Visualization Technology for Flow-based Networks and Communication Services

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The huge volume of communication requests experienced immediately after the Great East Japan Earthquake in 2011 made it impossible to provide communication services with the usual quality. An effective approach to absorbing such congestion would be to implement a communication infrastructure based on server virtualization that could effectively provide the communication resources needed to match demand. Additionally, the transport networks connecting the communication resources in the affected areas were severely damaged, which prevented the provision of sufficient communication paths. An effective approach to using communication paths more effectively even under such conditions would be to use a more flexible routing method, such as flow-based routing. Flow-based routing is also effective for dynamically changing routes in accordance with changes in communication resources. At the same time, there is a need for visualization technology to accurately visualize the operation status of such dynamically reconfigurable virtual resources and to facilitate the operation of services. Methods are thus needed to construct logical representations for resources (separate from physical representations), to enable resource status to be grasped by filtering only quality-related information on specific services, and to visualize massive traffic flow in a form understandable by operators. This paper summarizes the operation of a communication system constructed with such dynamically reconfigurable communication resources. It also presents the problems in managing the configuration of a flow-based control network and describes Fujitsu's development of visualization technology to solve these problems.

1. Introduction

The Great East Japan Earthquake in March 2011 resulted in the generation of about 60 times the usual number of communication requests in the Tohoku region and about 50 times that even in Tokyo's 23 wards.[note)] This spike in communication needs presented a major obstacle to providing stable communication services.[1)] An effective means of mitigating network congestion at such a challenging time is to apply server virtualization technology to the communication infrastructure so that communication resources can be increased or decreased dynamically.

The transport network interconnecting communication equipment at each network hub was also heavily damaged at the time of this earthquake, resulting in the inability of some hubs to establish sufficient communication paths. The introduction of a flow-based network[2)] providing flexible path control in a disaster-stricken transport network should result in the effective use of the surviving communication paths and mitigate bandwidth shortfalls. A flow-based network can also be used to track increases and decreases in communication resources and to change paths in order to free resources accordingly.

This paper discusses problems surrounding dynamic control of communication resources and the management of a flow-based network and introduces solutions to these problems using Fujitsu's server virtualization technology.

note) The epicenter was approximately 170 km (105 miles) east of Sendai, the most populous city in the Tohoku region, in the Pacific Ocean. Sendai is located north of Tokyo, and the epicenter was approximately 390 km (242 miles) northeast of Tokyo.

2. Problems in operations management

This section summarizes the problems related to operating and managing resources on a communication infrastructure based on server virtualization technology.

2.1 Visualizing communication services

Controls for dynamically increasing and decreasing communication resources can mitigate communication congestion at the time of a disaster through the following process.

1) Allocate virtual resources on a communication infrastructure based on server virtualization technology to a variety of communication services (voice, mail, rich media content, etc.).
2) In normal times, allocate many virtual resources to rich media services that generate large volumes of traffic.
3) At the time of a disaster, reduce the allocation of virtual resources to rich media services and allocate more than the usual number of virtual resources to high-priority voice and mail services. This will increase the capacity of voice and mail services and ease communication congestion.

There is a problem, however, when attempting to operate and manage communication services driven by communication resources for which the configuration can dynamically change as described above: how to effectively determine in real time the relationships among the virtual resources, the hardware housing those resources, and the communication system configured on top of those resources and hardware. There is also a need for a management information model to manage this system configuration.

2.2 Determining virtual resource conditions

Applications for conventional communication systems were developed to run on a dedicated hardware/OS and to extract maximum performance from that hardware/OS combination. As a result, it was the application that actually controlled those resources. In contrast, applications cannot directly control the resources of hardware and the OS for the dynamic control because they are general-purpose products. As a result, application functions are unable to accurately identify free hardware resources. Furthermore, as the location of application deployment is dynamically changing, interference with other applications can be expected, resulting in degraded performance even if the application has resources to spare. Thus, without recourse to applications, determining resource usage conditions becomes a problem.

