A study of a new routing scheme for QoS improvement using SDN

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***Abstract*—This paper proposes a new multi-pathization method for TCP and UDP with SDN. To consider both of congestion and packet losses caused by link quality degradation, the proposed method consists of the three controls and select dynamically one of them. Moreover, the controls are independently configured to handle the two protocols, TCP and UDP. This paper utilizes OpenFlow architecture as a SDN platform. The authors implement their proposal and evaluate it by actual experiments. From the results, the authors confirm the effectiveness of the proposal.**

I. INTRODUCTION

The development of IoT technologies and the resulting diversification and sophistication of ICT services have led to the widespread use of IoT networks in various fields, such as disaster prevention/mitigation, medicine, education, etc. On the other hand, the increase in the number of these services and their users has led to increased Internet traffic. This causes network congestion and then various problems over the Internet. Since traffic is expected to keep growing even more rapidly in the future, congestion control is indispensable to cope with these increases. For example, in 2020, YouTube temporarily reduced the quality of its service to control congestion.

One practical solution for controlling congestion is using multiple paths to distribute traffic and preventing traffic from concentrating on a single path. However, in the current major transport layer protocols, TCP and UDP, a single connection or stream cannot use multiple paths simultaneously. Thus, some next-generation transport layer protocols, such as MPTCP (Multipath TCP) [1], are being standardized to use multiple paths simultaneously. Moreover, SCTP (Stream Control Transmission Protocol) [2], a message-oriented transport layer protocol similar to UDP, supports multiple streams and can handle multiple data flows simultaneously over a single stream. However, the introduction of the above-mentioned new protocols is costly and time-consuming. Consequently, a congestion control that can utilize existing protocols without modification is required.

This study proposes a new congestion control by Software Defined Networking (SDN), which flexibly controls multiple paths without using any new protocol. The control changes the path to transmit traffic according to its priority at regular intervals. This paper implements the proposed control and evaluates its effectiveness through experiments in an actual environment.

II. SDN

A. Outline

SDN refers to a network or technology that enables a network manager to dynamically configure and change a network's configuration, functions, and performance through software operations alone [3]. In legacy network management, the network configuration change requires a network manager to perform extensive work, such as adding servers and new devices that construct the network and changing the network settings of applications. Since SDN separates the control function from the data transfer one and centrally manages the control function through software, network managers can flexibly configure the behavior of each device without individual device settings.

B. OpenFlow

OpenFlow [4] is one of the most well-known implementations of SDN. The main components of OpenFlow are the OpenFlow controller, OpenFlow switches, and hosts. The OpenFlow controller collectively manages the behavior of OpenFlow switches. Flow entries define the behaviors of packets entering an OpenFlow switch, and the OpenFlow switch determines the output port for incoming packets according to these flow entries. Each flow entry contains matching rules, actions, and statistics. A matching rule defines conditions for packets for the flow entry. The matching rules can specify input/output ports, destination/source IP addresses, IP protocol numbers, etc. Each OpenFlow switch operates packets that match the rules. An action indicates what the switch will do for a packet that matches the matching rule. Finally, the statistics represent information such as the number of packets and bytes per flow entry.

III. PROPOSAL

The proposal uses SDN to switch the path for transmitting traffic through OFS; it uses a list that describes the control for each priority and the time to perform the switch for each priority level. The list is referred to as a Route Control List (RCL).

The proposed method utilizes the following three sub-controls. The first sub-control forwards packets of a designated priority to one of the paths randomly at a fixed interval of r seconds. For convenience's sake, this control is denoted by R. The second sub-control calculates the amount of traffic on each path at fixed intervals of p seconds and then forwards packets of a designated priority to the path with the lowest amount of traffic. This control is used to minimize QoS degradation for high-priority traffic. This control is referred to as P. Note that, in P, the amount of traffic is calculated according to the OFS statistics. The third sub-control drops packets with a designated priority by forwarding the traffic to no path. The control can be applied to low-priority traffic to reduce the congestion of a path. The sub-control is described as R. Table I shows an example of an RCL in which traffic with high priority is prioritized and that with low priority is discarded at fixed intervals.

TABLE I
EXAMPLE OF ROUTE CONTROL LIST

Time	S4	S3	S2	S1
T_1	R	R	R	R
T_2	P	R	R	R
T_3	P	R	R	D

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IV. EXPERIMENT

This study performs experiments under a simple experimental environment with actual devices and evaluates the effectiveness of our proposal from obtained results.

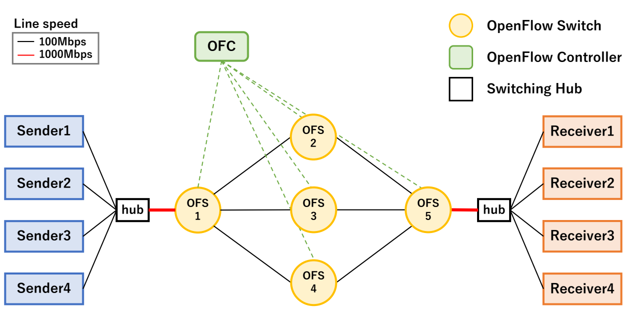


Fig. 1. Experimental network

Figure 1 shows the experimental network. The network consists of four Senders (S1-S4) that generate and send traffic, four Receivers (R1-R4) that receive the corresponding traffic, one OpenFlow Controller (OFC), five OpenFlow Switches (OFS1-OFS5), and two switching hubs that are not an OpenFlow switch. S1 through S4 send traffic of priority 1 through 4, respectively. Note that the more significant number of the priority means the higher priority.

