Multipath TCP Westwood over Wireless Networks

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Abstract

In this work, we propose an extended version of TCP Westwood for multiple paths, called MPTCPW. To start with the analysis model of TCPW, MPTCPW is designed as a coordinated congestion controller between paths which allows load-balancing, fair sharing to regular TCPW at bottleneck. Our simulation results show that MPTCPW can achieve higher throughput than MPTCP in wireless environments, fairness to regular TCPW.

1. Introduction

In this paper, we are interested on an extended version of TCP Westwood for multiple paths, called MPTCPW. To start with the analysis model of TCPW [5], MPTCPW is designed as a coordinated congestion controller between paths which allows balancing the loads between the paths, while ensuring fair bandwidth allocation to regular TCPW at shared bottleneck.

The rest of this paper is organized as follows: We describe the details of the TCPW analysis model in Section 2, and then its extension for multiple paths in Section 3. We evaluate our simulation results in terms of fairness, and throughput over wireless links in Section 4. Finally, we conclude our work in Section 5.

2. TCP Westwood Background

TCPW estimates bandwidth available based on inter-arrival time of ACK packets at the sender. Whenever the sender receives an ACK, it computes an available bandwidth sample. In the congestion avoidance phase, TCPW remains the window growth function based on the additive increase function as used in regular TCP (TCP Reno) as follows:

$$\text{Increase:}\; w^{TCPW}(t) \leftarrow w^{TCPW}(t-1) + 1 / w^{TCPW}(t-1),$$

$$\text{Decrease:}\; w^{TCPW}(t) \leftarrow \hat{B}(t) \times RTT_{min},$$

where $\hat{B}(t) = \hat{w}^{TCPW}(t) / RTT$ [3]. The packet drop probability p in the steady state [3] is

$$p = RTT / q(\hat{w}^{TCPW})^2 \quad (1)$$

where $\hat{w}^{TCPW}$ is the equilibrium value of $w^{TCPW}(t)$, $q = RTT - RTT_{min}$ denotes the total queueing delay.

3. Extending TCPW towards MPTCPW

Now, we propose MPTCPW's congestion window growth in additive increase function over path s as follows:

$$\text{Inc.:}\; w_s(t) \leftarrow w_s(t-1) + \min(\delta / w_s(t-1), 1/w_s(t-1)),$$

$$\text{Dec.:}\; w_s(t) \leftarrow \hat{B}_s(t) \times RTT_{min,s}. \quad (2)$$

So the fluid model corresponding to such increase-decrease function is

$$\frac{d}{dt} w_s(t) = \frac{w_s(t)}{RTT_s}\left[\min\left(\frac{\delta}{w_s(t)}, \frac{1}{w_s(t)}\right) - \frac{q_s}{RTT_s} w_s(t) p_s\right],$$

we have the fixed point of above equation as

$$\min\left(\delta / \hat{w}_s, 1/ w_s\right) = q_s / RTT_s \hat{w}_s p_s. \quad (3)$$

We substitute p_s from (1) into (3) to obtain

$$\hat{w}_s^{TCPW} = \max\left(w_s \delta^{-1/2}, \hat{w}_s\right). \quad (4)$$

To improve throughput and to preserve fairness, the total throughput of a MPTCPW flow should be equivalent that of a TCPW flow on the best path for it [4]. This implies that

$$\sum_s \hat{w}_s / RTT_s = \max_s \left\{ w_s^{TCPW} / RTT_s \right\}. \quad (5)$$

By solving for δ from (4) and (5)

$$\delta = \max_s \left\{ \left(\hat{w}_s / RTT_s\right)^2 \right\} / \left(\sum_s w_s / RTT_s\right)^2.$$

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To perform load-balancing between the paths, the congestion window on the congested path must be grown more gradually than that on the better path [4]. This implies that δ for the worse path would be the smaller value. Therefore we slightly modify δ, and then replace δ with δ_s as $\delta_s = \hat{w}_s \max_s\{w_s^{2-\gamma}/RTT_s^2\}/\left(\sum_s \hat{w}_s/RTT_s\right)^2$, where γ is a trade-off parameter between load-balancing and protocol fluctuation, $0 \le \gamma \le 2$. In our experiments (not reported in this paper), γ = 1 gives a reasonable trade-off between fluctuation and load-balancing.