2.3 Visualizing a flow-based network

A flow-based network typically uses dedicated control equipment to calculate an optimal path for each traffic flow and to set that path automatically. However, when implementing countermeasures to large-scale damage at the time of a disaster or mishap by making use of the features of a flow-based network, deciding on the priorities and on which paths should be selected is important to making full and effective use of the surviving or partially restored network.

The optimal paths cannot be easily calculated, so the only recourse is to rely on the judgment of an operations manager in response to actual disaster conditions. However, the number of traffic flows that need to be managed is in the tens of millions, far exceeding the number that an operations manager can oversee. This presents an operational dilemma.

One approach to solving this dilemma is to simply group a number of flows into meaningful units. This approach, though, is problematic.

1) What kind of units and grouping are effective in flow control at the time of a disaster?
2) How can such virtual grouping be connected to actual packet flows, and how can changes in packet flow caused by failed communication paths and quality degradation be represented?
3) How can virtual entities be visualized, and how can an operations manager deal with the real entities behind the virtual ones?

The following section describes Fujitsu's approach to solving these problems.

3. Fujitsu's approach to visualizing communication services

Achieving a virtual communications system with a dynamically changing configuration requires that two requirements be met in terms of configuration management.

1) The configuration of the virtual communications system must be completely separated from the

configuration of physical resources.

2) It must be possible to place a logical resource on any physical resource.

To meet these two requirements, the basic numbering plan for identifying resources must consist of basic numbers for logical resources and basic numbers for physical resources, and the plan must be managed in a form that allows for mutual conversion between these two types of numbers.

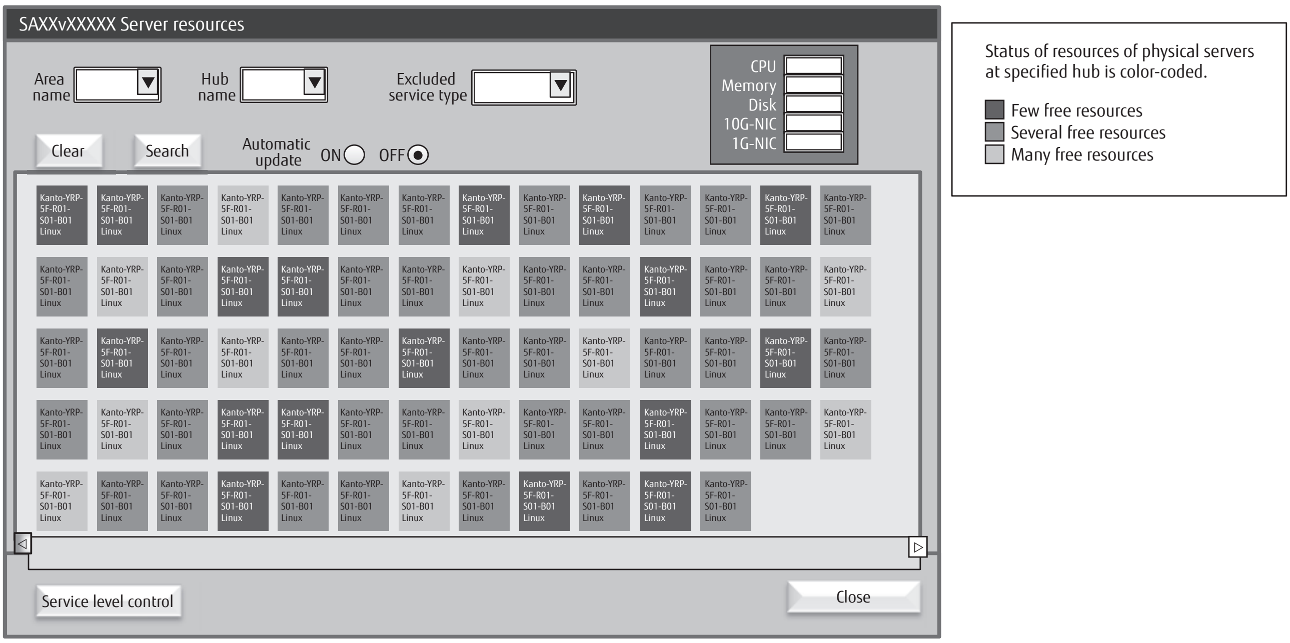
Similar to existing resource management systems, basic numbers for managing physical resources are configured on the basis of physical information such as the area, building, floor, rack, and shelf where the physical resource is installed. Basic numbers for identifying logical resources, meanwhile, are configured on the basis of non-physical information such as service provision area, node type (network function provided by the resource), and unit number (serial number assigned to node or redundant configuration identifier). Mutual conversion can be enabled by managing information on what unit is installed on what virtual machine (VM).

