

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

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

*6 **EOL:** Termination of product support.

sign of the functional components of communications APLs and design work related to processing performance and fault resistance was carried out based on the network's hardware configuration. However, when running communications APLs in a cloud environment, actual hardware is concealed by VMs, which generates new issues such as greater processing delay and degraded fault resistance. These issues are described below.

1) Processing Delay in Communications APLs (Issue 1)

The advantage of concealing physical resources from communications APLs is that applications can be mounted and executed as needed without having to worry about the wiring between servers and network devices, the actual server configuration, etc. On the other hand, arranging applications on a resource pool means that specific physical servers cannot be specified. There is therefore concern that VMs will be unintentionally arranged in such a way that they use physical resources that are a high hop count*7 away, or that CPUs or memory will be used in an inefficient manner within the internal structure of a server as shown in **Figures 2** (a) and (b). In any case, the end result will be a processing delay. When introducing a virtualization platform, an application will be mounted on multiple VMs depending on the configuration of the application's components and the VMs will be placed on free resources in the resource pool. However, considering that the internal structure or bandwidth of a physical server cannot be optimized and that variation in processing time will arise due to the introduction of a hypervisor (described below), processing

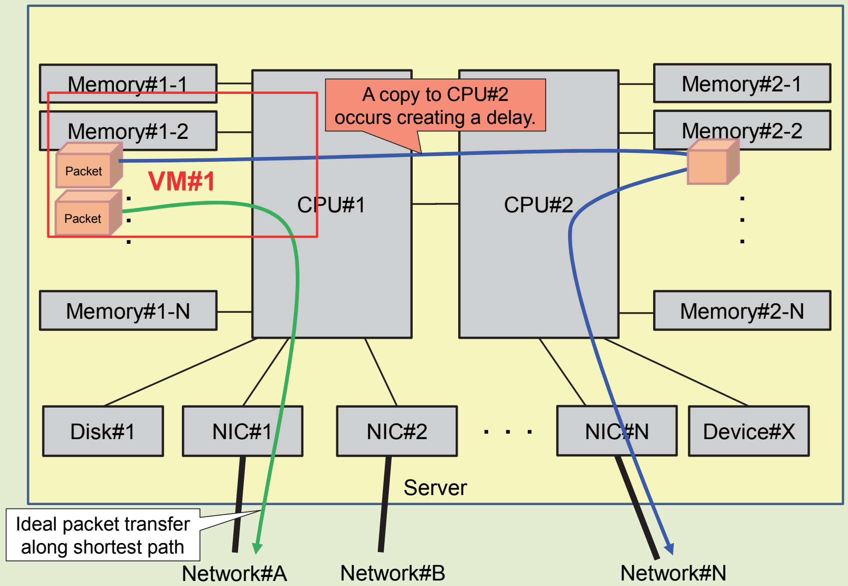

Figure 2 (a) Example of inefficient server use (1)

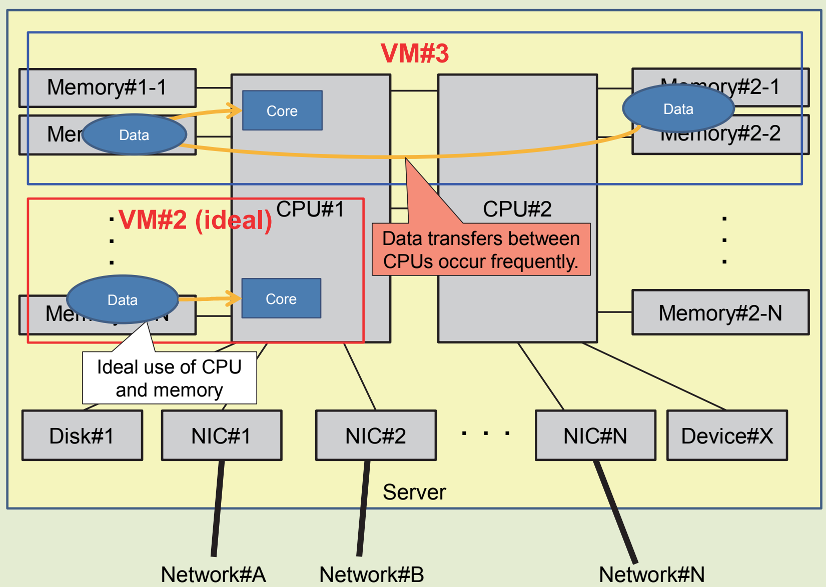

Figure 2 (b) Example of inefficient server use (2)

