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Comparison Study to Choose the Best Congestion Control for Wireless Networks

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ABSTRACT: Transmission Control Protocol (TCP) provides end to end transmission service which provide a significant contribution in congestion control in the network. TCP throughput is better in wired network than in wireless network, because TCP first designed to work in wired network. The main problem with TCP in wireless network is that no differentiation between network congestion and packet or wireless loss. Many versions of congestion algorithms has been built to accomplish an ideal state of congestion control in both wired and wireless networks. This paper provides a comparison study of congestion control in different popular versions of TCP designed in literature. The aim of this study is to pick up the best procedure to develop a novel version for wireless network which can be developed and used to solve the problem with congestion control in wireless network. According to the comparison, a hybrid TCP that use the network beside the sender and receiver to detect the congestion and processing it, will be the best choice to develop a novel TCP for both wired and wireless networks.

KEYWORDS: TCP Congestion Control; Packets loss; Standard TCP; Network Cooperation TCP; Hybrid TCP.

1 INTRODUCTION

Transmission Control Protocol (TCP) is a connection oriented protocol attached in transport layer. TCP provides end to end transmission service which is also contributing in congestion control in the network. The main features provided by TCP are [1]: flow control, reliability, congestion control, and connection management. TCP shows better throughput in wired network than in wireless and that because TCP first designed to work in wired network.

The aim of this paper is to discuss different development directions for TCP congestion control and pick up the best for wireless network. The standard in comparison is how to solve the problem of differentiation between network congestion and packet or wireless loss. Not only that but also what is the best and compatible for both wired and wireless networks.

2 TCP CONGESTION CONTROL

The important service done by TCP is providing end to end transmission. This service has a significant role in congestion control in the network. Congestion free network which is an ideal network means taking the advantage of all the bandwidth in the network.

Among the most popular versions of TCP congestion algorithms, five different mechanisms of congestion control will be discussed in this paper which are: Tahoe, Reno, Vegas, Modified Reno, and Veno. According to the direction used in developing the congestion control of TCP, the five versions can be classified to three classes as following:

1) The Standard versions in which either the standard congestion control is used or slightly modified model (examples: TCP Tahoe, TCP Reno, and TCP Vegas).

2) Network cooperation versions in which sender, receiver, and network router cooperate to build the congestion control algorithm [2] (example: TCP Modified Reno).

3) Hybrid versions in which two or more mechanisms from different version are mixed to build a new version (example: TCP Veno).

All the TCP versions share the four phases of congestion control used in the standard TCP congestion control algorithm [3]. The four phases of congestion control are mentioned in Table 1. The important factors used by these four algorithms are shown in Fig.1.

Table 1. The four phases of congestion control algorithm

Phase 1	Slow Start Algorithm
Phase 2	Congestion avoidance Algorithm
Phase 3	Fast retransmission Algorithm
Phase 4	Fast recovery Algorithm

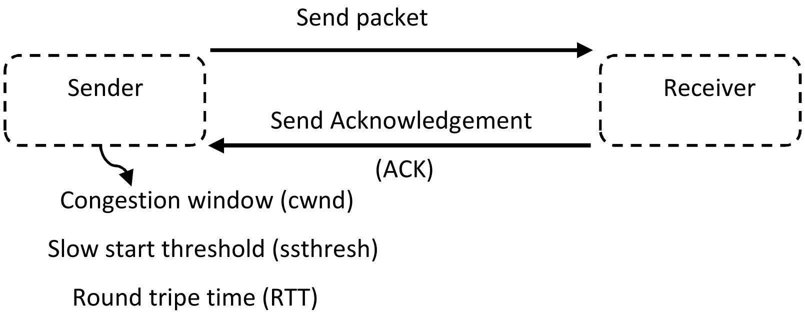

Fig. 1 Common factors used in congestion control

3 TCP VERSIONS

3.1 TCP TAHOE

TCP Tahoe uses only the first three algorithm mentioned in Table 1 which are Slow Start, Congestion Avoidance, and Fast Retransmit [4]. To simplify the idea discussed in [4] algorithm steps with and without congestion will be shown here.

A) The procedure without congestion or loss packet will be as following (All terms taken from Fig.1). The procedure start with congestion window of size equal to one packet and any time we have a complete transmission (the source received an acknowledgement for sent packet before timeout status) the congestion window grow by one packet.

cwnd<= ssthresh
Connection start : cwnd=1 packet.
Each ACK : cwnd+=1 packet.

B) The procedure when we have any one of the following states: the congestion window exceeds the ssthresh, timeout, or receives three duplicate acknowledgements by source.

ssthresh = cwnd/2
cwnd = 1
Congestion avoidance
Fast retransmission
Slow start state: when ACK received for retransmitted packet.

