ENHANCING TRANSMISSION CONTROL PROTOCOL (TCP) FOR MANET: A STUDY OF FEDERAL UNIVERSITY OF TECHNOLOGY (FUTO)

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ABSTRACT

Transmission control protocol (TCP) was not originally designed for use in mobile ad hoc network (MANET) environment but for wired network. Transport layer issues such as link failure, network congestion and wireless channel error, degrade TCP performance in wireless networks including MANET. Mobile ad hoc network in Federal University of Technology, Owerri (FUTO) only covers three departments with AODV routing protocol and Tahoa, using one node each for the three departments. There is need to increase the coverage to eight departments and since increase in number of nodes decreases throughput, developing a model for improving TCP performance is required to achieve an efficient design and deployment of MANET to cover the eight (8) departments. In this work, Three different routing protocols; Temporally ordered routing algorithm (TORA), Dynamic source routing (DSR) and Ad hoc on demand distance vector (AODV) were evaluated with three different TCP variants (Tahoe, Reno and New Reno) using traffic of three different packet sizes, 512, 1000, 1500 bytes each, all of them being tested in three different scenarios having 3, 5 and 8 nodes (3, 5 and 8 departments). The goal of this study is to determine which TCP variant and routing protocol provides the best performance with regards to throughput and multiple data recovery when there is increase in number of nodes. The performance parameters on the basis of which routing protocols were graded were mainly throughput, congestion window and delay. Simulation showed that when the number of nodes were increased (from 3 to 8) AODV provided better throughput performance than DSR and TORA, (AODV=575MB, DSR=320 and TORA=160MB all at 10secs) and when AODV was used with New Reno it offered better multiple data recovery than when used with Tahoe and Reno. Therefore, AODV and New Reno are best suited for MANET enhancement in FUTO. I went further developing another AODV routing protocol called New AODV (NE-AODV) with ns-2 simulator to enhance the effect of the selected New Reno TCP.

Keywords: Transmission Control Protocol (TCP), Mobile Ad-hoc Network, Temporally Ordered Routing Algorithm (TORA), Dynamic Source Routing (DSR), Ad-hoc on Demand Distance Vector (AODV), Tahoe, Reno, New Reno, Throughput.

1.0 INTRODUCTION

A mobile ad hoc network (MANET) is made up of a peer-to-peer, self-forming, self-configuring infrastructure-less network of mobile devices connected without wires. Ad hoc in Latin language means “for this purpose”. Each device in a MANET is free to move independently in any direction and will therefore change its link to other devices frequently leading to constant change of topology. Each device must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic but such networks may operate by themselves. The growth of laptops and IEEE 802.11 / Wi-Fi wireless networking has made MANETs a popular topic since the mid-1990s [1].

Ad hoc networks are completely wireless networks of mobile hosts, in which the topology rapidly changes due to the movement of mobile nodes. This frequent topology change may lead to sudden packet losses and delays. Transport protocols like Transmission Control Protocol (TCP) which has been designed for reliable fixed networks misinterpret this packet loss as congestion and invoke congestion control, leading to unnecessary retransmissions and loss of throughput. To overcome this problem, a feedback scheme is proposed so that the source can distinguish between route failure and network congestion. When a route is disrupted, the source is sent a route failure notification packet, allowing it to invalidate its timers and stop sending packets. When the route is reestablished, the source is informed through a route reestablishment notification packet, upon which it resumes packet transmission. TCP is a reliable and connection oriented protocol developed in 1981[2]. It is based on simple sliding window flow control. During the early stages, congestion collapses occurred because of lack of congestion control mechanism. With the advent of Jacobson congestion algorithms for TCP as a remedy, TCP is updated to a version known as TCP Tahoe and then TCP Reno which is widely used in Internet. TCP Tahoe congestion Control includes slow start, congestion avoidance and fast retransmission. TCP Reno also adds the fast recovery algorithm. TCP is designed for wired network, but with the technology emerging towards wireless medium, the need to implement TCP in wireless networks is of great importance but it faces many problems especially in ad hoc networks. The typical applications of MANETs include conferences or meetings, emergency operations such as disaster rescue, and battlefield communications. TCP has poor performance in MANET due to dynamic topology, shared medium, high error ratio, channel connotation and multi hop architecture [2].

Ad hoc networks are growing dynamically and its true development fact lies in the problems associated with the seamless internet access and connectivity. Mobile ad hoc network is a sub field with enormous educational, commercial, industrial and military growth with realistic practical approach for internet access. Most important things to know about the technology are the ability of autonomously establishing and managing the network.

