Research and Development on Autonomic Operation Control Infrastructure Technologies in the Cloud Computing Environment

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Abstract

As the cloud computing environment spreads, importance of IT/network resource operation increases. For example, swiftness of configuration changes and flexibility of resource deployment are required. Therefore, this research and development has proceeded with research on the new autonomic operation control information network architecture, route information sharing technique, and virtualization equipment profiling technology. By interlocking these mutually, realization of the autonomic operation control infrastructure in the cloud computing environment is aimed.

Keywords

autonomic operation, autonomic control, Publish/Subscribe
information sharing, route control, profiling

1. Introduction

As the cloud computing environment spreads, importance of IT/network resource operation increases. For example, swiftness of configuration changes and flexibility of resource deployment are required. Therefore, this research and development has proceeded with research on the new autonomic operation control information network architecture, route information sharing technique, and virtualization equipment profiling technology. By interlocking these mutually, realization of the autonomic operation control infrastructure in the cloud computing environment is aimed.

2. Research and Development on the Autonomic Operation Control Infrastructure Technology in the Cloud Computing Environment

2.1 Entire Picture of the Research and Development Project

In the cloud computing environment, changing in the resource volume or configuration according to the users' needs is required. To meet these requirements, it is necessary to build the autonomic operation control technology for rapid optimization of the resource volume and configuration by the IT/network system itself according to the situation through mutual linkage of respective tasks in addition to automation of individual tasks for observation, analysis, support, and control.

To achieve this autonomic operation control technology, we undertook three research tasks. For the first task, we focused attention on reduction in the information transfer delay. For rapid linkage of observation → analysis → decision → control, reduction in the information transfer delay is required. Therefore, we conducted research and development on the autonomic operation control information network architecture utilizing the OpenFlow technology and on its information transfer mechanism.

For the second task, we addressed the route information sharing approach in network route control. To set the optimum route rapidly, it is necessary to reduce the load while maintaining the route control accuracy. Therefore, we conducted research and development of the autonomic operation control information sharing platform that reduces the volume of information to be handled to the extent that the route control accuracy is not affected.

For the third task, we focused on improvement in stability of the network control server. To run the network control server stably, it is necessary to select the virtual equipment that is capable of absorbing the load fluctuation. Therefore, we estimated performance of the virtual equipment and performed research and development of the profiling technology that selects the optimum virtual equipment.

By solving these technical tasks, we aim for realization of the autonomic operation control infrastructure in the cloud computing environment.

2.2 Autonomic Operation Control Information Network Architecture

The target of this research task is to design a new autonomic operation control information network architecture using the OpenFlow technology and its information transfer mechanism. As described above, autonomic operation control for IT/network resources repeats the cycles of observation → analysis → support → control. In the course of this cycle, when attention is focused on the information flow in the individual tasks, the collection (many to 1) type, search (mesh) type, linkage (bus) type, and allocation (multicast) type are considered depending on the respective tasks as shown in **Fig. 1** . When the management contents are focused, there are various items such as the CPU usage, memory usage, disk space, bandwidth, delay, etc. The information transfer quality required depends on the management purpose. Then, as the requirements for the autonomic operation control information network architecture, the network building feature and network resource allocation feature by management purpose are raised. Therefore, we designed the method that defines the flow for each management purpose, dynamically builds the network for each flow, separates the network for each management purpose, and allocates resources for each network using the OpenFlow technology.

In the environment where resource operation is flexibly performed depending on the situation, overheads occur in, for example, the network status observation feature and route control feature because the equipment to be managed increase or decrease. To reduce such overheads, we examined application of the Publish/Subscribe communication model as the autonomic operation control information network. This communication model consists of the Publisher, a data sending feature, the Subscriber, a data receiving feature, and the information transfer feature that loosely couples them. In this loosely coupled communication, the Publisher and Subscriber are isolated from each other and communication is performed using the information transfer feature as an intermediary. As a result, configuration changes in the cloud computing environment can be hidden in the operation control server. For example, even though the equipment to be managed increase or decrease, the increase/decrease is hidden by the Publish/Subscribe layer as long as the collected information is the same. Thus, a simple architecture can be attained by letting the Publish/Subscribe communication layer absorb the characteristics while permitting the resource increase/decrease. So, we designed the features of the autonomic operation control information network node and OpenFlow switch control node.

