PERFORMANCE EVALUATION OF TCP VARIANTS IN WI-FI NETWORK USING CROSS LAYER DESIGN PROTOCOL AND EXPLICIT CONGESTION NOTIFICATION

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ABSTRACT

TCP was mainly developed considering assumption of wired network, ignoring the properties of wireless transmission. Wireless transmission links are highly unreliable causing loss of packets all the time. The proper approach to dealing with lost packets is to send them again, and as quickly as possible. This paper aims at studying the effects of unidirectional and bidirectional networks on various TCP variants. The effect of application of SNOOP and ECN on the performance enhancement of TCP along with TCP variants is assessed, improving the performance of TCP over wireless network by implementing cross layer design protocol (Snoop). ECN is used to avoid congestion and Snoop aims at retransmitting the lost packets from base station, avoiding retransmission from the transmitter. The performance of different TCP variants such as TCP Tahoe, Vegas, Reno, New Reno, Sack are analyzed on Wi-Fi scenario. These results can be analysed from throughput and congestion window plots in the paper. The simulator used for implementation in Network Simulator-2 (NS2).

KEYWORDS

Explicit Congestion Notification (ECN) Transmission Control Protocol (TCP), Snoop Protocol, Network Simulator-2(NS)

1. INTRODUCTION

In recent years, issues regarding the behavior of TCP in high-speed and long-distance networks have been extensively addressed. The packet loss in heterogeneous network environment into three categories:

(1) packet loss due to overflow in intermediate routers.
(2) packet loss due to high bit-error-rate in wireless links.
(3) packet loss due to user mobility (e.g. handoff).

The well known problem of TCP in high bandwidth delay product networks is that the TCP Additive Increase probing mechanism is too slow in adapting the sending rate to the available bandwidth. Various TCP Variants[1,2] have been suggested for this, such as TCP Vegas, Reno, NewReno, Tahoe, Sack. The performances of various variants are analyzed in bidirectional scenarios using throughput and congestion window plots. For the purpose of analyzing the effects of reverse traffic, i.e. congestion and other losses due to wireless environment, a scenario of bidirectional wifi network has been created and all the simulation results have been tested on the same scenario.

DOI : 10.5121/ijwmn.2011.3309

The first kind of packet loss has been taken into consideration in traditional TCP design and implementation. The congestion control mechanisms in Reno TCP are aimed to tackle this kind of packet loss. When the wireless links become parts of TCP connection, the second and third kind of packet loss occur, which break the assumption that packet loss is only caused by the congestion in the intermediate routers and thus it could degrade the TCP performance. Snoop protocols [3, 4] can significantly improve the TCP performance in that it hides the second kind of packet loss from the TCP sender by means of local retransmission and local timeout mechanism at base station. Moreover, Snoop protocol addresses the third kind of packet loss by using routing technology. Snoop protocol [5] is to alleviate degradation in performance of TCP over heterogeneous network. They improve the end-to-end performance on networks with wireless links without changing existing TCP implementations at hosts in the fixed network and without recompiling or re-linking existing applications. They achieve this by a simple set of modifications to the network-layer (IP) software at the base station. These modifications consist mainly of caching packets and performing local retransmissions across the wireless link by monitoring the acknowledgments to TCP packets generated by the receiver. Snoop protocol can achieve speedups of up to 20 times over regular TCP in the presence of bit errors on the wireless link. It also is significantly more robust at dealing with multiple packet losses in a single window as compared to regular TCP. Snoop protocol is a cross layer design protocol i.e. transports aware link layer protocol [6].

1.1 Related Work

In paper [2] the author have incorporate non congestion-related random losses and round-trip delay in this model, and show that one can generalize observations regarding TCP-type congestion avoidance to more general window flow control schemes. They consider explicit congestion notification (ECN) as an alternate mechanism (instead of losses) for signalling congestion and show that ECN marking levels can be designed to nearly eliminate losses in the network by choosing the marking level independently for each node in the network. While the ECN marking level at each node may depend on the number of flows through the node, the appropriate marking level can be estimated using only aggregate flow measurements, i.e., per-flow measurements are not required.
The throughput of an user using ECN marks is much better (about 5 times) than a user without ECN marks. This improvement in performance is due to the user attributing all losses to random losses in the network. Since, the marking level makes sure that there are very few congestion related losses, most of the packet losses seen by the user are indeed due to random losses.

