Dynamically Reconfigurable Network Nodes in Cloud Computing Systems

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Abstract

As communication uses broader bandwidths and communication needs become diversified, a wide variety of equipment is introduced into network infrastructures. In the cloud computing environment, it is essential to support services that frequently occur and the changing requirements. The dynamic reconfiguration technology realizes the network nodes with excellent performance scalability and functional scalability supporting the cloud computing environment. Further, this technology is also applicable to the middlebox virtualization enabling performance scale-out and system optimization.

Keywords

dynamic reconfiguration, network nodes, middlebox, flow switch

1. Introduction

As communication uses broader bandwidths and communication needs become diversified, it is required that the configuration is dynamically changeable in real time and high efficiency according to service change requests that frequently occur in cloud computing, instead of traditional feature-oriented nodes. This paper introduces the node architecture that is dynamically reconfigurable to support such requirements and an example of application to its front end system.

2. Requirements for Network Nodes and Systems

2.1 Issues in Traditional Network Nodes and Systems

Fig. 1 illustrates the issues in network nodes and systems using a traditional data center network as an example.

First, terms used in this paper are explained. Network nodes are defined to be the elements constituting the network such as communication equipment including the router and switch as well as appliance equipment including the bandwidth control device and load balancing device. The network system means a system consisting of network nodes. For example, it is the data center network illustrated in Fig. 1.

Now, we will explain the issues in network nodes. Traditional network nodes are designed to support the maximum speed of the communication line. Therefore, even though the actual traffic is low, nodes with the maximum performance must be deployed. As a result, the equipment cost increases as an issue.

Additionally, to reserve flexibility of network nodes according to the diversified communication needs, realizing the network process on a general-purpose server can be considered. However, for many communication processes, the general-purpose server alone does not have sufficient performance and functions, and in terms of performance, it is hard to achieve the required performance as an issue. Further, power efficiency is low in the communication process on the general-purpose server as another issue.

Against such issues, an architecture is offered that realizes high-speed and flexible nodes by closely combining the dedicated processing resource such as the hardware engine with a general-purpose processor. For example, there is a form that connects a dedicated hardware engine board to the general-purpose server via the internal bus. However, such an architecture has been applied to a specific application. Although the issue in performance can be solved, it is hard to change the configuration dynamically according to changes in requirements as an issue. For the hardware engine achieved with FPGA, etc., there are issues in rapid support for new requirements and functional flexibility in terms of development man-hours.

Next, we will explain the issues in network system configuration. To meet various requirements that vary depending on the cloud, it is considered, using existing technologies, to connect middle boxes such as the load balancer and firewall to the server and storage for support. However, there is a problem that freedom in configuration changes is low for such systems. For

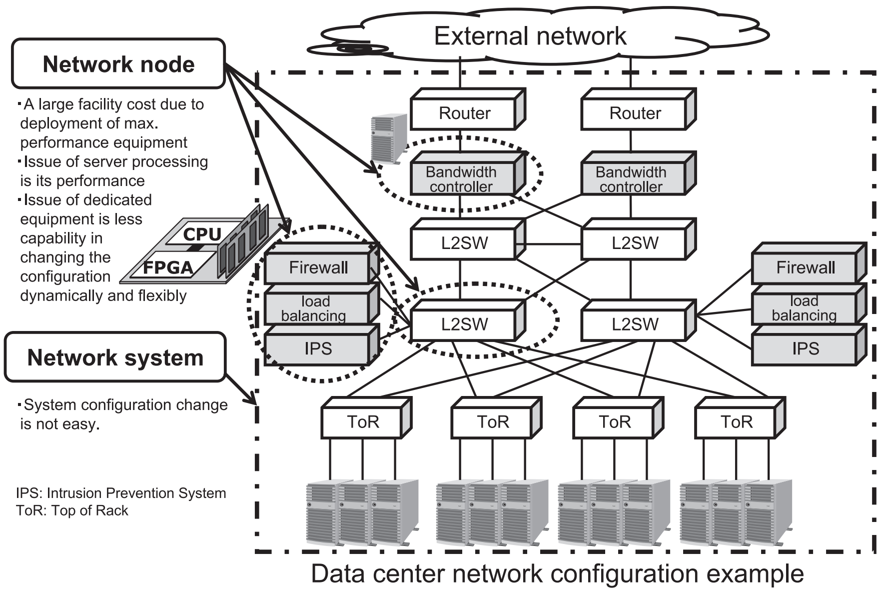

Fig. 1 Issues in network nodes and systems.

