Technology Reports | Network Virtualization | Orchestration | Upgrade without Service Interruption

Migration to ETSI NFV Stage 3 Specification-compliant Multivendor MANO Configuration on Network Virtualization Platform

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NTT DOCOMO commercially introduced a virtualization platform for its core network at the end of FY2015, and has continued to operate it stably since then. This virtualization platform supports multivendor configuration and also is able to accommodate the operation of many virtualized core network functions running on it. To address the EoL of NFVO and VNFM, which are components of the virtualization platform, we have developed a multivendor configuration framework over the virtualization platform that incorporates the latest ETSI NFV Stage 3 specifications. Also, we succeeded with the migration from the legacy virtualization platform to the new one without service interruptions or negative impacts on communications services. This article describes these activities.

1. Introduction

At the end of FY2015, NTT DOCOMO became the first company in the world to configure a virtualization platform on which a core network*1 is running in an operational environment consisting of products from multiple vendors. This reduces communications network CAPital EXpenditure (CAPEX)*2/OPerating EXpense (OPEX)*3 [1] [2]. Since then, NTT DOCOMO has continued to virtualize more core network functions and operate the virtualization platform stably. By the end of

*1 Core network: A network comprised of switching equipment, subscriber information management equipment, etc. A mobile terminal communicates with the core network via a radio access network.
*2 CAPEX: The amount of money expended for hardware and hardware installation.
*3 OPEX: The amount of money expended for maintaining and operating facilities.

FY2020, more than 50% of these core network functions had been virtualized, with more than 400 running on the virtualization platform. The lifecycles of these virtualized core network functions (Virtual Network Functions (VNF)*4) are managed by Management ANd Orchestration (MANO)*5. Lifecycle management includes automatic healing to recreate Virtual Machines (VMs)*6 on normally operational hardware if a hardware or VM failure occurs, scaling to optimize processing power by increasing or decreasing processing resources according to the load on the hardware and VMs, and VNF upgrading to update the communications software and VM-related software when adding new services or solving issues. To provide stable communications services, this virtualization platform runs as a mission-critical*7 system (**Figure 1**).

As mentioned above, NTT DOCOMO's virtualization platform is composed of products from multiple vendors. These products differ in their End of Life (EoL)*8 timing, the version of standard specifications they support, their Application Programming Interfaces (APIs)*9, input/output parameters*10, and attributes*11. Each vendor decides these items based on standardization work and future trends, releases plans of them and specifications based on operator requirements. Therefore, when upgrading a system that is made by combining products from multiple vendors, the complexity of integration*12, including the design of InterFace (IF) specifications between products, is an issue. Addressing this, NTT DOCOMO actively participates in standardization at the European Telecommunications Standards Institute (ETSI)*13 Network Functions Virtualization (NFV)*14 [3] and has contributed to the development of Stage 3 specifications*15 [4]. We continue to work on standardization in consideration of integration, reliability, and

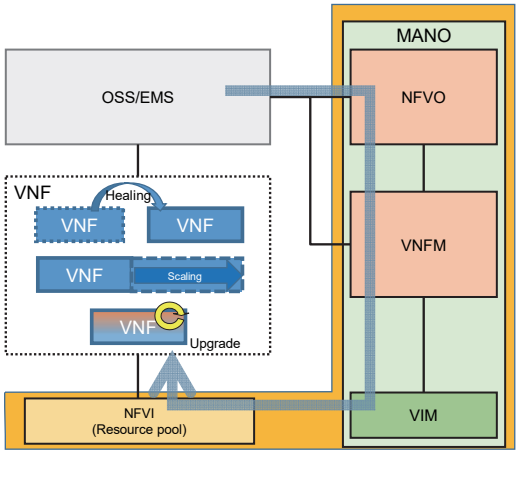

Figure 1 Healing, scaling, and VNF upgrading on the virtualization platform

*4 VNF: Virtualized communications functions (communications systems).
*5 MANO: A generic term that summarizes the functional blocks of NFVO (see *16), VNFM (see *17), and VIM (see *18).
*6 VM: A computer (virtual machine) created in a virtual manner by software.
*7 Mission-critical: Refers to elements essential to the execution of businesses or services for which termination or interruption is not allowed.
*8 EoL: Refers to cessation of product manufacture and sales, cessation of software product support services, or cessation of provision of modification/update programs for bug fixing and functional improvements.
*9 API: A specification for exchanging information for connecting software components and products.
*10 Parameter: A generic term for a set of data exchanged between systems in ETSI NFV. When using an API, the data passed by the system that calls the API is called the input parameter, and, as execution results, the data returned by the system that opens the API and executes the API is called the output parameter.

operational efficiency among multivendor products.

In this article, we describe our activities to coordinate IF specifications to comply with ETSI NFV Stage 3 to handle product EoL. The article also describes a method of upgrading systems without stopping communications services, a fundamental requirement of telecommunications providers. Systems to be upgraded are NFV Orchestrator (NFVO)*16 and VNF Manager (VNFM)*17, which are key components of MANO. However, since Virtual Infrastructure Manager (VIM)*18, which manages virtual resources in the cloud*19 environment, is not upgraded, we have to upgrade these systems while VIM is in service.