In [7], have described the design and implementation of a protocol, called the snoop protocol, which improves TCP performance in wireless networks. The protocol modifies network-layer software mainly at a base station and preserves end-to-end TCP semantics. The main idea of the protocol is to cache packets at the base station and perform local retransmissions across the wireless link. The experiments show that it is significantly more robust at dealing with unreliable wireless links as compared to normal TCP. The throughput speedups achieved of up to 20 times over regular TCP in experiments with the protocol.

In [5] paper includes a simulation-based performance analysis of the most important TCP versions over wireless networks. In addition, analyzing those TCP versions in the same environment but including the Snoop protocol. In the paper the segments sequence numbers vs. time graph for all TCP versions considered over the plain wireless network. From the graph it is noticed that all TCP versions perform as expected. However, it is found that in TCP Vegas, not many analyses are available to conclude about its behaviour. They were in the process of identifying the ground causes for this behaviour analyzing the congestion window and how the error model affects Vegas. Initial analysis tells us that Vegas is affected more than the other TCP versions whenever the length of the error bursts is more than four packets.

TCP Vegas, is the best performing version with Snoop, and trying to find the reasons behind this behaviour and the behaviour of other TCP Variants. They had stated that, there are unknown interactions between the snoop protocol and these TCP versions that need a more detailed investigation.

The above work showed that ECN improves TCP performance in Congestion related losses and Snoop improves in wireless related losses. Hence in [8],[9],[10]analysis were done to improve the performance of TCP using both ECN and Snoop both applied in a Wi-Fi and Wi-Max Scenario which showed improved result.

Also, the performance and behaviour of all TCP Variants with the Snoop protocol needed to be analyzed and hence this paper investigates the behaviour of TCP Variants with and without the Snoop Protocol. ECN is also applied to Vegas (E-Vegas) to further improve its performance in a unidirectional network.

