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Performance Upgrading of TCP Using Cross Layer Mechanism in Infrastructure Network

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ABSTRACT*:* The Transmission Control Protocol (TCP) is a connection oriented transport protocol used by many end-user applications. The problem that arises in the usage of TCP over wireless networks is due to the fact that wireless links have different characteristics with respect to wired ones, in terms of less reliability and time-variant behavior, fading / shadowing problems, node mobility, hand-offs, limited available bandwidth and large RTTs.The problem of network congestion is considered as the main reason for potential performance degradation.The proposed cross layer solution, L2-CLAMP, avoids TCP ACK transmission over the wireless link through local generation of ACKs at the sender node or at the base station. The congestion measure is also calculated at the Access point / Base station based on which the receiver advertised window is calculated. The protocol performance is compared with existing TCP NewReno. From the experiments it is concluded that L2-CLAMP results has shown better performance with respect to all the parameters.

KEYWORDS: Access Point, Base Station, Cross Layer, Link Layer, Transmission Control Protocol

I. INTRODUCTION

Wireless network uses the same protocols and addressing schemes as a wired network. 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.Wireless networks suffer from several performance limitations such as transmission spectrum, employed modulation and available transmission power.

The reliable, but complex transfer-layer protocol in the network communication is the Transmission Control Protocol (TCP).TCP must establish a connection with each other before they can exchange data.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.Flow control defines the amount of data to be sent before receiving an acknowledgement from the destination. TCP can send one byte of data and wait for an acknowledgement before sending the next byte. This is an extremely slow process.The TCP can also send all the data without worrying about the acknowledgement. This speeds up the process but the receiver is overwhelmed. If some data part received is lost or out of order or corrupted, the sender will not know until all the data is checked by the receiver.To accomplish flow control, TCP defines a sliding window protocol. TCP sends data as defined by the sliding window protocol.TCP delivers the entire stream data to the other end in order, without error and without any loss or duplication. Error control includes mechanism for detecting corrupted, lost, out-of-order and duplicated segments.

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 handling at the TCP layer.

A traditional and widely implemented approach to increase reliability of wireless links is based on the usage of an automatic repeat request (ARQ) protocol at the link layer.ARQ provides a dynamic way to decrease error rate present on the wireless links by increasing the delivery delay.Error control in the data link layer is based on the Automatic Repeat Request.The TCP algorithms are Slow Start, Congestion Avoidance, Fast Retransmit and Fast Recovery.

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Queue management is obviously about managing queues in forwarding devices such as routers and switches.The next category of schemes applies some level of intelligence to deal with queues when congestion is detected, and as such are classified as active queue management algorithms.the layered architecture have served well for wired networks, they are not suitable for wireless networks. To prevent congestion loss, an active queue management is required to avoid buffer overflow and also a fair scheduling is necessary to allocate bandwidth.

Sharing the knowledge about layer state and conditions proved to be a promising paradigm for performance optimization in wireless networks. A certain level of QoS may be required to support future applications in wireless networks. One possible alternative is by cross-layer design and adaptation.Several Alternatives have been proposed to alter the existing TCP protocol to suite the wireless domain.

This paper target cross-layering as a possible solution, presenting a novel cross-layer approach, called Link Layer CLAMP (L2-CLAMP) TCP, where the acknowledgement at the receiver is suppressed and is generated at the base station. The congestion measure is also calculated at the base station and is attached with the acknowledgement. The main performance advantages are achieved through the optimization of interlayer automatic repeat request (ARQ) scheme functionality.

II. TECHNICAL BACKGROUND

The proposals for TCP performance optimization over wireless networks target the root of the problem, i.e. TCP flow control and error recovery mechanisms, introducing different TCP modifications.

A well-known modification in the considered scenario is TCP Westwood [7] with its variations. An estimate of the available capacity on the end-to-end path is computed by using appropriate filtering of returning ACK flow. Then, upon loss detection, the outgoing rate is adjusted to fit the available bandwidth-delay product instead of performing blind window reduction.