2. Virtualization Platforms Landscape

2.1 Trends in Virtualization Platforms

NTT DOCOMO actively participates in standardization at ETSI NFV Industry Specification Group (ISG) and has contributed to the growth of NFV technologies and NFV standards adoption. As NFV becomes more widespread as a global standard, virtualization platforms are being deployed by many telecommunications operators. However, as well as single-vendor deployment, the type of deployment differs from operator to operator, with additional challenges including multivendor configuration aspects such as that of NTT DOCOMO. Furthermore, from the deployment perspective, since VNF architectures running on virtual platforms may differ, use cases and development methods for VNF LifeCycle Management (LCM)*20 can also vary. This means the way operators use ETSI NFV specifications and the scope of IFs virtualization platforms must support also differ.

2.2 Utilization of Global Products in a Multivendor Environment

In recent years, the application of cloud technologies has significantly changed the way operators develop their businesses. As cloud technology evolves more quickly and product lifecycles get faster, it is becoming less efficient to develop everything in-house. Meanwhile, it has been difficult to use systems other than those developed in-house for operation and maintenance, because each country has different legal frameworks and different geographical conditions, and operators must comply with different organizational structures and operational flows.

Therefore, as shown in **Figure 2**, it is extremely important to move from the legacy development processes based on an operator's own business analysis (an example of waterfall development) to new style that involves 1) the promotion of operator collaboration based on multifaceted business analysis considering the different operational workflows and needs of each operator, 2) the promotion and description of common requirements and development of common specifications through external standardization activities, and 3) the acceleration of development of standardized products that satisfy the needs of operators.

These activities will make products with uniform specifications globally available to many operators, thereby maintaining interoperability in a multivendor environment while lowering costs.

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*11 Attribute: A generic term for resource information held by each functional block in ETSI NFV. Since the ETSI NFV specification is based on REST (see *36), the resources held by each functional block are called attributes, and are distinguished from input/output parameters in APIs.

*12 Integration: The incorporation of equipment or systems on a network operated by an operator.

*13 ETSI: The standardization organization concerned with telecommunications technology in Europe.

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

*15 Stage 3 specifications: A general term for specifications of signaling protocols among the standardization methods in telecommunications specified in International Telecommunication Union-Telecommunication sector (ITU-T) I.130.

*16 NFVO: The system that performs comprehensive management of virtual resources that span multiple VIMs (see *18).

*17 VNFM: The system that controls VNF such as launching and terminating VNF LCM.

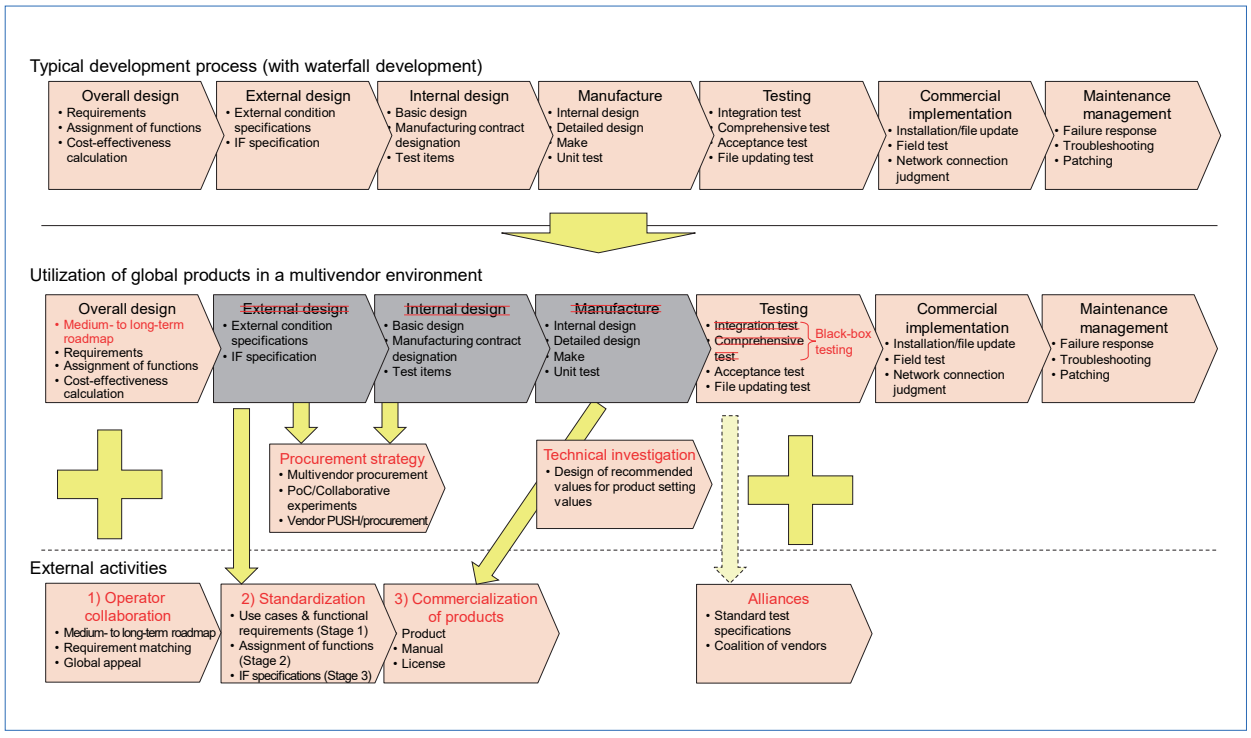

Figure 2 Utilization of global products in a multivendor environment

1) Operator Collaboration

Requirements need to be common among operators to ensure wide adoption of specifications. To achieve this, it is important for each operator to create its own medium- to long-term roadmap, and jointly coordinate requirements specifications with other operators (to build global appeal).

