IJournals: International Journal of Software & Hardware Research in Engineering
ISSN-2347-4890
Volume 4 Issue 1 January, 2016

Performance Improvement of TCP using MAC layer Loss Differentiation Algorithms

Ankur Macwan[1], Sanjay Shah[2], Hitesh Chaukikar[3]
Madhuben & Bhanubhai Patel women institute of engineering, Anand, Gujarat[1,2,3]
aamacwan@mbict.ac.in[1];skshah@mbict.ac.in[2], hachauki@mbict.ac.in[3]

Abstract—Internetworking has evolved as backbone of communication in recent years. TCP/IP protocol suite is an inseparable part of internet. Hence the efficiency of the protocols plays a vital role in performance of internet. The protocol suit that was originally designed for a wired network is now required to function in the internet with wireless extension employed to reach remote areas.

In a wired network, most packet losses are due to congestion. TCP exploits this characteristic of wired networks and tuned to perform well in such an environment. But in wireless environment, losses due to errors over the wireless hop also contribute significantly to the cumulative packet losses. The fact is TCP cannot distinguish problems that typically occur in wireless networks from congestion. If TCP is used over wireless link, its performance is severely degraded.

If losses due to errors can be categorized apart from losses due to congestion, then irrational decision of cwnd reduction can be avoided. This will surely lead to performance improvement due to effective bandwidth utilization.

Performance of TCP is based on assumption on reliable lower layer. In Link layer Adaptation the value of Retry Limit is dynamically changed according to channel conditions and it will try to locally enhance the problem of link error loss so that TCP will not start its congestion control algorithm and will not decrease its cwnd unnecessarily. It adapts the behavior of the MAC layer to avoid a costly end-to-end TCP resolution. This will ensure improved performance of TCP over wireless networks.

I. Introduction

Wireless networks are becoming more widely deployed and more often used to access services in the internet. The Transmission Control Protocol (TCP) has become the predominant transport protocol in the internet today and convergence of mobile and fixed technologies. It is important to understand its performance especially over wireless links. The performance of the Internet protocols has been reported to be much lower than in fixed networks. TCP works less efficiently in wireless networks. In fixed network less than 1% of the packet losses is considered being due to link errors[1]. A missing packet means in most cases that the network is congested and in reaction TCP triggers the congestion algorithm aimed at reducing throughput. In the wireless network, however, packet losses occur more frequently due to link error because of unreliability of the physical link. This implies the unnecessary invocation of the congestion algorithm. Moreover this reduces the throughput drastically and causes severe performance degradation.

A wireless network consists of mobile stations and various intermediate nodes. Some type of intermediate node is required to connect a wireless network with a wireline network. A cellular telephony network, for example, is connected to a wireline network by an inter-working unit, and a wireless local area network (WLAN) is interconnected with an access point (also called base station).

Wireless links are not as robust as wire line links, since the radio quality may vary considerably over time, the bandwidth is usually lower, and transmission errors occur more frequently. Sending signals over an Omni directional radio based medium gives rise to more errors than in a guided medium such as fiber or coaxial cable. Signal strength weakens with the distance between the mobile station and the base station, and radio waves bounce off objects, giving rise to interference and multi-path effects. In order to shield upper protocol layers from transmission errors both error correction, interleaving and retransmissions can be used at lower layers. In many wireless networks, the data link layer performs error recovery according to some automatic repeat request (ARQ) protocol. Fig.1.1 shows basic idea of wireless network.

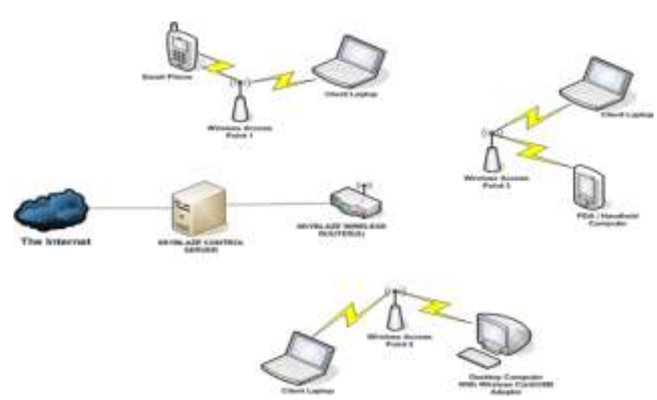


Fig.1.1 Wireless Network

Wireless networks are formed by devices that are able to communicate with each other using a wireless physical medium without having to resort to a pre-existing network infrastructure. This implies that this network is a network established for a special, often extemporaneous service customized to applications. So, the typical wireless network is set up for a limited period of time. The protocols are tuned to the particular application. The application may change dynamically. Because of its mobile, non-infrastructure nature, the wireless network poses new design requirements. The first is self-configuration in the face of mobility. Wireless networking brings features like easy connection to access networks, dynamic multi hop network structures, and direct peer-to-peer communication. Wireless network gives better performance than cellular network in terms of set up cost, set up time, adaptive changes in network as well as in infrastructure.