TCP Veno [4] implements delay-based congestion control by estimating the number of backlogged packets in the bottleneck buffer – a technique originally proposed in TCP Vegas[14]. In addition, it tries to distinguish between congestion- and loss-related losses based on the estimated bottleneck buffer size preventing window reduction for non-congestion related losses.

On the contrary, flow control solutions adjust outgoing rate without providing reliability of data delivery, for real-time multimedia traffic applications. Proposals in this category can be implemented as an additional transport layer protocol or flow control above transport layer on top of unreliable UDP or RTP protocols.

The main drawback preventing deployment of the proposed TCP modifications and other rate control protocols is in the requirement for sender protocol stack modification which is difficult to perform in world-wide scale. This motivated multiple attempts to hide undesirable characteristics of the wireless links from the transport layer while keeping TCP sender’s stack unchanged.

One of the first of such attempts to mask losses on the wireless link from a fixed sender is proposed in [14], the snoop agent introduced at the base station performs local retransmissions triggered by sniffing duplicate ACKs coming from the wireless receiver.TCP ACK transmission over the wireless link can be avoided through local generation of ACKs at the sender node or at the base station, thus improving throughput [2]

A protocol CLAMP was suggested [1] [3] [4] on the receiver side and provides a separate queue at the AP. The CLAMP protocol removes the window fluctuations and achieves much better fairness than TCP NewReno.The four algorithms, Slow Start, Congestion Avoidance, Fast Retransmit and Fast Recovery are described [13].

The report is organized as

Section III describe the TCP-New Reno variant

Section IV deals with the architecture of the proposed, cross layer L2-CLAMP agent and the receiver agent algorithm.

Section V specifies the simulation requirements, analyses 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 VI describes the conclusion and future work towards the enhancement of the existing design for better performance improvement.

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III. TCP NEW RENO

TCP New Reno is a variant of TCP-RENO. It is able to detect multiple packet losses and thus is more efficient than RENO in the event of multiple packet losses. New-Reno enters into fast-retransmit when it receives multiple duplicate packets, but it differs from RENO in that it doesn't exit fast-recovery until all the data which was out standing at the time it entered fast recovery is acknowledged. Thus it overcomes the problem faced by Reno of reducing the CWND multiple times. Since all versions of TCP interpret the AWND as an upper limit on the allowable window size, which is a mechanism to avoid an overflow of the receiver buffer. This provides an effective method of control provided that the AWND value is smaller than the CWND value calculated by the sender.

IV. L2-CLAMP PROTOCOL

The proposed scheme enhances the protocol stacks of the wireless sender (or a base station /Access Point) and the receiver with Link Layer -CLAMP (L2-CLAMP) agents which support ACK suppression. The network scenario taken is infrastructure based and is shown in Fig. 1

The scenario consists of four sources (S1, S2, S3 and S4) and three mobile receivers (MN1, MN2 and MN3). Four different flows F1, F2, F3 and F4 are shown in Fig. 1. Flow F1 is between source S1 and Mobile node MN1. F2 is between S2 and MN2 and the flows F3 and F4 starting from source S3 and S4 respectively reach the same mobile node MN3 through the access point.

The L2-CLAMP agent suppresses the outgoing L2-CLAMPTCP ACKs at the receiver side and generates them locally at the sender or base station. The basic idea behind approach is to shift TCP ACK generation point from mobile receiver to the base station. L2-CLAMP-TCP requires implementation of a software module, called L2-CLAMP agent, inside base station / access point (BS / AP) protocol stack above the link layer. The L2-CLAMP agent sniffs the ingress traffic from the fixed network assuming to have access to the network and transport layer headers.

