Wi-TCP: Performance Enhancement of TCP in Wireless Networks Using Window Management and Route Optimization Concept

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Summary:
This paper proposes a Wi-TCP to improve the performance of traditional TCP in the scenario of frequent handoff in route optimized Mobile IP based network. Presented scheme does not require any modification in the route optimization as it simply exploits the optimized feature, and hence reduces packet loss during handoff. Authors believe that one can get improved performance during handoff by combining cross layer feedback at agent with optimized route. Also, this scheme evades ongoing data transmission during disconnection which results in avoiding network bandwidth wastage. In proposed scheme, agent informs the sender about the status of mobile host by sending EHO-ACK and EHC-ACK to avoid retransmissions during disconnection.

Keywords:
Exclusive Handover Acknowledgement (EHO-ACK), Exclusive Handover Completion Acknowledgement (EHC-ACK), Mobile Internet Protocol (MIP), Care-of-Address (COA), Home Agent (HA), Foreign Agent (FA), Mobile Host (MH),Route optimized Mobile IP(ROMIP)

1. Introduction

Lately varieties of wireless networks are accessing the Internet. Some of the applications in the Internet require guaranteed delivery and therefore most reliable transport layer protocol; TCP [1] is used, though it was basically designed for wired network. It performs inadequately in cases of end user device being mobile host; this is because of frequent disconnection of MH. In such scenarios TCP mechanism detects losses via time-outs and concludes packet loss due to congestion but cannot distinguish between the other factors like link failure, temporary disconnection, handoff etc. This is a fundamental design problem in TCP. If mobile host moves from one network to another, mobility itself can cause packet loss and TCP performance is degraded in such environment. There were number of solutions proposed to improve the performance of TCP in wireless environment such as split connection approach [2][3], link-layer scheme[4], explicit loss notification approach, receiver-based approach, and such other modifications to TCP. Prediction of signal strength concept is exploited in Freeze TCP [5] and hence performance improvement of this scheme is dependent on accurate prediction of disconnection by the MH. In M-TCP [6], base station handles disconnection problem. Route optimized Wi-TCP improves TCP performance in mobile IP based networks with route optimization concept where TCP sender[1] can distinguish packet losses by the handoff[2], not by the congestion.

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2. Impact of mobility on TCP

For unpredictable mobile and wireless environments many researchers suggested solutions to improve TCP performance. Some of the works are centered on link disconnections while few others deal with handoff. Here we discuss the existing solutions which deal temporary disconnections caused by handoff. Freeze-TCP and M-TCP used the approach of forcing sender into persist mode during handover. In case of [5] MH sends Zero Window Advertisement (ZWA) on the basis of signal strength. In M-TCP [6], base station handles disconnection problem. Another method [7] is proposed to alleviate the performance degradation as a result of disconnections due to handoffs. In [8] if the sender receives an ACK with Explicit Handover Notification (EHN) indication, it resets the retransmission timer and adjusts its sending window in response to the sequence number in EHN packet. ATCP[9] uses network layer feedback to modify congestion control mechanism to improve TCP when MH gets disconnected and reconnected to the network. In Proactive-WTCP [10] MH monitors receiving signal strength. A threshold of receiving signal strength is set to foresee the impending disconnection. When the signal strength is lower than the threshold, MH predicts disconnection. To enhance traditional TCP performance with handoff loss in [11] proposes the concept of active-mobile-host, which maintains the original end to end semantics, assuming MH

[1] Terms sender and FH are used interchangeably
[2] Terms handoff and handover are used interchangeably

has the knowledge of Round Trip Time (RTT), which may not be practical since RTT is often measured very coarsely by the sender instead of the MH itself. The idea of active-mobile-host is to let the MH actively advertise a zero-window-size (ZWS) ACK to the sender just at the time instant of crossing the boundary of Core Area. Upon receiving ZWS, the sender will freeze all retransmission timers and enter a persist mode. But the sender keeps sending zero-window-probe packets to the MH until the MH's windows opens up. Some of the works discussed above only consider an intra–sub network handoff, and verifies the TCP performance, while others investigate the impact of handover on TCP, which support inter–sub network handoff but do not address the issue of route optimization concept [12].