Without going in details of these algorithms we can notice some weak points in this procedure. [4] Tahoe procedure starts with a small size for transmission window which is equal to one packet. As a response to any congestion the window is doped to one packet again. Repeating the procedure of dropping the transmission window for each packet loss or congestion has a severe effect on network bandwidth. This procedure didn't have any solution for the main problem in wireless network which is differentiation between network congestion and packet or wireless loss. All that mean we provide a good TCP for wire network but it is not the good one for wireless network.

3.2 TCP RENO

TCP Reno [5] uses the entire four algorithms for congestion control mentioned in Table 1. The new procedure looks like the one used in TCP Tahoe when respond to timeout. But for three duplicate acknowledgements another procedure will be used which is like following:

ssthresh = cwnd/2.
cwnd = ssthresh + 3. (fast recovery)
first ACK: cwnd +=1.
next ACK cwnd = ssthresh.

The simulation done in [5] uses two senders and two receivers to test different scenarios of congestion control and Round-trip time RTT. According to the results of simulation, the raise of RTT occurs only when there is a congestion in the network. The raise in RTT property is used to timing the sender with the difference of RTT in current cycle and the previous one. The negative sum of RTT differences means we have no congestion in the current cycle of transmission while the positive sum of RTT differences means the transmission is in congestion state or will have a congestion in next cycles. The algorithm of TCP Reno will be like the following:

```
RTT_diff_sum=0;
when the sender recieves a ACK;
RTT_diff = RTT - RIT_last;
RTT_diff_sum + = RTT_diff;
if(dup_ACKs> =3)
(if(RTT_diff_sum >O) Ilin congestion state
{ssthresh=min(cwnd,rcv_window )/2;
cwnd = ssthresh+ 3*MSS;  //lower transmission rate
retransmit the lost packet;
} else  //in non-congestion state
{ only retransmit the lost packet;
}
}
```

With all the improvements done in [5], TCP Reno is not the best choice to use with wireless network. The new procedure doesn't provide a way to differentiate between packet loss caused by congestion in network and packet loss when network suffer from random bit error in wireless links.

3.3 TCP VEGAS

TCP Vegas is an extension of TCP Reno [6]. The new model proposed in [6] has no modifications in the main features of TCP. All the modifications related to sender side and how can it provide accurate calculation to network congestion.

TCP Vegas keep using the four algorithms used in TCP Reno so it has the fast retransmit and fast recovery algorithms. New mechanisms used in Vegas to provide accurate calculation to RTT. When the connection start it will use the RTT calculated for the first segment sent. The sender will keep calculating RTT every pre specified time (500ms in [6]) and any increasing in RTT detect congestion in the network.

Vegas also have a new retransmission procedure which is used with duplicated acknowledgments. It calculates RTT for each ACK and depending on it the retransmission decision will be taken. The new procedure used also with normal ACK to make retransmission decision.

The new TCP version has a novel react to timeout and duplicated acknowledgements. With new procedure used in Vegas lost packets can be detect from the first or second duplicate ACK. This procedure will give a chance to detect lost packets those does not have duplicated acknowledgements.

3.4 TCP Modified Reno

In [2] a very novel TCP version has been proposed, see Fig.2. The design provides a new mechanism to differentiate between packets loss caused by high bit error and packets loss caused by network congestion. Sender, receiver and middle router all of these parts cooperate to detect congestion and control it.

The new modified Transmission Control Protocol (TCP Reno) is able to monitor the loss of wireless packets in real time. By detecting a router's buffer mechanism in response to congestion occupancy, the modified Reno is able to monitor wireless packet loss; thus being able to react accordingly and decrease the rate of wireless package loss. This is important because when high volumes of information packets are sent it can have problems reaching the desired recipient. Communication over wireless links [2], between computer networks and various systems, is filled with random rates of high bit error and connectivity that is intermittent due to the frequency of handoffs. Mechanisms such as random early detection (RED) were used to find possible problematic packets in their early stages.

The modified TCP Reno uses Explicit Congestion Notification (ECN), which is an extension of REDs. This mechanism can allow the system to properly tell the difference between random wireless link errors and errors caused by the congestion of network links. It can also monitor the rate at which wireless packets are lost in a manner that helps the sender select the appropriate segment size at the right moment when packet loss is identified. These modifications to Reno, after plenty of tests and simulations, have shown to have merit and even improve the TCP efficiency; it can do this with no changes in the protocol itself which makes the modified Reno easy enough to use.

