Transport Control Protocol (TCP) enhancement over wireless environment: Issues and challenges

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TRANSPORT CONTROL PROTOCOL (TCP) ENHANCEMENT OVER WIRELESS ENVIRONMENT: ISSUES AND CHALLENGES

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Abstract- **With the advancement of technology, handheld devices like smart phones, ipods, PDAs, etc. have become very popular now-a-days. The real flavors of these emerging smart technologies are perceived when they are interconnected by means of wireless networks. In real-life scenario, the networks are highly heterogeneous in nature and the most popular, traditional and reliable protocol for communicating among these networks is the Transmission Control Protocol (TCP). TCP is a transport layer protocol of the internet protocol suite which provides services for host-to-host connectivity in a connection-oriented manner. In a wired network, the TCP is well tuned to give a good performance for communication. The primary reason of packet losses in case of wired networks is the congestion in the network. However, the scenario is different in case of wireless communication. Here, the TCP performance issues crop up mainly due to errors in transmission and handoffs. The paper presents a comprehensive survey of various approaches pertaining to the improvement in TCP performance in wireless networks. It summarizes the various proposed methodologies and also presents the advantages and disadvantages of those approaches.**

Keywords- TCP, wireless network, enhancement, survey, throughput.

1. INTRODUCTION

As a result of rapid advancement in portable computing platforms, wireless networks have been growing at a lightning pace over the recent years. TCP is the most vital transport layer protocol that aids in communication among these networks. In the beginning, it was developed for wired networks. TCP provides end-to-end delivery of data between the hosts reliably. Many researches are being done to fine-tune the TCP for the wired networks and maximize the throughput.

In wired systems, transmission errors occur once in a while and the primary reason behind packet loss is network congestion. Network congestion takes place when the network node is bombarded with huge number of requests that exceeds its serving capacity. This can happen in cases of limited bandwidth of communication links, less buffer space or small serving capacity of the routers.

Advancement in communication systems plays a critical part in the militaries, government, and non military personnel surroundings. Presently days, with the simple access of little convenient gadgets and the advancement in wireless technology, portable computing is turning out to be extremely prevalent.

The TCP layer is responsible for controlling and minimizing packet loss thereby providing a reliable service by packet retransmission [1]. In today's internet era, TCP is widely used. It provides services for application program and internet protocol. TCP is byte-stream protocol since TCP flow control mechanism and acknowledgment are dependent on byte number.

TCP/IP is the distinct layer of OSI reference model that provides functionality in communication. In the continuous stream of segments, performance of TCP is very well as well as congestion control mechanisms and recovery mechanisms are operational as intended [2].Congestion control comes into play when the allotment of resources in a network system in such way that network may work at a satisfactory level as the demand defeat the limit of the network resources [3]. Cautious design is recommended to provide good service covered by overwhelming burden. Conversely, there might be a congestion reduction that prompts to exceedingly resource outrageous and results in undesirable condition of operation. In continuation with today's internet milestone, there is necessity to modify the regular TCP to increase performance. As TCP applied to wireless environments, its performance diminishes and acts erroneous as compared with wired connection. So that it is essential to use proper enhancements techniques for TCP over wireless environments.

The main cause for performance diminishing of TCP is loss of packet. It supports that packet loss and poor performance of TCP is due to congestion in network with other reasons for packet loss. In a wireless network, packet losses will show up by ideals of high Bit Error Rates (BERs) than congestion [22]. As applying TCP over wireless networks, it accepts that every packet loss on account of congestion and call to congestion control measures at the source. This finishes up in thorough performance degradation.

TCP/IP provides a reliable and prominent technology for expanding communication platform. Despite being popular, modification in transport layer is a necessity for its usage in wireless domain. If there is an issue of constant transmission error in the network, then the transmission rate becomes nearly zero. If transmission error takes place regularly, the transmission rate of wireless interconnection becomes nearly zero. TCP/IP protocol is the prominent architecture for expanding computing platform. In spite of being a popular technology, modification requires in transport layer that to be used in wireless scenario.

In wireless environment, The reason for packet loss is the congestion. The transport layer protocol used for wired network, where physical connection are reliable and loss of data packet is arbitrary, cannot used directly in wireless environment. In short, TCP is extremely responsive to packet losses and needs more upgrades to better oblige to the wireless environments. It ought to empower to between wireless related losses and congestion related losses and be adjusted to exploit accessible network resources successfully. There are some approaches that lead to reduction of packet loss and increase in throughput of TCP. These are discussed in next section.