However, it must be kept in mind that the "service provision area" identifying a logical resource is unrelated to the "area" or "building" identifying a physical resource. For example, it would be permissible for a logical resource providing a service for the Sapporo district to exist in the physical area of Tokyo. It is still important, though, to identify the physical area in order to determine and maintain free resources. Thus, when visualizing these physical and logical configurations, it is still necessary to display the associations between physical and logical resources.

Information gathering is performed for the physical and logical resources referenced below to enable current communication-service conditions to be determined. The information gathered in this way is managed by assigning visualization information (labels) to it on the basis of the basic numbers described above. The operations management system performs the following operations at this time.

1) Periodically monitor the configuration and state of physical servers and virtual resources (i.e., VMs) and detect changes in their configurations.
2) Detect hardware faults on physical servers.
3) Perform "dead-or-alive monitoring" of virtual resources (i.e., VMs).
4) Periodically gather performance information on physical servers and virtual resources (i.e., VMs).

Visualization of server resource conditions based on gathered information is shown in **Figure 1**.



*Original is in Japanese.

Figure 1
Virtualization of server resource conditions.

4. Fujitsu's approach to determining virtual-resource conditions

We have introduced external monitoring technology to determine resource conditions without having to rely on the applications themselves. It is obvious that a deficiency arising in certain resources will usually affect services provided by a system running on those resources. It is therefore possible to detect system anomalies by externally monitoring service conditions. Furthermore, it should be possible to visualize the resource conditions of a communication service by detecting degraded performance in a communication application running on a virtual resource.

To check the operating conditions of a service, an operations manager can check its operation at individual nodes and can also perform external monitoring[3] by deep packet inspection (DPI) at appropriate points in the network. Thus, collecting only quality-related information on a specific service and displaying it together with the operating conditions of related resources enable an operations manager to directly and easily obtain an understanding of service operating conditions.