In the Publish/Subscribe communication layer, we examined the routing system based on the management information name (information name). In this system, the autonomic

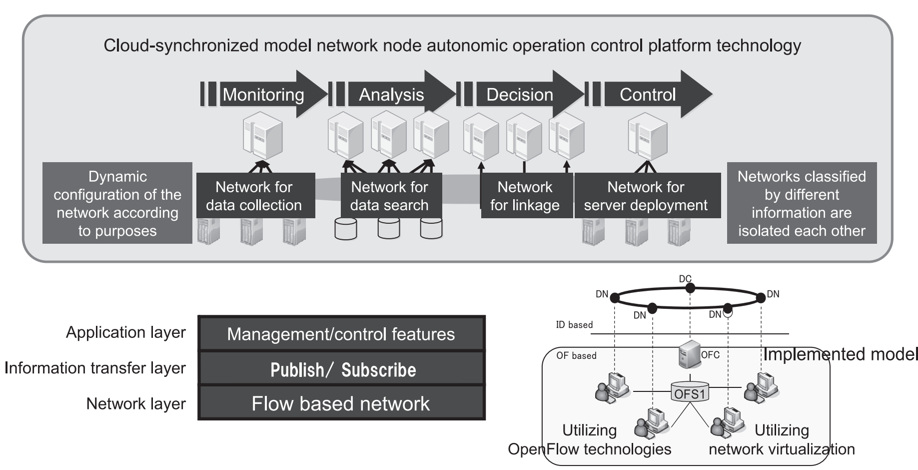

Fig. 1 Autonomic operation control information network architecture.

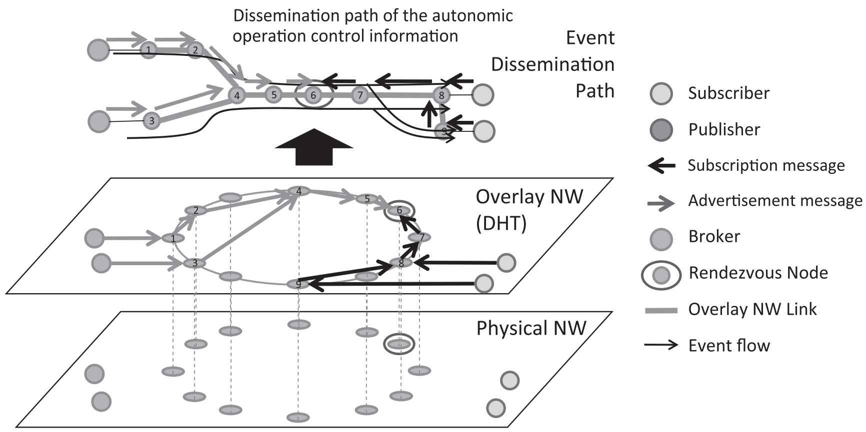

Fig. 2 Distributed event routing.

operation control information entered from the Publisher is, as illustrated in **Fig. 2** , transferred to the Subscriber via the distribution path built on the overlay network. This distribution path is built in advance by the advertisement process and reception registration process in Publish/Subscribe communication. In the advertisement process, the Publisher hashes information to create a unique ID. On the other hand, in the reception registration process, the Subscriber hashes information name to be received and creates an ID. Since the node having the same logical node ID as the ID created in the advertisement/reception registration process becomes the advertisement/reception registration destination, the autonomic operation control information is delivered from the Publisher to the Subscriber via this node as an intermediary.

As described above, this research task aims for contribution to reduction in the information transfer delay and improvement in the system autonomic operation through realization of the new autonomic operation control information network architecture using the OpenFlow technology and its information transfer mechanism.

2.3 Autonomic Operation Control Information Sharing Platform

This task researched the autonomic operation control information sharing platform that reduces the volume of information to be handled to the extent that the route control accuracy is not affected. For example, when a node failure or link overload status is detected in a network, the network may change the route in collaboration with peripheral networks. If servers managing respective networks mutually share all the failure information and load information, the accuracy in route control becomes higher but the processing cost for such information sharing increases. As a result, rapid response and scalability are adversely affected. Therefore, a scheme is required that lets share the necessary information for route control efficiently while maintaining the route control accuracy.

This time, as illustrated in **Fig. 3** , we used a simple model with the node status management feature that collects link information of individual network nodes and the route control feature that performs route calculation, to examine the information sharing feature that allows for efficient link information sharing between the features and developed a simulator.