II. *WIRELESS NETWORK CHARACTERISTICS*

The wireless networks hold following characteristics.

A. Mobility

The nodes can be rapidly repositioned or moved. The mobility model can have major impact on the selection of a routing scheme and can thus influence performance.

B. Multi hopping

A multi hop network is a network where the path from source to destination traverses several other nodes. Nets often exhibit multiple hops for obstacle negotiation, spectrum reuse, and energy conservation.

C. Self-organization

The wireless network must autonomously determine its own configuration parameters including: addressing, routing, clustering, position identification, power control.

D. Energy Conservation

In wireless networks mobile nodes are battery powered. The choice of the power level fundamentally affects many aspects of the operation of the network including quality of received signal, range of transmission and many more as well as lifetime of network.

E. Scalability

In some applications the wireless network can grow to several thousand nodes. For wireless “infrastructure” networks scalability is simply handled by a hierarchical construction. Thus, mobility, jointly with large scale is one of the most critical challenges in design.

III. PROBLEMS FOR TCP/IP OVER WIRELESS NETWORK

TCP is used in many popular internet applications, such as e-mail, web browsing and remote login. TCP was designed for networks with wired links and stationary hosts. In these networks, data is lost mainly due to congestion. TCP interprets all data loss as congestion in the network, and in case of data loss TCP slows down its transmission rate in order to reduce the congestion. In a wireless network, it is no longer appropriate to assume that most losses are caused by congestion. Data loss is often caused by the relatively low quality of the wireless link. Terminal mobility, which is supported by many wireless networks, may also result in data loss. If data gets lost for some other reason than congestion, then performance is unnecessarily degraded as TCP reduces its transmission rate in response to the loss.

The performance of TCP is generally lower in wireless networks than in fixed. This is explained by the fact that TCP cannot distinguish problems that typically occur in wireless networks from congestion. The congestion control algorithms in TCP are based on the assumptions that data is lost mainly due to congestion and that data loss due to transmission errors is rare. Therefore, data loss is interpreted as a signal of congestion in the network. Even in a wireless network, where data loss may not be related to congestion, data loss still signals congestion to the sender. TCP segments may be lost if the radio conditions are poor and the link layer protocol provides a low reliability. After some retransmission attempts the link layer protocol gives up and leaves further error recovery to TCP. Handover events may also lead to data loss. A whole window of data may be lost due to handover. Data loss due to an unreliable link layer or a handover may cause a timeout event followed by slow start or three dupacks followed by fast retransmit and fast recovery. In either case, the congestion control action taken by TCP is unnecessary. Directly after the loss event, the radio quality may become high again, and after handover data may be transmitted without problems to the new base station.

TCP may also misinterpret a sudden increase in the round trip time as data loss. If the delay is long enough for the retransmission timer to expire before an acknowledgment is received, then TCP misinterprets the delay as an indication of data loss due to congestion. The delayed data is unnecessarily retransmitted and TCP enters slow start. A highly variable round trip time can also lead to a large RTO, since the RTO is base both on estimates of the round trip time and on variations in the round trip time. If the RTO is large, then TCP reacts slowly to data loss. Variations in the round trip time can be caused by link level retransmissions of a wireless link. If the link layer frames that contain a TCP segment must be retransmitted because of a poor radio environment, then the whole segment is delayed. Round trip time variations may also be caused by handover or competing traffic. Queuing in routers, base stations, and other intermediate nodes may also lead to a long round trip time. A long round trip time may cause low throughput and underutilization of the network, since it takes a number of round trip times before the congestion window reaches the capacity of the network. TCP performance is degraded, especially for short lived flows, which transmits a small amount of data.

IV. Factors Affecting On Performance Degradation of TCP Over Wireless Network.

Compared with wired networks, wireless networks have some inherent adverse characteristics that will significantly deteriorate TCP performance described below.

