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Performance Enhancement of TCP in Wireless Environment Using Cross Layer Mechanism

Sridhar P, Kavitha B

Senior Lecturer, Department of Computer Engineering, IRT Polytechnic College, Chennai, India

Lecturer, Department of Electronics and Communication Engineering, IRT Polytechnic College, Chennai, India

ABSTRACT - Wireless networks suffer from several performance limitations from the layering paradigm employed for the TCP/IP protocol stack design. Indeed, TCP/IP was originally designed for wired links. On the contrary, in the wireless domain, performance is constrained by available transmission spectrum, employed modulation and available transmission power.Temporal link disconnection during handoff introduces consecutive packet losses in wireless and mobile network. These causes force TCP to aggravate the bandwidth utilization of wireless Networks. A Path Recovery Notification (PRN) mechanism to prevent performance degradation during a handoff is proposed. The proposed protocol, TCP–PRN, quickly recovers lost packets by restoring the congestion window, preventing the congestion window to decrease or immediately initiating the slow start algorithm. When a TCP receiveris attached to a new access point after a disconnection period or handoff, it sends a special Acknowledgement (ACK).

This ACK consists of two components: one is a PRN option, and the other is a TCP SACK option which contains information on the sequence numbers of the lost packets. This ACK notifies a TCP sender that which packets are lost due to the temporal link disconnection. Then, the TCP sender immediately attempts to retransmit those lost packets. The performance improvement of this approach is evaluated using the simulator NS–2 and observed that PRN outperforms SACK in more real wireless environment, where RTT is varied according to the wireless link and the networks status.

KEYWORDS: Acknowledgement, Cross Layer, Disconnection, Receiver, Sender, Throughput

I. INTRODUCTION

Wireless networks suffer from several performance limitations, in some cases related to excessive burden deriving from the layering paradigm employed for the TCP/IP protocol stack design. Indeed, TCP/IP was originally designed for wired links which general characteristics include high bandwidth, low delay, and low probability of packet loss (high reliability), static routing, and no mobility. On the contrary, in the wireless domain, performance is constrained by available transmission spectrum, employed modulation and available transmission power. Loss probability experienced by packet transmission is in general higher on the wireless medium rather than on wired links.

Transmission Control Protocol (TCP) provides a connection oriented, reliable byte stream service. The term connection oriented means, the two applications using TCP must establish a connection with each other before they can exchange data. It is a full duplex protocol, means that each TCP connection supports a pair of byte streams, one flowing in each direction. It establishes a virtual path between the source and the destination. TCP uses an acknowledgement mechanism to check the safe and arrival of data. TCP provides the following facilities – Stream Data Transfer, Reliability, Flow Control, Multiplexing, Logical Connections, and Full Duplex.

The adaptation of TCP to congestion causes a lot of problems in wireless domain. The wireless domain has high packet loss and variable latency, which may cause TCP to respond with slow start mechanism. Bandwidth utilization is further reduced due to retransmission of lost packets.

One of the earliest suggested alternatives for improving the performance of TCP over wireless networks was to ensure that the link layer corrected all errors itself over the wireless interface, thereby eliminating the need of error

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handling at the TCP layer. One of the suggestions is to use FEC to correct small errors. FEC incurs overhead even when there are no errors as there must be redundant parity bits to allow error detection and correction.

Several Alternatives have been proposed to alter the existing TCP protocol to suite the wireless domain. The simplest idea would be to design a TCP protocol for the wireless domain. There are various approaches to improve TCP performance in the wireless domain.

The concept of cross-layer design is about sharing of information among different protocol layers for adaptation purposes and to increase the interlayer interactions. In wireless networks there is tight interdependence between layers. Cross-layer design can help to exploit the interactions between layers and promotes adaptability at various layers based on information exchanged. However, such a design process needs to be carefully coordinated to avoid unintentional and undesirable consequences.

a. Allow interactions between various protocols of non-adjacent layers through introduction of new interfaces
b. keep the impact of design violations as small as possible

Cross-Layer approaches violate the traditional layer architecture
a. creation of new interfaces
b. merging of adjacent layers
c. sharing of variables and parameters among multiple layers

A Selective Acknowledgment (SACK) mechanism, combined with a selective repeat retransmission policy, can help to overcome these limitations. The receiving TCP sends back SACK packets to the sender informing the sender of data that has been received. Then the sender retransmits only the missing data segments.