2) Standardization

Based on the common requirements specified by operators, use cases will be created jointly during the development of standards. By clarifying use cases, functional requirements will become clearer (Stage 1). Next, different functionality will be split into functional blocks and the information flows among them (Stage 2) can be specified. Finally, IFs (Stage 3) will be specified. Creating standard specifications among operators and vendors will make global products interoperable in a multivendor environment.

3) Promotion of Commercialization in Compliance with Standard Specifications

When operators procure products that comply with standard specifications from vendors, the products will become commercialized (product manufacture, manual creation and licensing).

Thus, there is no significant difference between development of virtualization platforms using global products and legacy development in terms of processes necessary for design, such as splitting

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

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

*20 VNF LCM: VNF lifecycle processing.

functions and establishing IF specifications, and product manufacturing and testing to verify that the product meets requirements. However, additional external activities are needed to develop common requirements and specifications.

3. NTT DOCOMO's Approach to MANO Upgrades

As mentioned above, since virtualization platforms require cloud technology, NTT DOCOMO has been working on standardization at ETSI NFV and has been promoting commercialization of products compliant with standard specifications while coordinating IF specifications for multivendor MANO configuration, and has been developing a framework for upgrading without interrupting services.

3.1 Identifying De Facto Versions and Promoting Commercialization

Communications equipment must continue to provide services for a period of 10 years, but as mentioned above, the adoption of cloud technology tends to shorten product lifecycles and frequently involves changes to the functions themselves. As the goal is to put communications equipment in the cloud, ETSI NFV is moving closer to a cloud computing culture, and its standard specifications will have a minor version upgrade every six months and a major version upgrade every two years with function addition and changes to the roles of functions occurring each time.

Therefore, when connecting multiple products, it is necessary to determine which version of which specifications is supported and the support period for that version, based on the assumption that operator use cases and requirements have been standardized through the aforementioned 1) Operator collaboration and 2) Standardization efforts. In addition, since supported functions and security-related specifications may change with each version, an operator must be able to ask vendors for specific versions that meet its requirements and cover its use cases.

While identifying de facto versions based on these considerations, it will be important to consider the aforementioned 3) Promotion of commercialization in compliance with standard specifications, provide education about de facto versions in an open forum, demand these de facto versions from product vendors and align functional requirements among operators. Therefore, it is important to raise the incentive for each product vendor to commercialize products in terms of what versions of what products are needed and by when.

3.2 Study of Methods to Start Upgrade Developments

IFs that comply with ETSI NFV Stage 3 are shown in **Figure 3**. Vendor products are basically commercialized based on market needs. Unlike communications equipment such as equipment that supports roaming[*21] which cannot provide communications services unless standard specifications are fully implemented, standard specification are not necessarily implemented with operation and maintenance equipment such as Operating Support System (OSS)[*22]/Element Manager (EM)[*23] and MANO.

*21 Roaming: A mechanism that enables mobile subscribers to receive services when visiting the service areas of partner telecommunications carriers, when traveling outside the geographical coverage area of their home networks.

*22 OSS: An operation support system for network operations for discovering, controlling, and dealing with faults and congestion in a mobile communications network. For a network operator, this means full or partial network or system fault management, configuration management, billing management, performance management and security management for usage of provided services.

*23 EM: A system that manages and monitors Faults, Configuration, Accounting, Performance and Security (FCAPS) for individual pieces of communications equipment.