*7 **Hop count:** In a communications network, the number of relays that must be passed through to arrive at the other party in the communication session.

delay will occur.

The issue of processing delay caused by virtualization is shown in **Figure 3**. Compared with the case of "no virtualization," that is, the direct use of physical equipment, virtualization produces a variation in processing time. This phenomenon occurs because controlling multiple virtual resources and physical resources by software via the hypervisor results in processing between virtual resources and processing by the hypervisor itself, which generates competition for physical resources (**Figure 4**). Consequently, a time offset can occur with local time due, for example, to non-uniform delay in time clock processing within a VM. For a similar reason, the Turn Around Time (TAT)*8 of communications APL processing can appear to fluctuate wildly to external

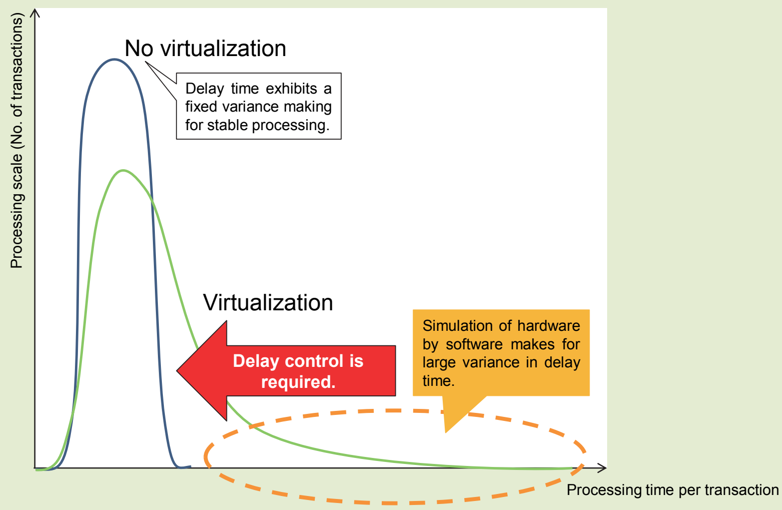

Figure 3 Distribution of processing delay by virtualization

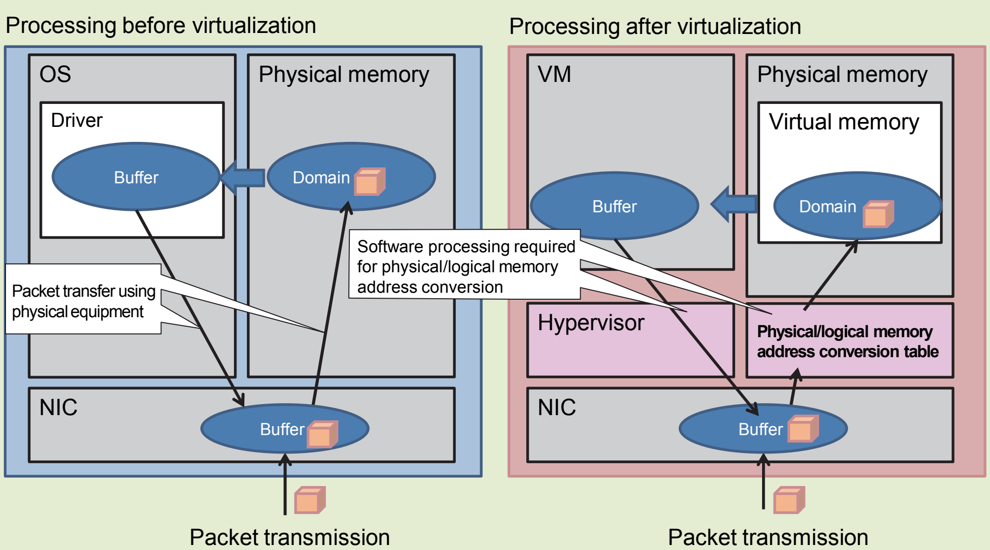

Figure 4 Mechanism of processing delay

*8 **TAT:** The time taken from the beginning of application processing to the output of results.