3. IP During Handover

3.1 Mobile IP

Mobile IP [13] is a standard for handling routing for hosts that have moved from home network. MH registers its new location with HA when it enters in foreign network. Network configuration of Mobile IP based Network with home network, HA, foreign network, FA, intermediate router (R) and MH is depicted in Fig1. Mobile IP solves the primary problem of routing IP packets. With the mobile IP protocol, all packets have to go through HA resulting in triangular routing. Fig. 2 shows the scenario of packet delivery, when MH moves from FA1 to FA2. During such handoff packets are lost, even though triangular route exists.

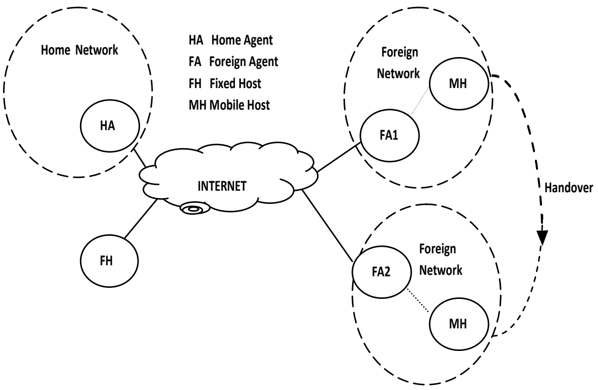


Fig 1. Network configuration of Mobile IP based networks

3.2 Route Optimized Mobile IP

Route optimized mobile IP [12] avoids triangular routing. On receipt of registration request the new FA sends the binding update message to the old FA informing new COA. When the old FA receives a packet from the sender it reverts back the binding warning message as sender does not know the new COA. When the sender receives the binding warning message, it requests HA and HA sends the binding update message to the sender in order to inform the new COA. After receiving the binding update message, the sender sends packets to the new FA instead of the old FA. Fig. 3 shows route optimized mobile IP protocol with four additional messages such as binding request, binding update, binding acknowledgement and binding warning. It shows data transfer in the case of MH movement from FA1 to FA2. Complete Registration process is not shown in the diagram.

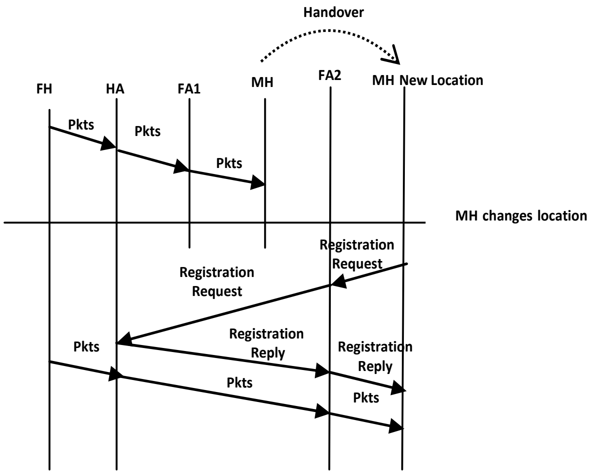


Fig. 2 Registration process and Data Transfer in Mobile IP when MH moves from FA1 to FA2

