IMPACT OF NODE VELOCITY ON TCP THROUGHPUT OF MOBILE AD-HOC DATA NETWORK (MADNET)

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ABSTRACT

A Mobile Ad-hoc Data Network (MADNET) is a self-configuring, infrastructure-less network of mobile devices (nodes) where nodes communicate and share data using wireless links. This type of network is mostly deployed in areas where centralized infrastructural setups like base stations are not available. It's mostly applicable in emergencies such as rescue operations, military applications and sharing of data in conferences. Node failures and arbitrary movement of nodes at higher node velocity break the routes and lead to the frequent operation of rebuilding routes that consume lots of the network resources and the energy of nodes. In this study, we analyze the impact of node velocity on TCP (Transmission Control Protocol) Throughput of MADNET. The network performance is evaluated on Iperf to determine the variations on the TCP throughput of the network at different nodal velocities. The study was carried out in two sections: In the first section, the client was put to motion and the server kept stationary whereas in the second section, we maintain the same conditions but the client was kept stationary and the server put to motion. Results show a drastic reduction in TCP throughput as the nodal velocity increased in the first section whereas there was little reduction in the TCP network throughput in the second section showing thatmobility is more effectively masked in when the client is stationary.

Keywords: Adhoc, Client, Iperf, MADnet, Server, TCP.

INTRODUCTION

The exploitation of the network functionality of computers is the backbone of the industrial evolution and revolution of the 21st century. Governments, businesses and individuals have tapped into it and have made communication, processing of information and sharing of information easier through the creation of both wired and wireless networks (Eng.Nassar Enad. GH. Muhanna 2013). In recent times, the wireless network is becoming more and more popular in network technology compared to the traditional wired network. Wireless networks are connected through wireless channels. Generally, there are two kinds of wireless networks: the WLAN and the cellular networks. The WLAN with a wired backbone in which the base station is the boundary node and the extended connection between the mobile user and the base station is wireless channel whereas the other is the wireless ad hoc network, which is an infrastructure-less self-configuring network with more than one hop wireless channels in the connection (Fan Bai and Ahmed Helmy, 2004). This kind of topology is not widely implemented yet, but there are several applications of mobile ad hoc networks such as disaster recovery operations, battlefield communications, data sharing in conference halls, etc (Dr. C. Rajabhushanam and Dr. A. Kathirve, 2011). One of the limiting factors of Mobile Ad hoc Networks (MANETs) using traditional message exchange is the inability to transmit and receive at the same time slot or frequency simultaneously [A]. Previous studies have shown the Transmission Control

Protocol and User Data Protocol as the most widely used transport protocols employed in the evaluation of mobile wireless ad-hoc networks.

LITERATURE REVIEW

Andreas Hafslund et al (2004) did an elaborate work on multi-homed wireless, ad hoc networks. Two different scenarios of TCP connections for analyzing TCP performance in a Linux testbed of six laptop PCs running on Linux, kernel 2.4.20, with two laptops acting as gateways to the Internet was setup. The results show that the TCP capture effect will degrade the TCP performance when more than one flow tries to use the same wireless link. This study also demonstrates that the multi-homing of an ad hoc network causes delays because of the rerouting, but this causes no problem for TCP. However, TCP adjusts when one of the gateways has a lower bandwidth link to the Internet without timing off due to congestion.