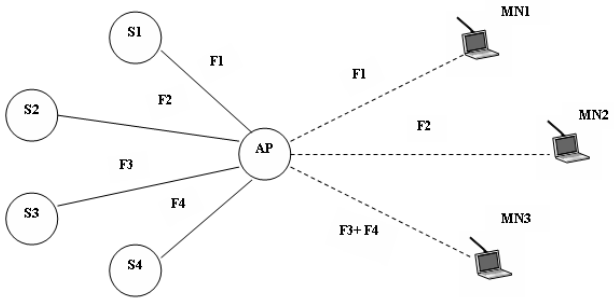

Fig1 - Infrastructure Network

The L2-CLAMP agent suppresses the outgoing L2-CLAMP -TCP ACKs at the receiver side and generates them locally at the sender or base station. The basic idea behind approach is to shift TCP ACK generation point from mobile receiver to the base station. L2-CLAMP -TCP requires implementation of a software module, called L2-CLAMP agent, inside base station / access point (BS / AP) protocol stack above the link layer. The L2-CLAMP agent sniffs the ingress traffic from the fixed network assuming to have access to the network and transport layer headers. Whenever a TCP data packet is detected, the L2-CLAMP Agent in the BA / AP, performs service rate, congestion measurement, received rate and calculates the AWND value, stores flow-related information such as flow sequence number carried by the packet, port numbers, ACK flag and ACK sequence number, along with the AWND value.L2-CLAMP agent calculates the desired size of the AWND window based on the values of congestion measure, received rate and RTT.

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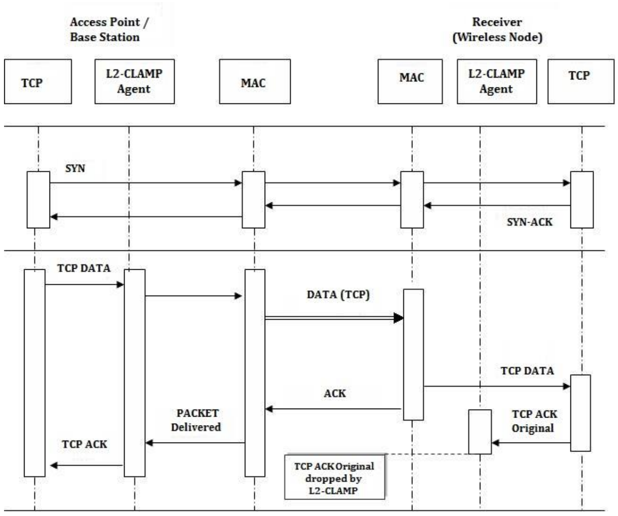

Fig 2 - Sequence of Process for Packet Delivery

To calculate congestion measure, a separate Sync packet is sent from the base station to the receiver and the acknowledgement for the Sync is received back by the sender, based on which the transmission time for each packet is calculated. This is done before actual TCP packet transmission.The parameters used for calculation of congestion measure is b, q, α, μ_c

$$p(q) = (bq - \alpha) / \mu_c \quad (1)$$

where b = 1 for safer purpose. $\tau$is the parameter (fixed size in bytes) used to calculate the value of AWND and α is used to calculate the congestion price signal. Similarly α is free to be chosen by the AP, but is fixed once chosen.

On the receiver side, module referred as L2-CLAMP client in Figure 2.silently drops all standalone non-duplicate TCP ACK packets. The generated TCP ACK packet is then forwarded to the sender. The AP maintains a separate queue for each receiver and acts as a router, routing the packets to the destined MN based on the address of the mobile. The TCP flows destined for the respective MN are put into the same queue.

In the scenario taken, a separate queue is maintained for flows F1 and F2 as they are destined to different mobile nodes MN1 and MN2. The flows F3 and F4 share a same queue as they are destined to the same mobile receiver MN3. A scheduler incorporated in the access point takes care of scheduling the two flows. The scheduler is based on the principle of multi-user diversity. At each slot, a new scheduling decision is made, and the general preference is for scheduling a mobile that is in a good channel state. At each slot, the scheduler picks the queue i with the largest utility that has data to send in this slot. The utility U_i is calculated as

$$U_i = \mu_i / r_i \quad (2)$$

μ_i is the is the current rate for the mobile i at the beginning of the slot andr_i is the exponential moving average of the rate obtained by mobile i with an averaging time constant of 100 ms.

V. Performance Evaluation

To observe how TCP performance is influenced by the L2-CLAMP approach, it is compared with existing TCP New Reno. The simulation is carried with Network Simulator-2. The simulation parameters are shown in Table 1.

