Technologies for Automating Network Development and Management in Cloud Era

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Cloud systems continue to grow as smartphones and cloud services become more prevalent. While their operation management has become highly automated by leveraging software technology, automation has not advanced in terms of building and managing networks. For example, software-defined networking (SDN) has only been partially adopted within cloud system networks despite its anticipated potential for automating network management by using software definition technology. Meanwhile, existing networks such as enterprise networks still need to be constructed manually and managed by experts. Pursuing the automation of network management, Fujitsu has been proactive in SDN-related activities, introducing it to businesses and telecommunication network carriers and participating in various communities related to open source software. This paper describes an end-to-end network design and development technology, which we have developed for automating network management. It also introduces a traffic abnormality detection technology designed to automatically identify abnormal network activities through AI-enabled data analysis. In addition, it explains about the Fujitsu Network Virtuora series, which uses these technologies to realize the automation of network management.

1. Introduction

Cloud systems that process a huge number of requests from devices such as smartphones are becoming ever larger and more sophisticated. Operation and management of huge cloud systems are costly and labor-intensive. As a solution, operation automation leveraging software technology is increasingly being used.

Meanwhile, automation of network construction and operation management has not progressed. Around 2009, research and development of flexible network service construction and operation automation, such as software-defined networking (SDN) and network functions virtualization (NFV) began. While these technologies are used for part of the network in the cloud and major telecommunications network carriers, most enterprise networks and the like are still dependent on manual configuration and expert management.

Fujitsu has actively been working in the area of SDN/NFV to promote automation of network construction and operation and management. In the area of SDN, Fujitsu has been dispatching researchers to the Open Networking Lab (ON.Lab) in the U.S., which is open-source community of SDN controllers for telecommunications network carriers, and it participates in the development of Open Networking Operation System (ONOS).[1] Further, Fujitsu develops SDN controllers based on OpenDaylight[2] at the Linux Foundation. The use of open source software is spreading not only among telecommunication network carriers but also among enterprise users, and activities in this area are important. In the area of NFV, we are making proposals for the establishment of standards to the European Telecommunications Standards Institute (ETSI), and we are developing NFV products based on standards. In recent years, we have also been participating in the Open Network Automation Platform (ONAP),[3] one of the open source projects of the Linux Foundation, and we have released software code for the project.

This paper describes technologies to realize automation of the network operation integrated with cloud systems. Further, it introduces operation automation technologies applied in the Fujitsu Network Virtuora series, Fujitsu's carrier scale network operation and management products.

2. Challenges for network operation automation

The following are some of the reasons why operation automation of networks is not making advances.