example, if middle boxes are being introduced to an existing network, network physical connection and setup must be changed. Therefore, the network is re-designed typically in advance consideration of effects to the network, then the configuration is changed along with service shutdown. Since this is accompanied by physical connection changes, man-caused failures may occur. Due to such reasons, the traditional network systems cannot accommodate the situation in which requirement changes occur frequently as an issue.

2.2 Requirements

To solve such issues, network nodes and systems must meet the following requirements:

(1) High-speed Network Process

As a result of mobile access speedup with optical access and WiMAX (Worldwide Interoperability for Microwave Access), 10Gbps communication processing performance is required on the nodes deployed in the core network where communication is consolidated. Since such network nodes contains many users, it is necessary to identify them and execute proper processes. Although performance reserved for individual processes by applying technologies such as load balancing, common processes such as user identification must be performed at a high speed.

(2) Performance Scalability

Traditional network nodes have an architectures assuming the maximum use of communication line bandwidths. New network nodes require an architecture that balances the load and is capable of scaling the performance through addition of features, according to the traffic in the communication line. Such a scheme enables power off of unnecessary physical machines, so it is considered that power optimization for network nodes can be attempted.

(3) Functional Scalability

Along with diversified communication needs, the network infrastructure is required to promptly provide for new communication processes. Under such circumstances, network nodes and systems require a configuration-changeable architecture that can support various needs while adding new features. It is also important that new features can be immediately added without effects to existing services.

(4) Reliability

The network infrastructure plays the role of a social infrastructure and it is indispensable to users' life. For the network as a social infrastructure, it is considered that different reliabilities may be required depending on the service because users' convenience may be enhanced in some level or various services such as mission-critical e-commerce and companies' mission-critical tasks may be required.

3. Dynamic Reconfiguration in Network Systems

The dynamic reconfiguration technology supports the network system requirements described above. If processes are represented by coupling of disassembled features, dynamic reconfiguration of network system has four elements; feature addition, deletion, moving, and connection change as illustrated in **Fig. 2** .

(1) Feature Addition

Feature addition means to add a new feature and reconnect features with each other according to the new feature added or a request for changing the process content. For performance enhancement, a copy of a feature may be made for load balancing.

(2) Feature Deletion

Feature deletion means to delete the unnecessary feature and reconnect features with each other as a result of requirement changes, etc. In load balancing against multiple features for performance enhancement, features may be reduced depending on the load.

(3) Feature Moving

Feature moving means to change the physical resource on which a feature is deployed to another physical resource and reconnect features with each other. Causes for feature moving considered are, for example, system optimization integrating a feature running on multiple physical machines into a machine for power saving, the failure of the physical machine on which a feature is deployed and optimization of the delay due to requirement changes.

(4) Connection Change Not Accompanied by Feature Change

Connection changes in (1) through (3) are accompanied by a feature change such as addition, deletion, or moving. Connection change not accompanied by feature change means that connection change only is performed according to requirements when multiple feature connections are available for configuring the process. For example, this corresponds to the case in which the process is duplicated.

4. Dynamically Reconfigurable Network Node Architecture

This section introduces the dynamically reconfigurable network node architecture. **Fig. 3** illustrates the dynamically reconfigurable network node architecture. This architecture is made by coupling a multi-core processor for network with a general-purpose server using a flow switch. As the flow switch, a programmable flow switch adopting the OpenFlow technology for the interface between the data transfer unit and control unit.