The selective acknowledgment extension uses two TCP options. The first is an enabling option, "SACK-permitted", which may be sent in a SYN segment to indicate that the SACK option can be used once the connection is established. The other is the SACK option itself, which may be sent over an established connection once permission has been given by SACK-permitted. The SACK option is to be included in a segment sent from a TCP that is receiving data to the TCP that is sending that data. Considered a particular simplex data flow; any data flowing in the reverse direction over the same connection can be treated independently.

The SACK option is to be sent by a data receiver to inform the data sender of non-contiguous blocks of data that have been received and queued. The data receiver awaits the receipt of data (perhaps by means of retransmissions) to fill the gaps in sequence space between received blocks. When missing segments are received, the data receiver acknowledges the data normally by advancing the left window edge in the Acknowledgement Number Field of the TCP header. The SACK option does not change the meaning of the Acknowledgement Number field.

A path recovery notification mechanism to improve the performance of TCP over wireless networks is proposed. PRN does not rely on the accurate prediction of an impending disconnection and information regarding the speed, as required by SACK. PRN executes immediate recovery of lost packets during a handoff and keeps *cwnd* and *ssthresh*to maintain its throughput. Through the extensive simulation, it is observed that PRN outperforms SACK in more real wireless environment, where RTT is varied according to the wireless link and the networks status.

II. Literature Survey

When TCP receiver is attached to a new access point after a disconnection period or handoff, it sends a special ack. This ACK consist of two components namely PRN option and TCP SACK. PRN option and TCP SACK option which contain information on the sequence number of the lost packets. This ACK notifies a TCP sender that which packets are lost due to this temporal disconnection. TCP sender immediately retransmits those lost packets. TCP-PRN shows more robust [1].

The performance of application on moving devices is affected by the device constraints of memory, processing power, and the variations in the wireless network. So Cross layer feedback in the protocol stack is useful to improve the performance of moving devices [2].

The F-RTO effectively avoids the unnecessary retransmissions following the spurious RTO. Based on the incoming acknowledgements, decisions are made whether to retransmit or continuing sending data. The use of F-RTO effectively avoids unnecessary retransmissions and it obviates the New Reno "bug fix" rule which disables fast retransmit during F-RTO recovery and it allows more efficient recovery from packet losses [3].

Adaptation TCP (ATCP) involves the modifications to the network stack only at mobile host and requires network layer feedback regarding the status of the connectivity. ATCP is designed to improve TCP performance in wireless and mobile networks in the presence of temporary disconnections caused my mobility [5].

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Freeze-TCP is that it needs the receiver to predict impending disconnections. If a disconnection cannot be predicted the behavior and performance will be exactly that of standard TCP. So Freeze-TCP can yield better performance than those that simply react after a disconnection occurs [6]. A Selective Acknowledgment (SACK) mechanism, combined with a selective repeat retransmission policy, can help to overcome these limitations. The receiving TCP sends back SACK packets to the sender informing the sender of data that has been received. The sender can then retransmit only the missing data segments [7].

The protocol changes are made to network-layer software at the base station and mobile host, and preserve the end-to-end semantics of TCP. One part of the modifications, called the snoop module, caches packets at the base station and performs local retransmissions across the wireless link to alleviate the problems caused by high bit-error rates. The second part is a routing protocol that enables low-latency handoff to occur with negligible data loss. [8].

The key ideas in the asymmetric protocol design, AIRMAIL(Asymmetric Reliable Mobile Access In Link-layer), consist of placing bulk of the intelligence in the base station as opposed to placing it symmetrically, in requiring the mobile terminal to combine several acknowledgments into a single acknowledgment to conserve power, and in designing the base stations to send periodic status messages, while making the acknowledgment from the mobile terminals. The forward error correction technique incorporates the levels of channel coding which interact adaptively [9].

The paper is organized as, Section 2 deals with Literature survey, Statement of the problem and objectives of the project, Section 3 deals with the system design, Architecture of the system and specifies the main goals to be achieved using the proposed design. It provides the view of the protocol stack of the proposed design. Section4 analysessimulation requirements the simulation results, describes the parameters used for the simulation process, specifies the performance metrics, performance obtained presented as Graphs and analysis of the result based on the graphical data, Section 5 describes the conclusion.