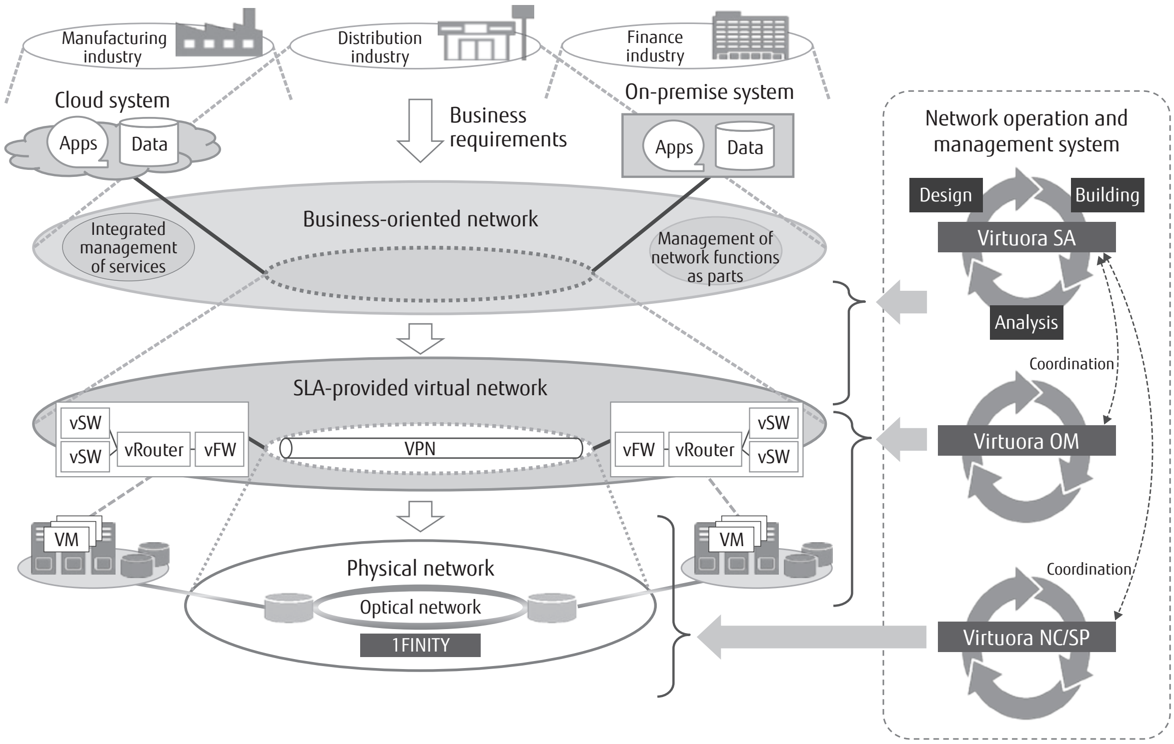
1) The network equipment used varies widely depending on its purpose.
2) The format of the configuration files in which the device setting information is described varies from vendor to vendor.
3) There is no unified interface for network equipment settings.
4) Like for enterprise networks, network construction according to each user's specific requirements is needed.

For these reasons, the operation and management of networks depends greatly on user-specific requirements and experts who are familiar with each network device. As a result network-specific operation and management on individual networks is widespread.

Meanwhile, with the evolution of cloud services, coordination of enterprise business systems in the cloud is becoming the mainstream. However, the coordination of information systems has not changed the fact that the network between the cloud system and the on-premise system at the site is important infrastructure. At present, operation management of the cloud system and the network system are independent and it is a factor that operation management costs increases from the viewpoint that seamless system operation can not be performed. Therefore, end-to-end network operation management including cloud systems is required.

3. Problem-solving points

We devised an architecture that makes it easier to automate the operation of the entire network by dividing the network connecting the cloud and on-premise system into three layers (**Figure 1**). Dividing user requirements in three following layer allows fine-tuned measures. Moreover, the various layers can collaborate to optimize the entire system.



1FINITY: Fujitsu's transport equipment
vSW: Virtual switch
vRouter: Virtual router
vFW: Virtual firewall
VPN: Virtual private network
VM: Virtual machine

Figure 1
Three-layers network architecture of operation management.

1) Business-oriented network

A network tailored for specific tasks that connect the cloud and an on-premise system and run business applications is defined as "business-oriented networks." It has the function of managing lower-layer virtual network functions (vFW, etc.) as parts, and providing the network functions required for business by combining those parts.

2) Virtual network

A virtual network is a logical network constructed on a physical network, and it provides the network functions required for business parts. To this end, it implements network functions as virtual network functions (VNF). Moreover, mapping physical network resources to virtual networks allows the provision of detailed service level agreements (SLAs) for individual tasks.

3) Physical network

A physical network is a network composed of routers, switches, transmission equipment, etc.

By coordinating this three-layers network operation management system, user requirements can be met in a detailed manner. For example, when it is necessary to make changes to a network due to relocation of a department, changing the address and functions of the physical network takes much time. In this regard, using logically separate virtual networks makes it easy to respond by simply making configuration changes and making VNF additions. Further, dealing with the need for greater network capacity due to the introduction of new services through virtual networks alone meant being limited to best-effort quality. In this regard, reliable quality can be provided through management in cooperation with physical network resources.