The dynamically reconfigurable network node consists of 1) Flow identification process that identifies the process to be applied to the received packet, 2) Processing resource that executes the feature consituting the process, 3) Switch feature (flow switch, inter-core switch, virtual switch (vswitch) that realizes flexible connection between features, and 4) Node management that manages the process as a feature connection and performs feature deployment and connection control collaborating with node resource management. The network

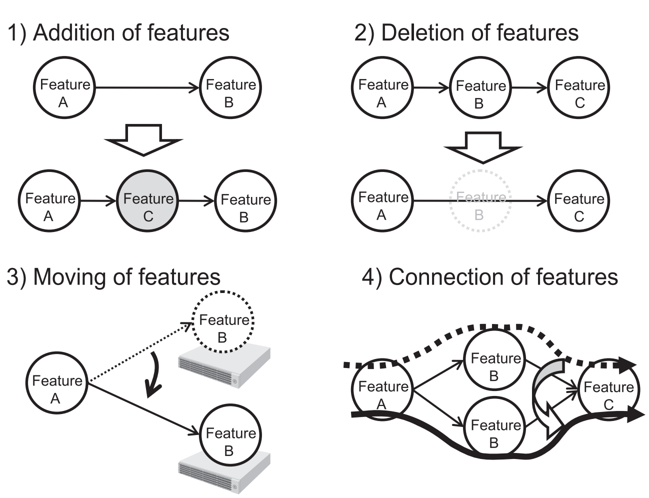

Fig. 2 Dynamic reconfiguration.

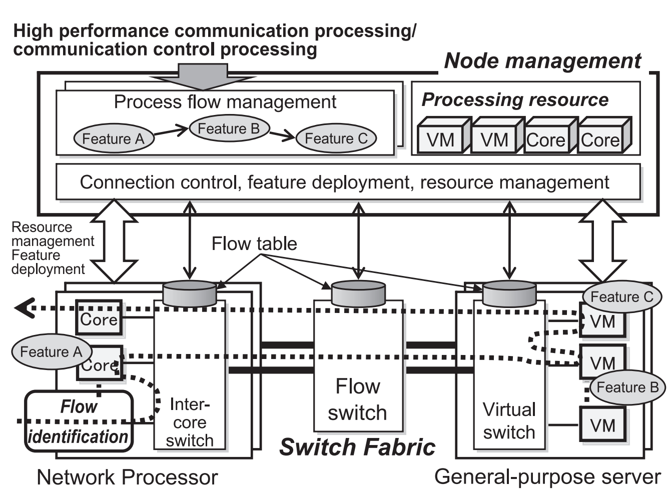

Fig. 3 Dynamically reconfigurable network node architecture.

node being offered manages the process with feature coupling, allocates each feature to the processing resource, and controls the connection between features to realize dynamic reconfiguration. Each feature runs as software on the virtual machine (VM) running on the general-purpose server or in the processor core of the multi-core processor for network.

Fig. 4 illustrates the operation flow of the network node being offered. The process provided by the node is managed as a process flow that is a connection between features. Each feature is allocated to the virtual machine or processor core in collaboration with resource management. Information on the connection between features is converted into the transfer information of the flow switch inside the node and registered in the flow table according to the feature deployment result. Information for identifying the user and determining the service to be applied is stored in the table of the flow identification unit. The process flow management information is updated according to the change in service requirements. According to the updated management information, the node management unit allocates the feature in the node or reconfigures the connection between features.

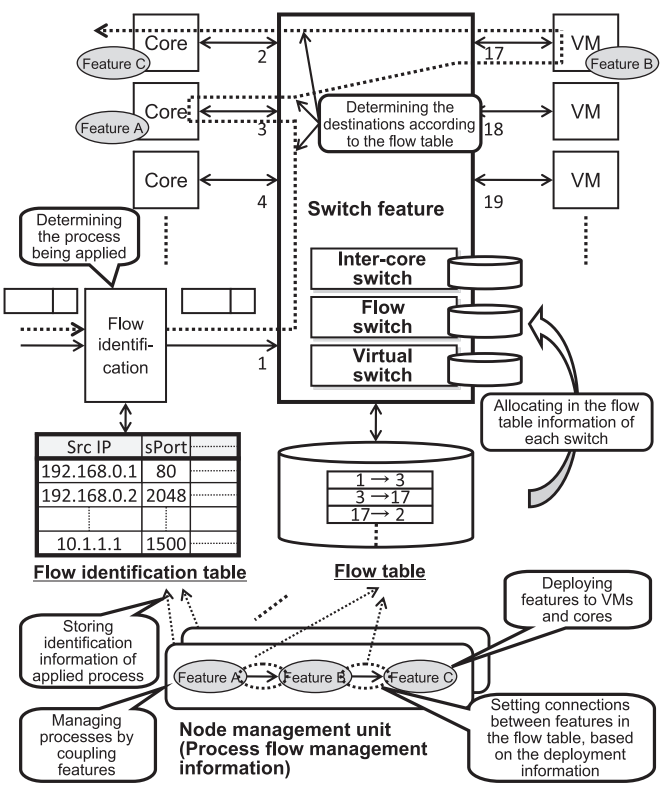

Fig. 4 Operation flow of the dynamically reconfigurable network node.