Some TCP related problems over wireless links are the focus in Shugong Xu and Tarek Saadawi (2001). The work is based upon simulations in ns-2 and demonstrates that TCP connections are unstable over wireless links. The study shows also that the TCP maximum window size has effects on the instability problem. They concluded by saying that the current version of the IEEE 802.11 MAC protocol does not function well in multi-hop ad hoc networks. In Kitae Nahm, Ahmed Helmy and C.C. Jay Kuo (2005), the effect of congestion and MAC contention on the interaction between TCP and on-demand ad hoc routing protocol in the 802.11 ad hoc networks was studied. and the result showed that the utility of TCP in 802.11 multihop networks lies in the ability to keep the network robust and stable. The study revealed that TCP induces the over-reaction of the routing protocol and hurts the quality of the end-to-end connection. To fix this problem, a fractional window increment (FeW) schemes for TCP was proposed in the study to prevent the over-reaction of the on-demand routing protocol by limiting TCP's aggressiveness. As shown in the simulation results, the proposed scheme can improve TCP performance and network stability in a variety of 802.11 multihop networks. The TCP performance and network stability of 802.11 multihop networks can be improved by the proposed scheme as demonstrated in the simulation results. The study demonstrated that, the proposed scheme outperforms legacy TCP by over 90%, and recent related variants of TCP (ADTCP, LRED) by over 70% in some chain-like topologies (Kitae Nahm, Ahmed Helmy and C.C. Jay Kuo 2005).

The analysis in Ruy de Oliveira and Torsten Braun (2002) detail why TCP perform poorly in ad-hoc environment. The study validated that the principal problem of TCP in the Adhoc environment is its inability to distinguish losses induced by mobility or lossy channel from the ones due to network congestion. It indicates that standard TCP is not only prone to poor throughput values but also to unacceptably long idle states because of the exponential backoff mechanism. It suggests that protocol layers cooperation is essential in the ad-hoc network and recommends that routing protocols should avoid using information that is cached for too long and struggle to provide symmetrical and shortest paths. This would mitigate the possible lack of ACKs at the transmitter and improve accuracy on RTT computations.
Foez Ahmed et al (2010) evaluated TCP performance in a multihop wireless network environment. It investigated the impact of a high bit error rate of wireless links on the performance of TCP through simulation in the ns-2 environment for both the chain and grid topologies. Severe performance degradation was observed from the simulation due to significant reduction in throughput and unacceptable delays for active connections. Moreover, route change which leads to dropping of active links also reduced the TCP throughput.

Transmission Control Protocol (TCP)
The Transmission Control Protocol (TCP) is a connection-oriented and reliable protocol, which provides reliable host-to-host data transmission in packet-switched computer communication networks (DARPA Program, 1981). In TCP, reliability is achieved by sequence numbers and acknowledgments (ACKs) (Chandrashekhar Goswami and Parveen Sultanah,2002). Hence, an average of the estimated delay and its average deviation is maintained by each TCP sender. Packets will be retransmitted if the sender receives no acknowledgment within a certain timeout interval (Xiang Chen, 2005).

TCP uses a sliding window mechanism in combination with timers to adapt to network conditions and retransmit lost packets to provide reliability. In TCP the window size determines the number of bytes of data that can be sent before an acknowledgment from the server must arrive. TCP establishes a full-duplex virtual connection between two endpoints which is defined by the IP address and the port number of each endpoint. The byte stream is transferred in segments. Typically, TCP is the best transport layer protocol for applications that require guaranteed delivery of data (Postel, 1980). Contrary to the characteristics of wireless links in the ad-hoc network, TCP appears to be relatively reliable in networks where most packet losses are caused by network congestion. In mobile ad hoc environment losses are more often caused by high Bit Error Rate (BER), route re-computation, temporary network partition, and multi-path routing (Foez Ahmed, 2010) . TCP reduces throughput which results to poor performance, even when the losses are not due to network congestion.

Challenges of TCP Performance In Madnet
Based on the fact that TCP is traditionally made for wired networks, it's usage in wireless networks introduces obvious challenges. These challenges are practically shown in the degradation of TCP throughput. The major reasons behind throughput degradation that TCP faces when used in ad hoc wireless networks are briefly discussed below. Wired networks suffer a major setback due to network congestion. In wired networks, network congestion leads to packet loss which is necessarily not true in the wireless network. Consequently, TCP was designed to control packet loss due to network congestion in wired networks.