2.WI-FI NETWORK SCENARIO

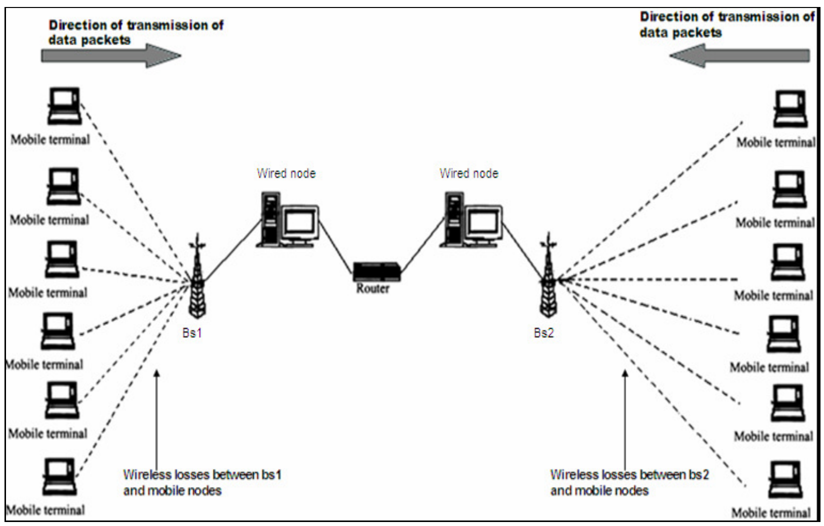

Fig 1. WiFi Network Scsenario

The Scenario shown in Fig 1 is a WiFi unidirectional/bidirectional network .It consists of 12 wireless nodes. There are 2 wired cum wireless base stations which are BS1 and BS2. The LAN bandwidth is of 10 Mbps. LAN may be implemented with Snooping agent. LAN nodes are connected to base station with a 1Mbps 1msec RED bidirectional link. Red link is for marking the packets in case congestion occurs [11]. Wireless nodes of base station 1 (BS1) are sending data to wireless nodes of base station 2 (BS2) and vice versa. The arrows in the figure shows the direction in which node transmits data .The protocols used are TCP variants such as Tahoe, Reno, New Reno, Vegas & Sack. They are attached with a File Transfer Protocol (FTP). The wireless routing protocol used is DSDV [12]. All the nodes start transmission simultaneously leading to congestion in base station 1 (BS1) and base station 2 (BS2). Wireless losses are introduced between base station 2 (BS2) and wireless nodes connected to base station 2 (BS2). Also wireless losses are present between base station 1 (BS1) and nodes connected to base station 1 (BS1). Here there are wireless losses introduced at both the ends and there is a very high possibility of congestion occurring at the base stations because of the high transmission rates. These two problems are then overcome using ECN and SNOOP.[8,9]The analysis is done for all TCP variants in unidirectional scenario where only nodes connected to base station 1

(BS1) are transmitting to nodes connected to base station 2 (BS2) and then the same analysis is done for the WiFi bidirectional scenario as shown in figure 1.

3. SIMULATION RESULTS OF WI-FI NETWORK:

3.1 Network parameters

Parameters	Value	Meaning
Channel	Wireless channel	channel type
Adhoc Routing	DSDV	Routing protocol
Error data packet size	100kb	
Wireless Error rate	5 %	
LAN bandwidth	10 Mbps	
Ifq	Drop tail	Type of queuing used
Application	FTP	
Mac standard	802.11	
Ifqlen	50	max packet in ifq
Ant	Omni Antenna	antenna model
opt(x)	600	X dimension of the topography
opt(y)	600	Y dimension of the topography
opt(netif)	Phy/WirelessPhy	network interface type

Table 1. Network Parameters

3.2 Simulation results for Wi-Fi unidirectional network

We will now analyse simulation results for various TCP Variants along with ‘EVegas’ (ECN [11] with Vegas) for the scenario as described above, however in this part we do not implement ‘Snoop’ on the given network.

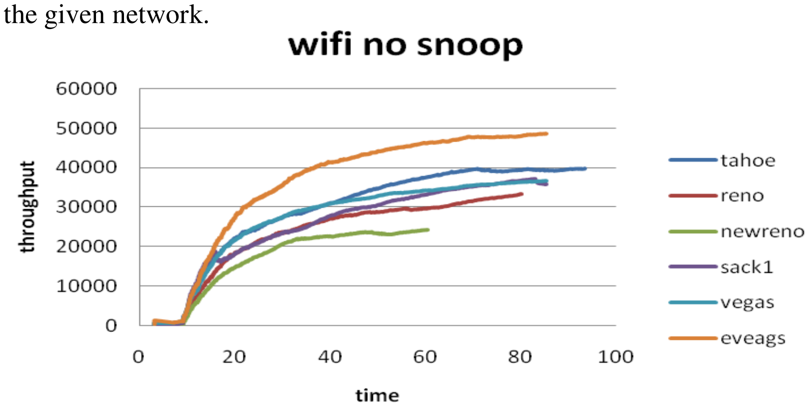

Figure 2. Throughput vs Time plot for TCP Variants in Wifi Unidirectional network (Without Snoop).

Above graph is the throughput plot for the given scenario with WIFI(IEEE 802.11). In the above figure various TCP variants such as NewReno, Reno, Sack1, Tahoe, Vegas, 'EVegas' are used. This is a plot for throughput vs. time which is total number of packets delivered per unit time. Throughput is calculated in bps(bits per second). The result was worst for TCP New Reno which is shown in green colour. The throughput for 'EVegas' (TCP variant is Vegas along with the congestion control protocol ECN)[11] is the best of all. E-Vegas reach to a maximum of (approx.) 49kbps which is much better than New Reno, Tahoe or 'Vegas'. Percentage increase of throughput of E-Vegas with respect to Vegas is 40%. However it was found out that the performance can be further improved using SNOOP on the above network.