The simulation is carried out considering the various simulation parameters- packet size, queue delay, simulation time and packet error rate.

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Table -5.1 Simulation parameters

S.No	Parameter	Value
1	Transmission Range	75 m
2	Propagation Model	Two-Ray ground
3	Wire Nodes	4
4	Base Station	1
5	Wireless nodes	10
6	Packet Size	250 – 1250 Bytes
7	Error Rate (Induced in Wireless Scenario)	0.05 – 0.25
8	Queue Delay	20 – 100 ms
9	Simulation Time	100 – 500 s
10	Propagation Delay (Wired)	20ms
11	Capacity (Wired)	0.5 Mbps
12	Protocols	TCPNewReno, L2-CLAMP

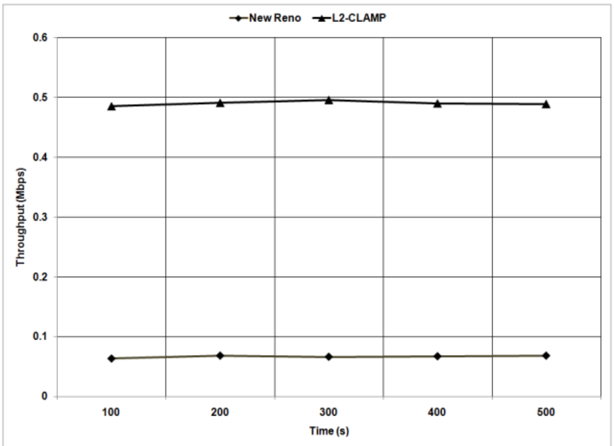

Fig3- Simulation Time Vs Throughput

With packet size as 1250 bytes and the delay in queue as 100 ms, simulation is carried over by varying the time between 100s and 500s. The results obtained shows that the L2CLAMP protocol has better improvement over the TCP NewReno protocol.

Figure 3 shows that the throughput of L2-CLAMP is better by 0.42 Mbps than that of the TCP NewReno.

Simulation is carried over by varying the packet size from 250 bytes to 1250 bytes with a queue delay of 100 ms for a duration of 200s.. The results obtained are shown above in Figure 4. Figure 4 shows the throughput for varying packet size. The throughput of the L2-CLAMP is 12 – 15 times higher than that of the TCP NewRenobetween the packet size of 250 – 750 bytes. The difference in throughput is nearly 0.42 Mbps – 0.45 Mbps between the packet size of 750 bytes and 1250 bytes.

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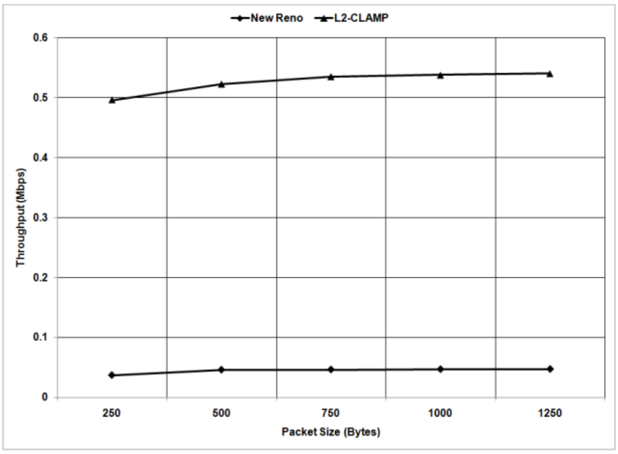