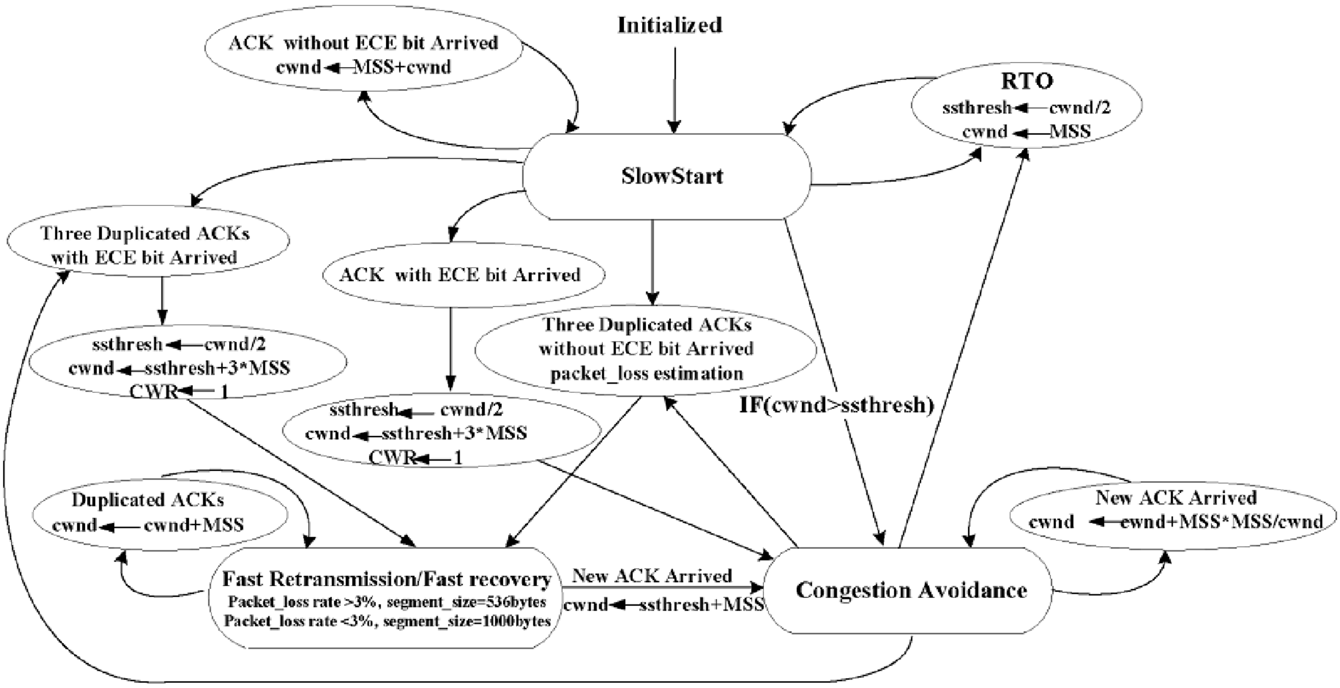

Fig.2 State machine of Modified Reno [2] (Where ECE: Echo of ECE, and RTO: Retransmit timeout)

3.5 TCP VENO

TCP Veno aims to provide the best TCP for both of the wired and wireless networks [7]. Tcp Veno is a combination of two versions of TCP which are Vegas and Reno versions.

TCP Veno proposed in [7] uses the same slow start algorithm of TCP Reno. The new version improves the performance of TCP-Reno by utilizing its Bandwidth Estimation scheme. In order to estimate the state of a connection, TCP-Veno uses a mechanism similar to TCP-Vegas.

Real time experiments done in [7] and showed that TCP Veno has effective work in both wire and wireless networks. By re-visit the distinguishing scheme which is borrowed from Vegas TCP and adopted in Veno TCP, there are two congestion levels - light congestion, and moderate congestion when three duplicate packets are received. At that time, Reno will halve its window, and more aggressive recovery scheme is taken over than that action corresponding to timeout occurrence.

This version is compatible with wire and wireless network but still not providing a complete solution to congestion control problem in wireless network.

4 CONCLUSIONS

This paper discussed the enhancement of congestion control in five different versions of TCP designed in the literature. When the enhancement related to the congestion algorithms without sharing the solution with the network (example: Tahoe, Reno, and Vegas) we do not provide the good solution for congestion control problem in wireless network. Another direction of enhancement is to create cooperation between sender, receiver, and network to detect and process congestion in the network. This direction is valuable for wireless network and provides the best throughput (example discussed in this paper was TCP Modified Reno). The last direction of enhancement discussed in this paper is hybrid TCP and the case was TCP Veno (from Vegas and Reno) and it is provide a good throughput for both wired and wireless networks. The third direction of enhancement is the best choice to develop a TCP congestion control for both wired and wireless network. But to build a novel TCP for wireless network, the paper support the hybrid TCP that use the network beside the sender and receiver to detect the congestion and processing it.

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