The following figure shows the simulation result for a network on which SNOOP was implemented

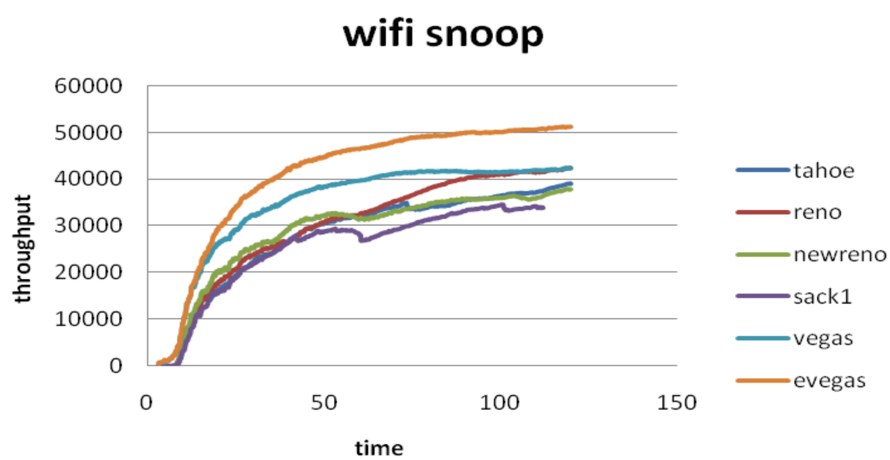

Figure 3. Throughput vs Time plot for TCP Variants in Wifi Unidirectional network (With Snoop).

In figure 3 various TCP variants such as, NewReno, Reno, Sack1, Tahoe, Vegas, EVegas [1]. Graphs are plotted for throughput Vs time. It can be observed that with the application of SNOOP over the network, the throughput of all the variants increases significantly. The However throughput for E-VEGAS reaches to a maximum of (approx.) 51kbps that is much better than other TCP variants, as shown in the graph. The maximum throughput achieved in case of 'Evegas', without SNOOP is 49Kbps and with SNOOP is 51Kbps. Percentage increase of throughput of E-Vegas with respect to Vegas is 4%. Hence it can now be concluded that 'EVegas' works better in both types of networks.

3.3. Analysis of Results

The same result can also be justified by using congestion window plot for all the TCP variants. Following figure shows the congestion window plot for the different variants. (Only the best four TCP variants have been considered.)

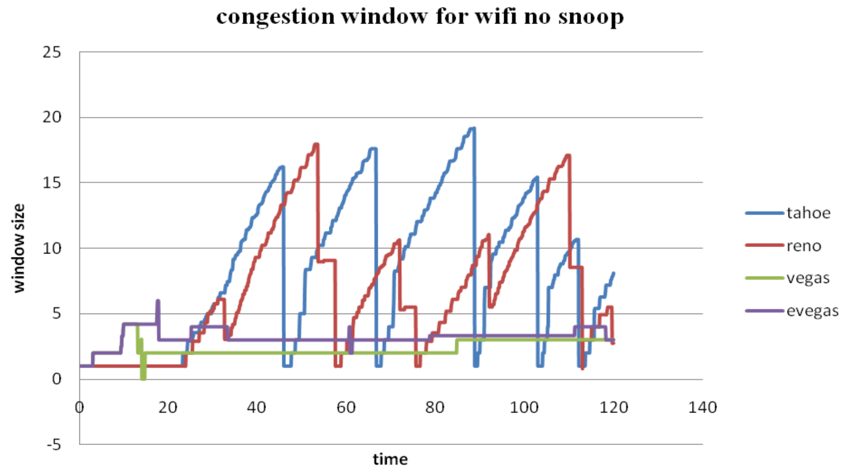

Figure 4. Congestion window plot for TCP variants in Wifi Unidirectional network.(Without Snoop)