Wireless Networks can be broadly categorized as Cellular Networks, Ad-hoc Networks and Satellite Networks, each of which is enumerated below.

A) Cellular Networks: In this category of networks, mobile host is interconnected to fixed networks through Base Stations. Currently this category of Wireless Network is the most prevalent among others. Examples of these networks are cellular phones, palmtops, etc. Majority of the techniques proposed for TCP on wireless networks are adapted to this network model. Most of the issues related to wireless networks fall in these fixed networks since majority of the service providers are on these fixed networks.

B) Ad-hoc Networks: In these networks, mobile hosts are connected among themselves through radio links. This network model is not fine deployed so that few solutions have been proposed.

C) Satellite Networks: In this category of networks, sender and receiver are connected by means of satellite link. Since the satellites are situated at a distance very far away from the surface of the earth, the network suffer from high latency and frequent BERs (Bit Error Rates).

2. MAJOR CHALLENGES AND ISSUES

In wireless network scenario, the performance of TCP is not satisfactory as it ought to. So, the need arises for employing proper enhancement techniques to mitigate the TCP performance issues. by diminishing packet loss due to network congestion and transmission errors.

To accomplish fine performance, it is mandatory to control network overcrowding so that data packets number underneath the level at which network performance degrades drastically. For picking up expand throughput and limit packet loss, there are different solutions or enhancements approaches however they have a few drawbacks of existing solutions. . Erroneous unstable wireless link leads to degradation of wireless network. Transmission channel with errors prompts to reduction of throughput. There might be chances of packet loss as the transmission channel has minor error.

Secondly, when user shift from one network to another network, data packets are omitted by means of mobility and congestion in network. Wireless media has narrow bandwidth as compared to wired network, results in degradation of performance of wireless network. To gain throughput enhancement, Fast retransmission of failed packet is necessary.

Earlier, as we have declared, when TCP applied to wireless environment, its performance degrades. So, it is necessary to use appropriate enhancement techniques. A mechanism is required to identify the cause of packet loss in wireless network through discriminating loss of packet because of congestion and loss of packet owing to transmission errors. By using proper enhancement, packet loss can be reduced. The problems belongs to bandwidth might be solved in wireless network.

In high speed network, large amount of bandwidth is available so that throughput efficiency and packet loss as well as infixed network, slow start mechanism in traditional TCP are measured as major design issue. Assumptions driven by TCP have been disregarded by network having high bit error rates. It results to degradation in end to end performance.

To attain the reduction of packet loss and maximize throughput, some approaches are discussed in next section. The proposed approaches can be classified into four groups; split-connection, link-layer, explicit notification and end-to-end protocols.

3. APPROACHES TO IMPROVE WIRELESS TCP PERFORMANCE

In this section, we addressed some protocols that have been proposed to increase the performance of TCP over wireless scenario.

3.1 SPLIT-CONNECTION PROTOCOLS

In split-connection protocols approach, each TCP connection are divided into two separate connections; first is between the fix host (FH) and the base station (BS) and the second between the base station(BS) and mobile host (MH).

3.1.1 INDIRECT TCP (I-TCP)

Indirect TCP (I-TCP) [1] is a split-connection that endeavors the resources of mobility support routers (MSRs) to offer transport layer communication between mobile hosts and fixed hosts. It helps the standard TCP for doing its connection over the wireless hop that attempt to separate loss recovery between wireless connection and wired connection. It guarantees that packet errors and delay deviation on the remote connection don't prompts to start of TCP congestion control measures or impact the TCP retransmission timer on the wired connection, and destroy the end-to-end retransmission of packets over the wireless connection.

I-TCP divides a conclusion to-end connection between Mobile Host (MH) and the fixed network (FH) into two separate associations; one between the Mobile Host (MH) and its mobile support router (MSR) at the Base Station (BS) upon wireless medium and another between the mobile support router (MSR) and the fixed network (FH) upon fixed network. Initially Data got by the MSR at the base station, it then returns acknowledgement to the FH and afterward the data is conveyed to the MH. This indirection support to shield the wired system from the unconventionality of the wireless network and the TCP/IP at the fixed host end require not be changed.

I-TCP improves the handoff through contracting the get window size at the MSR that powers the FH to quit sending data as MSR supports are full. After the handoff, the new MSR ready to acknowledge more data from the FH and the data rate on the association returning back to normal.