Problems associated with MANET performance include evaluation and optimization techniques for better execution of the transmission medium. Pledged data delivery is TCP utmost drawback in wireless networks but possible solutions are available to recognize the data transmission effects. To enhance TCP performance in FUTO, MANET simulation study has been conducted in practice. MANET utilizes TCP and UDP (User Datagram Protocol) for data transmission but this dissertation focuses on different variants of the TCP particularly **Tahoe**, **Reno** and the improved variant known as **New Reno** explicitly using Temporally Ordered Routing Algorithm (TORA), Dynamic Source Routing (DSR), and Ad hoc on Demand Distance Vector (AODV) protocols in focus. This work involves the development of another AODV routing protocol called New AODV (NE-AODV) to increase the effect of New Reno TCP [3].

2.0 TRANSMISSION CONTROL PROTOCOL (TCP)

TCP is a network communication protocol designed to send data packets over the internet. TCP is a transport layer protocol in the OSI layer and is used to create a connection between remote computers by transporting and ensuring the delivery of message over the supporting networks and the internet. TCP is one of the most used protocols in digital network communication and is part of the internet protocol suit, commonly known as the TCP/IP suit. Primarily, TCP ensures end-to-end delivery of data between distinct nodes. TCP works in collaboration with internet protocol, which defines the logical location of the remote node, whereas TCP transports and ensures that the data is delivered to the correct destination. Before transmitting data, TCP creates a connection between the source and destination node and keeps it live until the communication is active. TCP breaks large data into smaller packets and also ensures that the data integrity is intact once it is reassembled at the destination node.

The congestion control algorithm employed by TCP is window based which uses three types of windows called congestion window (cwnd), advertize window (awnd) and send window (swnd). Congestion windows shows the total amount of data the sender is allowed to output to the network. While advertise window indicates the amount of data the receiver is ready to accept which is equal to the available buffer size on the receiver. The send window (flight mode) is the minimum of congestion window and advertise window. Basically, the congestion control mechanism has two phases, the slow start phase and congestion avoidance phase. When a connection is established, the initial size of congestion window is set to one Maximum Segment Size (MSS) [4].
on receiving data from the sender, the receiver acknowledge (ACK) the reception of data to the sender, the receiver is actually indicating the sequence number of next expected data segment in the acknowledgement message, from which the sender concludes that all the data segments which have sequence number less than the indicated one are delivered correctly. While in case of packet loss, out-of-order packets arrive at the receiver and then the receiver sends a duplicate ACK to the sender in response to each out-of-order packet arrival. When the sender receives three duplicates ACK, it is concluded that the packet is lost and retransmission of data packet takes place [5].

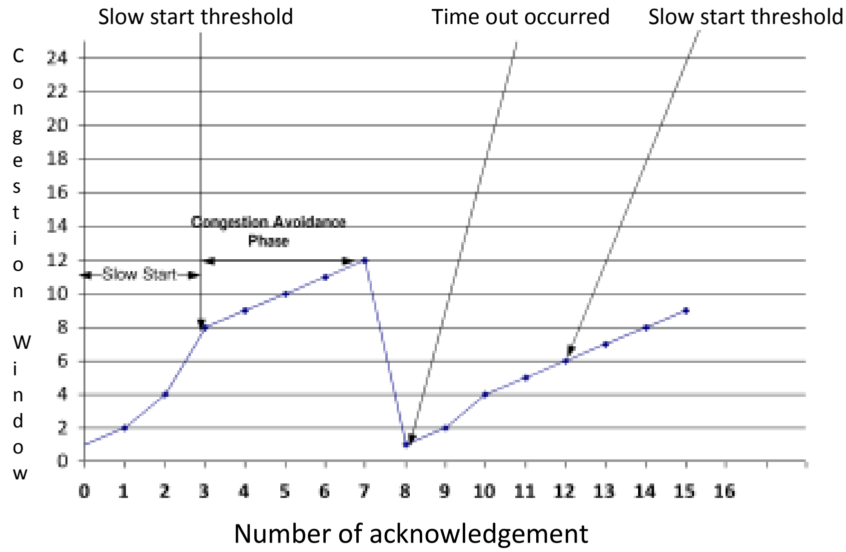


Figure 1: Slow Start and Congestion Avoidance Mechanism

2.1 NODE MOBILITY.

Node mobility is the movement of a node in an arbitrary speed towards an arbitrary direction. As illustrated in figure 2, the movement of the nodes is in a continual and arbitrary state and it is a nature of MANETs [3].

