The Effect of Routing Path Buffer Size On Throughput of Multipath TCP

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Abstract— **Multipath TCP (MPTCP) is based on TCP and MPTCP transmits data through multiple paths. It is well known that MPTCP shows better throughput than single path TCP (SPTCP). In this paper, we investigate the effect of router buffer size on throughput of MPTCP. We observe that MPTCP, which uses Lowest-RTT-First scheduling algorithm and Opportunistic Linked-Increases Algorithm (OLIA), may show worse throughput than SPTCP when the router's buffer on transmission path of lowest RTT is small.**

Keywords MPTCP, Buffer Size, Routing Path, Throughput.

I. INTRODUCTION

Multipath TCP (MPTCP) was developed based on legacy single path TCP (SPTCP) by Internet Engineering Task Force (IETF) [1][2]. Every application of TCP-based could utilize MPTCP without any modification or installation. MPTCP generates multiple subflows to transmit data on LTE, Wi-Fi, Ethernet or 5G [3]. MPTCP's purpose is to achieve higher throughput using multiple paths. It is well known that MPTCP shows better throughput than SPTCP [4].

However, MPTCP should be consider several variables because MPTCP uses multiple subflows. If MPTCP has an inferior transmission path, MPTCP should not assure better throughput than SPTCP.

In this paper, we investigate the effect on throughput of MPTCP by the router's buffer size on transmission path. And we propose to using SPTCP when one path's Round Trip Time is lowest than other path's and buffer size is small.

The rest of this paper is organized as follows. In section 2, we explain MPTCP and some packet scheduling algorithms considering RTT. In section 3, we investigate throughput of MPTCP considering Round Trip Time. Then the result compare with SPTCP's throughput. In section 4, we investigate throughput of MPTCP considering Round Trip Time and router's buffer size on transmission path. Finally, we conclude the paper in section 5.

II. RELATED WORK

MPTCP is an attempt to extend the TCP protocol to perform this role. MPTCP transmits data from a SPTCP connection across multiple subflows, each of which may take a different path. First, MPTCP connection for transmission data creates a single subflow by using the TCP three-way handshake as SPTCP, and detects whether MPTCP should be enabled while this connection setup phase. If the connection is multi-path capable, then subflows should be created the number of network interfaces at source and destination. MPTCP has two types of sequence numbers, subflow sequence number and data sequence number. Subflow sequence number and data sequence number provide reliability and global ordering. Each subflow has their own subflow sequence to conduct both loss detection on the subflow and retransmissions. Then MPTCP scheduler sets the data packets from the output queue, and places them on each subflow according to the scheduling algorithm. Since each subflow path has variety RTT, the packets may be received out-of-order at the MPTCP receiver. Therefore, the data sequence number is kept at the connection level so that the data packets are reassembled at the receive buffers.

A. Packet scheduling algorithms considering RTT

MPTCP uses multiple paths, so MPTCP was greatly affected by RTT of subflow. Therefore, some scheduling schemes have been proposed.

If one subflow's RTT is much greater than other subflows, other subflows were greatly affected. So MPTCP's performance is getting lower. Then MPTCP considers RTT and other variables, MPTCP does not use the subflow [5].

Packet scheduling scheme and Receiver-Based recovery scheme also consider RTT and loss packet on receiver [6]. Receiver should reassemble receiving packets. If packet loss is happened on bad subflow, recovery time is very long time. Then this scheme recovers loss packet to using good subflow. Packet scheduling scheme and Receiver-Based recovery scheme are reduced loss of performance.

And OTIAS algorithm [7] is based on the idea of scheduling more segments on a subflow than what it can currently send. Queues may therefore build up at each subflow of the sender, under the assumption that these segments will be sent as soon as there is space in the CWND for the subflow. When asked to schedule a new segment, the algorithm estimates its arrival time if sent over each subflow, and chooses the subflow with the earliest arrival time. The estimation is performed based on a subflow's RTT, its CWND, the number of in-flight packets and the number of already queued packets.

However, this schemes do not consider the buffer size. So we investigate the effect on throughput of MPTCP by the router's buffer size on transmission path.