Fig 4 - Packet Size Vs Throughput

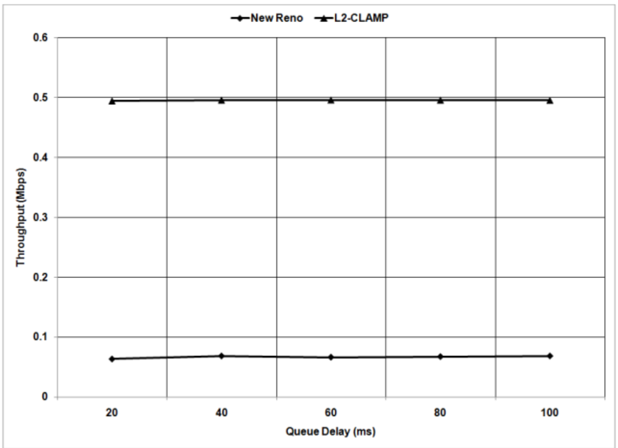

Fig 5- Queue Delay Vs Throughput

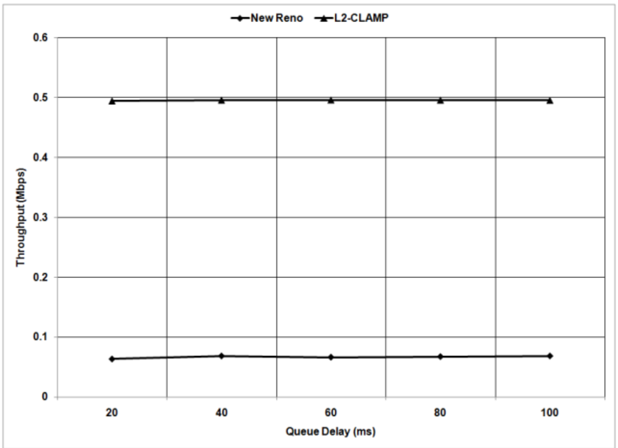

Fig6- Packet Error Rate Vs Throughput

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Figure 5 shows the Queue delay with respect to throughput. The results obtained shows that the L2-CLAMP protocol has better improvement over the TCP NewReno protocol.

Performance is also analyzed with respect to Packet Error Rate. The error rate is varied between 0.05 to 0.25 with packet size of 1250 bytes and queue delay of 100 ms.

Figure 6 represent the error ratio with respect to throughput and delay for a packet size of 1250 bytes with a delay of 100ms and simulation time of 200s. The throughput of the L2-CLAMP proportionally decreases with increase in Packet Error Ratio (PER).

Figure 7 represent PER with respect to delay. The delay decreases with increase in PER in L2- CLAMP.

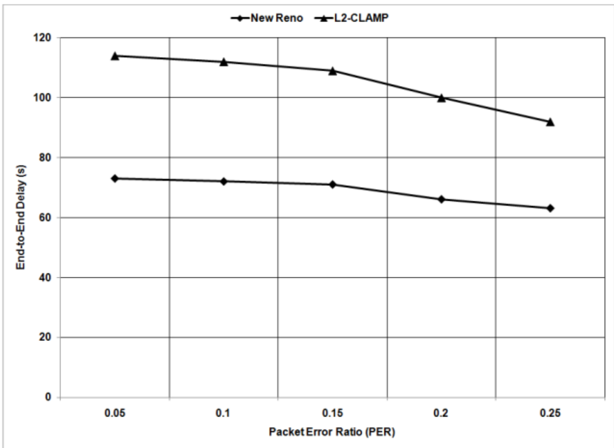

Fig 7- Packet Error Rate Vs Delay

VI. CONCLUSION AND FUTURE WORK

This paper presented a novel yet generic approach forperformance enhancement of TCP over wireless networks.Performance improvement comes from cross-layeroptimization. The proposed solution, L2-CLAMP, avoids TCPACK transmission over the wireless link through localgeneration of ACKs at the sender node or at the base station.The congestion measure is also calculated at the base stationbased on which the receiver advertised window is calculated.The protocol schedules the flow to the destined receiver. The protocol performance is compared with existing TCPNewReno.

The protocol performance is compared with existing TCP NewReno.From these experiments it is concluded that the results has shown better performance with respect to all the parameters. In the scenarios tested L2-CLAMP has achieved better fairness in error free and error prone environment. The scheduling is done properly by allocating required bandwidth to the users. On employing L2-CLAMP in AP, it is found that the scheduler is able to achieve better fairness than TCP NewReno.

A flexible on/off switch to operate the modules depending upon the operating capacity of the AP can be provided. The simulations can also be extended for more number of mobilenodes.

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