Dynamic Segment Size Adjustment for TCP Performance in Cellular Networks

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***Abstract*— In this paper, we analyze the impact of the maximum segment size (MSS) on TCP performance in cellular networks and propose a scheme alleviating the performance drop of TCP, which adjusts the segment size dynamically.**

I. Introduction

In cellular networks a frame, unit of transmission in physical layer, has very small size to reduce the frequent errors in hostile wireless channel conditions. Thus, a segment of TCP is splitted into several frames and, then, transmitted one by one. The problem is that the whole segment is corrupted when even a frame consisting of it is lost (See Fig. 1). So, the segment error can occur very often though the frame error rate is low. It becomes worse when the segment splits into large number of frames. It is very important to investigate the relationship among the frame size, the segment size and the frame errors closely since it makes severe influences on TCP performance. We define some symbols to clarify the following discussions.

- s : payload size of a TCP segment.
- H : header size of IP and TCP layers.
- M : payload size of a frame in physical layer.
- n : number of frames consisting of a segment.
- p : segment corruption rate.
- e : frame error rate.

The number of frames n is given as

$$n = \left\lceil \frac{H+s}{M} \right\rceil, \tag{1}$$

and the segment corruption rate is

$$p = 1-(1-e)^n. \tag{2}$$

For example, when $s+H$ is 1500, M is 128, and e is 1%, p becomes about 11.4%. It says that the segment corruption rate can be extremely high even with small frame errors, depending on n.

II. Simulation Result and Analysis

We can guess that TCP throughput will degrade severely regardless of the segment size when the frame error rate is high since it shows cruel performance decrease for the multiple segment losses. However, the amount of reduction depends on the segment size.

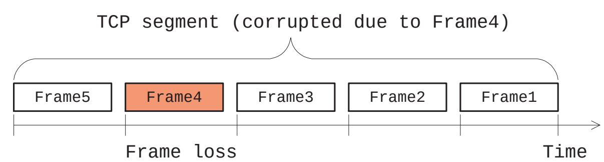
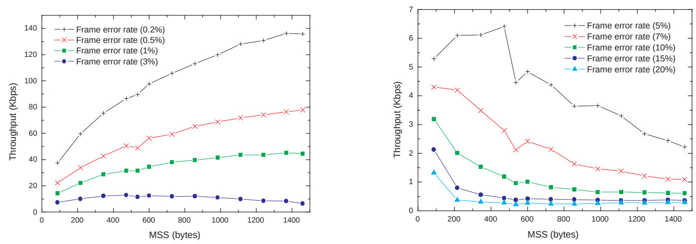


Fig. 1. Frame loss and segment corruption.

The protocol efficiency, which is defined as $\frac{s}{H+s}$, becomes high as the segment size increases. So, WAP forum recommends that TCP should determine the maximum segment size (MSS) through the MTU discovery mechanism[1] such as its optimization method for Wireless Profiled TCP [2][1]. But, a big segment results in the large number of frames and can be corrupted often. It leads to the following proposition; TCP throughput increases with the large segment size when the frame error rate is low, and it increases with the small segment size when the error rate is high. This statement is justified by the simulation results below.

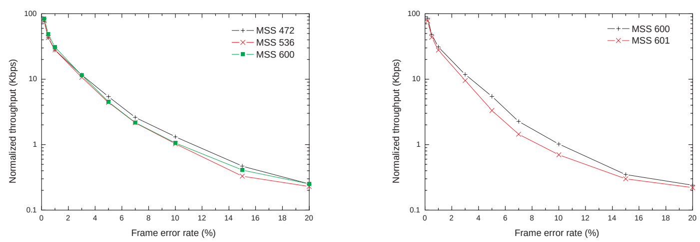
We measured TCP Reno's throughput for several segment sizes varying the frame error rate from 0 to 20%. The frame size is fixed to 128 bytes. Fig. 2 shows the results for the segment sizes 88, 216, 344, 472, 536, 728, 856, 984, 1112, 1368 and 1460, which includes packet sizes frequently observed in IP networks. The gaps of TCP throughput between the high and the low error cases are so large that we present two separate figures. We can see that the throughput increases with the segment size in Fig. 2(a) and decreases with it in Fig. 2(b), which supports our conjecture. Another observation is that the throughput is remarkably low for the segment size 536 and 1460, which is the most common packet sizes in the Internet. They are not optimized in terms of the segment size and the protocol efficiency, which will be explained in more detail below. The simulation results implies that we can prevent the drastic performance drop by adjusting the segment

[1]According to RFC 793, the IP packet size is set to 576 bytes for external networks.