OFC connects OFS1 through OFS5 via a network for management separated from the SDN. To prevent congestion in the paths between OFS1 and the switching hub and between OFS5 and the switching hub, which are not controlled by OFCs, the line speed of their paths is set to 1000 Mbit/s while that of the other paths is 100 Mbit/s. As the first step of our study, the traffic sent and received under this experimental environment is only UDP traffic generated and received by iperf [9]. Thus, the experiment treats the UDP packet loss rate as a QoS parameter.

The experiment consists of two sub-experiments. One is a sub-experiment for comparing the QoS of the RCL(???) with that of only R and P sub-controls, and the other compares the QoS of the RCL with that of R, P, and D sub-controls.

A. Experiment 1

In Experiment 1, the RCLs shown in Table II prioritize only the traffic of priority 4, which has the highest priority. According to Table II, all traffic is randomly forwarded to one of the paths from time 0 to time t, and traffic of priority 4 is only sent to the path with the least amount of traffic from time t to time 100. The packet loss rate of UDP is measured when the time t in Table II varies from 0 to 100.

B. Experiment 2

In Experiment 2, the RCLs in Table **??** avoid congestion by prioritizing traffic of priority 4 and intentionally dropping packets of priority 1, which is the lowest one. In Table **??**, all traffic is forwarded to one of the paths randomly from time 0 to time 40, and traffic of priority 4 is only forwarded to the path with the least amount of traffic from time 40 to time t. The traffic of priority 4 is only forwarded to the path with the least traffic, and packets of priority 1 are discarded from time t to time 100. We measure the packet loss rate of UDP when the time t in Table 2 varies from 90 to 100.

TABLE II
ROUTE CONTROL LIST (EX1)

Time	S4	S3	S2	S1
$0{\sim}t$	R	R	R	R
$t{\sim}100$	P	R	R	R

TABLE III
ROUTE CONTROL LIST (EX2)

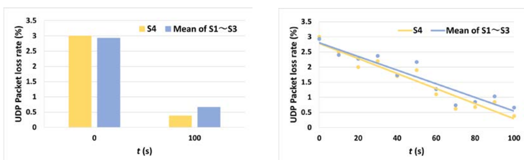
Time	S4	S3	S2	S1
$0{\sim}40$	R	R	R	R
$40{\sim}t$	P	R	R	R
$t{\sim}100$	P	R	R	D

V. RESULTS AND CONSIDERATIONS

A. Results of Experiment 1

Figure 2(a) plots the results of Experiment 1 when time t in Table II is 0 and 100.

In Figure 2(a), the abscissa represents time t (second), and the ordinate means the packet loss rate of UDP (%). Note that, in this figure, S4 indicates the packet loss rate of UDP for the traffic of priority 4 while the Mean of S1 to S3 is the mean packet loss rate of UDP for the traffic of priorities 1 through 3. From Fig. 2, we see that the increase of t decreases not only the packet loss rate of UDP for the traffic of priority 4 but also that for the other traffic. This is because prioritizing traffic of priority 4 prevented all traffic from concentrating on a single path. As a result, the packet losses of UDP for the traffic of priorities 1 through 3 were improved. On the other hand, the difference in the packet loss rates of UDP between priority 4 and the other traffic when t was 0 is more significant than that when t was 100. Figure 2(b) shows the experimental results when the value of time t is varied from 0 to 100.



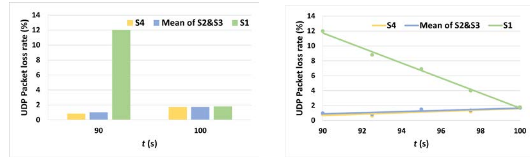
(a) (b)

Fig. 2. UDP Packet loss rate (a)(t = 0, 100) (b)(t=0～100)

Figure 2(b) displays that the overall packet loss rate decreases as t increases, but the difference between the packet loss rate of the traffic of priority 4 and the other one increases. The result indicates that increasing t can suppress the packet losses of high-priority traffic. Moreover, the difference between the packet losses of high-priority traffic and that of the other traffic becomes larger by increasing t. Therefore, the value of t should be set appropriately according to the requirement of the packet loss rate.

B. Experiment 2

Figure 3(a) plots the results with the value of t 90 and 100. In Figure 3(a), the abscissa is t, and the ordinate means the packet loss rate of UDP (%). In this figure, S4 is the packet loss rate of UDP for the traffic of priority 4, the Mean of S2-S3 indicates the packet loss rate of UDP for the traffic of priorities 2 and 3, and S1 means the packet loss rate of UDP for the traffic of priority 1. From Fig. 3(a), we see that by discarding priority 1 traffic at OFS1, packet losses for the traffic of the other priorities are suppressed. However, when t is 90, the packet loss rate of UDP for the traffic of priority 1 increases by about 10%. Thus, to study the packet loss rate of UDP in detail, we show the results when t varies from 90 to 100 in Fig. 3(b).



(a) (b)

Fig. 3. UDP Packet loss rate (a)(t = 90, 100) (b)(t=90～100)

Figure 3(b) indicates the following. The packet loss rate of UDP for the traffic of priority 1 increases by 1% per second by increasing the time to discard traffic by 1 second, while that of priority 4 decreases by only 0.1%. This means that this control is effective only for specific environments. However, since the time for P is fixed at 40 seconds, it is necessary to investigate whether changing the time and RCL settings will make it effective.

VI. Conclusions

This paper proposed a new path control scheme for improving QoS using SDN and evaluated its QoS through experiments with actual devices. The experimental results show that our proposal is effective by appropriately configuring RCLs according to the environment.

The following is our future work. Although the experiments used two RCLs, it is necessary to use various RCLs for evaluation.

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