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LETTER

A low-cost centralized network management method to reduce management workload instead of replacing software-defined networking-enabled network devices

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Abstract We propose a network management method using a novel adapter that translates OpenFlow-based commands and vendor-specific commands using a single-board computer to achieve a low-cost centralized management of heterogeneous network devices including various vendors. The adapter is implemented in wired and wireless network devices and its operation is verified. Moreover, we compare the cost in two scenarios, i.e., the management of a smart home network and a small- and medium-sized enterprise network. The results show that the proposed method works efficiently and is low-cost than the conventional method.

Keywords: software-defined networking, OpenFlow, common management interface, single-board computer, Raspberry Pi
Classification: Network management/operation

1. Introduction

In recent years, information communication technology has developed not only in data centers and large enterprise networks but also in small- and medium-sized enterprises (SMEs) and home networks. As a result, various network devices, such as wired and wireless network devices, are involved in various vendors. The increase in the number and type of network devices also leads to the increase in the operation and management workload of the network manager, leading to configuration mistakes and operation errors. To reduce the workload, OpenFlow (OF) [1] has been proposed to realize software-defined networking (SDN)-based operation methods [2]. However, OF-based network operation and management require the replacement of all the network devices with OF-enabled ones. However, OF-enabled network devices are generally expensive, making the replacement and running cost a problem [3]. Therefore, we proposed a network management method using a single-board computer as an adapter to centrally manage wired network devices from various vendors at low cost [4]. As shown in Fig. 1, the proposed network management method is performed as follows:

(1) Transmission of the control messages.
To configure the parameters of network devices, the control messages are transmitted through the user interface of the network manager provided by the OF controller or applications. These applications then pass the received control messages to the controller through a northbound application programming interface (API). The controller produces OF messages based on the control messages provided directly by the network manager or indirectly by applications.

(2) Transmission and reception of the OF messages.
As shown in Fig. 1(a), the OF protocol transmits OF messages to OF-enabled network devices. The network devices are configured to the messages. The OF protocol transmits OF messages to an adapter (Fig. 1(b)). The received messages are then analyzed and translated into vendor-specific control commands.

(3) Transmission of vendor-specific control commands.
As shown in Fig. 1(b), a vendor-specific protocol, such as telnet or ssh, is used to transmit vendor-specific control commands from the adapter to the conventional OF-disabled network devices. The devices are configured based on the reception of the commands.

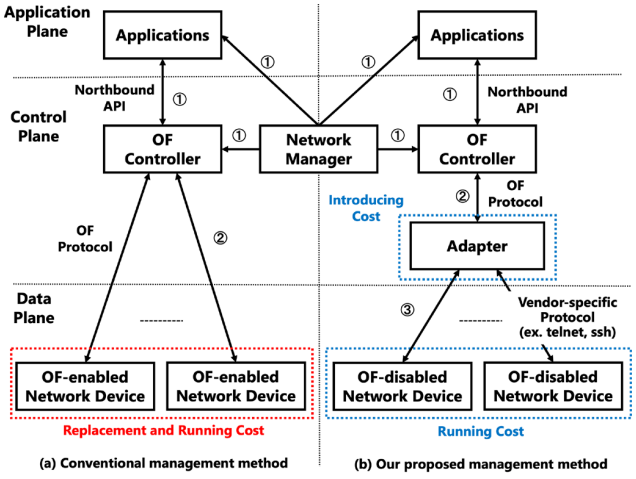

Fig. 1 Proposed network management method

As shown in Fig. 1(a), replacing OF-disabled network devices with OF-enabled ones is necessary to centrally manage the network devices using OF. However, OF-enabled network devices are expensive, making the replacement and running cost a problem. In contrast, as shown in Fig. 1(b), the proposed method requires only the running cost of conventional network equipment and the additional cost of an inexpensive single-board computer which is installed in the

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adapter function. Therefore, network devices are managed centrally and economically in multi-vendor environments.

Although we implemented and verified the system with wired network devices [4], we couldn't implement and verify the system with wireless network devices used in the SME and home networks and compare the cost. The rest of the paper is summarized as follows. We propose an economical centralized network management system for wireless and wired network devices in Section 2. The experiment and cost comparison are provided in Section 3. Finally, we summarize this paper in Section 4.

2. Proposed network management system

Figure 2 shows the proposed network management system using the proposed method. Figure 2(a) shows the overview of the implementation of the proposed system. The network manager inputs control commands to change the configuration of network devices from a personal computer (PC) browser. The Web server receives the control commands and passes them to the OF controller. The OF controller then sends the control commands as OF messages to the adapter. The adapter analyzes the received OF messages and translates them into vendor-specific control commands. Finally, vendor-specific control commands are sent to wired or wireless network devices to change their configuration. The Web server and OF controller are based on open-source software, Apache [5] and Ryu [6], and are implemented in a general-purpose server. The adapter function uses the twink [7] library, which is open source and includes an OF switch function, and is implemented in a single-board computer.