In simulation validation with the network simulator (NS-2), we employed QOSPF (i.e. route control that selects the minimum-hop route that meets the required bandwidth and assures the bandwidth along the route) as a control approach that performs route control from link information and modified the information sharing part for controlling the shared information volume to evaluate the reduction in the information volume to the data flow quality. This modification allows for route calculation according to the pre-defined control policy. For execution, we used a network model containing 5 domains with each domain having 10 network nodes. As a result, total throughputs of respective data flows (**Fig. 4**) to the shared information volume (1: 100% shared, 0: 0% shared) and the percentage (**Fig. 5**) of the bandwidths actually in use among all link bandwidths is shown. For these, the averages obtained from the results of 30 trials are used. According to Fig. 4, if the shared information volume is approximately 60 to 70%, throughput drop is small but it increases if the volume is smaller. In other words, we found that network quality would not be greatly affected if the volume is approximately 30% as a minimum even though the shared link information is reduced. Also, Fig. 5 shows quality degrades from the border of 70%. This means that efficient route control cannot be performed and traffic is concentrated on the limited links if percentage is below 70%. According to these results, we found the network quality would not be adversely affected if reduction in link information was approximately 30% when the link information volume to be shared by the node status management feature and the route control feature was 100.

Finally, we assigned IDs in the order of links that creates useful information for route decision and measured the maximum throughput when link information observed on the respective links was randomly missing. **Fig. 6** shows the

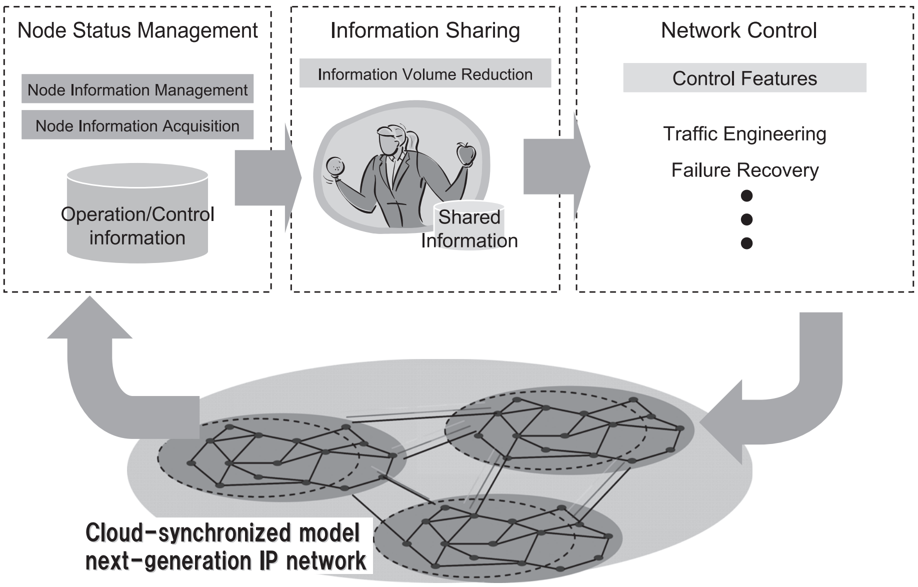

Fig. 3 Network operation control diagram.

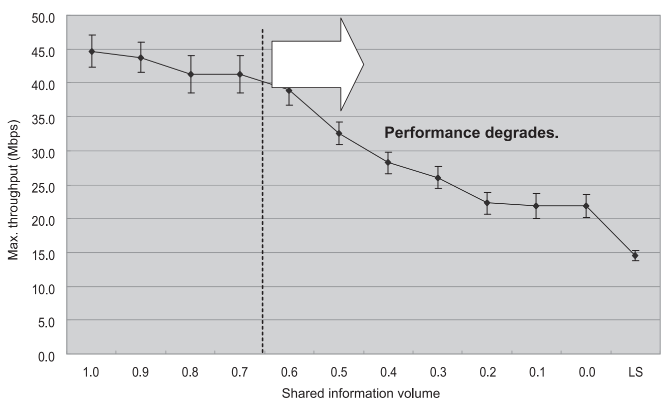

Fig. 4 Changes in the maximum throughput depending on the shared information volume.