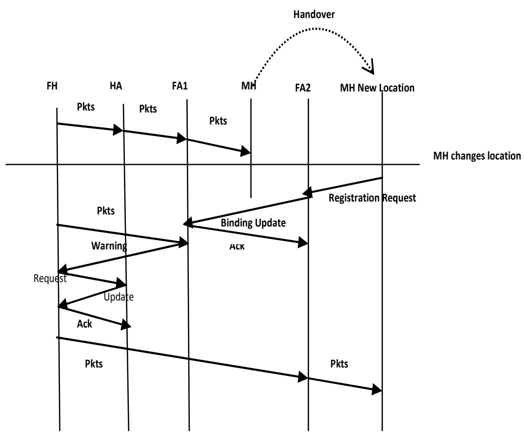


Fig. 3 Data Transfer in Route optimized Mobile IP

4. Simulation Model

The topology was simulated using ns-2 [14] simulator shown in Fig. 4. The system model consists of wired link of 10 Mbps, 10 ms delay between FH and router R , wired link of 10 Mbps and 5ms between R and HA/FA and a

2Mbps wireless channel. The packet size is set to 1040 bytes (including TCP + IP header) and the queue size at all links is fixed at 50. The queues used in all links are drop tail except wireless link have priority queue. In the given scenarios TCP traffic is used. An end to end TCP connection is assumed with a maximum window size of 20.

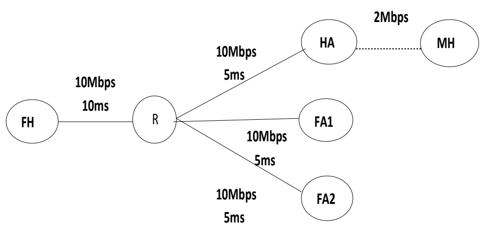


Fig. 4 Simulation setup

5. Mechanism of Route Optimized Wi-TCP

Wi-TCP is designed to improve TCP performance in wireless mobile networks in cases of disconnections caused by mobility. The Media Access Control (MAC) layer informs the TCP layer by way of cross layer feedback, about loss of connection whenever MH gets disconnected and forcing agent to send EHO-ACK to sender. On receipt of EHO-ACK, current *cwnd* and *ssthresh* values are stored separately by sender and suspension of transmission activity. Two handover events are discussed here, first of handover from home agent to foreign agent and second of from one foreign agent to another foreign agent.

Case I (HA-FA): When MH registers with foreign agent; FA sends EHC-ACK to sender to resume communication with the same rate as was before handoff.

Case II (FA1-FA2): When MH registers with FA2, FA2 will immediately notify the FA1 by sending binding update message and upon receipt of binding update [12] it sends EHC-ACK to sender. On receipt of notification, sender restores *cwnd*, *ssthresh* and begins to transmit immediately with the same rate to that of prior to handoff with optimized route. Fig. 5 shows complete mechanism of Wi-TCP with binding update though normal registration process is not shown.

In simulation experiments, assumption is made that packet loss takes place due to handover only and not by network congestion or transmission error. Also home agent or foreign agent in each sub network plays the role of base station. In Fig. 4 the wired path between TCP sender and R the last router, could consists of several hops but in Fig.4 we have considered single hop, as it would not affect the performance. Wi-TCP performance depends only on, how it behaves during handover.

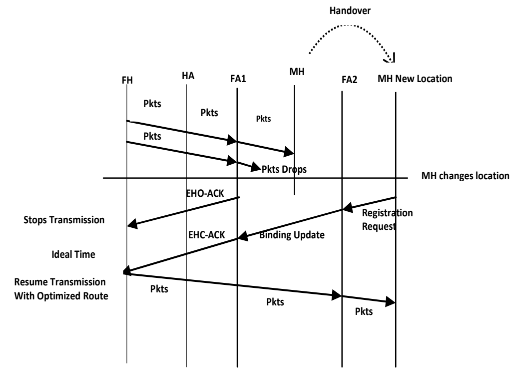


Fig. 5 Modification to route optimization mobile IP to enhance Wi-TCP performance

6. Result and Performance analysis

In order to access the TCP throughput of Wi-TCP in non overlapping cells where long disconnections can occur during handoffs, we compared the effectiveness of our implementation with traditional[1].Two situations may occur in such cases: all in-flight packets are lost or some of the packets are lost as mobile host has not reached in the vicinity of the new agent for long time. Loss recovery method in traditional TCP is slow start phase only for longer disconnection. In fact, Reno sender always encounters a timeout, when three or more packets are dropped and New-Reno sender is able to recover 3-4 lost packets only and then New-Reno sender enters slow-start phase after timeout similar to Reno. We compared Wi-TCP with traditional TCP .

