Primary Path Effect in Multi-Path TCP: How Serious Is It for Deployment Consideration?

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ABSTRACT

This poster provides an in-depth analysis of the primary path effect in Multi-path TCP using thorough experimentation over a realistic network setup. We observe the impact of various primary path parameters, like bandwidth, delay and loss, over the end-to-end performance. It is shown that under certain circumstances overall network performance can be improved by more than 50% with proper primary path selection. This study may drive the research community towards the design of new segment scheduling algorithms considering the effect of primary path selection over Multi-path TCP.

CCS CONCEPTS

• **Networks** → *Transport protocols*;

KEYWORDS

MPTCP, Primary Path Effect, Performance

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1 INTRODUCTION

With the advent of multi-interface communication supports over personal computing devices like smartphones and tablets, the concept of multi-path protocols have gradually become popular for large scale deployments. The networking community has started exploring pros and cons of various aspects of multi-path support over the popular and widely accepted transmission control protocol (TCP), called Multi-path TCP (MPTCP) [3], that uses multiple end-to-end paths through multiple interfaces attached with the end hosts. MPTCP initiates an end-to-end connection using three way handshaking with MP_CAPABLE flag, through one of the available interfaces known as the *primary path*. Once the end-to-end connection is established over the primary path, MPTCP explores the alternate paths, and appends those *secondary paths* to the main flow to aggregate available bandwidth over multiple paths.

Although a few existing works [1, 2] have observed that the overall MPTCP performance depends on the selection of primary path, however, there is no concrete study on how various primary path parameters, like bandwidth, delay and packet loss, impact end-to-end transport performance. In this poster, we explore scenarios when primary path selection can be a serious issue that need to be considered while designing the path scheduler. We discuss our observations from thorough experiments over a realistic MPTCP setup, where we measure the effect of delay, bandwidth and loss rate of primary path over the MPTCP performance. We observe that under certain scenarios, MPTCP performance can be improved as high as around 60%, if the primary path is chosen properly. This study provides a strong motivation for driving the research community towards the development of path selection algorithms based on the end-to-end path properties.

2 EXPERIMENTAL ANALYSIS OF PRIMARY PATH EFFECT

The experimental setup has been built over Mininet network emulator platform where two hosts H1 and H2 are connected via two paths, Path A and Path B, through two different interfaces at each host. The end hosts as well as all the network switches in the path use Linux based operating system, and we use Linux tool `iperf` to generate the network traffic. The Linux kernel at the hosts are configured with MPTCP V0.90[1]. All the experiments are carried out for two cases – one by selecting Path A as the primary path and the other with Path B as the primary path. The bandwidth, delay and loss rate for Path B is kept constant at 10 Mbps, 15 ms and 0%, respectively. We have carried out three experiments by varying the parameters {bandwidth, delay, loss rate} for Path A – (a) **Exp 1 (delay difference)**: $\{10Mbps, 250ms, 0\%\}$, (b) **Exp 2 (bandwidth difference)**: $\{5Mbps, 15ms, 0\%\}$, and (c) **Exp 3 (loss rate difference)**: $\{10Mbps, 15ms, .5\%\}$.

2.1 Effect on Transport Layer Throughput

Fig. 1 represents the difference in throughput when there exists a significant delay difference between the primary path and secondary path. The overall throughput reduces significantly in case of Primary Path A (slower path). The results also show that, the number of out of order segments (OOS) generated are significantly higher in case of slower primary path (i.e. Path A). MPTCP retransmission due to OOS is handled by resending the segments

[1]https://www.multipath-tcp.org

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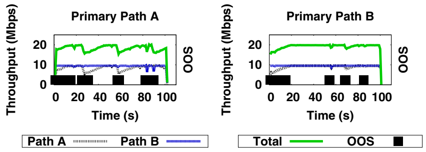

Figure 1: Effect of Delay (Exp 1)

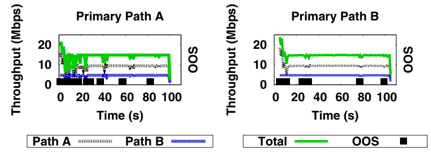

Figure 2: Effect of Bandwidth (Exp 2)