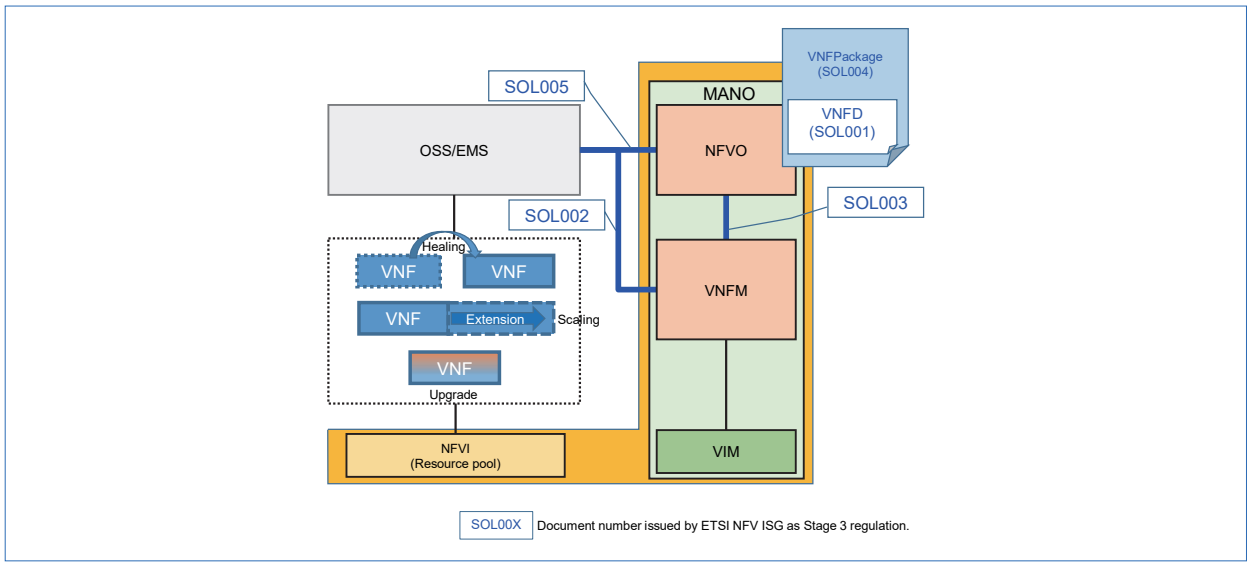

Figure 3 ETSI NFV Stage 3 IF

In the case of operation and maintenance equipment, the functions required are completely different depending on the operator's workflows, so vendors implement only the essential common functions and IF specifications requested by the majority of operators in their products. As a result, when connecting different MANO products, even if the IF specification is defined as a standard specification, each product might support different APIs with different attributes and values*24. For this reason, a feasibility study to connect MANO products is required.

To ensure compliance with standard specifications, it is necessary to complete the use cases of a company as soon as possible, as described in 1) to 3) below, and to clarify and request from the vendor the minimum necessary functions compliant with standard specifications for the deployment of new versions of equipment. In addition, if an operator requires implementation of non-standardized functions or extensions*25 in products to realize a use case, it should not prevent stable upgrades, and the operator should carefully consider selecting interoperable versions to avoid problem solving difficulties during the testing process or commercial operations. Therefore, it is important to have strong policies to prevent non-compliance with standard specifications to maintain interoperability between products. Towards the development of version upgrades, the following is a list of considerations to achieve these goals.

1) Create a Product-to-product Sequence*26 and Determine the Assignment of Functions in New Versions

Sequences using standard specifications must be considered based on a company's own use cases. The major types of sequences are (1) deployment*27 (onboarding*28 and instantiation), (2) update

*24 Value: The specific value passed by an attribute. In REST (see *36), this is passed by a key value pair consisting of an attribute and a value.

*25 Extension: Parameters for APIs and VNFDs (see *35) that have been extended to allow products to use their own functions.

*26 Sequence: The order of processing agreed upon between systems, functional blocks, etc.

*27 Deployment: Installing applications by placing them in their execution environments.

*28 Onboarding: Registering a VNF Package in the MANO system.

(healing, scaling and file update), and (3) removal (termination*29). To achieve these goals, it is necessary to determine products that will take on the role of VNF Instance*30, Virtual Resource*31, and VNF Package*32 resource owner*33, and to create the sequence.

2) Determination of Error-handling*34 Methods and Manual Recovery Procedures Based on Assignment of Functions

ETSI GS NFV-SOL 003 specifications describe policies and specifications for error-handling, although the supported functions and implementation-dependent error cases need to be well investigated. In particular, it is necessary to confirm detection and recovery methods to address communication failures - whether to recover using the retry method or the rollback method for each use case - and the error-code and recovery method when VNF LCM fails.

3) Determination of Parameter Values to Use

In ETSI NFV standardization, many parameters and attributes have been defined to support different use cases, and many options regarding information flows are available. Therefore, based on the sequence in 1) and the error-handling method adopted in 2), it is necessary to determine how main parameters are exchanged among multiple systems, what should be described in the VNF Descriptor (VNFD)*35, and which parameters and attributes are necessary to realize a use case. In particular, it is necessary to determine the network connectivity information between VNFs, the placement policy for VMs to form a redundant configuration to maintain reliability, the identifiers of VIMs and VNFs used in virtual resource management, and naming rules so that each piece of equipment can uniquely determine these parameters.

Through these studies, it is important to document the sequence, error-handling, each parameter value, etc., and request them from each vendor as mandatory features of each product. To implement future upgrades smoothly, NTT DOCOMO has contributed to the standardization of sequences (procedures), parameter exchange (key information exchange) between pieces of equipment, competitive conditions (dependent and non-dependent side procedures) in REpresentational State Transfer (REST)*36 environments and main error-cases as ETSI GS NFV-SOL 016.

3.3 Upgrade without Service Interruption

More than 400 core network VNFs run on NTT DOCOMO's virtualization platform. Any negative impact on these functions will directly lead to degradation of user services, such as connection difficulties or suspension of user communications. Therefore, when upgrading NFVOs and VNFMs, the upgrade must not affect the communications services provided by operational VNFs .

The following are requirements for upgrading NFVO and VNFM without impacting communications services.