6.1. Window management and Retransmissions

Case I (HA-FA): In implementation packets 759-778 are sent and handoff takes place. During handoff it is observed that packets 769-778 are dropped at home agent at 11.533 seconds while acknowledgements 759-768 are dropped at MH at 11.5543 sec, as MH moves out of the home network. On the basis of cross layer feedback, home agent sends EHO-ACK to sender to stop transmission. At 15.585 first handoff (point A in Fig. 6) has completed, after registration, new foreign agent sends EHC-ACK. After reception of EHC-ACK, the transmission window restores to previously stored *cwnd* and *ssthresh*, packets flow resumes (point B in Fig. 6, point A and B are in reference to x2-y2 axes) with optimized route after MH successfully registers in the foreign network with a same rate to that of prior to handoff.

[1] Term traditional TCP is interpreted as TCP Tahoe, TCP Reno and TCP New Reno

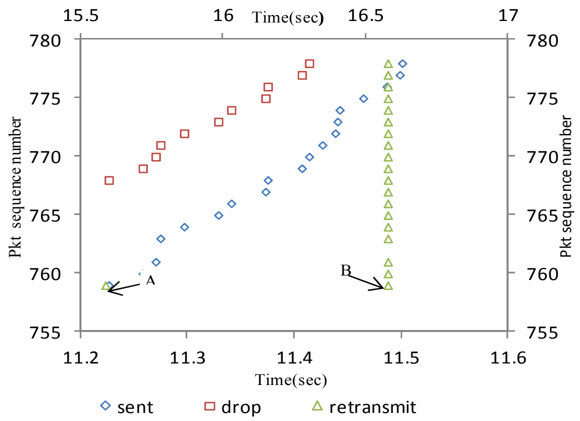
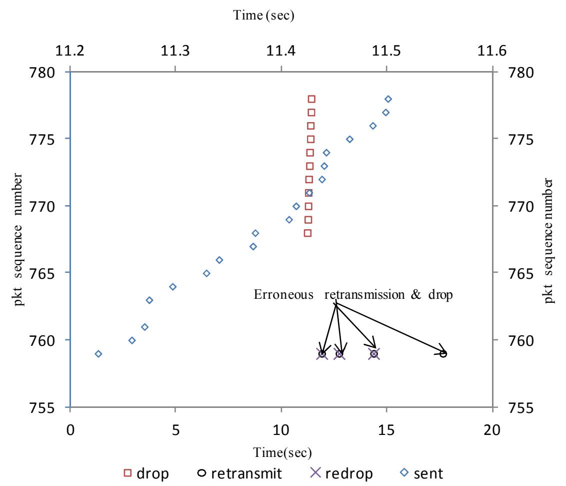


Fig. 6 Loss Recovery in Wi-TCP

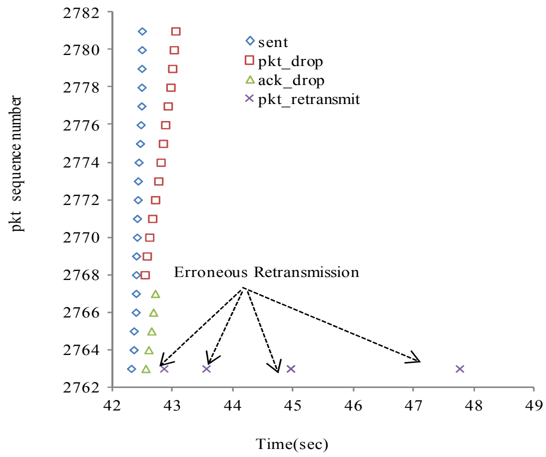
In case of traditional TCP, the handover delay is more than the sender's RTO estimation. During handoff there is a timeout at 11.57 second, as a result, the sender enters slow start phase and it reduces *cwnd* to 1 and *ssthtresh* to *cwnd* by half. Sender retransmits lost packet 759 (erroneous retransmission shown in Fig. 7). It goes through successive timeouts and erroneous retransmits packet 759 at exponentially increasing intervals with continuously reducing *cwnd*, even after handoff has been completed which leads to high performance degradation. It can be seen that repetitive data transmission (11.910883 to 17.650883 seconds) results in wastage of network resources. We plotted erroneous retransmissions and drops in Fig. 7.