The above graph (figure 4) is the congestion window plot for Wi-Fi unidirectional network without SNOOP. It is found that, though the window sizes of different TCP's are greater than the window size of TCP Vegas or 'EVegas', still the throughput of TCP Vegas was better than most of the variants and performance of 'EVegas' is the best. This is because the congestion window resets for a greater number of times in other TCP variants as compared to TCP Vegas and E-Vegas. In these cases it maintains low and steady transmission rate. However the better performance of 'EVegas' over TCP Vegas can be attributed to the fact that the size of window for 'EVegas' is greater than that of TCP Vegas.

Similarly, the congestion window plots for the same four TCP variants were plotted for a network on which SNOOP was implemented.

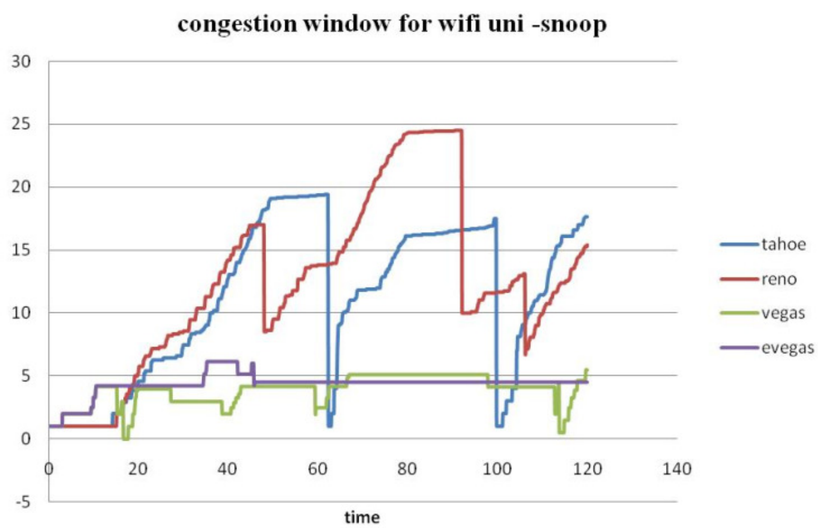

Figure 5. Congestion window plot for TCP variants in Wifi Unidirectional network.(With Snoop)

Now analyzing figure 5, that the number of window resets in case of all TCP variants have reduced drastically. This accounts for the increased rate of throughput as seen from the diagram above (figure 3.). This is primarily due to the implementation of SNOOP, which doesn't all the backward transmission of duplicate acknowledgement to the source and hence the source does not have to reduce its window size as well as transmission speed even when the packet is lost at the receiver side.

It can also be seen that in case of TCP-Vegas or 'EVegas' it maintains a low but constant transmission rate. On observing the two figures (4,5) it can be seen that the window size of TCP Vegas and 'EVegas' in figure (6) is higher. Hence the performance of TCP-Vegas and 'EVegas' is better than all the other TCP Variants. However in TCP Vegas we can see that the window size goes to half its actual size because of congestion losses. As we already know that these congestion losses can be taken care of applying ECN[11] over Vegas. Hence in the graph for ECN Vegas (EVegas) we see that it does not reset at all. Which is the main reason why the performance of EVegas is better than Vegas. The RED queuing mechanism helps to detect congestion before it occurs and ECN notifies the sender for it.

4. SIMULATION RESULTS FOR BIDIRECTIONAL WIFI NETWORK

The analysis of simulation results for various TCP Variants along with 'E-Vegas' and 'E-New Reno' for the bidirectional scenario is described below. ('E-Vegas' and 'ENewReno' are TCP Variants 'Vegas' and 'NewReno' implemented with ECN.)