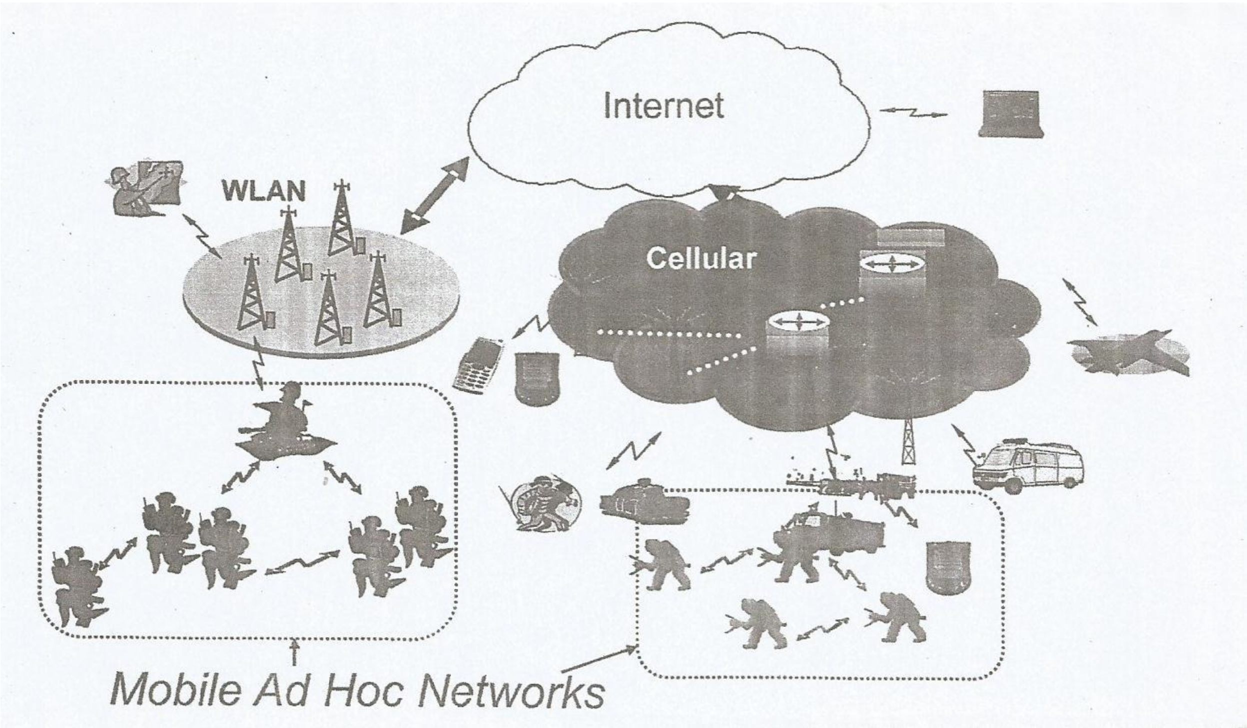


Figure 2: Diagram of Wireless Networks with MANET

2.2 NETWORK ANALYSIS OF ROUTING PROTOCOLS

i. Direct Source Routing (DSR)

In this protocol, the source starts a route discovery when sending data packet to the destination but have no routing information. To set up a route, the source floods RREQs (route requests) message with a distinctive request ID. When the destination receives this request message then it transmits RREP (route reply) message back to the source with route information [6]. Figure 3 shows route discovery of DSR. Node 2 is the initiator and node 9 is the target.

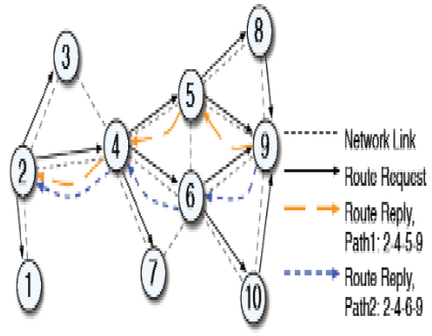


Figure 3: Route Discovery for Target Node

ii. Temporally Ordered Routing Algorithm (TORA)