A. Channel error

In wireless channels, relatively high bit error rate because of multipath fading and shadowing may corrupt packets in transmission, leading to the losses of TCP data segments or ACKs. If it cannot receive the ACK within the retransmission timeout, the TCP sender immediately reduces its congestion window to one segment, exponentially backs off its RTO and retransmits the lost packets. Intermittent channel errors may thus cause the congestion window size at the sender to remain small, thereby resulting in low TCP throughput.[2]

B. Mobility

Cellular networks are characterized by handoffs due to user mobility. Normally, handoffs may cause temporary disconnections, resulting in packet losses and delay. TCP will suffer a lot if it treats such losses as congestion and invokes unnecessary congestion control mechanisms. The handoffs are expected to be more frequent in next generation cellular networks as the micro-cellular structure is adopted to accommodate an increasing number of users. Thing could be worse if TCP cannot handle handoffs gracefully. Similar problems may occur in wireless LAN, as mobile users will also encounter communication interruptions if they move to the edge of the transmission range of the access point.[2]

C. Communication asymmetry

In one-hop wireless networks, the wireless link between a base station and a mobile terminal in nature is asymmetric. Compared with the base station, the mobile terminal has limited power, processing capability, and buffer space. Another asymmetry stems from the vastly different characteristics of wired links and wireless links. The former is reliable and has large bandwidth while the latter is error-prone and has limited and highly variable bandwidth. For example, the bandwidth of a typical Ethernet is 10Mbps (100Mbps or even higher for fast Ethernet) while the highest bandwidth for 3G networks is only about 2Mbps[2]. Therefore, the wireless link is very likely to become the bottleneck of TCP connections.

D. Higher end-to-end delay

As the wireless link capacity is limited, the data rate on wireless can not reach values that are frequent on wired links. The presence of wireless section on a end-to-end connection will therefore slow down data traffic and increase the end-to-end delay. Retransmissions caused by erroneous packets also add a supplementary delay that should be taken into account in the global delay calculation. Moreover wireless systems often turn to coding and interleaving to cope with high error rate. These methods can increase the wireless delay to up to 100ms.[2]

E. Frequent disconnections

Handovers for instance often result in variation in packet delays or in packet losses that can lead to disconnections lasting from some packets (a few ms) up to a few frames (around 1 second). Besides, if a cell contains many users, some connections (of newly arriving mobiles) may not receive bandwidth for a long period of time – this call-blocking event can also be considered as disconnection. These disconnections result in TCP timing out and lowering its congestion window, thus reducing the efficiency of the transmission. As the mobile will reconnect, it will have to wait for TCP to time out before receiving more data. This trouble will become even more crucial in the future with the development of pico-cells. In fact this cell size reduction will lead to small cell latencies i.e. the user will not stay for long in a given cell but rather roam from one cell to another quite often.[2]

V. TCP PERFORMANCE IMROVEMENT OVER WIRELESS NETWORKS

Because of all above factor the performance of TCP is degraded in wireless network. Several solutions have been proposed to address the known problems that TCP faces when running over wireless networks. Of those solutions, the cross layer approach is most effective[4]. Cross layer means information available at one layer is use in decision making of another layer. These solutions are based on the distinction between the loss of signal and TCP congestion.

VI.

Loss Differentiation Algorithms (LDA) is currently used to determine the cause of packet losses with an aim of improving TCP performance over wireless networks [7]. There are two types of LDA schemes.

- The LDA acts at TCP level and its objective, complementary to the MAC level one, is to distinguish packet losses due to congestions from those related to short and repetitive signal losses due to interferences caused by other close transmissions in the same frequency band. This differentiation is realized through the monitoring of MAC level parameters.

Hence, a cross-layer solution will allow to classify efficiently the three different loss causes (congestions, signal losses and interferences) and to react accordingly either at the MAC or TCP level.

VII. MAC Layer LDA

Since signal failures due to distance or obstacles are resolved by the optimizing Retry Limit, the objective here is to differentiate segment losses due to interferences from those due to congestion.