3.1.2 MOBILE-END TRANSPORT PROTOCOL (METP)

Mobile-End Transport Protocol (METP) [1] comes to dispense with the TCP and IP layers from mobile hosts. A mobile host will substitute TCP/IP headers of the packets transmitted over a wireless connection where header containing de-multiplexes keys and the IP locations of source and destination. METP manages hop between a mobile host and its base station which is either the first or the last one along an data path. Here, just a part of the IP functionality requires to be moved to the base station. In the interest of the mobile host, all TCP connections are taken care of by METP at the base station; it meet with another host to build up or close a TCP connections. At the point when a TCP segment planned for the mobile host, METP put it in the getting support and returns an acknowledgement to the source through any congestion control or congestion avoidance mechanism of TCP which reverberate in the condition of the wired connection.

3.1.3 MOBILE-TCP (M-TCP)

M-TCP [2] is formulated to work within the sight of frequent disconnections and low bit-rate wireless connections. It preserves end-to-end semantics. In M-TCP, every TCP connection is separated in two; one is unmodified form of TCP between fixed host (FH) and SH; second is modified version of TCP connection amongst SH and mobile host (MH). Wireless bandwidth is a limited, rare resource with the goal that it must be sensibly utilized. There is some inconsistency in the available transmission capacity in heterogeneous network. A module exists in SH guarding of this task. The FH sends a segment, which SH gets and sent to the MH, where M-TCP exist in. At that point MH returns recognizes. In the wake of getting acks to SH, acks turn around to the FH. Contrary, keeping in mind the end goal to anticipate loss of remarkable packets, it spares the ack of the last byte.

3.1.4 SPLIT-CONNECTION MOBILE TRANSPORT PROTOCOL (SCMTP)

In SCMTP [4] fascinate a standard TCP protocol on the wired connection between the fixed host and base station, and additionally the light weight transport protocol on the wireless connection. By the way, it entrance an automatic repeat request (ARQ) protocol to handle the wireless error and uses of a different channel access protocol; time division multiplexing (TDM) is utilized to assign the forward-connection amongst BS and MH has an ability to every mobile host, and a time-division multiple access (TDMA) is interested by every portable host on the reverse-link. If there exists multiple traffic between the base station and available mobile host, then scheduling algorithms at the base station and mobile host determine flow sharing between the forward-link and reverse-link capacities correspondingly.

3.2 LINK-LAYER PROTOCOLS

Link-layer protocols are another decision for upgrading the performance of TCP over wireless connections. The thought behind this is to assemble the wireless link layer same to the wired connection for TCP by enhancing the wireless error locally. There are a few proposals for reliable link-layer protocols. The principle approach working by these protocols is forward error correction (FER) and automatic repeat request (ARQ) [5]. ARQ is a great part of the time utilized as a information interchanges conventions. At the point when a frame is distinguished mistakes in the wake of decoding, it is disposed of and an ACK is return back to the sender by asking for a retransmission of the frame. This is effective method for retransmission known as selective retransmission.

3.2.1 SNOOP PROTOCOL

The Snoop protocol [11] is a TCP-aware connection layer convention. It utilizes interface layer retransmission to enhance the unwavering quality of the remote connection, and effectively tries to stay away from superfluous TCP retransmissions. In this technique, the base station is outfitted with a module called snoop agent, the usefulness of which is to screen the TCP packets transmitted from a fixed host to a mobile host and the other way around. The agent reserves every one of these packets locally and utilizes this data to distinguish wireless packet losses and timeouts. On account of recognizing a wireless packet loss, it retransmits the packet instantly and suppresses the duplicate ACK achieving the TCP sender. In this way, it keeps the sender from invoking unnecessary fast retransmissions and congestion control algorithms.

3.2.2 ADAPTIVE-TCP PROTOCOL

Adaptive TCP (A-TCP) [21] is a TCP aware link layer protocol and keeps up end-to-end semantics of TCP. The basic thought of the protocol is to make a wireless connection look like a wired connection by using an A-TCP agent in the base station. This is alluded to as a virtual host model. The A-TCP agent completes three basic capacities, for instance, local retransmissions, sender freezing and A-TCP flow control to conceal the wireless environment form the fixed host. The local retransmissions diminishes the effect of high bit errors.

On getting copy ACKs, the A-TCP agent, like the Snoop agent, filters the duplicate ACKs and locally retransmits the lost packet. It likewise keeps a retransmission timer of the standard TCP sender. When it lapses for a specific section, the A-TCP agent expeditiously retransmits that segment. Long-term channel disconnections are managed by the use of sender freezing. The A-TCP flow control is the essential part to enhance the TCP performance in a wireless domain.

In the A-TCP flow control, the A-TCP agent indicate the window field of acknowledgement segment with a retransmission support buffer size, thus avoiding remote connection flood. In this way, the TCP congestion control at the sender won't be actuated by wireless link overflow.