The following sections describe technology for the end-to-end design and construction of cloud networks as well as traffic change detection technology that analyzes data using AI for automatic detection of network abnormalities.

4. End-to-end network design and construction technologies

This section describes three technologies for automatically constructing end-to-end networks that connect the cloud and on-premise systems.[4)]

1) Infrastructure abstraction technology

This is a technology that abstracts different infrastructures elements such as cloud, on-premise systems, and wide-area networks to build a virtual network. To manage these elements in a unified manner, virtual network objects with network functions not linked to physical devices are used.

This technology maps virtual network objects to a plurality of network infrastructure elements. By simply designing a logical network on a virtual network, users can easily design, build, manage, operate, monitor, maintain, and discard virtual networks. Further, users need not be aware of virtual private network (VPN) connection relationships among the various network infrastructure elements. Business-oriented networks can then be built using these virtual network objects.

2) Automatic supplementation technology

This is a technology to automatically supplement virtual network objects that are missing from a virtual network during logical network building. When a user connects subnets in the cloud and on-premise system with a router, this technology automatically supplements the missing virtual switch (vSW) and VPN functions.

3) Technology for automatic construction of virtual networks

This is a technology that builds networks by mapping virtual network objects to network infrastructure to ensure proper performance and security. To appropriately deploy virtual network objects, the attribute information of devices and applications is collected via gateways installed on-premise or the like. Then, to achieve the predetermined SLA in accordance with environmental changes, which virtual network objects to assign to which infrastructure resources is determined.

5. Traffic change detection technology

Collecting and analyzing the amount of traffic flowing in the network, the logs obtained from devices, and so on, to monitor the health of the network is the first step for operation automation. The number of objects to be monitored has increased in proportion to the scale of the network. Moreover, with the increasing diversification of network services, traffic characteristics are also changing in a complex manner. For these reasons, the feasibility of manually analyzing and judging the state of network has reached a limit.

In recent years, network analysis technology that uses deep learning, a field of AI technology, has advanced remarkably, and expectations for more efficient and advanced network operation management are also increasing. We are working on traffic change detection technology that analyzes data collected on the network through AI technology and automatically detects network abnormalities.[5]

The backbone network that connects the sites of a company generally consists of leased lines provided by telecommunication network carrier as shown in **Figure 2 (a)**. As such networks are not created by the companies that use them, they are very much a black box to those companies. Therefore, when an abnormality occurs on a network of company, it is difficult for the company to determine whether the cause of the abnormality lies in the network of the company or the backbone network managed by the telecommunications network carrier.

To address this issue, we have developed traffic change detection technology that employs deep learning and uses as learning data the input traffic volume from sites to the backbone network and the output traffic volume from the backbone network to the sites.[6] We used average transmission and reception traffic measured at 5-minute intervals as learning data, and the average data of the five days prior to the prediction target date as training data. As the deep learning parameters, the number of units in the input and output layers, it was set to 26 and in the hidden layer was set to 30, and the number of hidden layers was set to two layers.

Figure 2 (b) shows traffic prediction results using year-end traffic data as an example of taking advantage of the highly accurate learning ability of deep learning. By way of comparison, the prediction results obtained with the change detection method using autoregressive integrated moving average (ARIMA), which predicts periodicity and trend components from past traffic volume data, are also shown in that figure. Whereas prediction by ARIMA showed large deviation from actual measurement past 3 p.m. on December 28, the last work day of the year the proposed traffic change detection technology yielded prediction results that closely approximated