Figure 2(b) shows the process flow of the proposed system. The network manager inputs the IP address and the control commands from a browser on the manager PC. The Web server receives the input commands, checks the IP address, and then passes the input commands to the controller. The controller analyzes the received control commands, assembles OF messages according to the defined policy in advance, and then sends these messages to the adapter. The adapter analyzes the received OF messages and translates them into vendor-specific control commands. Finally, the adapter sends vendor-specific control commands to wired or wireless network devices, which has input IP addresses by the manager. The proposed system operates according to the above process flow and can centrally manage wired or wireless network devices from different vendors.

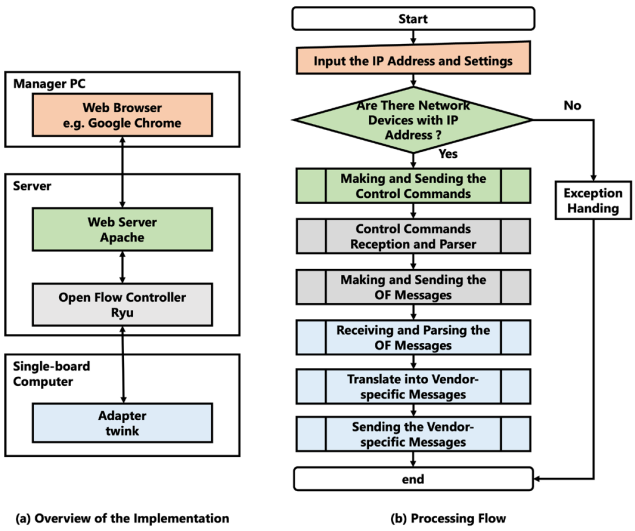

Fig. 2 Proposed system

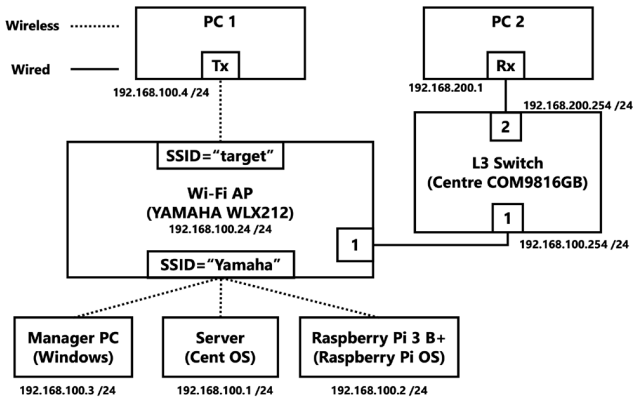

Fig. 3 Experimental system

3. Validation

We verified the proposed system using the experimental system shown in Fig. 3 and compared the cost using two scenarios, namely, the management of a smart home network and an SME network.

3.1 Experimental validation

We use iperf3 [8] which is the software of traffic generator, PC1, and PC2 as the traffic sender and receiver, the iperf transmitter, and the iperf receiver, respectively. We also use the Wi-Fi AP by Yamaha and layer-3 switch (L3SW) by Allied Telesis as wireless and wired network devices, respectively. In addition, we use Raspberry Pi 3B+ [9], an inexpensive and widely used single-board computer.

Two service set identifiers (SSIDs), i.e., "yamaha" and "target," are set up for the Wi-Fi AP. The manager PC, server, and Raspberry Pi 3B+ connect to the "yamaha" SSID, while PC1 connects to the "target" SSID. The wired port of the Wi-Fi AP is connected to the wired port of the L3SW, and PC2, as an iperf receiver, is connected to another port

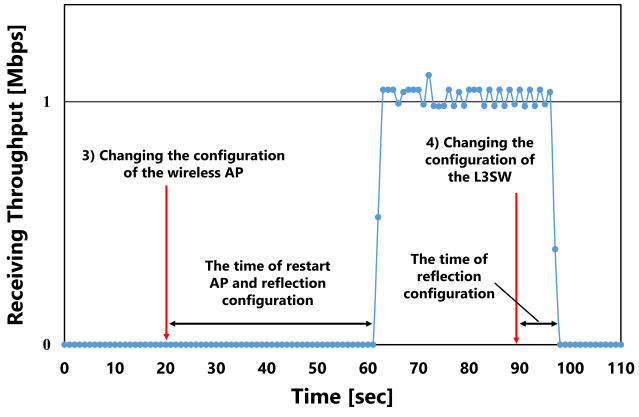

Fig. 4 Experimental results

on the L3SW. The experimental procedure is performed as follows:

1) Initial setting
   As shown in Fig. 3, Wi-Fi AP, L3SW, manager PC, server, Raspberry Pi 3B+, PC1, and PC2 are configured. The "target" SSID of the wireless AP is only turned off.
2) Start of the iperf
   Iperf3 is executed, and user datagram protocol (UDP) [10] traffic is sent at 1 Mbps from PC1 to PC2. In PC2, it is assumed to receive zero throughput by the iperf receiver as the "target" SSID is turned off.
3) Changing the configuration of the wireless AP
   Approximately 20 s after iperf3 is executed, a control command is sent from the browser of the manager PC to turn on the "target" SSID of the Wi-Fi AP. If the proposed system works correctly, the "target" SSID of the Wi-Fi AP is turned on and is assumed to receive the UDP traffic by the PC2.
4) Changing the configuration of the L3SW Approximately 90 s after iperf3 is executed, a control command is sent from the browser of the manager PC to turn off the wired port 2 of L3SW. If the proposed system works correctly, the wired port is turned off and is assumed to receive zero throughput again as the port is turned off.

3.2 Experimental results

Figure 4 shows the experimental results. After executing iperf3, the throughput of the iperf3 receiver remains at zero. However, about 40 s after executing procedure (3) in Section 3.1, the throughput reached 1 Mbps. This shows that the proposed system works properly and sends the configuration command to the Wi-Fi AP and that it takes about 40 s to reflect the reconfiguration and restart the AP. Procedure (4) in Section 3.1 is executed about 90 s after executing iperf3, and the throughput is zero again about 100 s later. This shows that the proposed system works properly and sends the configuration command to L3SW and that it takes about 10 s to reflect the reconfiguration. Therefore, the results confirm that the proposed system works properly.

3.3 Cost comparison

A cost comparison is performed to demonstrate that the proposed method is low-cost than the conventional method. As presented in Table I [11, 12, 13], two scenarios are used for the cost comparison, i.e., the management of a smart home network and the management of an SME network.

A variety of Internet of Things (IoT) devices are used in the smart home network, requiring vendor-specific and communication protocol-specific IoT wireless gateways, such as Bluetooth, Zigbee, Wi-Fi, Google, and Amazon. Furthermore, wireless routers are required to aggregate these gateways and connect them to the Internet. Therefore, many wired and wireless network devices from various vendors are used in the smart home network and SME network. If the conventional method is used, replacing all network devices to OF-enabled network devices is necessary. However, if the proposed method is used, conventional network devices can be employed, and only an inexpensive single-board computer is required.

Table I Scenario and device costs

(I) Smart home network	Wireless network device	Cost
(I-a) Conventional method	AT-TQ5403 (Allied Telesis)	90,000 yen [11]
(I-b) Proposed method	WLX212 (Yamaha)	29,800 yen [12]

(II) SME network	Wireless and wired network device	Cost
(II-a) Conventional method	AT-TQ5403 (Allied Telesis)	90,000 yen [11]
	AT-x930-28GTX (RoHS) (Allied Telesis)	990,900 yen [11]
(II-b) Proposed method	WLX212 (Yamaha)	29,800 yen [12]
	AT-GS980MX/28 (RoHS) (Allied Telesis)	207,900 yen [11]

Proposed method (I) and (II)	Raspberry Pi 3B+	5,582 yen [13]

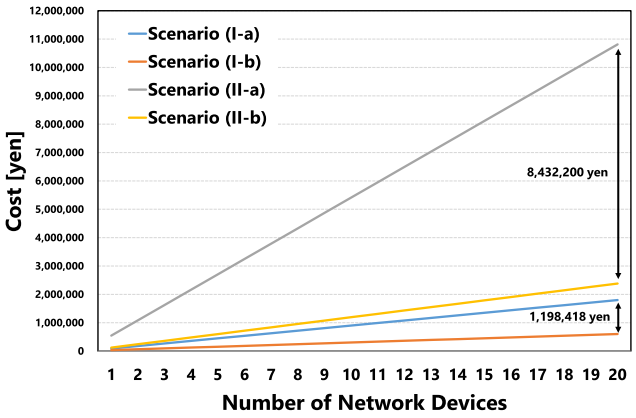

Fig. 5 Cost comparison results

If conventional and OF-enabled devices have the same durability, we compare the costs of the conventional and proposed methods using the network devices and Raspberry Pi 3B+ presented in Table I.

From Fig. 5, it can be observed that the proposed system is less expensive than the conventional system for smart home network and SME network management. OF-enabled network devices with high specifications are relatively more expensive than those with low specifications. Therefore, the proposed method is more effective for the SME network that uses high-specification L3SWs. Moreover, to some extent, the proposed method is also effective for smart home networks because it is desirable for the user to manage smart home networks at as low a cost as possible.

4. Conclusion

In this paper, we proposed a network management method using a novel adapter that translates OF-based commands and vendor-specific commands using a single-board computer. We also implemented the proposed and verified the system for wired and wireless network devices. The proposed system was shown to work efficiently at a low cost. In future research, we will consider the management of IoT

devices and optical network devices, such as smart light bulb and reconfigurable optical add drop multiplexer.

Acknowledgments

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