Throughput vs. Time Plot for TCP Variants in a wifi bidirectional scenario (without Snoop):

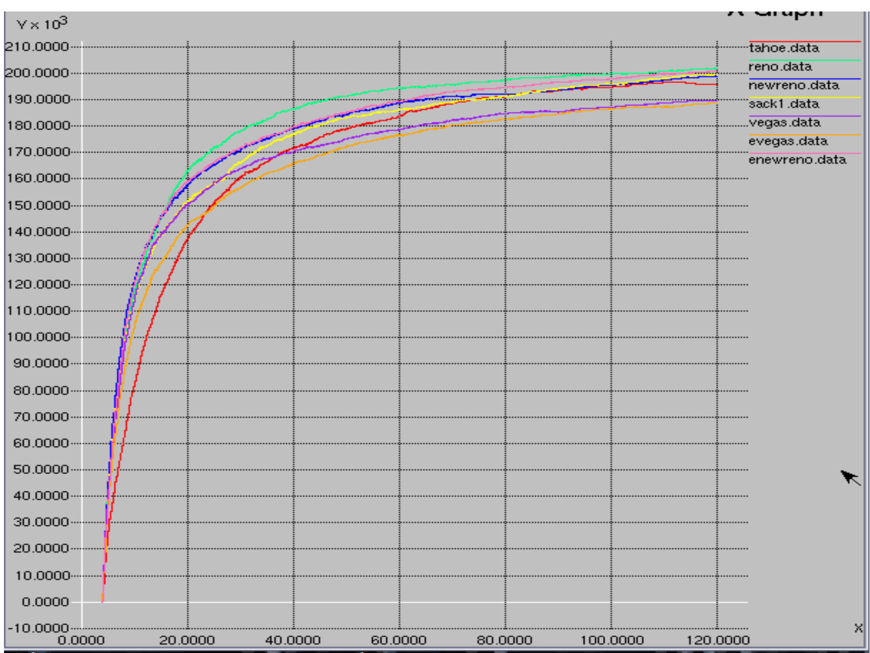

Fig 6. Throughput Vs Time for TCP Varients without Snoop

Throughput vs. Time Plot for TCP Variants in a wifi bidirectional scenario (with Snoop):