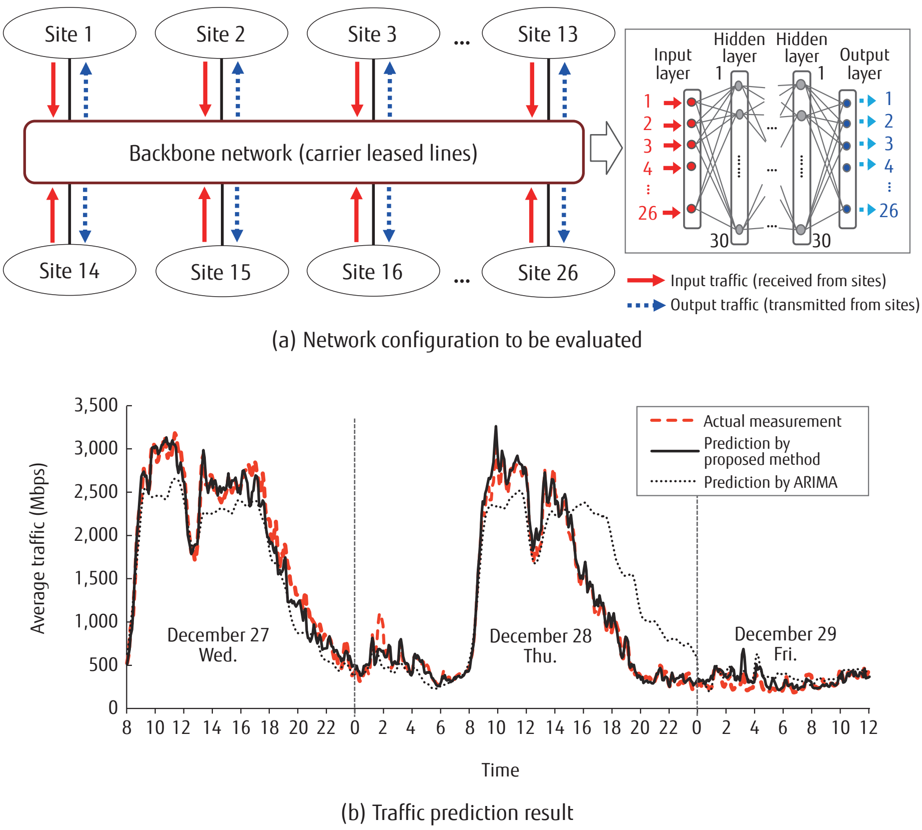


Figure 2
Traffic change detection using deep learning.

the actual measurement results. Thus, the proposed method can deal with events that differ from the usual without additional processing.

The interpretation of prediction basis through deep learning is currently being studied. When the correlation of traffic among various sites is strong, highly accurate predictions can be made. This technology allows automated traffic monitoring with less false detection even in large-scale networks where detailed internal information cannot be obtained. As a result, it can reduce the burden on network operators and speed up troubleshooting.

6. FUJITSU Network Virtuora

Fujitsu has commercialized the FUJITSU Network Virtuora series as software for the integrated management of virtual networks and physical networks for the purpose of providing business-oriented networks and achieving network operation automation. Through this, integrated operation management across three layers (hereafter, operation lifecycle) is realized.

6.1 Service orchestration: Virtuora SA

FUJITSU Network Virtuora SA powered by UBiqube (hereafter, Virtuora SA) easily realizes integrated operation and management of various network devices and security devices including virtual appliances, as well as various services, in the business-oriented network layer.

Operation in a vendor neutral integrated environment is achieved by using a management mechanism that abstracts differences in equipment operation and management among vendors and operation management differences among different versions of the same equipment. Moreover, the replacement or addition of equipment has only a local influence on operation, which makes changing the configuration of user systems easy.

Virtuora SA provides a mechanism that converts the operation workflow of users into scenarios that can be executed automatically. All these things can be achieved by using the microservices of the equipment management and business flow prepared in advance in the software package. In this way, it is possible to define business flow scenarios without the need to be aware of differences among equipment, and this allows flexibility when building automatic execution environments for business flows.