Case (HA-FA)

Fig.7 Retransmission of dropped packet in TCP-Tahoe(MIP and ROMIP)

Case II (FA1-FA2): When MH leaves FA1 and registers with FA2, packets loss occurs at 42.524 second. In case of traditional TCP with mobile IP it is observed that packets 2768-2775 are dropped at FA1, and acknowledgements 2763-2767 are dropped at MH. In traditional TCP with route optimization packets 2768-2775 are dropped at FA1, and acknowledgements 2763-2767 are dropped at MH. In Wi-TCP acknowledgements 2850-2867 are dropped at MH. Packets sent, packets and acknowledgement dropped and retransmitted packets are shown in Fig.8-Fig.10 .From the statics of sequencing it is seen that Wi-TCP is approximately 100 packets ahead in transmission (ie gain of 100 packets).

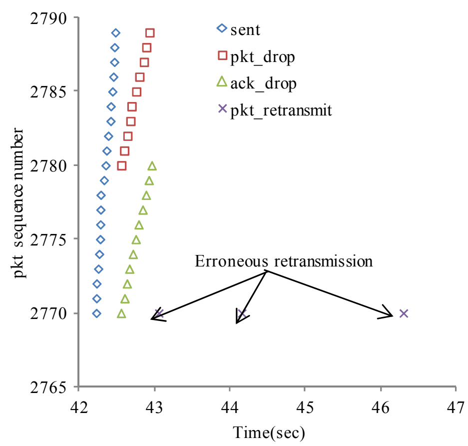


Case (FA1-FA2)

Fig.8 Retransmission of dropped packet in TCP-Tahoe(MIP)

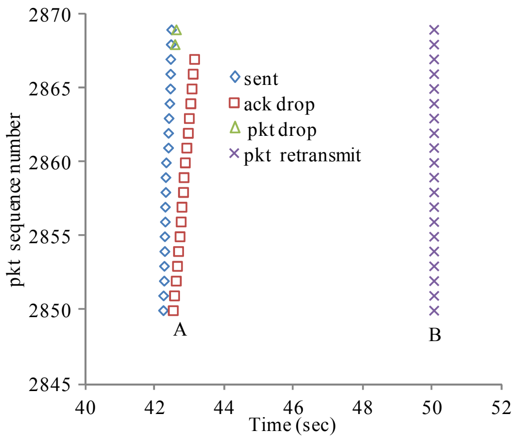
In Fig. 10 between point A and point B, there is no retransmission of packets results in avoiding wasting of network bandwidth. From Fig. 8 and Fig. 9 it is inferred that route optimization has not resulted in substantial performance improvement in traditional TCP.

Comparative congestion window status for three cases is depicted in Fig. 11. For traditional TCP ,only TCP Tahoe results are shown as TCP Reno and TCP New Reno results are same. Wi-TCP congestion window are plotted in x2-y2 axes of Fig. 11



Case (FA1-FA2)

Fig.9 Retransmission of dropped packet in traditional TCP(ROMIP)



Case (FA1-FA2)