In the example illustrated in Fig. 4, the process flow consists of coupling features A, B, and C together. The process flow management information is divided into the setting of the flow identification process table for identifying the process to be applied and the setting of the flow table for controlling transfer, then they are registered in respective tables. On the network node, the flow identification process determines the process to be applied to the received packet on this node. Based on the flow table, the packet is transfer by the flow switch based on the flow table and the process is executed in the order of features A, B, and C.

Fig. 4 shows the flow table is shown for the switch feature integrating the inter-core switch, flow table, and virtual switch. However, it is actually allocated and set in the flow table information of each switch.

NEC is conducting research and development on the high-speed flow identification technology, virtual switch technology, and the node management technology including process flow management technology as the element technology for the dynamically reconfigurable network node being offered by this paper. Further, NEC is proceeding with research activities to establish the dynamically reconfigurable network node based on the element technology.

5. Application to the Middlebox Virtualization

As an application of the dynamic reconfiguration technology, an example of middlebox virtualization is introduced below.

In the network of data centers or the like, middlebox such as firewall, load balancer, bandwidth controller, etc. are deployed as appliance devices in addition to the L2/L3 forwarding process by the switch. The network must be designed based on the information about application of the features in what order, so changes of deployment of the equipments are not easy after operation is started. Therefore, it is necessary to install the equipment with a sufficient margin based on the estimation of the performance that will be required in the future. As a result, the equipment cost increases as an issue.

For virtualization of the middleboxes, multiple appliance devices are managed as a virtual device. Then, the reconfiguration process is enabled to add or delete physical appliance devices to or from the virtual device according to the

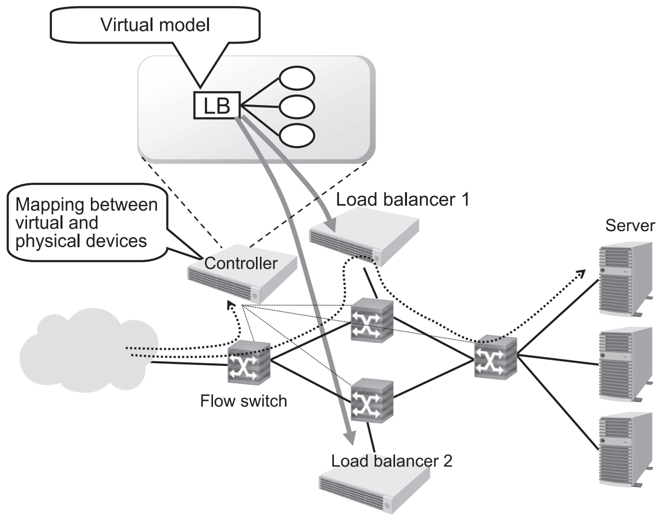

Fig. 5 Virtualization of the middlebox.

performance requirements.

Fig. 5 illustrates the configuration overview. In this example, the switch controller manages load balancers 1 and 2, which are physical appliance devices, as the virtual load balancers. When packets of a new flow arrive at the flow switch, they are fed to the switch controller to identify the transfer destination. The switch controller determines the load balancer to which the input flow to be mapped based on the virtual load balancer information. According to the performance and feature defined on the virtual device, the controller controls the connection relationship about the destination physical device for packet transfer to realize the dynamic configuration change for the virtual device.

This dynamic reconfiguration process allows for attempting performance scale-out for the virtual device or optimization of the physical processing location in the network system. Thus, improvements in use efficiency of the network bandwidths and device resources, as an issue on the data center network, are realized.

6. Conclusion

This paper analyzed the issues on traditional network nodes and systems and introduced the research about the dynamically configurable network node architecture that can accommodate service change requests that frequently occur in cloud computing.

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