Furthermore, Virtuora SA provides other functions such as integrated log management, portals for network operators and end users, and multi-account and tenant management. **Figure 3** shows the image of integrated operation and management by Virtuora

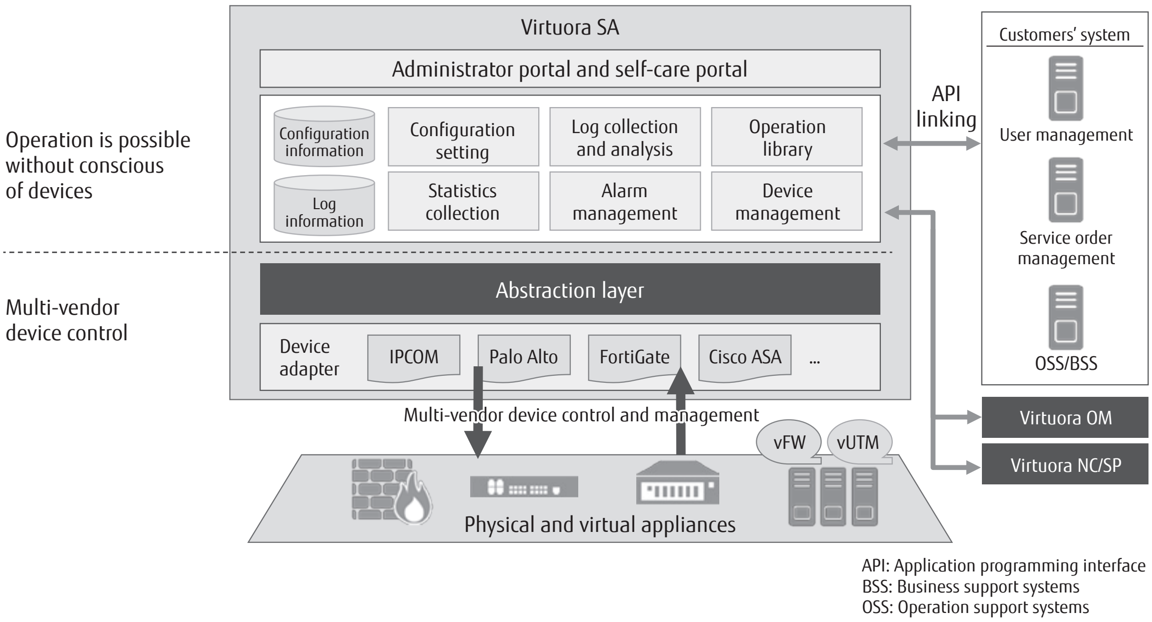


Figure 3
Integrated operation and management by Virtuora SA.

SA. Finally, as the result of work automation, beneficial effects such as the elimination of work errors, reduction of operation costs, and shortening of the service introduction period, can be expected.

6.2 Operational lifecycle automation and ICT virtualization platform: Virtuora OM

FUJITSU Network Virtuora OM is software that connects applications according to users' requests in the virtual network layer and virtually builds and operates network services. In the ETSI NFV architecture, it covers NFV orchestrator (NFVO) and VNF manager (VNFM). Note that VNF functions well even if it is installed in a low-priced server such as an Intel architecture (IA) server.

Virtuora OM realizes chaining of network services combining multiple applications such as vSW, vFW, and virtual unified threat management (vUTM), which are all implemented in the virtual space of the cloud network. This requires no special header processing and can be done by using existing layer 2 switches (L2SW). Further, by defining deployment conditions in the configuration definition of applications, efficient deployment of resources independently from the environment is possible. **Figure 4** shows the image of NFV orchestration by Virtuora OM.

Virtuora OM has an auto scaling function that monitors the status of the CPU, memory, hard disk, and so on, and scales out the processing performance according to the load on the virtual machine (VM). It has also an auto healing function that automatically restores services in a short time when a VM fails or restarts. These functions simplify user operation procedures and improve reliability.

6.3 Service-oriented network optimization control: Virtuora NC

FUJITSU Network Virtuora NC is software for managing and controlling wide area networks that is based on an open platform, and has the following features.