A. Misinterpretation of Packet Loss
According to *G.* Sankara Malliga, Dr.Dharmishtan K Varughese (2010) TCP is a transport protocol originally designed for networks where packet losses are caused by network congestions. In a wireless network, however packet losses will occur more often due to unreliable wireless links than due to congestion. Wireless links can have high bit error rates and high probability of packet loss even when there is no congestion (Andreas Hafslund et al 2004). During such instance, TCP will assume that the network is congested, and 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

(Gavin Holland and Nitin Vaidya, 2002). Channel errors at some intervals may hence cause the congestion window size to remain small at the sender; as a result the TCP throughput becomes low. (Hari Balakrishnan and Randy H. Katz, 1998) and (Hari Balakrishnan, 1996) Presented a novel protocol based on Explicit Loss Notification (ELN) to improve performance when the mobile host is the TCP sender. ELN has the advantage of making TCP to respond only to network congestion even when wireless bit-error-rates are high by maintaining a large TCP congestion window.

B. Frequent Path Breaks

The second challenge is related to mobility, all hosts in the network are mobile, and hence the topology can be highly dynamic in the mobile ad-hoc data network. From the perspective of a single end-to-end connection, not only are the end-hosts mobile, but the intermediate "routers" are mobile too (Karthikeyan Sundaresan, 2003). Previous studies show that TCP timeouts take place when multiple disconnections and reconnections occur in the network. The resultant effect is the lowering of the congestion window, and TCP will take a long time to recover. Mobility can also cause the arrival of out-of-order packets (Andreas Hafslund et al 2004). An ACK will be generated by the TCP sender for the highest packet received in-order. This will result in duplicate ACKs, and when three duplicate ACKs have been received, TCP goes into the fast retransmit phase (Andreas Hafslund et al 2004).

METHODOLOGY

The main focus of this chapter is to practically implement a data ad-hoc network and evaluate the impact of mobility on data throughput of the network. Network throughput is the performance metric we adopted in this study. According to Changhua He (2003), throughput and delay are the most important parameters to evaluate the performance of wireless ad hoc networks. In this study, the capacity represents the throughput (megabytes) of the whole system. We adopted Iperf as our performance tool which we installed in the laptops and configured one as the client (Iperf –c) and the other as the server (Iperf -s) using Iperf commands in each section of the experiments. We carried out an ad-hoc TCP measurement between two computer nodes. The study was carried out in two different sections; first we kept the server stationary while the client was put into motion at varying velocity by a car which maintains a specified velocity for a given time and in a given direction. Secondly, we reversed the process by keeping the client stationary while the server is put into motion at varying velocity by a car that maintains the specified same velocity for the given same time and in the same direction as in the first section. The client sends data to the server for 10 seconds while moving at a given nodal velocity. We took a record of the throughput and the delay encountered during transmission. The measurement is taken twice for each connection and the average recorded. We then observed the impact of the node velocity on the performance of the network based on the variations on the throughput of the network. The result was simulated on an excel platform to make conclusions and recommendations.

Table 1: Wireless Connection Specifications

SPECIFICATIONS	VALUE
Wireless Standard	IEEE 802.11g
Data Rate	54mbps
Frequency	1.2GHz
Radio Channel	6
Modulation	OFDM
RF Power	20dbm (maximum)
Operating System	Win 7

Experimental Requirements

We adopted two similar Compaq 2710p laptop computers with 64-bits Microsoft Windows 7 Ultimate in this study. Both computers have Intel(R) Core (TM)2 Duo CPU (Centrino technology), 2GB memory and 100GB hard disk. We installed two identical IEEE 802.11g wireless adapters within the two computers using 1.2GHZ frequency with the theoretical bandwidth up to 54mbps. Both the client’s and server’s wireless adapters were set to ad-hoc mode and the number of channels is set to six. The subnet mask is set as 255.255.255.0 with gateway function disabled.