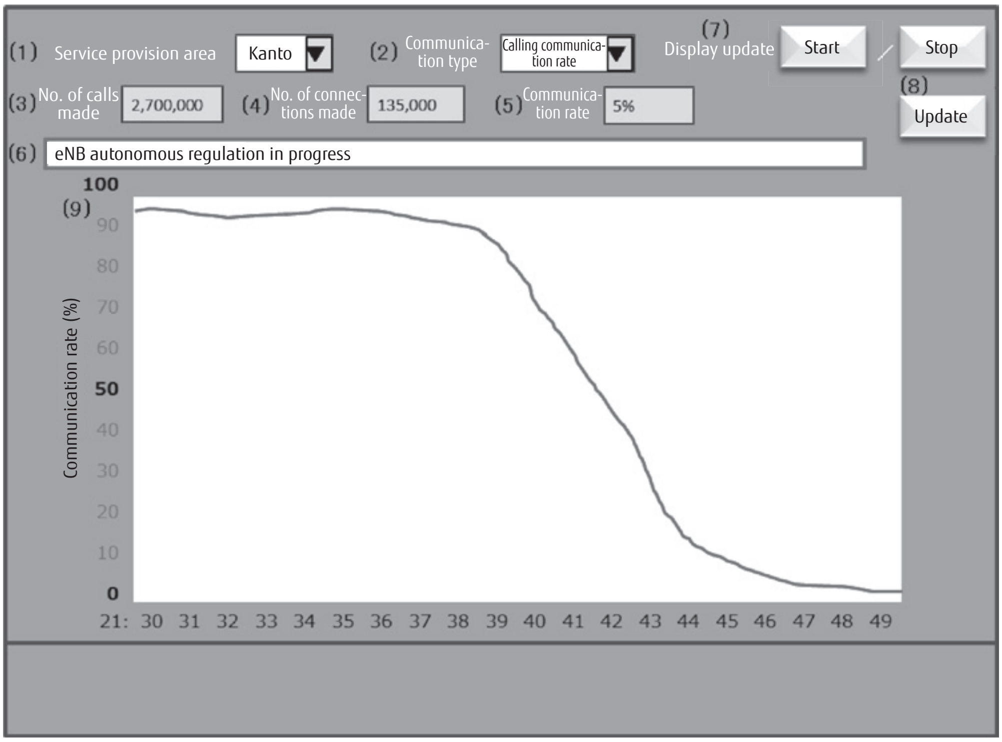
We are now constructing a test bed to emulate a mobile communications network servicing about 500 000 subscribers and plan to measure the following values through packet capture to test whether an understanding of service operating conditions can be obtained.

- Voice communication rate
- Quality of Real-time Transport Protocol (RTP)
- Packet loss/delay in Transmission Control Protocol (TCP) flow for mail and rich media content

A screen shot of a voice-communication-rate display based on data obtained through packet capture is shown in **Figure 2**.

5. Fujitsu's approach to visualizing flow-based networks

A key feature of flow-based networks is the ability to connect the source end point and destination end point of the path (flow) for each packet. However, depending on the network configuration, the number of flows that need to be controlled in this way is of



*Original is in Japanese.

Figure 2
Screen shot of voice-communication-rate display.

the order of one million for a mobile communications network serving 500 000 subscribers. Needless to say, managing each and every flow manually is unrealistic. The usual approach is to have these paths determined automatically by dedicated control equipment. When dealing with large-scale damage at the time of a disaster, however, it is necessary that the operations manager perform path control in accordance with the amount of damage sustained. One idea for meeting this requirement is to simply group a number of flows into meaningful units and thereby reduce the total number of flows.

We have introduced "access flow" as a unit for grouping flows in a mobile access network when visualizing service conditions, changing paths, etc. We have also introduced an access-flow ID in the interface between flow-based control and the operations management system. It consists of the four elements listed below. This scheme makes it possible to identify which hub the access flow comes from, which is information that can be used in priority control for each service.

1) Direction

Indicates whether the access flow is in the uplink or downlink direction

2) eNB group

Indicates the eNB (eNodeB) group formed by the subnet of the IP address in question

3) Node/station

Expressed as the "node + station" ID corresponding to the IP address of the core-side END (equal to IP dst addr for an uplink flow and IP src addr for a downlink flow)