(1) No need to recreate the VNF

One possible upgrading method is to create a new VNF (instantiation) on a new system built separately from the old system, and switch to the newly deployed VNF. However,

*29 Termination: Stopping a VNF and removing it from a virtualization platform.
*30 VNF Instance: A VNF entity created (instantiated) on a virtualization platform by a MANO system.
*31 Virtual Resource: Virtualized hardware resources (CPU, memory, hard disk, etc.).
*32 VNF Package: A package containing VNFD (see *35) that defines VNF functions and operations, ancillary information and VNF images.
*33 Resource owner: The system from which VNF instance, virtual resources and package resources are managed.
*34 Error-handling: Responses when errors occur.
*35 VNFD: The definition file for VNF to be created on the virtualization platform.
*36 REST: An API that sends GET, POST, PUT, and DELETE requests to each resource (URL) and receives the response in XML, json, or other format (the format of the response is not specified).

with some core network functions, communications services may be impacted when switching VNFs, and recreating and switching more than 400 VNFs requires a huge period of time and cost. Therefore, it is preferred that VNFs must not have to be recreated.

(2) The lifecycle management for the VNF that is running should be executable (stopping for a certain period of time is acceptable).

On a virtualization platform, healing is a type of lifecycle management which improves reliability when a hardware failure occurs. Specifically, when failures occur, VMs in which VNFs are deployed are recreated on other normally operating hardware to maintain redundancy. If healing is not possible, VNF redundancy cannot be maintained, and the risk that the next hardware failure will affect the communications service provided by VNFs is high. Therefore, it is necessary to be able to continuously perform healing.

(3) The upgrade process must be reversible.

It is necessary to be able to revert an upgrade and restore normal operations when abnormalities occur during the upgrade.

We upgraded the NFVO and VNFM by meeting these requirements and not impacting communications services. The mechanism is described below.

1) Mechanism to Eliminate the Need for VNF Recreation

To provide VNF LCM functions, NFVOs and VNFMs maintain management data about the virtual resources of the VNFs that they run (hereinafter referred to as "VNF data"). To eliminate the need to recreate VNFs when upgrading, it is necessary to move the VNF data managed in the old system to the new system, so that VNFs can continue to run on the new system.

In general, there are two possible ways to upgrade a system that has inherited data: update an old system to a new system on the same server, as in an OS update, or build a new system on a different server from the old system and switch to it after data migration. Since the hardware requirements of the target NFVO and VNFM were changed in this upgrade, a new system was built on a separate server and switched after data migration. The NFVO manages multiple VNFMs, including VNFMs that are not upgraded. The upgrade was performed in two stages, NFVO and VNFM, as shown in **Figure 4**.

As for data migration, both NFVO and VNFM will need to be converted to the new data format when VNFM is upgraded in the second stage. Since the upgraded NFVO and VNFM will be compliant with the ETSI NFV Stage 3 specifications, they will involve some changes in the assignment of functions from the current system. The structure of the VNF data to be managed and the parameters of the inter-system IF will be significantly different. Therefore, we found that migrating data from the current system to the new system required complex and extensive data conversion and harmonization across NFVO and VNFM (**Figure 5**). The development of these processes involves a risk