equipment. Under these conditions, virtualization cannot produce stable processing speeds making it difficult to maintain the processing performance of communications APLs. This situation calls for a resource control method independent of hypervisor processing.

2) Fault Resistance in Communications APLs (Issue 2)

Resource sharing means that multiple VMs can be mounted on a single physical server, but doing so means that the failure of one physical server can have a great impact on communications APLs thereby degrading user services.

It is therefore necessary to consider a redundant configuration for each component making up a communications APL as well as a VM arrangement technique that prevents a "double failure" scenario from occurring.

2.2 Maintenance of Virtual Applications (Issue 3)

The addition of virtual applications is expected to expand the cloud environment and resource pool. Moreover, VMs that execute communications APLs will move about the resource pool as part of an auto-healing function provided by the virtualization platform. In short, it goes without saying that maintenance will become increasingly complicated compared with the integrated maintenance of hardware and software in conventional systems. As a consequence, the volume of maintenance operations will increase and personnel with an expanded skill set will be needed to troubleshoot network faults. To facilitate fault troubleshooting based on the state of communications APLs or the NFV Infrastructure (NFVI)*9, the operating conditions of VMs and servers need to be visualized.

2.3 Requirements of a Virtualization Platform in a Cloud Environment

To deal effectively with the issues described above, a virtualization platform that accommodates communications APLs must be able to:

(1) Construct virtual resources that eliminate delay by monopolizing physical resources
(2) Construct a resource pool enabling definition of a VM arrangement policy
(3) Visualize the logical and physical configurations of communications APLs

3. Practical Implementation of a Virtualization Platform

3.1 Construct Virtual Resources that Eliminate Delay by Monopolizing Physical Resources

1) Countermeasure to Delay in Data Transfers

The application of paravirtualization technology [2] is a common method for improving performance in a virtual environment. In this method, physical hardware that incorporates virtualization support functions substitutes for the hypervisor in performing some of its software-based processing. Paravirtualization makes it possible to control the delay associated with hypervisor intermediary processing and avoid the effects of that delay (**Figure 5**).

However, when applying paravirtualization technology, functions are provided by physical hardware, so the communications APL or virtualization platform will have to issue control instructions depending on the functions or system configuration of concern. It will also be necessary to define in detail the relationship between virtual resources and physical resources, which can complicate the construction of a common resource pool. As a result of the above, the application scope of paravirtualization has its limits.

In the case of a communications APL, the location for controlling delay would be mainly the data transfer section. Accordingly, we define the combination of a CPU and Network Interface Card (NIC)*10 as a cell that can provide maximum communications performance and apply paravirtualization to only those NICs for which delay is not allowed. Here, by applying virtualization to memory and storage as before, we can create a common resource pool by simply choosing which servers and cells to use in arranging VMs and deciding whether to use any NICs that apply paravirtualization (**Figure 6**).

*9 **NFVI:** Generic name for general-purpose servers, storage, and network devices making up a cloud infrastructure.

*10 **NIC:** An extension card for connecting a general-purpose server with a LAN.