Network Performance Tools

We adopted Iperf as our network management and performance tool. Iperf is a tool to measure maximum TCP bandwidth on IP networks, allowing the tuning of various TCP parameters and UDP characteristics. Iperf reports throughput, bandwidth, delay jitter and datagram loss. We also configured iperf Qos on the laptops we used and installed and embedded the iperf in the Operating System. We used Iperf as our performance tool to measure the throughput from client to server by transmitting data for 10 seconds (-t). We used Iperf commands to configure PC1as the server (Iperf - s) and assigned it an IP of 169.192.2.300, and PC2 as the client (Iperf -c) with IP of 169.192.3.100 as shown below

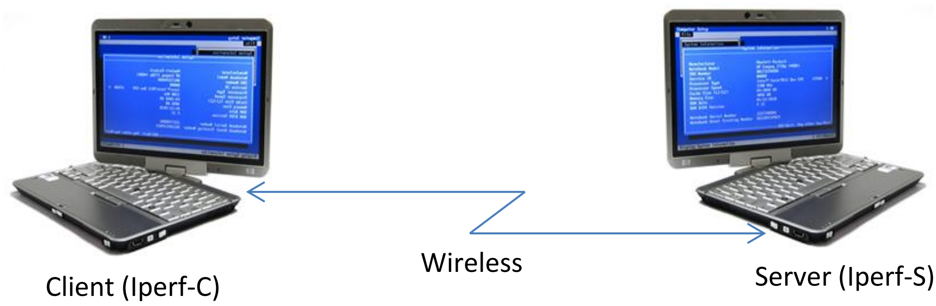

Figure. 1. Madnet setup

RESULT

As stated previously, the study was carried out in two different sections and each test connection was repeated and the average throughputs at corresponding nodal velocities were determined. In the first section of the study, we kept the server (Iperf -s) stationary and the client (Iperf -c) was put into motion by a car whereas in the second section we maintained the same setup but the client was stationary while the server is put into motion. The client was considered as the transmitting node. In this study, each connection was carried out for 10secs with 6 TCP connections. Readings were taken and the average determined for each connection at maximum velocities of 2.8m/s, 5.6m/s, 8.3m/s, 11.1m/s, 13.9m/s and 16.7m/s which are equivalent to 20km/h, 30km/h, 40km/h, 50km/h and 60km/h respectively using TCP window size of 64kb, TCP port number of 5000. The data transferred at the respective velocity was got and recorded in the table below.

Table 2: TCP Throughput

VELOCITY (M/S)	SECTION A THROUGHPUT(MB)	SECTION A THROUGHPUT(MB)
2.80	18.20	21.80
5.60	20.95	21.80
8.30	20.80	21.40
11.10	17.15	21.00
13.90	15.0	20.95
16.70	10.33	20.95