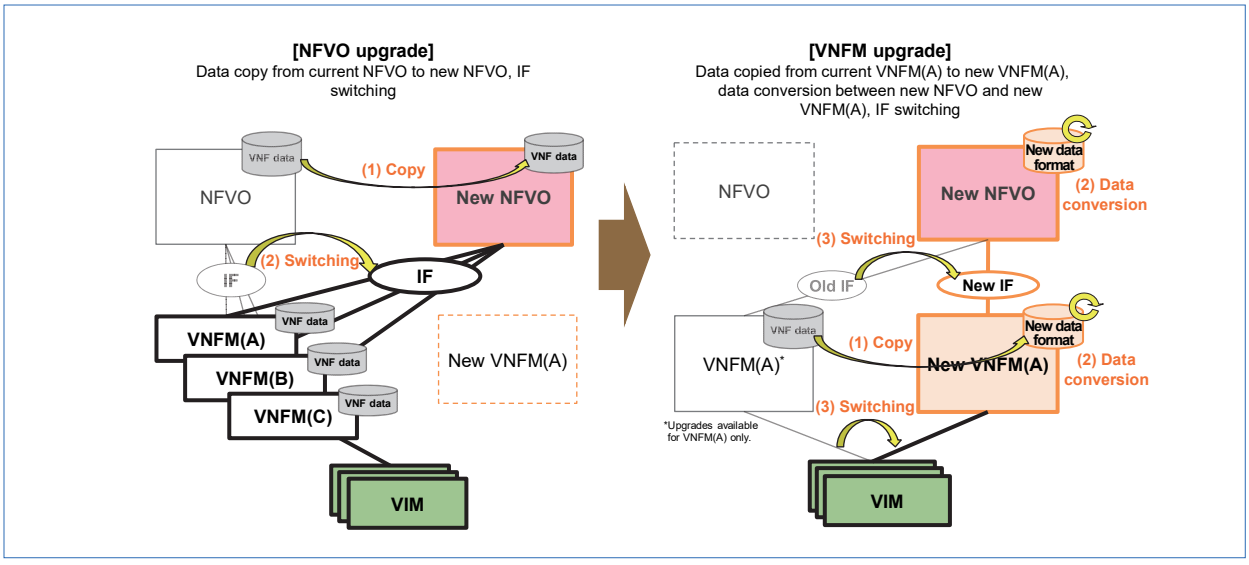

Figure 4 Upgrade method

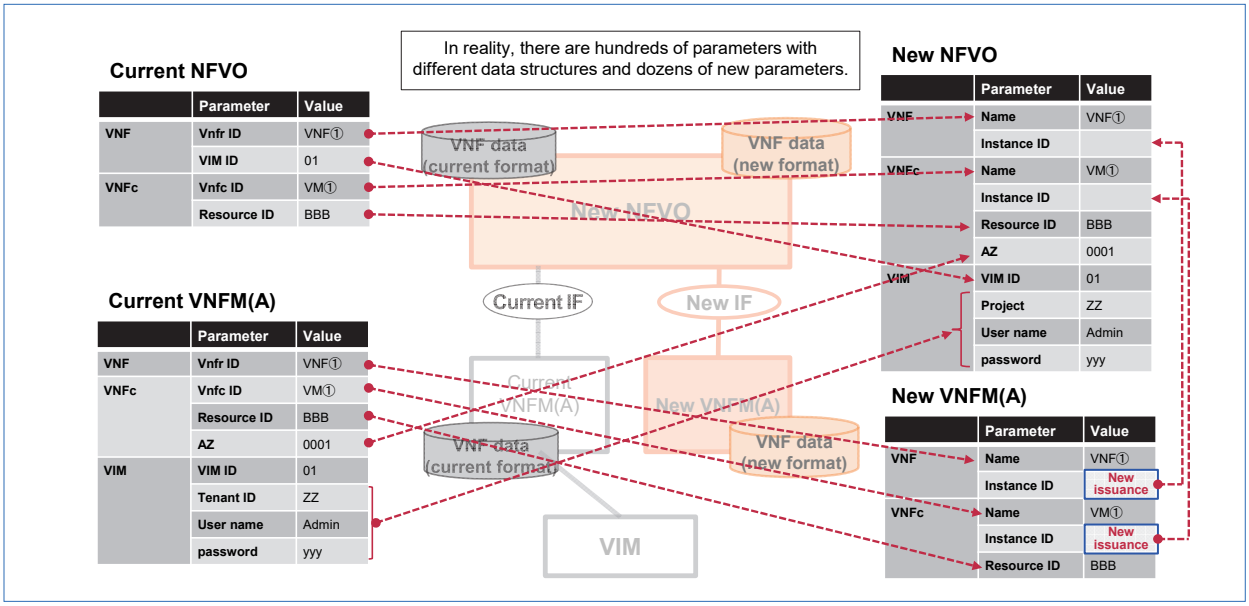

Figure 5 Data conversion and migration image

of errors in the migrated data because the data must be converted between systems manufactured by different vendors, and because various data patterns need to be considered. Therefore, as a mechanism for efficient data migration while ensuring reliability of migrated data, we considered

a method that uses the instantiation function, which is a basic lifecycle function of NFVO and VNFM, instead of developing data conversion and harmonization processes.

Instantiation is a technique to create a new VNF on NFV Infrastructure (NFVI)*37 by collaboration of NFVO, VNFM and VIM based on the VNF Package, which includes VNFD and VM images defining VNF functions and operations. The data in a new format is generated by pseudo-execution of instantiation only between new systems (NFVO, VNFM), without creating a new VNF on NFVI. This is called pseudo-instantiation (**Figure 6**). By pseudo-instantiating the VNFs that are running on the current system on a new system, VNF data in a new format are generated on the new system (NFVO, VNFM), thus enabling the migration of data of VNFs that are running without developing a new data conversion process.

To migrate data by pseudo-instantiation, the new NFVO and the new VNFM support the following functions, respectively.

(a) Automated pseudo-instantiation (new NFVO)

Conventionally, instantiation requires a maintenance technician to operate the NFVO for each VNF after registering the VNF package. However, with the migration data for more than 400 VNFs, there are concerns