III. BACKGROUND

In this section, we investigate the relation between RTT and the throughput. We consider the simulation scenario where a device has two wired transmission paths. System Model

The network topology is shown in "Fig. 1". We set the one sender and one receiver as "Fig. 1". And the sender and receiver connect two subflows, Path 1 and Path 2. Then Router 1 and Router 2 replace on each of Path 1 and Path 2 between sender and receiver as "Fig. 1". Our simulation parameters are given in "Table I". For simulation, we use NS-3-dce [8][9] and MPTCP-OLIA [10].

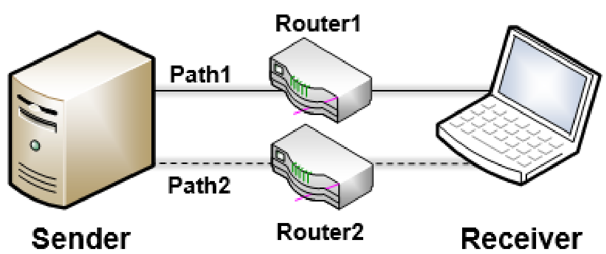

Figure 1. Simulation Topology

First simulation investigates the relation between RTT and the throughput with various Path 2's delay in "Table I". Path 1's delay is always fixed to 1ms. And Second simulation investigates the relation between Router 1's buffer size and the throughput. Router 1's buffer size is 5KB and Router 2's buffer size is 45KB.

Table I. Simulation Parameters

Parameter	Value
Path1, 2's Bandwidth	10Mbps
Path 1's Delay	1ms
Path 2's Delay	1, 50, 100ms
Simulation Time	20ms
Router 1's Buffer Size	5, 45KB
Router 2's Buffer Size	45KB
Client's Buffer Size	4MB

A. Effect on RTT differenceModel

First, we investigate throughput of MPTCP considering RTT. We investigate the relation between RTT and the throughput, varying Path 2's delay from 1, 50 and 100ms. Path 1's delay is fixed to 1ms. Both Path's Buffer sizes are same 45KB. In order to compare with MPTCP's performance, we investigate SPTCP's performance using Path 1. This simulation results are shown in "Fig. 2".

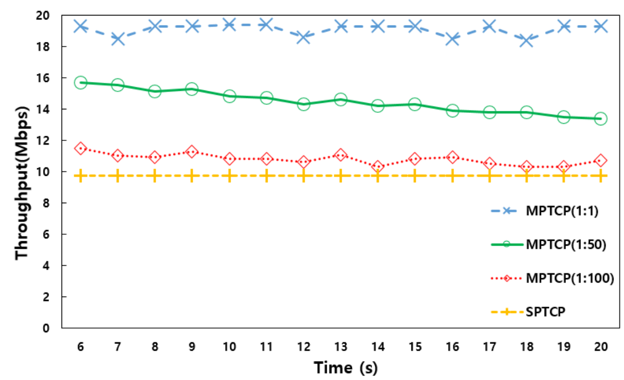

Figure 2. Throughput of MPTCP and SPTCP
when Path 1's delay = 1ms and Path 2's delay = 1, 50, 100ms

In "Fig. 2", x-axis is time (sec), y-axis is throughput (Mbps) of MPTCP and SPTCP. MPTCP (1:1) as Path 1's delay is 1ms, Path 2's delay is 1ms, MPTCP (1:50) as Path 1's delay is 1ms, Path 2's delay is 50ms and MPTCP (1:100) as Path 1's delay is 1ms, Path 2's delay is 1ms. SPTCP is throughput of SPTCP to using Path 1, delay is 1ms. Lastly, two path's buffer size are same as 45KB.

It is shown MPTCP's throughput decreases gradually because MPTCP's throughput affected about RTT. When both RTT is same (MPTCP (1:1)), MPTCP shows much greater throughput. However, subflow's RTTs are different (MPTCP (1:50), (1:100)), MPTCP uses the subflow of lower RTTs in principle. When Path 2's delay much greater than Path 1's delay, MPTCP more use the Path 1 than Path 2. So as in "Fig 2", MPTCP's throughput decreases gradually. However, MPTCP's throughput is always better than SPTCP's throughput in this case.