3.2.3 ASYMMETRIC RELIABLE MOBILE ACCESS IN LINK-LAYER (AIRMAIL) PROTOCOL

The AIRMAIL protocol gives a reliable link layer in conjunction with forward error correction. In this approach, keeping in mind the end goal to save entire window of data, the base station sends a whole window of information before an ACK is returned by the mobile receiver. A result of this approach is that there is no way to correct errors until the finish of a entire window, which can make TCP time out if the error rate is extensive or cause a large dissimilarity in delay relying upon the position of the loss inside the window. In AIRMAIL, an essential Stop-and-Wait protocol is used over the wireless connection to quickly retransmit packets before TCP finds the loss.

3.2.4 RADIO LINK PROTOCOL

The Radio Link Protocol (RLP) [15] is a link layer protocol. RLP parts the TCP segment into frames and utilizations robust error correcting codes and quick retransmission schemes to shield the wireless channel related losses from the TCP sender, consequently preventing TCP throughput degradation. The fragmentation is done to expand the granularity of the transmission. If there should be an occurrence of any error, a RLP frame which is of a smaller size is affected as opposed to the whole TCP segment. The RLP utilizes an ARQ error recovery mechanism to recover a lost RLP frame, which can be an acknowledgement based (ACK-based) or negative acknowledgement based (NACK-based). Since the reverse link connection is exceptionally costly on most cellular networks, most RLPs execute NACK-based schemes in which the recovery process is started by the receiver by asking for a retransmission of only the missing or erroneous frame. RLP's error recovery persistency can be arranged by means of a parameter that characterizes the maximum number of retransmission of a single frame. At the point when the RLP sender identifies that frame couldn't be transmitted effectively after all the requires-retransmission attempts, it disposes of that frame, as well as resets the link connection.

3.2.5 TULIP PROTOCOL

The transport unaware link improvement protocol (TULIP) [8] is to upgrade the TCP performance over lossy wireless connections without the need to adjust the transport layer protocol. Regardless, it doesn't require an intermediary at the base station and keeps no TCP states. TULIP gives solid administration of TCP data traffic and an unreliable service for UDP and TCP ACKs. TULIP does not give solid administration to TCP ACKs in light of the way that resulting ACKs supersede the information in the lost ACK. The recipient just buffers packets and leaves them behind to the following layer all together; thus shielding TCP from producing duplicate ACKs if a package is lost from the expected sequential packet stream. This limit of TULIP to keep up local recovery of every single lost packets at the wireless connection with a particular ultimate objective to unnecessary and delayed retransmission of packet over the entire path. TULIP keeps up timers that rely on upon a most extreme propagation delay over the connection, rather than playing out a round-trek time estimate of the channel delay.

3.3 EXPLICIT NOTIFICATION

Various explicit notification scheme has been proposed to enable the TCP sender to perceive distinctive sorts of packet losses. Examples of this approach consolidate Explicit Congestion Notification (ECN), Explicit Loss Notification (ELN). The thought behind this approach is to engage the TCP sender to perceive packet losses because of congestion.

3.3.1 EXPLICIT CONGESTION NOTIFICATION

In this technique, a TCP receiver educates the TCP sender with respect to the system congestion expressly through one of the reserved bits in the TCP header, called the ECN-Echo (ECE) flag, which screens the average queue size and stamps packets as opposed to dropping them in view of statistical probabilities. This is valuable for protocols like TCP that are sensitive to even a single packet loss, as Since ECN marks packets before congestion occurs. The packets gave ECN support is intimated as ECN capable packets. ECN requires support from both the routers and the end hosts. It requires the routers to have the capacity to distinguish packets that are ECN competent and to mark only such packets from ECN capable hosts.

3.3.2 EXPLICIT LOSS NOTIFICATION

Snoop protocol has some limitations that could cured by Explicit loss notification with acknowledgement (ELN-ACK). In the ELN-ACK scheme, another type of acknowledgement packet called ACKELN is utilized to convey the reason for packet losses to the TCP sender and no packets are cached at the base station.

3.3.3 SYNDROME

It is a light-weight approach to enhance TCP performance in wireless environments. In syndrome approach, the base station counts the quantity of packets it has relayed to the destination host for every TCP connection and incorporates this in the TCP header option. The destination host will utilize both the syndrome counter and the sequence number to figure out if the packet is lost because of the congestion or because of wireless error. Gaps in the sequence number but not syndrome counter will specify that packets lost due to congestion in wired network.