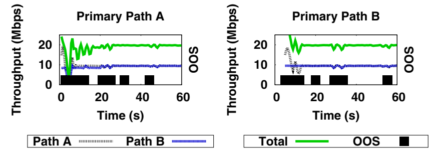

Figure 3: Effect of Loss Rate (Exp 3)

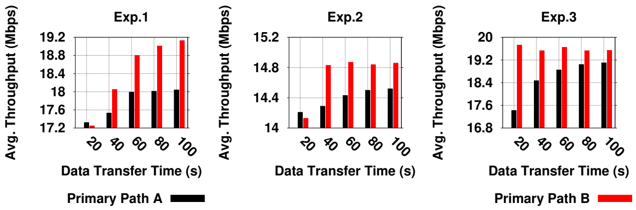

Figure 4: Effect of Flow Duration

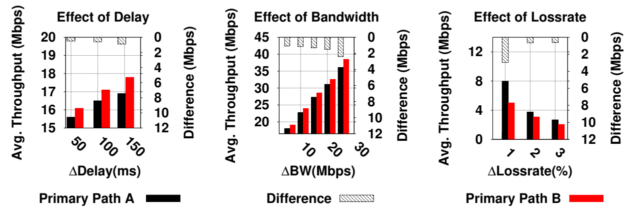

Figure 5: Throughput variation

via the same path for two times, and after that, the segment is assigned to a different path. A retransmission due to three duplicate acknowledgement affects severely in case when the primary path is Path A. The primary path takes longer time to converge to the highest attainable bandwidth due to higher round trip time (RTT). Retransmission in primary path due to OOS further worsen the convergence. This phenomenon is absent in the case when the primary path is Path B, as generation of OOS can be quickly mitigated by retransmitting the segment via that path due to less end-to-end delay. Due to this behavior, the selection of primary path is more significant in case of delay deference, even for longer flows. Fig. 4 shows the impact of flow duration on the MPTCP performance for the three experimental scenarios. As flow duration increases, delay difference has more impact on the throughput difference based on the primary path selection.

In case of a bandwidth difference in between the primary and the secondary path, we see a similar effect (Fig. 2). This result also suggests that choosing a higher bandwidth path as the primary path can significantly reduce the generation of OOS. Fig. 3 shows the results when primary path has higher loss rate than that of secondary path. The results suggests that, choosing a high loss rate path as the primary path can reduce the overall throughput. Further from Fig. 4, we observe that the impacts of bandwidth difference and loss rate difference are more in case of short duration flows.

2.2 Impact of Parametric Difference Between Two Paths

Next we analyze how the delay, bandwidth and throughput difference between the two paths impact the MPTCP throughput based on primary path selection. Fig. 5 represents the change in aggregated throughput with the change in delay, bandwidth and loss rate difference between the two paths. From these figures, it is clear that the increase in variability between the two paths have significant impact on the throughput performance based on the selection of primary path. The impact is significant under certain cases. For example, in case of loss rate (Exp 3), selecting a low loss rate path as the primary path can improve the MPTCP throughput as high as 60%, as we can observe from Fig. 5.

2.3 Summary of Observations

From the experimental results, we observe that a primary path with lower bandwidth, higher delay and/or lower loss rate gives rise to OOS at the receiver (Fig. 1, Fig. 2 and Fig. 3). Such an increase in OOS increases the number of triple-duplicate ACKs at the sender causing the reduction in the congestion window. This unduly reduction in congestion windows adversely affects the aggregated throughput of the network. The main reason behind the increase in OOS is, traditional RTT based congestion control algorithms are not suitable for disparate path characteristics between sender and the receiver.

It can also be observed from Fig. 4 that the effect of delay disparity between paths is more detrimental than the effect of bandwidth disparity between paths. This is due to the very nature of congestion control algorithm and its direct dependence over the RTT. Moreover, the effect of path selection is visible for both the short flows as well as the long flows.

3 CONCLUSION AND NEXT STEPS

In this poster, we have raised a serious issue on MPTCP performance considerations that need to be addressed properly for its practical deployment scenarios. For smartphone with multi-interface (say cellular and Wi-Fi) support, selecting the cellular interface in a poor connectivity region for setting up the primary path may adversely effect the MPTCP performance. Our study gives a few preliminary insights of the primary path effect on MPTCP performance, which can drive the research community to dig into the details of this phenomenal problem.

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