4. Simulation results

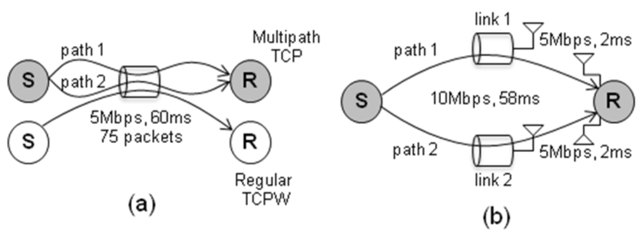

Figure 1. Simulation scenarios

In this section, we evaluate fairness and compare performance with MPTCP [2] in wireless networks. We use NS-2 [1] in our experiments, and SACK option. The scenarios are shown in Fig. 1 with a 1000-byte data packet, and RED.

4.1 Fair Sharing

In this section, we show how a multipath transport protocol fairly shares with a single-path protocol at a common bottleneck without common link detection. We use a dumbbell scenario as shown in Fig. 1(a), where a two-path MPTCPW flow competes against a regular TCPW flow at the shared link. Fig. 2 shows that the single-path TCPW gets its congestion window twice.

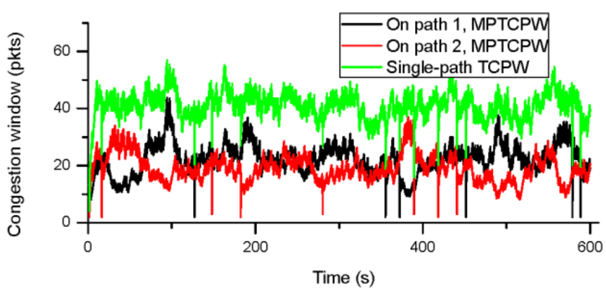

Figure 2. The congestion window evolution of a two-path MPTCPW flow competing against a regular TCPW flow in a shared bottleneck.

4.2 Throughput over Wireless Links

In this section, we evaluate throughput performance of MPTCPW compared with that of regular MPTCP. The simulation scenario is shown in Fig. 1 (b). The experiments were run for 600 seconds under wireless link's random error varying from 0.001% to 5% in packet loss rate. Fig. 3 shows the average throughput of MPTCPW and MPTCP when the packet loss rates on two paths are equal. MPTCPW throughput is higher than that of MPTCP in any packet loss rate. Outperforming of MPTCPW is come from adaptive updating *ssthresh* and *cwnd* to the estimated available bandwidth on paths as detecting a packet loss or timeout event.

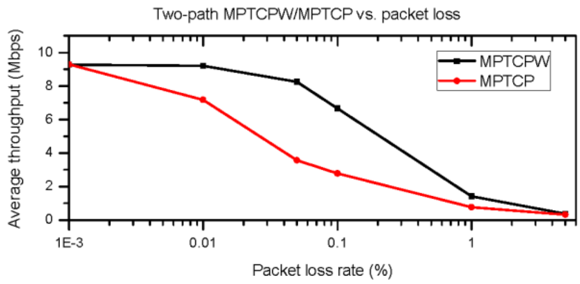

Figure 3. The average throughput of two-path MPTCPW and MPTCP.

5. Conclusion

In this paper, we propose an extended version of regular TCP Westwood for multiple paths over wireless networks, called MPTCPW. To start with the analysis model of TCPW, MPTCPW congestion control is designed as a coordinated control between paths which allows load-balancing feature between paths, fair sharing to regular TCPW at bottleneck. Our simulations show that MPTCPW can achieve higher throughput compared with MPTCP, fair sharing to regular TCPW.

References

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