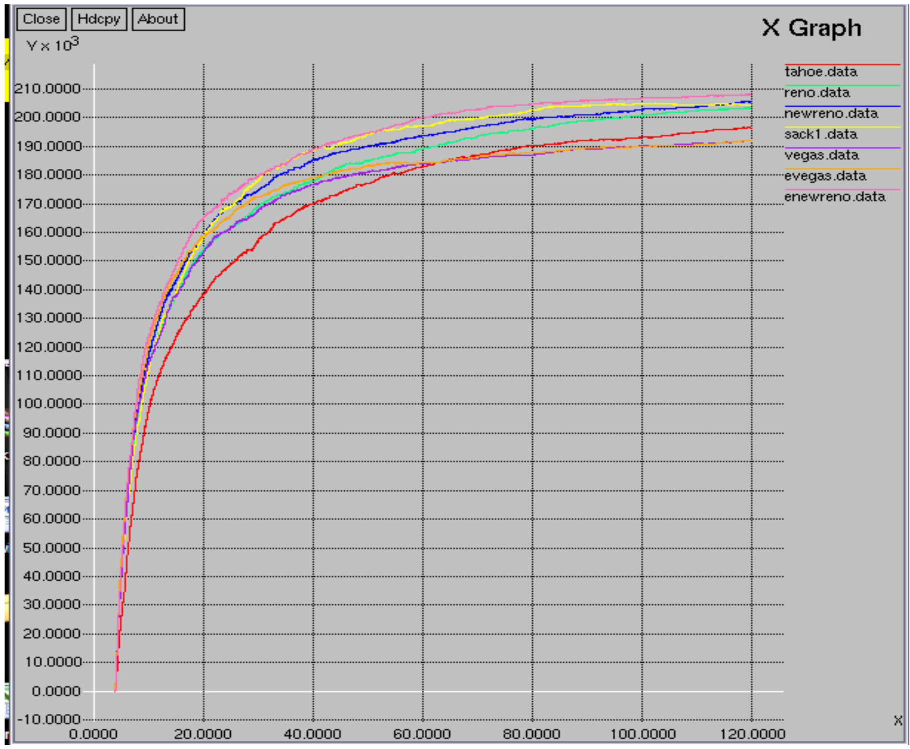

Fig 7. Throughput Vs Time for TCP Variants with Snoop

Fig 6 is the throughput plot for the given scenario (Fig 1) Here various TCP variants[13] are used. According to the analysis done on unidirectional networks it was seen that the performance of 'EVegas' was the best amongst all TCP variants, hence the testing of all the TCP variants is done in bidirectional scenario by implementing ECN with them. However in this case it is seen that the performance of New Reno was better than the other variants (figure 6), this is because of the modifications in TCP Reno which were incorporated in New Reno.[14] So to further enhance its performance a congestion control protocol (ECN)[8] is applied to this network and the performance of New Reno along with ECN (E-NewReno) is analysed.

Figure 7 is the throughput plot for all TCP Variants with cross layer design protocol SNOOP applied to the network(fig 1). The performance of all the variants has improved; this is because of the application of SNOOP protocol. It is observed that the performance of E-New Reno can be regarded as the best amongst all the variants. The maximum throughput achieved in case of 'ENewReno', without SNOOP is 200Kbps and with SNOOP is 208Kbps It is been found that there is approximately 4% improvement in the performance of E-NewReno, after the application of SNOOP protocol to the network. Hence we observe that for bi directional scenario the best TCP variant is TCP NewReno and E-NewReno is even better.