III. System Design And Implementation

A novel cross-layer approach designed for performance enhancement of TCP over a large variety of wireless mobile networks. The proposed scheme is Path Recovery Notifications (TCP-PRN) mechanisms. Here when a TCP receiver is attached to a new AP after a disconnection period or handoff, it sends a special ack. This ACK consist of 2 components namely PRN option and TCP Sack.

a. TCP Sack which contains information on their sequence numbers of the lost packets. This acknowledgement notifies a TCP sender that which packets are lost due to the temporal link disconnection. Then the TCP sender immediately attempts to retransmit those lost packets.

b. TCP-PRN is used to fast recover the adverse impact of the temporal link disconnection due to the handoff.

The network scenario taken is infra-structure based with three different senders (S_1, S_2 and S_3) and ten receivers (R_1, $R_{2...}$ R_{10}) and is shown in Figure 3.1. Figure 3.1 also shows ten different flows (F_1, F_2 … F_{10}) from sender to receiver through the access point and the flows are destined to the corresponding receivers.

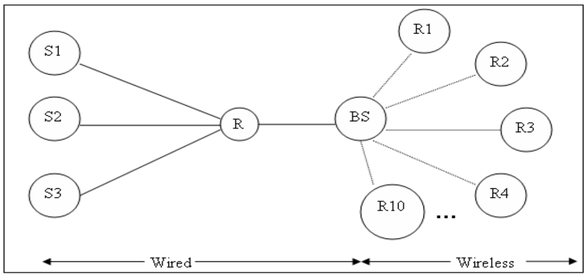

Figure1- Network Scenario

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3.1 TCP-PRN

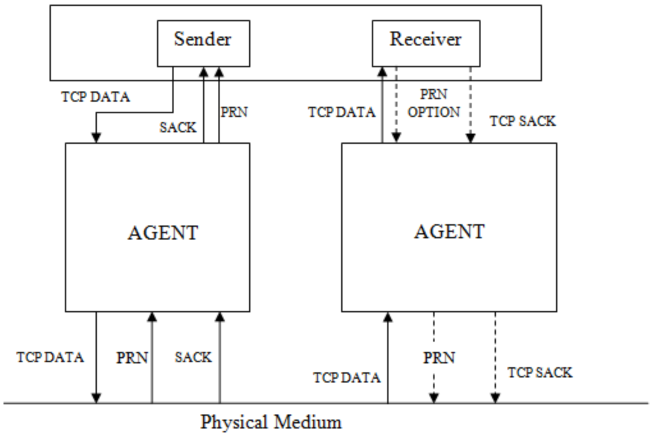

Figure 2- Architecture of TCP-PRN

The figure2 represents the architecture of TCP-PRN. When a TCP receiver is attached to a new access point after a disconnection period or handoff it sends a special ACK. This ACK consist of two components namely PRN option and other is a TCP SACK. PRN option plays a role in notifying the sender that a wireless link was temporarily disconnected and reconnected. The option is set to one of three condition flags. They are reconnection (RC), partial loss (PL) and no packet arrival (NPA). TCP SACK contains information on the sequence numbers of the lost packets. This ACK notifies a TCP sender that which packets are lost due to this temporal link disconnection. Once the receiver knows that the wireless link has been reconnected, it informs the sender with this information by sending an ack with a PRN option set to the condition flag. The sender immediately checks if the sender's retransmission timer has passed. Before the PRN timer expires if new packet arrival at the receiver, it is possible that they includes gaps in the sequence numbers. In that case the receiver sends an ACK packet with a PRN option set to PL flag. This ensures that the sender only transmits the lost packets. Then the receiver cancels the PRN timer. If no new packets arrive at the receiver and the PRN timer expires, the receiver sends an ACK packet with only the PRN option to set to NPA. This forces the sender to send all unacknowledged packets to perform the process.

IV. SIMULATION RESULTS AND ANALYSIS

The basic principle of TCP–PRN is to fast recover the adverse impact of the temporal link disconnection due to a handoff. To alleviate the influence of packet losses during the disconnection, a TCP receiver on an MN notifies its TCP sender on a FN of the temporal disconnection through a special ack. Then, the TCP sender retransmits the lost packets and restores the reduced cwndand ssthresh, if a false RTO occurs.