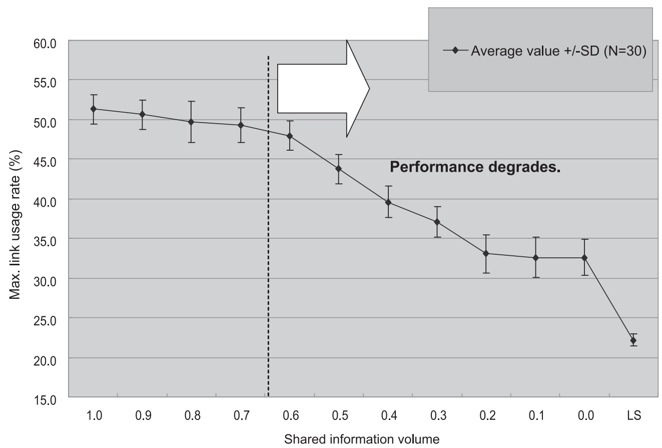

Fig. 5 Changes in the maximum link usage depending on the shared information volume.

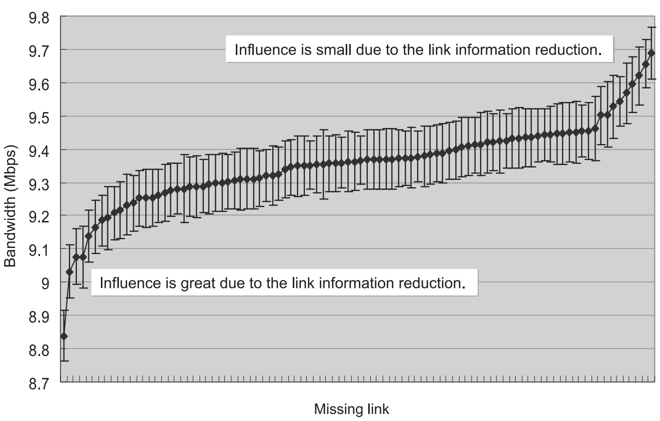

Fig. 6 Effect of link information missing to the total throughput.

measurement result, which indicates the maximum throughputs measured in the order of link IDs. In the link information relating to the link shown at left is deleted, the maximum throughput tends to decrease. Therefore, if 10 sets of link information from the left end were deleted, the maximum throughput dropped to 8.5Mbps. In contrast, if link information at right is deleted, the maximum throughput tends to increase. Therefore, if 10 sets of link information from the right end were deleted, the maximum throughput increased to 10. 2Mbps. Therefore, we found that approximately 20% performance improvement could be expected by reducing strictly selected 30% link information, rather than randomly selected 30% link information.

As discussed above, we have proceeded with research and development, focusing on information volume reduction in the node status management feature and the route control feature. In general, the processing load increases non-linearly against the increase in the information volume. For reduction in the shared information volume described above, we consider that further effects can be expected for actual reduction in the processing time in a large-scale network at a level of thousands to tens of thousands of nodes. In the future, we will proceed with the study on more operation control items to apply this system.

2.4 Virtual Resource Profiling Technology

This research task performs research and development for improving stability of the autonomous operation control infrastructure. Generally, a stable system has a high operating rate and a high availability. Technologies such as clustering are applied to these systems that never result in system down even though errors or failures occur in several parts. However, in the cloud computing environment to which the virtualization technology is applied, new elaborations will be necessary. Physical resources to be used by the IT/network equipment virtualized in the cloud computing environment may be provided by physical equipment and devices with different performance and capacities installed in different locations. Under such circumstances, to operate virtual equipment stably, it is necessary to prepare resource consumption characteristics of the virtual equipment, select candidates of more suitable physical resources, and select the optimum physical resources from these candidates.

Therefore, in this research and development, we developed - as shown in **Fig. 7** - the virtual resource profiling technology consisting of the "characteristics measurement technology" that generates various loads for profiling and measures the performance characteristics of the virtual equipment that runs the network control server and the "characteristics measurement framework" that estimates and compares vacant resources that lie scattered in the cloud computing environment from the measured performance characteristics data and the physical equipment running status.