The Proposed Scheme

The idea of algorithm is to count the number of MAC retransmissions for each of the *n* segments composing the current TCP window when the TCP layer is alerted by the reception of three duplicated acknowledgements. If for one of these not acknowledged segments at least, the number of MAC retransmissions (*Retry Count*) is equal to the threshold (*Retry Limit*), we consider that the loss is due to interferences and not to TCP congestion. Indeed, in the case of congestion, the surplus of segments is eliminated from the queue of the concerned node and MAC retransmissions are theoretically not used; inversely, in case of persistent interferences, the segment is dropped by the MAC layer after reaching the *Retry Limit* threshold. This algorithm assumes that for all the not acknowledged TCP segments, the value of *Retry Count* is stored. The *ACK Failure Count* counter available in the 802.11 *Management Information Base* (MIB) gives the number of times that an expected ACK is not received and consequently the value of *Retry Count*.

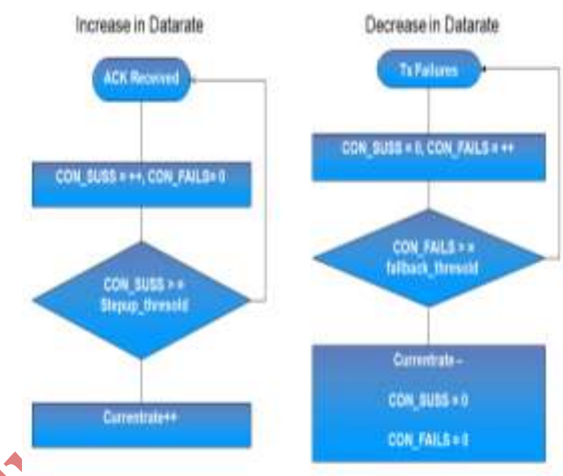
The algorithm works as follows:

Pseudo-code for NS2 implementation

```
if (Datarate >= 12000000)
RL = 6;
  else if(DataRate > 6000000)
  RL = 12;
    else if(DataRate <= 6000000)
    RL = 18;
      if (new TCP segment && Last segment dropped)
      {
      RL = RL + 6;
      }
end if
end if
```

In the MAC 802.11 frames, the "signal" field specifies the current throughput used to transmit the following data (*Data Rate*). This throughput indication depends on the measured power received by the station before its transmission and is thus proportional to the SNR. In addition, this throughput is related to the *Auto Rate Fallback* (ARF) procedure implemented by all the 802.11a, b or g card manufacturers. Let us recall that this procedure automatically reduces the throughput when a drop in the SNR is sensed. This can be due either to distance or obstacles.

Algorithm for ARF works as follows:

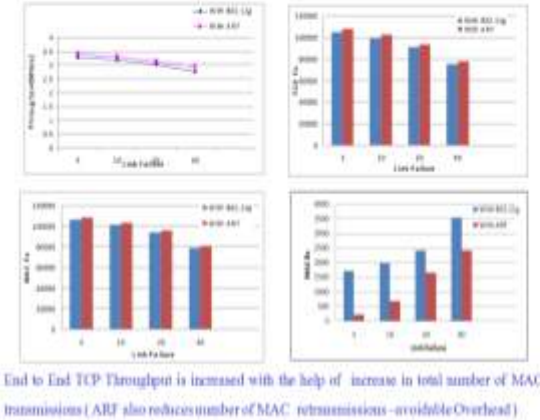


VIII. Simulation Result

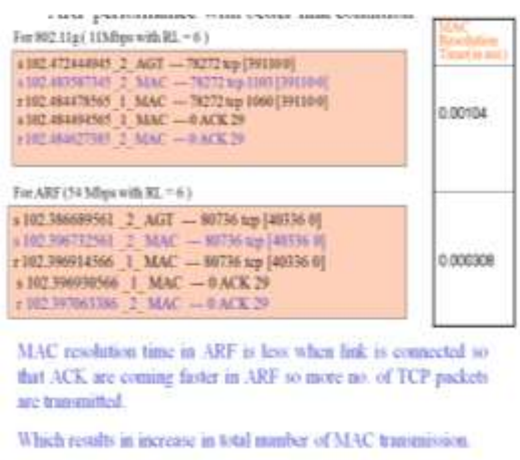
In order to analyze the performance improvements brought by the MAC layer LDA, simulation is carried out using NS-2. The 802.11 implementation already available within NS-2 have been extended in order to incorporate the more recent 802.11g specificities
The simulation is carried out using a wired-cum-wireless scenario in which last hops is wireless. This wireless hop sends a TCP traffic flow to a wired network as shown in Fig.

In scenario signal failures are obtained by moving node_0 to the limit of the coverage area. In simulation the Newreno is used as agent for TCP traffic generation. The total simulation time is 250s. In the simulation 802.11g is used for wireless hop which is displaced at the coverage area during simulation time. The wired line has capacity of 100Mbps and delay is 10ms.