TCP–PRN requires modifying both the sender's and receiver's operations on the TCP–SACK option. Some variables included in TCP–PRN are listed as follows.

PRN option - This option plays a role in notifying the sender that a wireless link was temporally disconnected and reconnected. The option is set to one of three condition flags: reconnection (RC), partial loss (PL), and no packet arrival (NPA).

Ocwnd - This variable is a copy of cwnd. It is used to restore cwndif an RTO occurred due to a disconnection.

Ossthresh - This variable is a copy of ssthresh. It is used to restore ssthreshif an RTO occurred due to a disconnection.

lsent_time - This variable indicates the time of the last packet transmitted from the TCP sender within a window due to a RTO or a fast retransmit.

PRN timer - If this timer expires, the PRN option with NPA is sent to the sender to notify that there may have been a loss of all packets.

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4. 1 SIMULATION PARAMETERS

The simulation parameters used for the infrastructure network scenario is presented in table. The rest of ns-2 configuration parameters are set to their default values unless explicitly specified.

Table -1 Simulation parameters

S.No	Parameter	Value
1	Channel Frequency	2.472 GHz
2	Transmission Power	31.6 mW
3	Receiver Sensitivity Threshold	5.82×10^{-9} W
4	Transmission Range	250 m
5	Propagation Model	Two-Ray Ground
6	Wire Nodes	4
7	Base Station	1
8	Wireless nodes	10
9	Packet Size	500 Bytes
10	Propagation Delay (Wired)	20ms
11	Capacity (Wired)	5 Mbps
12	Protocols	SACK,PRN

4. 2 PERFORMANCE METRICS

4.2.1 Throughput

Throughput is defined as the number of bits passing through a point in a second. On extending from bits to packets and from a point to a network, it is defined as the number of packets passing through the network in a unit of time. The unit of throughput is Mb/s. Throughput is represented as

T = b / time * 8 /1000000

Where b = bandwidth (in Mb/s)

4.2.2 Disconnection Period

Disconnection period is defined as the duration for which a node moves out of transmission range (disconnects the network) and reconnects the network

4.2.3 High Bandwidth Low Delay

Throughput is measured with bandwidth of 50 mb and delay of 5 milliseconds

4.2.4 Low Bandwidth High Delay

Throughput is measured with bandwidth of 5 mb and delay of 50 milliseconds

4.3 SIMULATION RESULTS

The analysis is done with the parameters as described above in table. The parameters are varied accordingly for each simulation process.

Simulation is performed with the parameters disconnection and number of disconnections on x-axis and metrics such as throughput on y-axis.

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With packet size as 500bytes, simulation is carried out for 500 s. The results obtained shows that the PRN protocol has better improvement over the SACK protocol.

4.3.1 High Bandwidth Low Delay

Throughput is measured with packet size of 500 bytes, bandwidth of 50 Mb and delay of 5 ms. Disconnection period is introduced and throughput of ACK and PRN are compared.