Fig.10 Retransmission of dropped packet in Wi-TCP

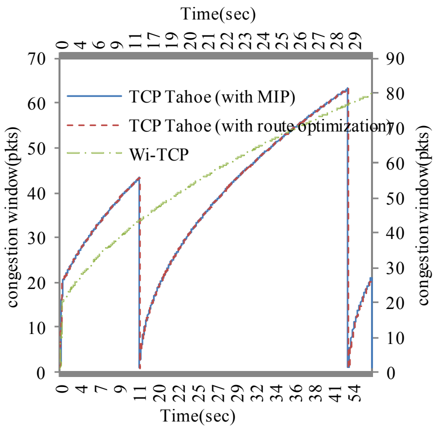


Fig.11 Congestion window status during handover

6.2 Delay Analysis

In Fig. 4 end to end round trip time between sender and MH receiver is indicated by RTT and round trip time between HA/FA and MH is indicated by rtt. Let t_o be the time of the packet sent by the sender which gets dropped. This packet reaches HA/FA at ($t_0+RTT/2-rtt$). Agent's Mac layer is unable to deliver packet due to handoff and informs TCP layer accordingly. HA/FA sends EHO-ACK to sender at approximately at time ($t_0+RTT/2-rtt+\alpha$). On receipt of EHO-ACK, sender suspends transmission activity. Approximate time at which sender received EHO-ACK is denoted by $T_{EHO\text{-}ACK}$.

$$T_{EHO\text{-}ACK} = t_0+RTT-2rtt+\alpha \qquad (1)$$

where α is the period from the time of packet delivery failure by MAC layer at agent to the time when agent sends EHO-ACK.

6.2.1 Calculation of TEHC-ACK

Case I (HA-FA): When MH registers with new foreign agent, new agent sends EHC-ACK to sender to resume communication with the same rate as that of prior to handoff. Some terminologies are used here to represent timings.

$T_{RECONNECT}$: The period from the time when the MH disconnects to the time when MH gets registered in the new network.

$$T_{EHC\text{-}ACK} = t_o+RTT/2-rtt+\alpha+T_{RECONNECT}+T_{FA\text{-}SENDER} \qquad (2)$$

where $T_{FA\text{-}SENDER}= RTT/2\text{-}rtt$

Case II (FA to FA)

$$T_{EHC\text{-}ACK} = t_o+ RTT/2\text{-}rtt +\alpha + T_{RECONNECT} +T_{NEWFA\text{-}OLDFA}+ T_{FA\text{-}SENDER} \qquad (3)$$

$T_{NEWFA\text{-}OLDFA}$: The period from the time when the new FA sends binding update to the time when old FA receives the same.

T_{IDEAL} : The period from the time when the sender suspends transmission to the time it resume transmission.

$$T_{IDEAL}= T_{EHC\text{-}ACK} - T_{EHO\text{-}ACK} \qquad (4)$$

From the above statistics it can be concluded that performance of Wi-TCP depends upon $T_{EHO\text{-}ACK}$ and α.If $T_{EHO\text{-}ACK}$ is more than the current RTO at sender ,slow start mechanism is invoked.

6.2.2 Impact of Delay between HA and FA

By varying the delay between home agent and foreign agent (Fig.4) we verified the impact on throughput, average throughput for three cases is depicted in Fig. 12 for 10ms and 20ms delay. It is observed that traditional TCP throughput decreases as the latency between the HA and FA is increases. However Wi-TCP provides almost constant throughput after handover as it uses optimized path and need not have to traverse through HA.