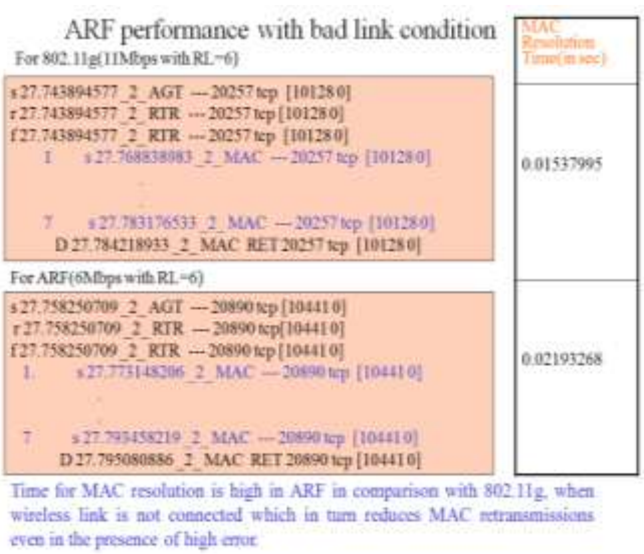
1) TCP Performance comparison between 802.11g and 802.11g+ARF



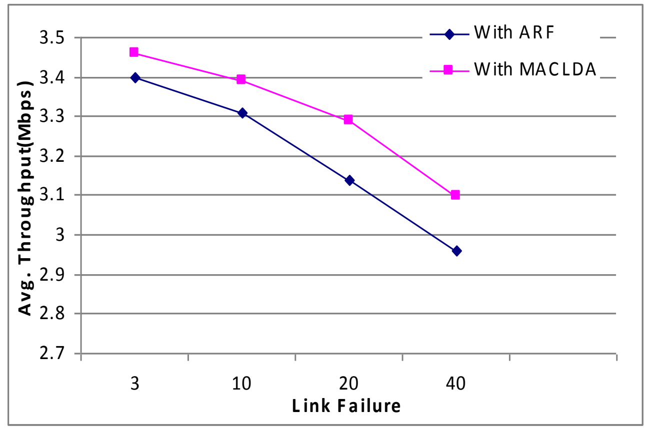
2) ARF Performance with better link condition



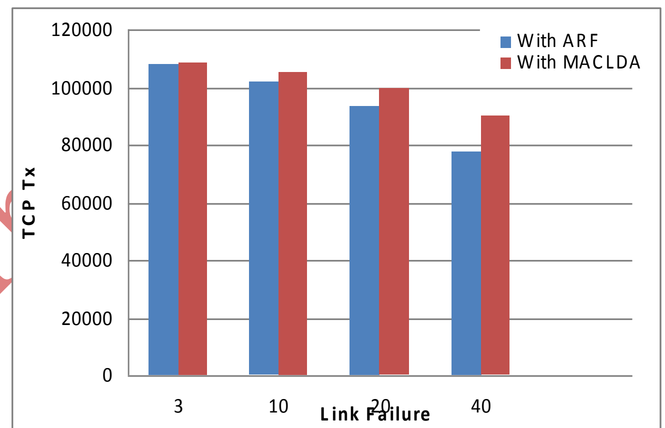
3) ARF Performance with bad link condition

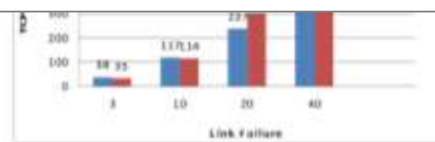


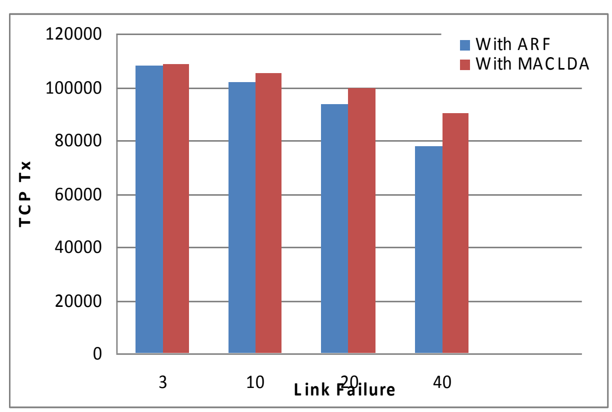
4) TCP Performance comparison between 802.11g+ARF and 802.11g with MAC LDA