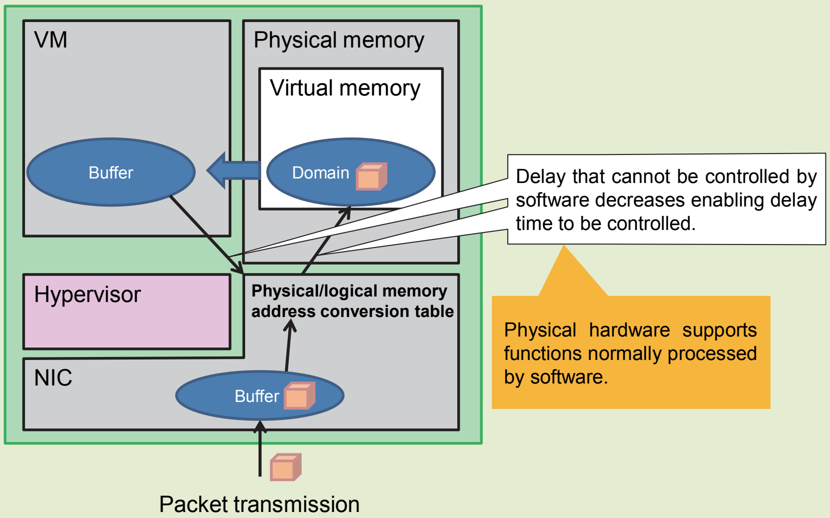

Figure 5 Use of paravirtualization technology

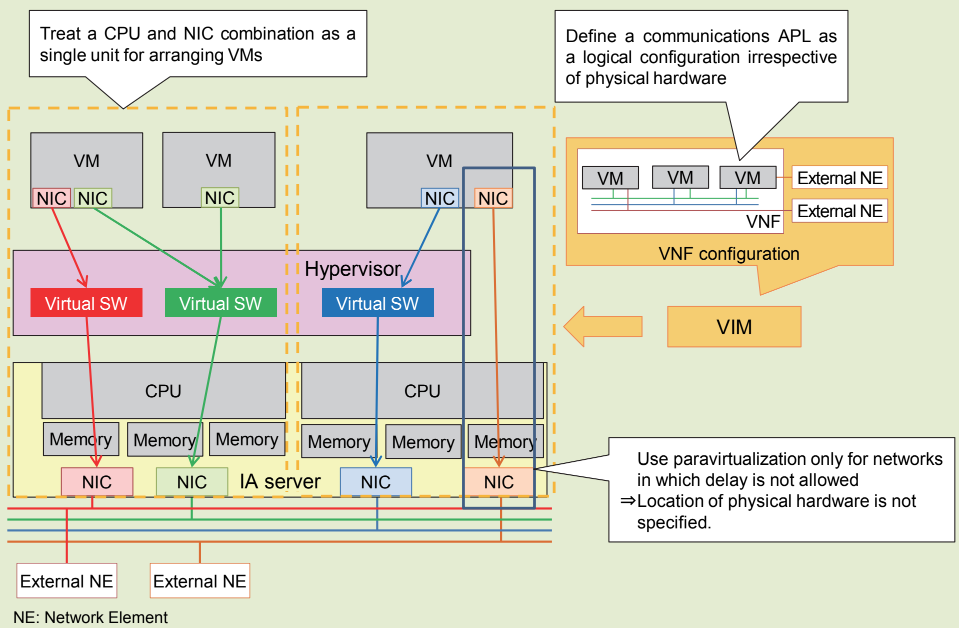

Figure 6 Adoption of paravirtualization technology

2) Countermeasure to Processing Delay in Executing a Communications APL

A communications APL runs on a VM, so a requirement for stable VM operation is CPU monopolization. In other words, more than one VM must not be allowed to run on the same CPU. We have achieved CPU monopolization by interpreting the CPU/memory/NIC structure of the target NFVI servers and defining a virtual resource as the number of cores*11 in a CPU deemed necessary for VM operation.

Applying the above countermeasures has enabled us to construct virtual resources that satisfy the performance

*11 **Number of cores:** The number of units performing processing within a CPU.

requirements of communications APLs.

3.2 Construct a Resource Pool Enabling Definition of a VM Arrangement Policy

In conventional systems, the functional components making up a communications APL were made redundant using an ACT[*12]-SBY[*13] configuration or nACT configuration[*14] to improve reliability and extendibility. However, if a VM with functional components having an ACT-SBY configuration is mounted on a single server, the failure of that server will bring about a double failure (in which both the active and standby systems fail) resulting in a service disruption. There is therefore a need to define VM arrangement rules so that redundant components are not arranged on the same server and to design a resource pool in accordance with those rules. It must be kept in mind here that VM arrangement on physical servers is executed in conjunction with control functions such as scaling[*15], healing[*16], and instantiation[*17].