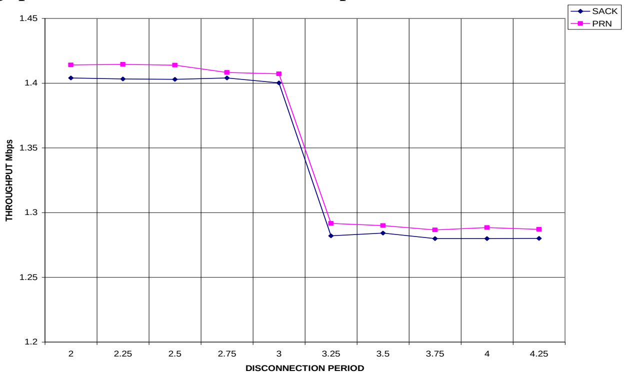

Figure 3 - Disconnection Period Vs Throughput

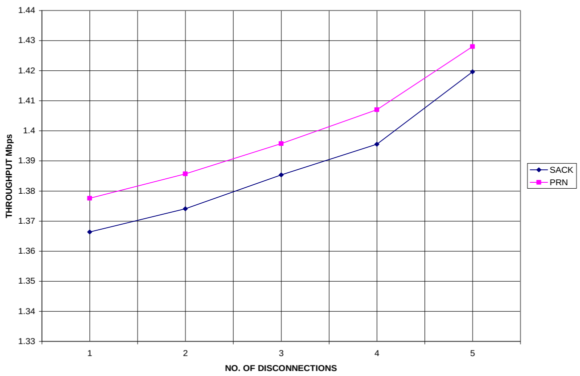

Figure 4 - Number of Disconnections Vs Throughput

Figure 3 shows that the throughput of SACK and PRN are degraded as disconnection period is increased. It is also observed that PRN shows better performance as compared to SACK during increase in disconnection period.

Figure 4 shows that the throughput of PRN increases by 0.02Mbps than SACK in case of increase in disconnections. It is also observed that PRN shows better performance as compared to SACK.

4.3.2 Low Bandwidth High Delay

Throughput is measured with packet size of 500 bytes, bandwidth of 5 Mb and delay of 50 ms. Disconnection period is introduced and throughput of SACK and PRN are compared. The figure 5 shows that the throughput of SACK and PRN are degraded as disconnection period is increased. It is also observed that PRN shows better performance compared to SACK.

The figure 6 shows that the throughput of PRN increases by 0.02Mbps than SACK in case of increase in disconnections. It is also observed that PRN shows better performance as compared to SACK.

From the results it is concluded that the TCP-PRN outperforms SACK in both casses.

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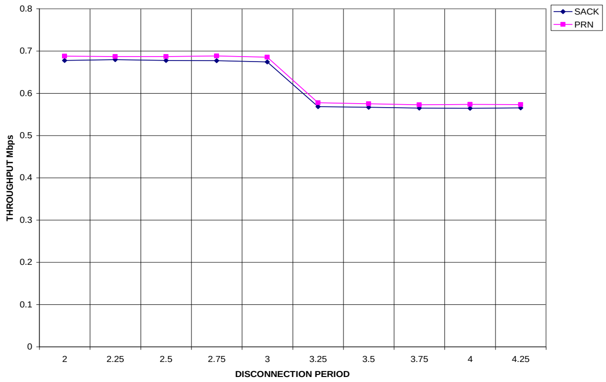

Figure 5 - Disconnection Period Vs Throughput

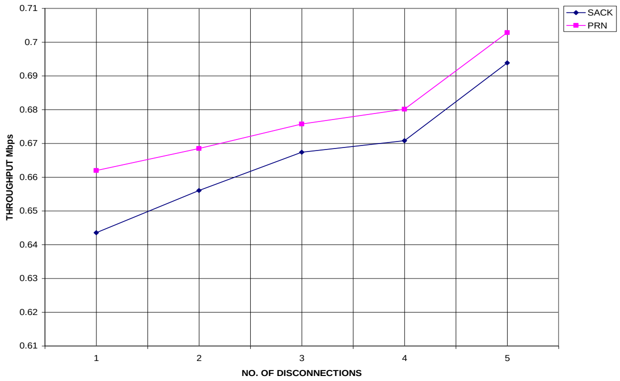

Figure 6 - Number of Disconnections Vs Throughput

V. CONCLUSION

A path recovery notification mechanism to improve the performance of TCP over wireless networks is proposed. PRN does not rely on the accurate prediction of an impending disconnection and information regarding the speed, as required by SACK. PRN executes immediate recovery of lost packets during a handoff and keeps cwnd and ssthreshto maintain its throughput. Through the extensive simulation, it is observed that PRN outperforms SACK in more real wireless environment, where RTT is varied according to the wireless link and the networks status. Especially SACK has a weakness of the following RTT variances. Usually, if an RTT is large, the time taken over wired networks is much longer than the time taken over wireless networks. In this case, the queuing delay becomes the critical factor of the RTT variance. Therefore, the networks congestion dynamics affects SACK. If an RTT is short, the time taken over wireless networks will be dominant rather than the time taken wired networks. In this case, the transmission delay variance of wireless link will be the critical factor. PRN does not require any modification of the network infrastructure except obtaining the handoff information from the lower layer. Because it only modifies the operation of TCP residing at the end nodes, it can be used over heterogeneous wireless networks.

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