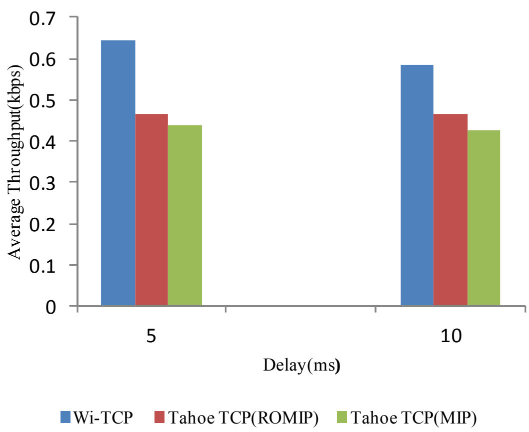


Fig. 12. Effects of delay on throughput

7. Conclusion

We have extended mobile IP in NS2 for optimized route. This optimization feature and cross layer feedback shows the improved TCP performance in Wi-TCP. Wi-TCP has 38% improvement over traditional TCP with route optimization MIP and 44% percent improvement over traditional TCP with MIP. Wi-TCP does not require prediction of impending disconnection at the MH and modifications need to be applied at the agent level only. Our scheme reduces the network congestion and traffic by way of stopping unnecessary retransmission of packets from sender as well as routing of packet in the routes connecting between MH and FA by directly sending from last router to the current agent connected to mobile host. Wi-TCP avoids network bandwidth wastage as in [5] as it suspends ongoing data transfer during disconnection. [8]has suggested to send Exclusive Handover Notification packet to the sender as soon as MH receives advertisement from new FA.In this approach the sender continues to send the packets even during disconnection. And hence; in flight packets are dropped until MH receives the advertisement from new FA and it is not able to avoid network bandwidth wastage. In [7], it was suggested to send 3 duplicate acknowledgements after reconnection but did not discuss the issue regarding if handover period is longer than the current timeout at the sender. As whenever it happens, sender enters into slow start phase resulting in performance degradation.

References

[1] Stevens W. R., 1994. TCP/IP Illustrated vol. 1, Addison-Wesley.

[2] Karunaharan Ratnam and Ibrahim Matta: "WTCP: An Efficient Mechanism for Improving Wireless Access to TCP Services∗", INTERNATIONAL JOURNAL OF COMMUNICATION SYSTEMS, Version: 2002/09/18 v1.01

[3] Ajay V Bakre and B. R. Badrinath: "Implementation and Performance Evaluation of Indirect TCP", IEEE Transaction on computers, vol 46, No 3, March 1997.

[4] Hari Balakrishnan, Venkata N. Padmanabhan Srinivasan Seshan, and Randy H. Katz. "A comparison of mechanisms for improving TCP performance in wireless networks". in ACM SIGCOMM Symposium on Communication, Architectures and Protocols, August 1996.

[5] T. Goff, J. Moronski, D.S. Phatak, and V. Gupta: "Freeze-TCP: A True End-to-end TCP Enhancement Mechanism for Mobile Environments", IEEE INFOCOM 2000, March 2000.

[6] K. Brown and S. Singh "M-TCP: TCP for Mobile Cellular Networks", ACM Computer Communication Review

[7] R.Caceres and L.Iftode: "Improving the Performance of Reliable Transport Protocols in Mobile Computing Environments", IEEE Journal on Selected Areas in Communications, Vol.13, No.5, pp.850-857, Jun.1995.

[8] Haruki Izumikawa, Ichiro Yamaguchi and Jiro katto: "An Efficient TCP with Explicit Handover Notification for Mobile Networks" WCNC 2004, IEEE Communication Society

[9] Ajay Kr. Singh and Sridhar Iyer: "ATCP: Improving TCP performance over mobile wireless environment", 2003

[10] Yizhou Li and lillykutty Jacob: "Proactive-WTCP an end to end mechanism to improve TCP Performance over Wireless links", IEEE LCN 03, 2003

[11] Fei Hu Neeraj K. Sharma; "The Quantitative Analysis of TCP Congestion Control Algorithm in Third-Generation Cellular Networks Based on FSMC Loss Model and its Performance Enhancement", IEEE INFOCOM 2002

[12] Charles E. Perkins,D,E Johnson, Route Optimization in Mobile-IP ,draft-ietf-mobileip-optim-10.txt,2000

[13] Charles E. Perkins,"Mobile IP", IEEE Communication Magazine, May 1997

[14] http://www.isi.edu/nsnam/ns