The following describes resource pool construction, definition of a VM arrangement policy, and the functions of the components making up the virtualization platform.

1) Resource Pool Construction

Resource pools are constructed in units of Virtualised Infrastructure Manager (VIM)[*18] blocks, with each such unit divided into multiple zones. Zones, in turn, are configured in units of racks that are given a redundant configuration to provide for failures in network devices. The relationship between a resource pool and zones is shown in **Figure 7**. As shown, a configuration that prevents a double failure from occurring at the time of a server failure or zone failure can be achieved by arranging a VM having ACT-SBY redundancy on different zones in the resource pool. In addition, a VM having nACT redundancy can prevent the effects of zone failures caused by multiple failures of network devices. While the number of required zones is equal to 'n' in "nACT," the specific number can be decided by the network operator based on the conditions of its facilities and the characteristics of its communications APLs.

2) Definition of VM Arrangement Policy

We here describe the allotment of functions in the virtualization platform in relation to defining a VM arrangement policy. The VIM is in charge of defining a resource pool and zones as well as controlling individual physical servers, while the Virtual Network Function Manager (VNFM)[*19] and NFV Orchestrator (NFVO)[*20] perform only control operations with respect to the resource pool (zones) [3]. In other words, while VIM would select a server within a chosen zone, VNFM would investigate the redundant configuration of each VM and choose zones according to an ACT-SBY or nACT configuration. The NFVO, meanwhile, would manage the capacity of the resource pool. This divi-

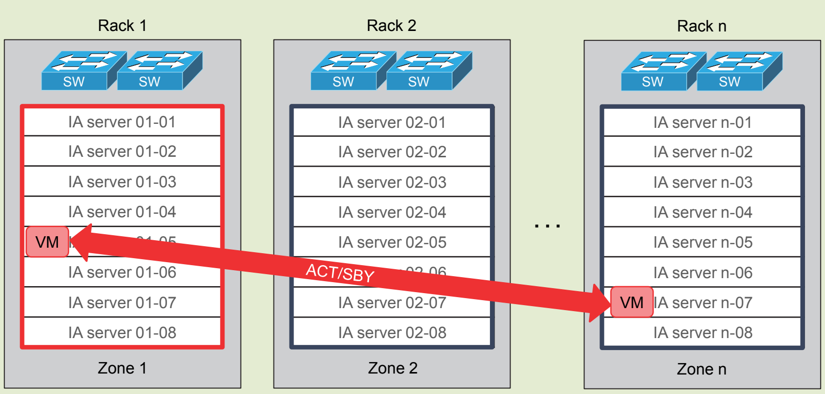

Figure 7 Relationship between resource pool and zones

*12 **ACT:** The parts of a redundantly configured communications application that are actually being used.

*13 **SBY:** The parts of a redundantly configured communications application that are currently on standby.

*14 **nACT configuration:** Distributes the load across n number of servers operating in parallel. If a server malfunctions, its processing can be taken over by another server.

*15 **Scaling:** The optimization of processing power by increasing or decreasing VMs that configure communications software whenever processing power is insufficient or excessive according to hardware and VM load conditions.

sion of functions on the virtualization platform enables a VM arrangement that maintains the fault resistance of communications APLs.

3.3 Visualize the Logical and Physical Configurations of Communications APLs

We here describe a method for maintaining communications APLs in a cloud environment. Communications APLs launched in a NTT DOCOMO cloud environment assume the software configuration of conventional communications APLs, which means that the Operation Support System (OSS)*21 that monitors and controls communications APLs can inherit conventional monitor and control functions.