1) Multi-vendor and multi-layer support

Virtuora NC provides a mechanism that allows

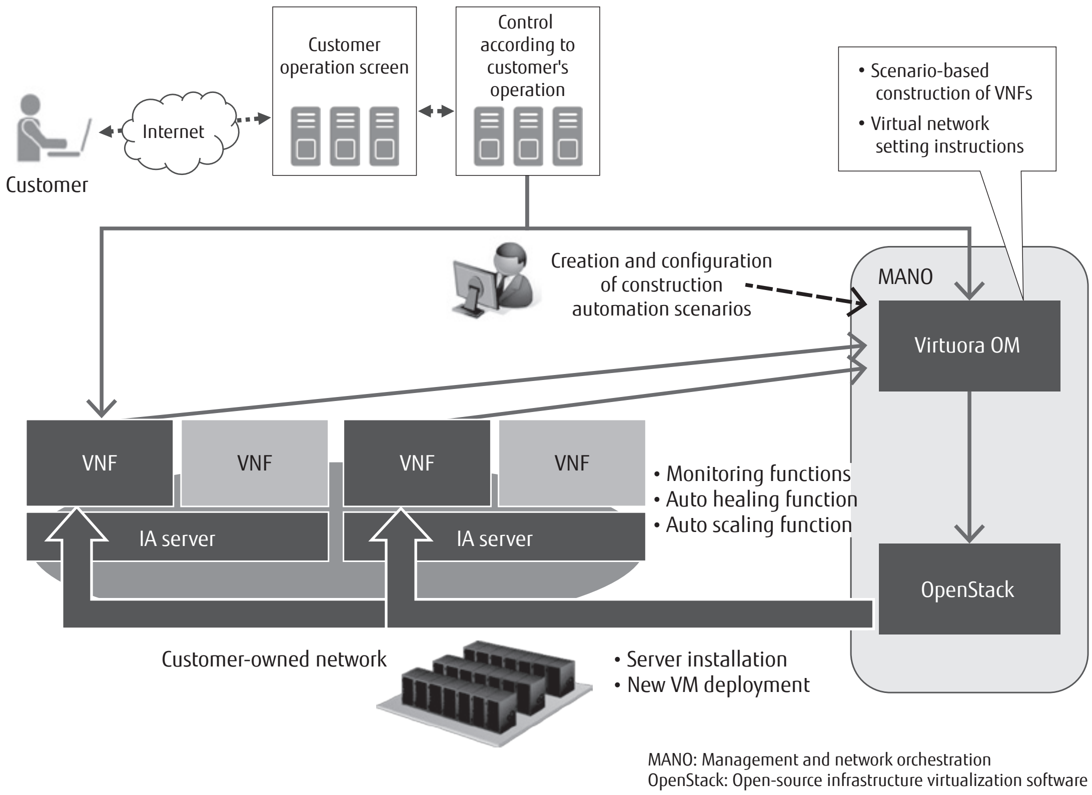


Figure 4
NFV orchestration by Virtuora OM.

management of networks and devices across multiple layers such as wavelength division multiplexing (WDM), optical transport network (OTN), and packet layers, reducing the burden on the operator. Moreover, the standard open reconfigurable optical add/drop multiplexer (Open ROADM)[7] is supported, allowing monitoring and control of other vendors' devices that have this interface.

2) Pursuit of operation automation

Until now, changing the configuration of a wide area network was a complex task involving device-specific settings. This was avoided by designing easy-to-understand settings that allow even administrators who do not have expert knowledge to design optimum paths. In addition, through cooperation with Virtuora SP, which will be described later, complex and time-consuming tasks can be made into scenarios in advance, and these scenarios can be run as needed to realize operation automation. **Figure 5** shows the configuration of wide area network automation by Virtuora NC and Virtuora SP.

3) Cooperation through open source design

The adoption of an open platform makes it possible for multiple systems until now operating separately to easily cooperate with each other, thereby forming one big ecosystem. The aim is not only to improve the efficiency of operation and maintenance but also to create new services.