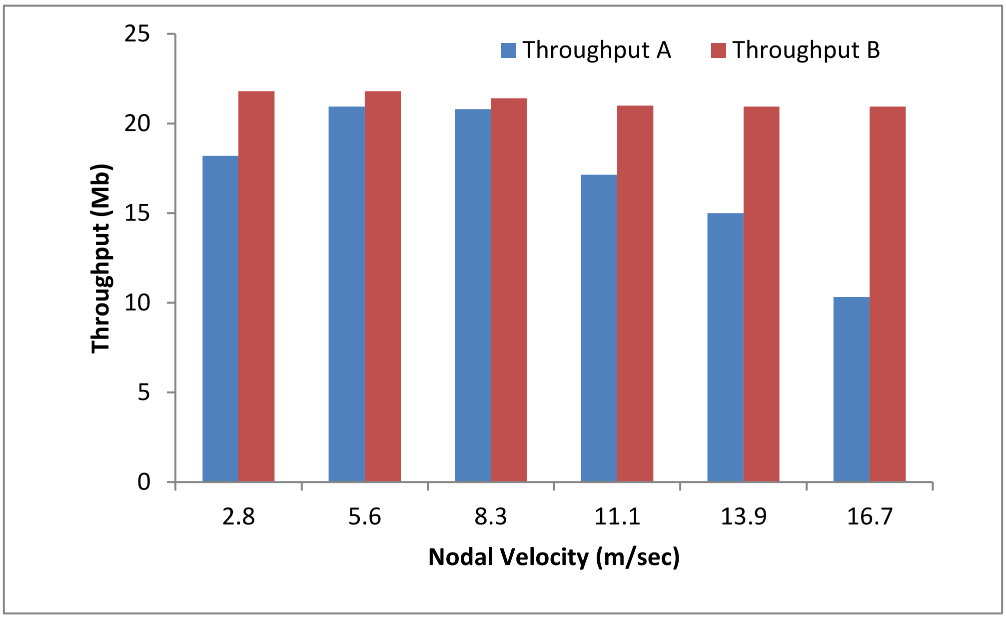

Figure. 2. Bar Chart of Throughput as a function of Nodal Velocity

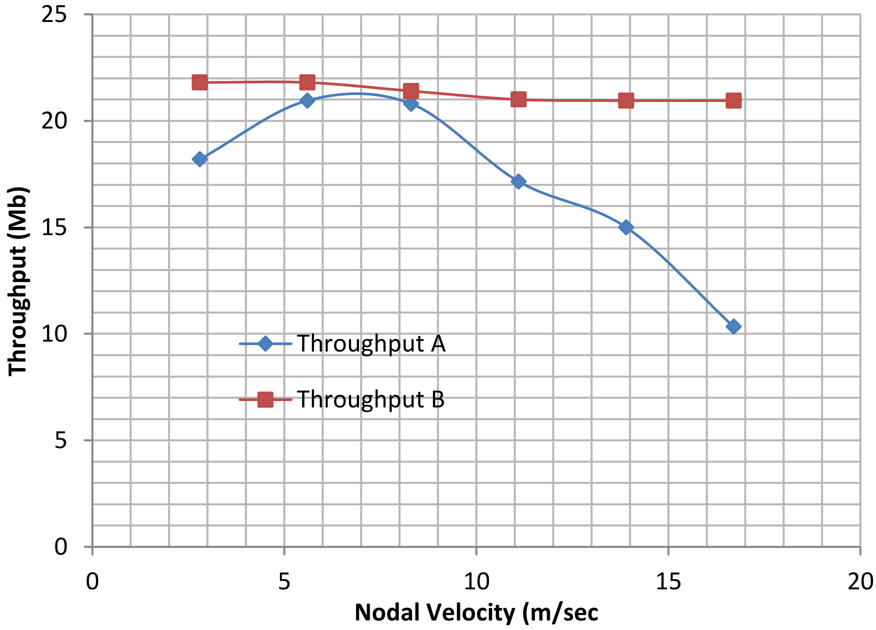

Figure. 3. Throughput as a function of Nodal velocity

DISCUSSION

The result which is displayed in figures 2 and 3 gives a clear response to the throughput of the network to the increase in node velocity. In section A of the study, where the client is set to move at corresponding velocity while the server is stationary, the result shows an increase in data throughput then thereafter a drastic reduction in the average TCP throughput of the network as the nodal velocity increases. However, in section B, there is a very slight descendant impact on the throughput of the network as the velocity increases. Therefore, by keeping client stationary, mobility is more effectively masked which is similar to the result in (Gavin Holland and Nitin Vaidya, 2002) but with different experimental approaches and setup. Therefore, the impact of nodal velocity is pronounced only when the client (Data source) is moving.