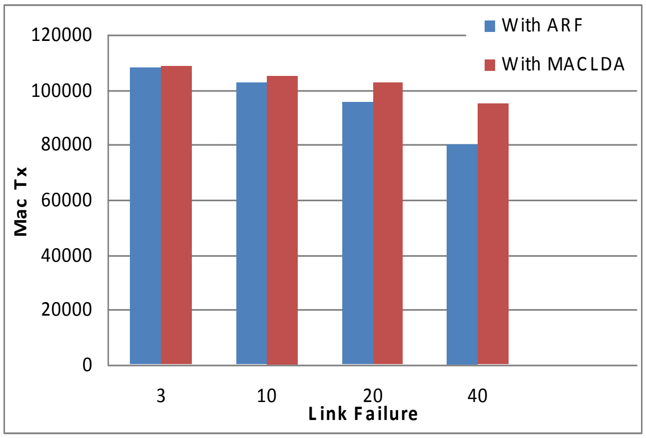


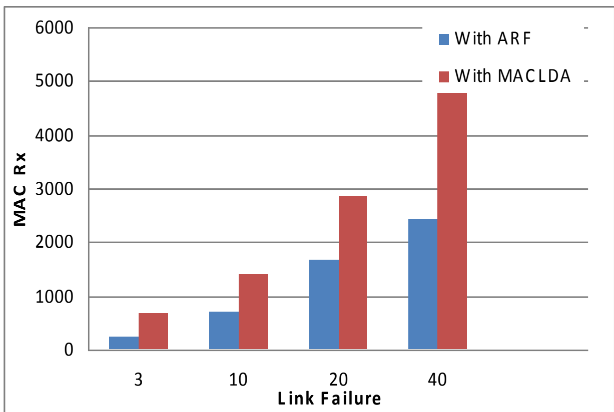
5) MAC LDA Performance analysis using trace file











Loss recovery at MAC improved with the help of increase in MAC retransmission. This results in increase in throughput.

IX. CONCLUSION

One of the main problems related to the use of TCP in wireless networks is to distinguish TCP congestion from a loss of signal. By using MAC Layer Loss Differentiation Algorithm *Retry* Limit is change at MAC layer on based on data rate which is set by Auto Rate Fallback algorithm. So it will try to locally enhance the problem of link failure. So throughput is increases. When datarate is increased, MAC layer Loss Differentiation Algorithm is not working properly, which is seen from results.

REFERENCES

[1] Fabienne LEFEVRE, Guillaume VIVIER: "Understanding TCP's behavior over wireless links", Motorola Labs – Centre de Recherche de Motorola – Paris.

[2] Hari Balakrishnan, Srinivasan Seshan, Elan Amir and Randy H. Katz. "Improving TCP/IP Performance over Wireless Networks."

[3] Dzmitry Kliazovich and Fabrizio Granelli. "A Cross-layer scheme for TCP Performance Improvement in Wireless LANs."

[4] S. Goel and D. Sanghi.: "Improving TCP performance over wireless links. *Proceedings of TENCON 98 - IEEE Region Ten Conference on Global Connectivity in Energy, Computer Communication and Control*, 1998

[5] Christina Parsa J.J, Garcia-Luna-Aceves"Improving TCP Performance over Wireless Networks."

[6] Stephane Lohier, Yacine Ghamri Doudane, and Guy Pujolle"Cross-Layer Loss Differentiation Algorithms to improve TCP Performance in WLANs".

[7] *Stephane Lohier, Yacine Ghamri Doudane, and Guy Pujolle:* " The Benefits of a Cross-Layer Approach for TCP Performance Improvements in WLANs"

[8] S. Cen, P. C. Cosman, and G. M. Voelker "*End-to-End differentiation of congestion and wireless losses*", IEEE/ACM Transactions on Networking (TON), 2003.

[9] S. Bregni, D. Caratti, F. Martignon "*Enhanced Loss Differentiation Algorithms for Use in TCP Sources over Heterogeneous Wireless Networks*", Globecom 2003.

[10] H. Balsrishanan, S. Seshan and R. H. Katz: "A comparison of mechanisms for improving TCP performance over wireless links", *Proceeding of ACM SIGCOMM'96, Aug. 1996*

[11] ns manual http://www.isi.edu/nsnam/ns/ns-documentation.