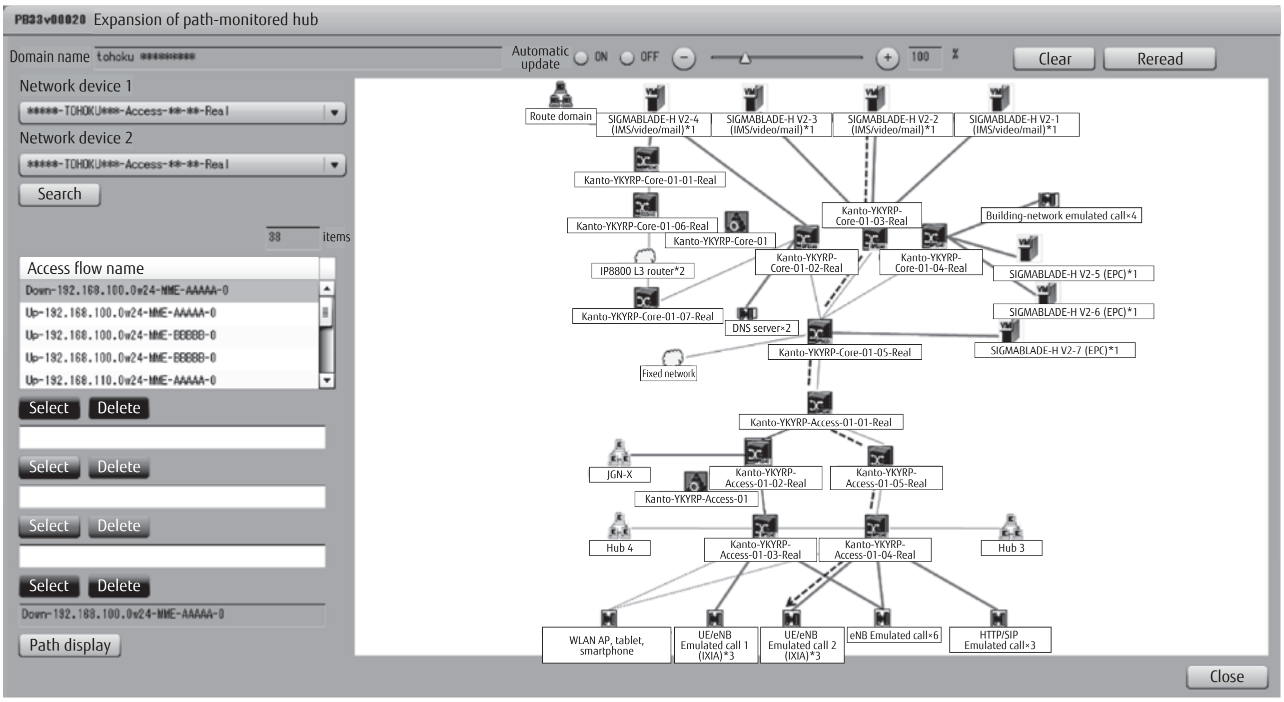
4) TOS (type of service)

Used for identifying a flow in priority control

An example of visualizing path conditions within a hub through access flow is shown in **Figure 3**.

6. Conclusion

Carrier networks need a new operation mechanism and system to deal with the spread of smartphones,



*1 NEC blade server
*2 NEC OpenFlow switch
*3 IXIA call-emulation server
Topology map above is for research test bed developed for Japanese Ministry of Internal Affairs and Communications project.

IMS: IP multimedia system
DNS: Domain name system
WLAN_AP: Wireless local area network access point

*Original is in Japanese.

Figure 3
Visualization of paths within hub through access flow.

the big data revolution (Internet of Things, etc.), new ways of using the next-generation network (software-defined networking [SDN], OpenFlow, etc.) and the introduction of new technologies. Our plan is to use the visualization technology described in this paper to improve availability (to deal with severe damage and ensure operations continuity), to facilitate the next-generation network (via SDN, OpenFlow, etc.), and to incorporate it in a new operations support system (OSS) solutions infrastructure. We expect that this new infrastructure will contribute to the further expansion of the network and to greater operation efficiencies in social systems.

This visualization technology was an outcome of research and development work performed under the "Research and Development to Strengthen Disaster Resistance of the Information and Communications Network" project of the Ministry of Internal Affairs and Communications.

A test bed emulating an actual mobile communications system is currently under construction on the Tohoku University campus. The plan is to use this test bed to evaluate this visualization technology and uncover any problems in actual operations.

References

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