CONCLUSION

In this study, we have practically shown that the mobility rate has a significant impact on MADNET. Secondly our study has shown clearly the rate of impact on the throughput of the network based on which node of the network is in motion and which is stationary. From the data we got, the impact of increasing the node velocity is more pronounced on the TCP data throughput when the client is the moving node. On the other hand, there is very little impact on the TCP throughput of the network if the client is kept stationary and the server is moving, the packet loss is very minimal. Based on these findings, we recommend that for better performance and reduced packet loss on TCP performance of MADNET, the client should always be kept stationary. The next study will be on the UDP delay variations at various nodal velocity.

REFERENCES

Andreas Hafslund, Lars Landmark, Paal Engelstad and Frank Y. Li (2004) "Testing and Analyzing TCP Performance in a Wireless-Wired Mobile Ad Hoc Test Bed" *International Workshop on Wireless Ad-Hoc Networks(IWWAN)*

Changhua He (2003) "Throughput and Delay in Wireless AdHoc Networks" *Final Report of EE359 Class Project.*

Chandrashekhar Goswami and Parveen Sultanah (2002) " A Study on Cross-Layer TCP Performance in Wireless AdHoc Network" *Research for Mobile Information and Communication Systems (NCCR-MICS) project, 2002.*

Dr. C. Rajabhushanam and Dr. A. Kathirve (2011) "Survey of Wireless MANET Application in Battlefield Operations" *International Journal of Advanced Computer Science and Applications(IJACSA), Volume 2 Issue 1.*

Eng. Nassar E and. GH. Muhanna (2013) "Computer Wireless Networking and Communication" *International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue.*

Fan Bai and Ahmed Helmy (2004) "Survey of Mobility Models in wireless Adhoc Network"*University of South California,U.S.A.*

Foez Ahmed, Sateesh Kumar Pradhan, Nayeema Islam, and Sumon Kumar Debnath (2010) "Performance Evaluation of TCP over Mobile Ad-hoc Networks" *(IJCSIS) International Journal of Computer Science and Information Security, Vol. 7, No. 1.*

G. Sankara Malliga, Dr.Dharmishtan K Varughese (2010) "Impact of Multihop Wireless Channel on TCP-AP with LRED" *International Journal of ComputerApplications* 1(11):102–110.

Gavin Holland and Nitin Vaidya (2002) "Analysis of TCP Performance over Mobile Ad Hoc Networks"

Hari Balakrishnan and Randy H. Katz (1998) "Explicit Loss Notification and Wireless Web Performance" *IEEE Globecom, Internet Mini-Conference, Sydney.*

Hari Balakrishnan, Venkata N. Padmanabhan, Srinivasan Seshan and Randy H. Katz (1996) "A Comparison of Mechanisms for Improving TCP Performance over Wireless Links" *ACM SIGCOMM '96, Stanford, CA.*

Karthikeyan Sundaresan,, Vaidyanathan Anantharaman, Hung-Yun Hsieh, and Raghupathy Sivakumar (2003) "ATP: A Reliable Transport Protocol for Ad-hoc Networks"

Kitae Nahm, Ahmed Helmy and C.C. Jay Kuo "TCP over Multihop 802.11 Networks: Issues and Performance Enhancement" *Proceedings of the 6th ACM international symposium on Mobile ad hoc networking and computing.*

ISSN 2056-5860

Postel, J. (1980). User Datagram Protocol; RFC 768 ISI

Ruy de Oliveira Torsten Braun (2002) ‘’ TCP in Wireless Mobile Ad Hoc Networks”

Shugong Xu and Tarek Saadawi (2001) “Does IEEE 802.11 MAC Protocol Work Well in Multi- hop Wireless AdHoc Networks*?” in IEEE Communications Magazine 39(6):130 – 137.*

Transmission control protocol DARPA internet program protocol specification (1981)

Xiang Chen, Hongqiang Zhai, Jianfeng Wang and Yuguang Fang (*2005*) ”A Survey on Improving TCP Performance over Wireless Networks”*Resource Management in Wireless Networking pp 657-695.*