The fact that a conventional communications APL has a configuration integrated with hardware enables an OSS that has received an alert from a communications APL to narrow down the location of faulty hardware. In a cloud environment, however, VMs move about under control of the auto-healing function, which makes it difficult to isolate the faulty VM and the server on which that VM is running. Thus, when troubleshooting a fault in a communications APL or on related equipment by investigating software (logical configuration) and hardware (physical configuration), visualization of the logical configuration and physical configuration is essential to identifying the server on which the VM is running.

In visualization of the logical configuration, we unified the naming rules for communications APL components and VMs so that a correspondence could be attached between those components displayed on the OSS and VM names on the resource pool. This clarifies the relationship between the components making up the communications APL and VMs making up the virtual resources.

Next, in visualization of the physical configuration, knowing that VIM manages the connection between servers and VMs on the resource pool, we pass that information to the OSS to enable the logical configuration and physical configuration of the communications APL in the OSS to be visualized. In this way, conventional monitoring and control methods can be inherited (**Figure 8**).

4. Conclusion

This article presented the issues surrounding the operation of communications APLs in a cloud environment and described the practical implementation of a virtualization platform that resolves those issues.

Network construction and maintenance operations need to be made more efficient to run communications APLs on the cloud. To this end, we plan to study a new network service*22 that can reduce the work of having to make var-

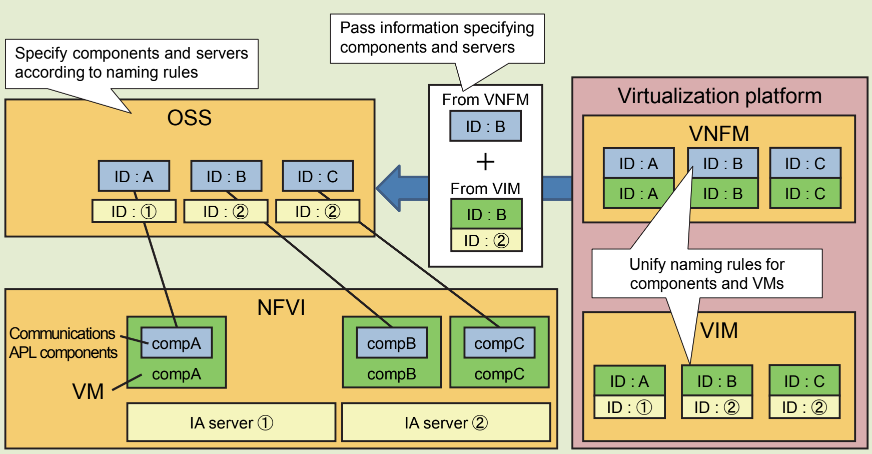

Figure 8 Visualization of logical/physical configurations of a communications APL

*16 **Healing:** A procedure for restoring communications software to a normal state in the event of a hardware or VM failure by moving the VM to (or recreating the VM on) hardware operating normally.

*17 **Instantiation:** A procedure for launching a communications APL in a cloud environment.

*18 **VIM:** The system that manages the physical resources on the virtualization platform consisting of physical computers, physical storage, and physical networks.

*19 **VNFM:** The system that performs VNF control operations such as launching and termination as VNF lifecycle control.

*20 **NFVO:** The system that performs comprehensive management of virtual resources that span multiple VIMs.

ious types of settings at the time of instantiation. We also plan to study automation in maintenance and network operations on a virtualization platform having a multi-vendor configuration.

References

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[2] ETSI GS NFV 004: "NETWORK FUNCTIONS VIRTUALISATION (NFV); VIRTUALISATION REQUIREMENTS," Oct. 2013.

[3] WIND RIVER White Paper: "HIGH PERFORMANCE, OPEN STANDARD VIRTUALIZATION WITH NFV AND SDN," Oct. 2015.

*21 **OSS:** A system for discovering, controlling, and dealing with faults and congestion in a mobile communications network, or an operations support system for network operators. For a network operator, this means network or system fault management, configuration management, charging management, performance management, and security management—all or in part—for operating provided services.

*22 **Network service:** A function for generating a virtual network to connect a communications APL launched by instantiation in a cloud environment to other communications APLs or virtualized communications APLs. The network service defined by NFV ISG.