As the performance characteristics analysis system in the characteristics measurement feature, we examined two profiling systems. The first system applies a dummy load to each resource such as the CPU load and network transmission, calculates the approximation function of performance characteristics from the measured values to generate fine-graded

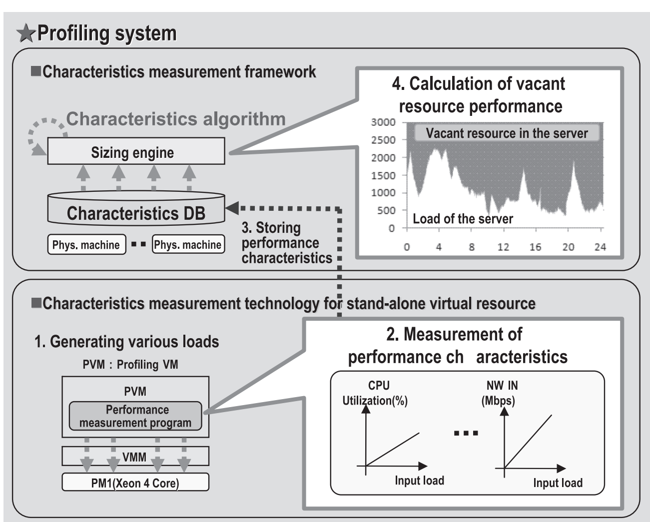

Fig. 7 Virtual resource profiling technology.

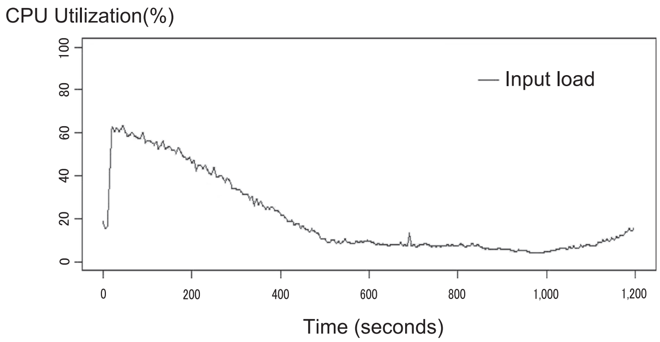

Fig. 8 Input load on SV#1.

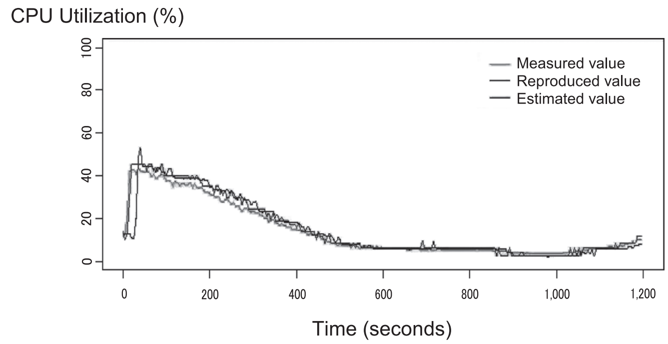

Fig. 9 Estimation result on SV#2.

performance characteristic values, and estimates the processing performance of virtual resources from these values. The second system simultaneously executes multiple system calls frequently used in application processes to measure the performance characteristics including the effects between the system calls then estimates the processing performance of virtual resources.

To verify the effects of these technologies, we experimentally produced a system that collects performance characteristics data from 2 physical servers; SV#1 and SV#2, and estimates the load index and performed evaluation with two types of loads (CPU and network output) assuming the CPU load through I/O virtualization. The measurement result in the first system is shown below.

Fig. 8 shows the CPU load of SV#1 when the Web server runs on the virtual machine as the input load to SV#1, while Fig. 9 shows three values; the measured value of the CPU load when the equivalent process is performed on SV#2, the estimated value of the load on SV#2 calculated from the profiling results of 2 servers, and the reproduced value by estimating the processed volume on SV#1 corresponding to the input load from the SV#1 profiling result and executing the process on SV#2 to reproduce a pseudo load. From Figs. 8 and 9, we verified that, since the difference in CPU performance between SV#1 and SV#2 was approximately 1.5 times, SV#2 with a higher processing capability showed a lower CPU usage (for example, the approximately 60% peak load on SV#1 was approximately 40% on SV#2). **Fig. 9** shows that we were able to estimate the estimated value and reproduced value in this system that were close to the measured value and we were able to estimate the load between physical servers having a significant performance difference. The rate of deviation indicating how far the estimated value and reproduced value were from the measured value was approximately 2%, so we were able to verify that these values are fully usable as the load estimated value.

3. Conclusion

This paper described the autonomic operation control information network, autonomic operation control information sharing platform, and virtual resource profiling technology as three element technologies constituting the IT/network operation control suitable for cloud computing. To put these technologies into practical use, we will contribute to enhancement of the NEC cloud computing products. This work was partly supported by Ministry of Internal Affairs and Communications.

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