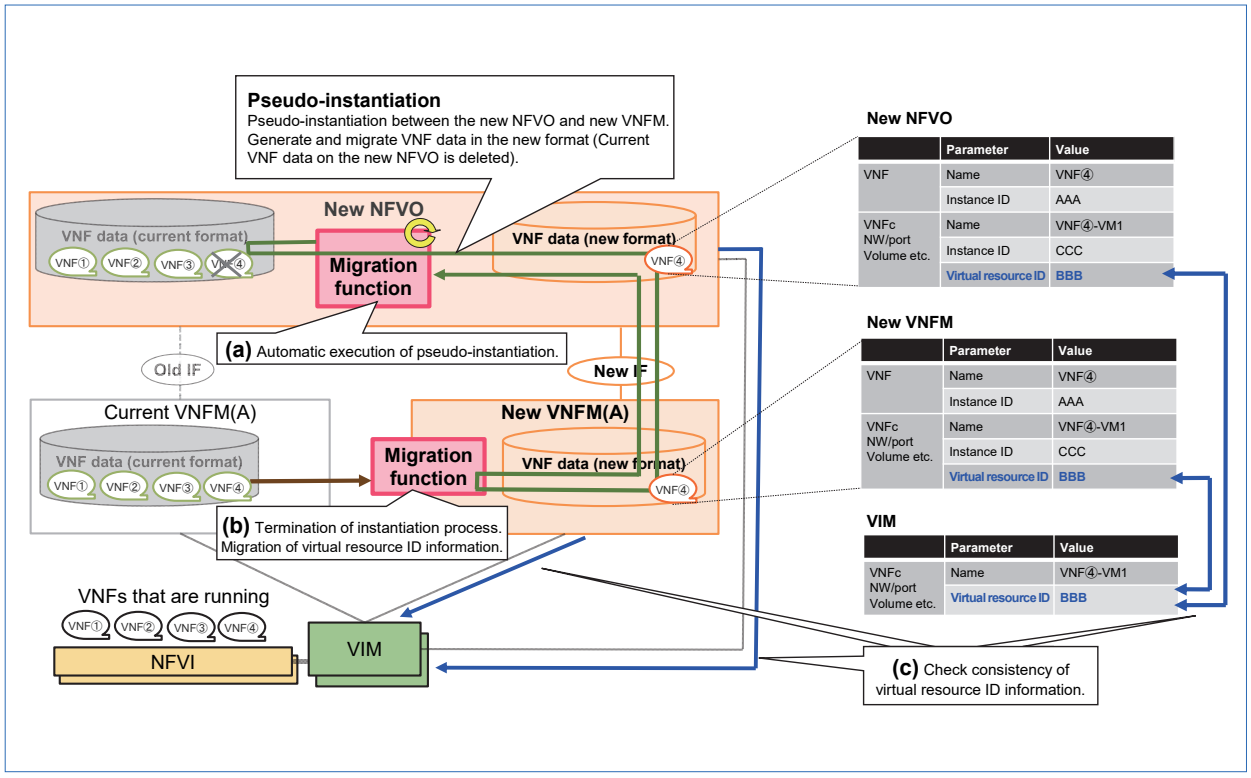

Figure 6 Mechanism of pseudo-instantiation

*37 NFVI: A generic term for the general-purpose servers, storage, and network equipment. Virtualization platforms are built using these resources.

about having to mobilize more maintenance staff and mistakes being made when making settings. To address this, the system automatically extracts the information that needs to be set during instantiation (Fig. 6 (a)).

(b) Termination of the instantiation process (new VNFM)

In normal instantiation, the VNFM performs virtual resource control to the VIM, but in pseudo-instantiation, the new VNFM terminates the process and does not perform virtual resource control to the VIM. Originally, as a result of virtual resource control to the VIM, the virtual resource ID information (ID information of virtual resources such as the generated VMs) for the deployed VNFs is collected from the VIM. However, as an alternative to this control, the virtual resource ID information is migrated from the current VNFM to the new VNFM in advance, and this information is obtained during the pseudo-instantiation process. This enables instantiation processes without implementing virtual resource control to the VIM (Fig. 6 (b)).

(c) Migration data consistency between systems (new NFVO, new VNFM)

In the new NFVO and VNFM, the virtual resource ID information generated as a result of pseudo-instantiation is checked against the virtual resource ID information managed in the VIM, and data consistency is ensured in the new NFVO, new VNFM, and VIM systems (Fig. 6 (c)).

2) Healing Continuation Mechanism

A VNF that has already migrated data through pseudo-instantiation is not able to execute its lifecycle until the switchover to the new system is completed. Also, while pseudo-instantiation improves the reliability of migrated data, it requires more time to migrate data for all VNFs since more than 400 VNFs are processed, and the period during which healing cannot be executed exceeds the allowed time (**Figure 7**).

Therefore, we designed the method to allow VNFM to perform healing alone by limiting the recovery method during the data migration period. We added a mechanism to simulate a limited period healing function that does not use the NFVO virtual resource management function (migration function) to the new VNFM, and continued healing by switching the VNFM to new NFVO connection to the VNFM to new VNFM during the data migration period (**Figure 8**). Since the NFVO virtual resource management function is not available, healing during the data migration period was limited to manual healing, which can be performed by a maintenance technician after checking the virtual resource status.

3) Reversion

To enable quick recovery and retry when a problem occurs, it is important that reversion in the upgrade process can be executed in steps that are as small as possible. In this upgrade, reversion was considered for each data migration and changeover process to the new system.