4.1. Analysis of Results using Congestion Window Plots

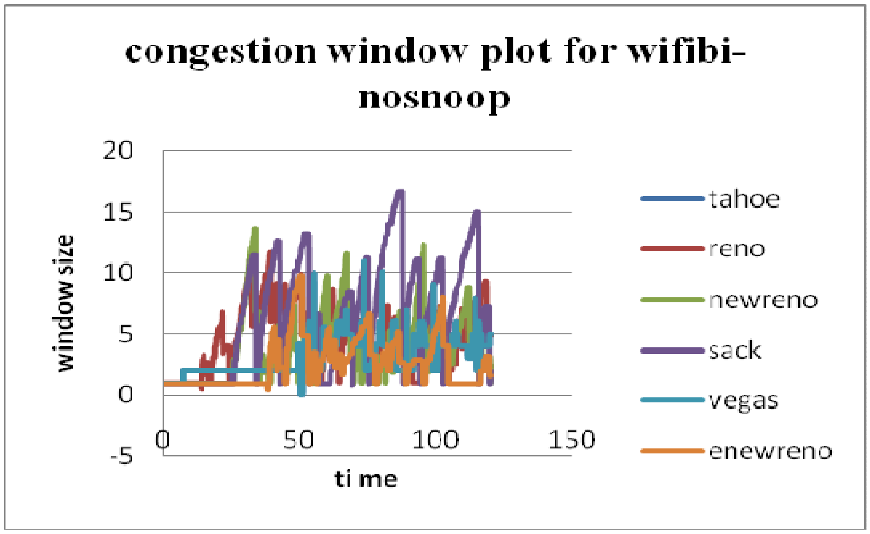

Fig 8. CWND Vs Time without Snoop

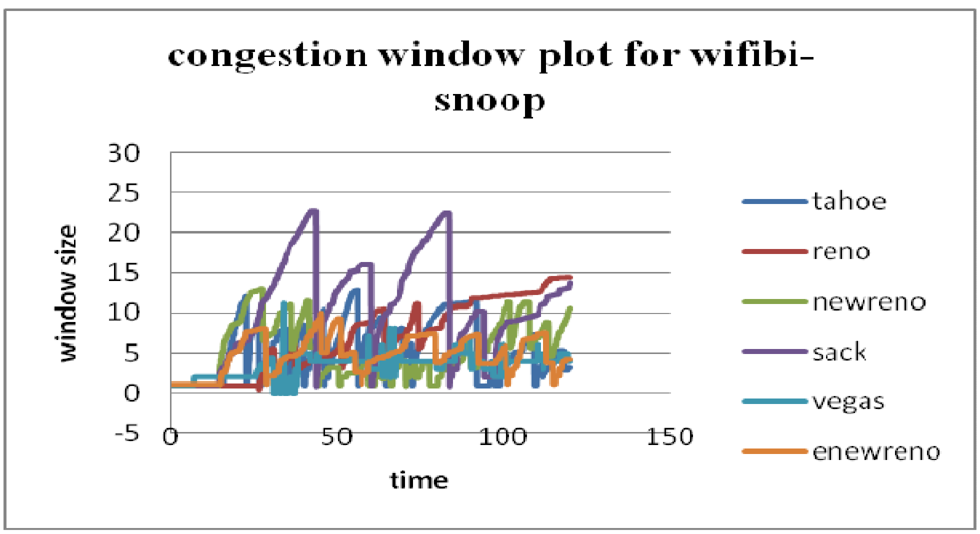

Fig 9. CWND Vs Time with Snoop

Fig 8 & 9 are congestion window plots for bi-directional network of various TCP variants. This graph helps us to further evaluate, why the performance of NewReno has improved whereas the performance of Vegas has degraded.

Vegas connection on the forward path additively shrinks the cwnd thus obtaining a poor utilization of the bottleneck link. Hence to optimize the full bandwidth Vegas needs to send packets at a fast rate, however due to its congestion control mechanism it is not able to transmit packets at a greater rate but it keeps a slow and steady flow of packets. Therefore the performance of Vegas degrades in a bidirectional networks [16].

In case of Bidirectional network, there is heavy traffic flow in both the directions. There also occurs loss of packets in wireless environments which is best overcome using a protocol which rapidly re-transmits the lost packets. However if congestion occurs at any intermediate bottle neck node then fast retransmission may lead to more congestion. Hence this congestion problem is best avoided by using ECN (Explicit Congestion Notification) along with TCP Variants. NewReno is seen to have a good transmission rate and it also works well when ECN is applied with it. This is also visible from the graphs where it can be seen that though the window size of Newreno is not the greatest, but it avoids window resetting when ECN is applied to it. This is the reason why the performance of 'E-NewReno' is seen to be better. Secondly the throughput performance of all the variants also increases with the application of cross layer protocol Snoop.

5. CONCLUSION

The analysis of the result shows improvement in throughput of Vegas and E-Vegas with and without snoop with respect to other TCP Variants ie Reno, Newreno, Sack, and Tahoe.

The analysis of the result for unidirectional network shows improvement in throughput of E-Vegas (49kbps) by 40% with respect to Vegas (35 kbps) (Fig 2.) and further the performance of TCP Vegas is improved by application of SNOOP in the Wi-Fi scenarios. The Throughput of all Variants increases and the throughput of E-Vegas reaches 51kbps(fig 3) which shows further 4% increase in the performance of TCP Vegas when snoop is applied.. ECN helps in congestion control and SNOOP will retransmit the packets that are lost from nodes in between, saving nearly half the retransmission time and avoiding the decreasing in transmission speed and an optimum transmission performance in a wireless network can be achieved. TCP Vegas is better than most of the TCP Variants and 'EVegas' is the best combination of variants for a unidirectional network, with as well as without SNOOP.

In bidirectional scenario the reverse traffic significantly affects the behaviour of protocols. Here from the research results that are achieved, it could be said that the performance of TCP NewReno was better than the other TCP variants. The throughput of Newreno without snoop is 180kbps(Fig 6.) and throughput with snoop reaches to 205kbps (fig 7) which shows improvement by 13.8% . This shows that Newreno shows much more improvement than all other TCP Variants. Also the application of ECN with NewReno (E-Newreno) further increases throughput performance in a bidirectional network.(Fig 7.)

6. FUTURE WORK

Further research is being carried out on the same direction on Wi-Max Networks.

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