3.4 END-TO-END PROTOCOLS

The standard TCP usage depends on packet loss as a marker of network congestion and do not have the capacity to recognize congestion losses from losses invoked by noisy links. In wireless connections, covering radio channels, signal attenuation and additional noises affect such losses. As a result, the standard TCP responds with drastic reduction of the congestion window, in this way degrading the performance of TCP. End-to-end recommendations make the TCP sender handle bundle packet losses about by both congestion and random wireless errors and requires no processing or minimal at the base station. Another preferred standpoint of these plans is that the end-to-end semantics of TCP is maintained. Some end-to-end approaches portrayed underneath.

3.4.1 END-TO-END SMART

SMART (Simple Method to Aid Retransmission) protocol consolidates parts of both the traditional techniques Go-Back-N (GBN) and selective retransmissions (SR). The key thought in SMART is to construct bit-mask of correctly received packets at the sender as opposed to conveying it in the ACK header. Each ACK accordingly conveys two pieces of information; the cumulative ACK as in the standard GBN and the sequence number of the packet that brought about that ACK to be created. The second piece of information not just permits the sender to distinguish which packets have been correctly received, additionally empower to infer which packets have been lost and to retransmit those lost packets specifically. At the point when the sender distinguishes gaps in the bitmask, it instantly accepts that the missing packets have been lost without considering about how possible it is that they essentially may have been reordered. Along these, this scheme exchanges off some strength to reordering and lost acknowledgements in return for a reduction in the overhead to produce and transmit acknowledgements. The SMART permits the sender to deal with multiple losses inside a window of outstanding data efficiently.

3.4.2 TCP WESTWOOD

TCP Westwood (TCPW) [22] is a sender-side modification of the TCP congestion window algorithm that enhances the performance of TCP Reno in wired and in addition wireless networks. The general idea is to utilize the bandwidth estimate BWE to set the congestion window (cwin) and slow start threshold (ssthresh) after a congestion episode. The recognizing highlight of TCP Westwood concerning TCP Reno is: TCP Reno halves the congestion window after three duplicate acknowledgements or after a timeout where as TCP Westwood endeavors to choose a slow start threshold and a congestion window which are steady with the effective bandwidth used at the time congestion is experience. TCP Westwood does not require investigation as well as interception of TCP packets at intermediate (proxy) nodes and conforms to the end-to-end TCP design principles. TCP Westwood is extremely powerful in blended wired and wireless networks. As random packet loss rate exceeds a few percent level in TCP Westwood, throughput and delay performance reduces poorly.

3.4.3 FREEZE-TCP

In this strategy, signal strength monitored by mobile host the sends zero window advertisement (ZWA) on the off chance that it identifies an impending disconnection. By misusing the properties the receiver advertised window, a TCP association can be solidified. In the event that the receiver sets the receiver window to zero, then the sender leaves its CWND unaltered until the receiver promotes another receiver window. This keeps segments from getting lost and unnecessary congestion control to be made by the sender. Upon reconnection detection, the receiver sends three duplicates of acknowledgements of last received prior to the disconnection, with a specific end goal to wakeful the sender and to continue the transmission at same rate as before. A possible drawback of Freeze TCP is that it relies on upon the capacity of the lower layers to distinguish an incoming disconnection and inform the TCP sender of this in a timely way.

3.4.4 TCP EIFEL

TCP Eifel takes care of the issues that have cropped up due to spurious timeouts and spurious fast retransmits thereby eliminating the retransmission uncertainty.

It permits the sender to identify whether an as of now started initiated error recovery mechanism is in certainty important or not by observing the first ACK that spreads already unacknowledged data. The sender utilizes the timestamp choice to decide this is an acknowledgement of the original fragment or of the retransmitted segment. On the off chance that this ACK is for the original segment, the sender considers the retransmission is spurious and it doesn't need to diminish the transmission rate. The original segment is not lost because of congestion, in this manner it ought to be postponed before it reached to the receiver.

4. CONCLUSION & FUTURE WORK

In this paper, an attempt has been made to identify the common qualities of heterogeneous systems, and the issues they pose to the traditional TCP usage. A complete overview of various proposed schemes are presented along with their characteristics and distinctive advantages and limitations.

The wireless networks also attract research in network congestion and host mobility separately. Majority of the techniques that are available in the literature, aim to increase the TCP throughput. The key aspect of these techniques is modification in the algorithms so that the TCP throughput is increased using the existing network infrastructure. As a future improvement to this work, a novel protocol coupled with the existing approaches would be developed in real protocol stack and tested with several real-life TCP implementations using an efficient network simulation tool.

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