Data migration by pseudo-instantiation can be performed for each VNF selected by a maintenance

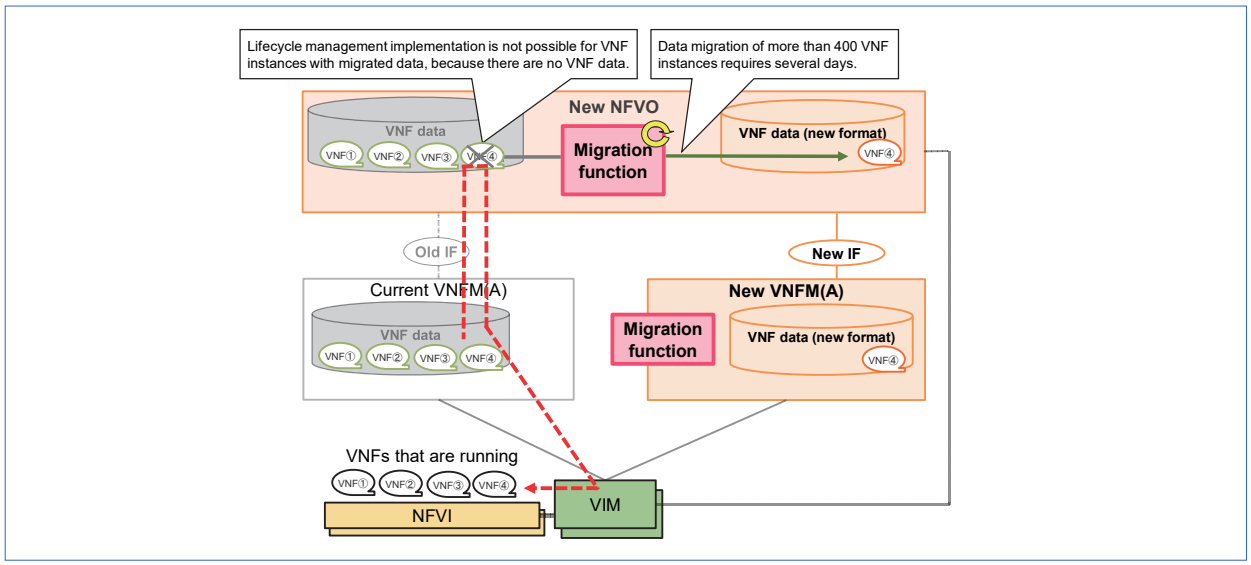

Figure 7 Challenges in continuing the VNF lifecycle during data migration

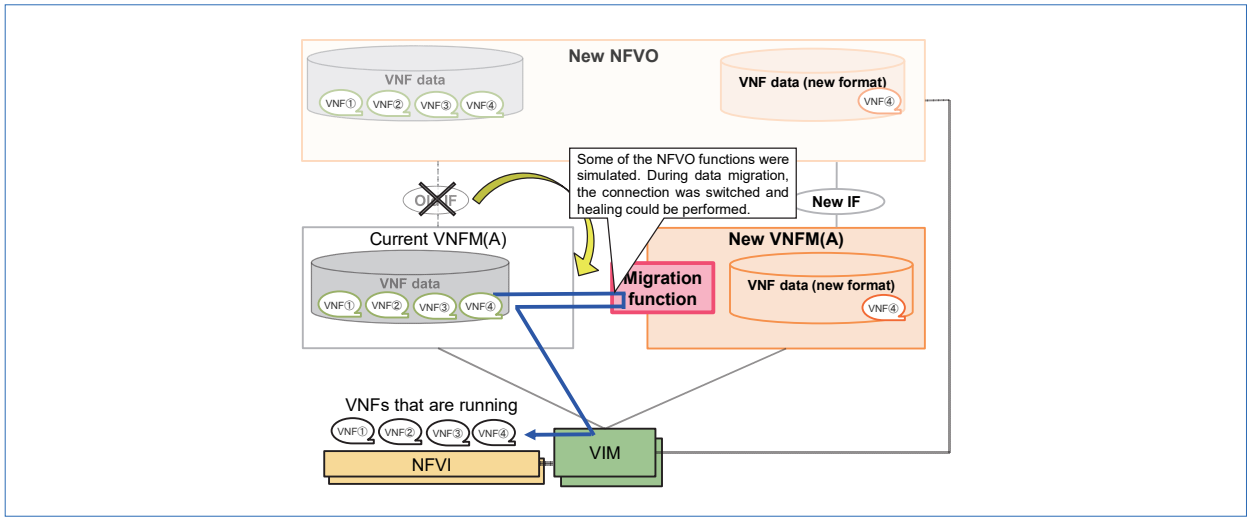

Figure 8 Mechanism for continuing healing during data migration

technician, and a rollback function is provided in case of errors. This makes it possible to revert and retry as many times as necessary, even if an issue occurs due to a VNF package creation error or data failure. In addition, when switching to the new system after data migration is completed, it is possible to switch back to the old system simply by switching networks. These were also used to deal with data correction and quick retries when problems occurred during the verification process,

which led to the completion of verification in a short period of time.

4. Conclusion

This article has described efforts to upgrade NFVO and VNFM on the NTT DOCOMO virtualization platform and a method to perform upgrades without interrupting communications services. This effort has established an upgrade method for NFVO and VNFM, as well as a multivendor environment in which ETSI NFV Stage 3 compliant products are interoperable.

To upgrade in a more efficient way, we will continue to actively contribute to ETSI NFV, collaborate with other operators in an open forum, and encourage vendors towards product commercialization. We also plan to promote and utilize Plugtest*38 [5] to ensure interoperability of multivendor products.

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*38 Plugtest: A joint testing program among various organizations (e.g., product vendors) performed in ETSI NFV to accelerate NFV adoption and interoperability.