IV. EFFECT OF BUFFER SIZE

In this section, we investigate throughput of MPTCP considering router's buffer size on transmission path.

We investigate the relation between Buffer size and the throughput, Path 1's delay is fixed to 1ms, Path 2's delay is fixed to 100ms. And Router 1's buffer size is fixed to 5KB, Router 2 is fixed to 45KB. The rest is same. In order to compare with MPTCP's throughput, we also investigate each SPTCP's throughput using Path 1 and Path 2. The results are shown in "Fig. 3".

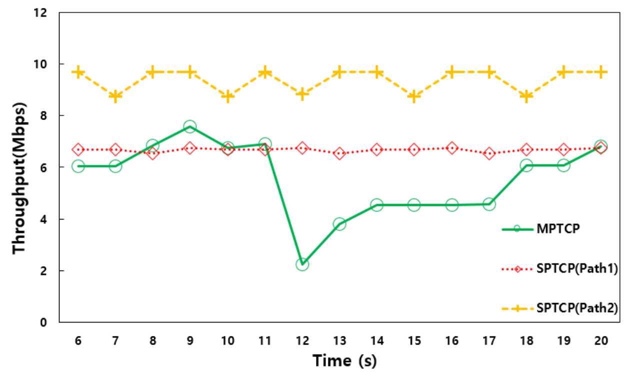

Figure 3. Throughput of MPTCP and SPTCP when B_1 = 5KB and B_2 = 45KB

In "Fig. 3", x-axis is time (sec), y-axis is throughput (Mbps) of MPTCP and SPTCP. MPTCP as Path 1's delay is 1ms and buffer size is 5KB, Path 2's delay is 100ms and buffer size is 45KB. SPTCP (Path 1) is throughput of SPTCP to using Path 1, delay is 1ms and buffer size is 5KB. SPTCP (Path 2) is throughput of SPTCP to using Path 2, delay is 100ms and buffer size is 45KB.

It is shown MPTCP's throughput is lower than both SPTCP's throughputs. Path 1's delay is 1ms and Path 2's delay is 100ms, Path 1 is better than Path 2 in terms of RTT. However, Router 1's buffer size is 5KB smaller than Router 2's buffer size. So we confirm Path 1's throughput (SPTCP (Path 1)) lower than Path 2's throughput (SPTCP (Path 2)). And we confirm the MPTCP more affected to using Path 1 and Path 2 simultaneously. Then MPTCP's throughput is lower than SPTCP's throughput.

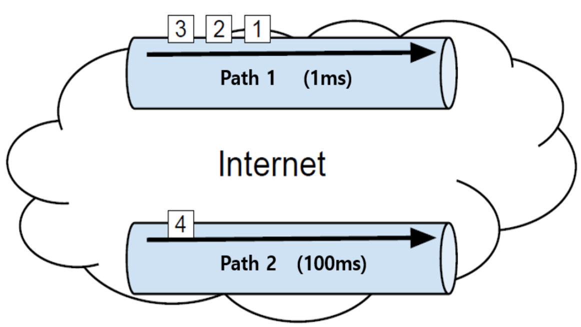

Figure 4. The Lowest-RTT scheduler from the Multipath TCP on the different TCP subflows.

MPTCP uses Lowest-RTT-First Algorithm [11] as "Fig 4". So MPTCP is scheduling first to Path 1 for transmission packets. The Contention Window is getting bigger when transmitting packets. Then Packet loss occurred because Router 1's buffer size is so small. Lastly Client should combine the receiving packets refer to the packet's sequence number. However, packet loss occurred while packet transmission, Client also occurred packet loss. Then MPTCP's throughput is lower than SPTCP.

V. CONCLUSION

Multipath TCP is developed based on single path TCP and it uses multiple paths to transmit data. Accordingly, Multipath TCP assures the better throughput than SPTCP. However, since MPTCP uses multiple paths, we should consider some variables. If some variables are not considered, MPTCP does not assure QoS.

In this paper, we investigate the effect on throughput of MPTCP by the router's buffer size and RTT on transmission path. If Routing path's buffer size in not enough, MPTCP should not assure the throughput for users. We will study scheme to improve this environment.

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