(a) Low error cases (b) High error cases

Fig. 2. Throughput of TCP Reno.



(a) MSS 472, 536, and 600 (b) MSS 600 and 601

Fig. 3. Normalized throughput of TCP Reno.

size dynamically according to the frame error rate and the frame size.

Fig. 3(a) says that the tendency of segment size and frame error rate is not always consistent. That is, ‘MSS 600’ shows better throughput than ‘MSS 536’ even when the error rate is high. The outstanding difference of the two cases is that ‘MSS 600’ is aligned with the frame size [2] while ‘MSS 536’ is not, though they have the same number of frames. Then, we observe the impact of the number of frames on TCP performance by comparing ‘MSS 600’ with ‘MSS 601’. Fig. 3(b) clearly shows the difference between 5 frames case (‘MSS 600’) and 6 frames case (‘MSS 601’). Even if the latter has better protocol efficiency, it shows less throughput than the former. These results give us the following guidelines.

- When the frame error rate is high, it is better to keep the segment size small.
- When the frame error rate is low, it is better to maintain the segment size large.
- In all cases, the segment size must be aligned to the frame size.

III. Heuristic Scheme

We propose a simple scheme adapting the MSS according to wireless channel conditions, whose operation is explained in Fig. 4. Two different values of MSS are defined, small MSS and large MSS. The small MSS is used in bad channel condition and its size just fits in a frame. On the other hand, the large MSS is used in good channel condition and its size is determined by the MTU discovery mechanism of TCP. We choose the frame error rate as an indicator of channel states, but various metrics can be utilized instead of it. The average SNR and the segment corruption rate can be good alternatives.

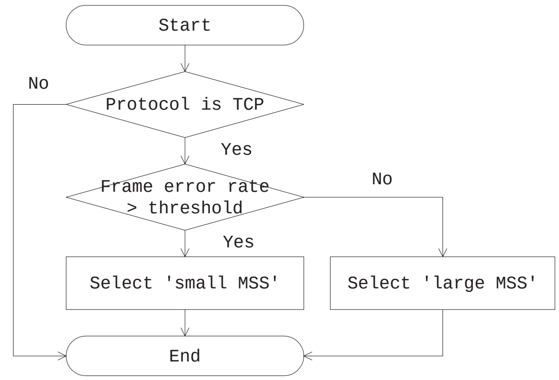


Fig. 4. State diagram of proposed scheme.

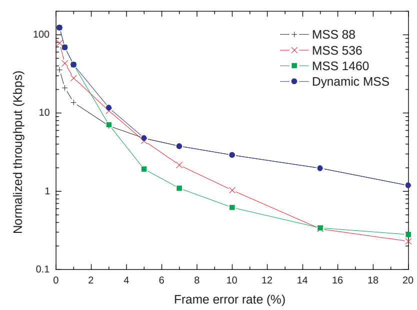


Fig. 5. Dynamic MSS adjustment.

Fig. 5 shows the performance of the proposed scheme. It keeps the TCP throughput approximately optimal value in almost every case.

IV. Conclusion

In this paper[3], we analyzed the impact of MSS on TCP’s throughput in cellular networks by extensive simulations, and derived some valuable guidelines for determining the segment size. Then, we proposed a scheme reducing the performance loss of TCP by adapting the segment size dynamically. Note that widely used MSS (536 and 1460 bytes) shows small throughput, compared to the well-chosen segment sizes based on our criteria.

References

[1] J.Mogul and S.Deering, *Path MTU Discovery*, RFC 1191, IETF, 1990.
[2] Open Mobile Alliance, *Wireless Profiled TCP*, WAP-225-TCP-20010331-a, 2001.

[2]Note that 600+40 (TCP/IP header size) is a multiple of 128, the frame size.

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