6.4 Automation of routine tasks: Virtuora SP

FUJITSU Network Virtuora SP scenarioizes know-how regarding the operation and maintenance of server, storages, and networks and thereby realizes automation by software. This greatly speeds up the delivery of services to users while reducing operation costs. Further, the automation of tasks that heretofore used to be done manually, such as the operation of equipment, the collection of logs, and resource management, improves the quality of operation and maintenance work through the reduction of work errors.

Automation work flow policies (hereafter, policy) usually must be written in a programming language. Virtuora SP adopts a flow style that complies with business process modeling notation (BPMN) for making descriptions with GUI based policy design tool. This makes it easy for service planners and operators to create policy definitions, a task that had previously been entrusted to developers. This allows also easy customization and fine-tuning of policies according to

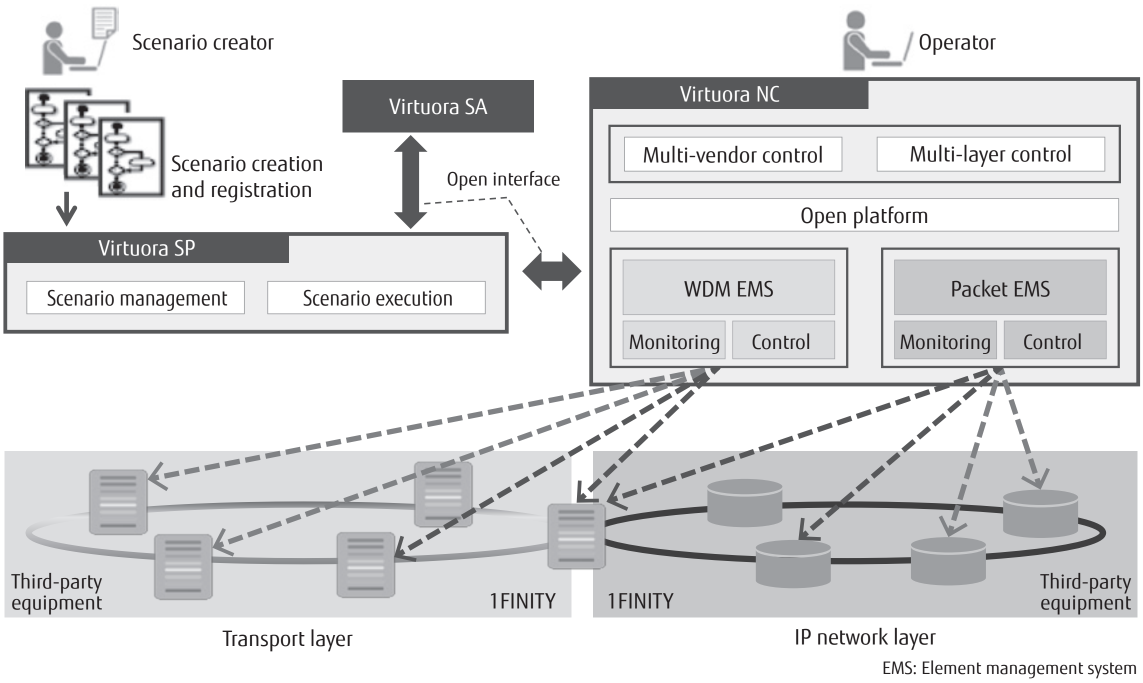


Figure 5
Wide area network automation by Virtuora NC/SP.

the demands of the operation site.

Usually, Secure Shell (SSH)/Secure Copy (SCP) and Representational State Transfer (REST) are used as control interfaces of network devices and systems. By using a simulator function, even if it is difficult to prepare network equipment and systems, we can verify the created workflows.

7. Conclusion

This paper described end-to-end network design and development technology and analysis technology for automating network management, including various challenges and the cloud. Further, it introduces the FUJITSU Network Virtuora series, a product aimed at network operation automation, and implemented operation automation technology.

Going forward, Fujitsu will continue working on the automation of network operation while making use of open-source software.

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