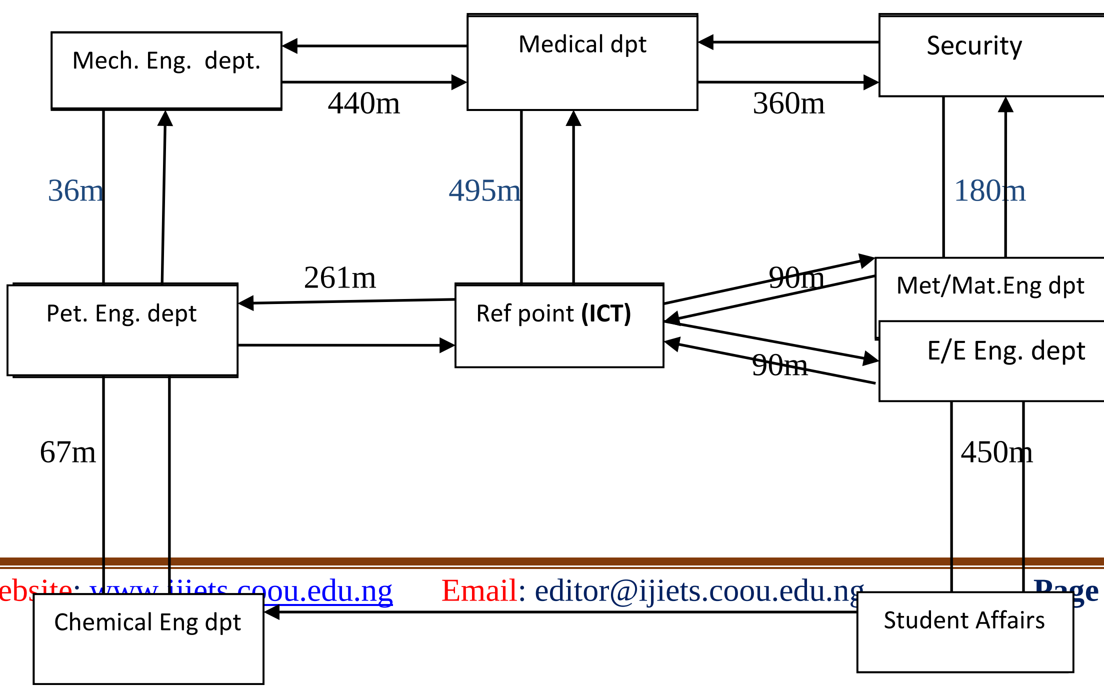
The functions of TORA emphasizes that Temporally Ordered Routing Algorithm (TORA) is a source-initiated on-demand routing protocol and it is a highly adaptive, proficient and scalable distributed routing algorithm based on the concept of link reversal. TORA is proposed for highly dynamic mobile, multi-hop wireless networks. It searches multiple routes from a source node to a destination node. The principal feature of TORA is that the control messages are localized to a very small set of nodes near the occurrence of a topological change. To achieve this, the nodes retain routing information about adjacent nodes [1].

iii. Ad-hoc On-demand Distance Vector (AODV)

AODV is designed for ad hoc mobile networks and of both routing, that is unicast and multicast routing. AODV establish routes between different nodes as needed by source nodes. AODV maintain these routes as well as form trees which connect different multicast group members. The group members compose the trees and the members are connected by the nodes. In an ad hoc network, when two nodes want to make a connection with each other, AODV enable multi-hop routes within the nodes. Ad hoc On-demand distance vector is free loop. DSN (Distance Sequence numbers) is used by the AODV to avoid counting to infinity, and this is one of the most important quality and feature of this algorithm. In a network, the requested nodes send the DSN with other routing information from the source to the destination. It has also the feature to select optional route which is based on the sequence number [7].

3.0 THE PROPOSED FUTO MANET

The MANET involves 8 departments using 1 node each. The node in the ICT is the reference point where the whole configuration is done.



225m

Figure 4: Proposed FUTO MANET Block Diagram

When a source node desires a route to a destination for which it does not already have a route, it broadcasts a route request (RREQ) packet across the network. Nodes receiving this packet update their information for the source node and set up backwards pointers to the source node in the route tables. In addition to the source node's IP address, current sequence number, and broadcast ID, the RREQ also contains the most recent sequence number for the destination of which the source node is aware. A node uses its IP address as the source address in the IP header of a message when it request for a route, and for broadcast 255.255.255.255. A node getting the RREQ may send a route reply (RREP) if it is either the destination or if it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, it unicasts a RREP back to the source. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ's source IP address and broadcast ID. If they receive a RREQ which they have already processed, they discard the RREQ and do not forward it. As the RREP propagates back to the source, nodes set up forward pointers to the destination. Once the source node receives the RREP, it may begin to forward data packets to the destination. If a link break occurs while the route is active, the node upstream of the break propagates a route error (RERR) message to the source node to inform it of the now unreachable destinations. After receiving the RERR, if the source node still desires the route, it can reinitiate route discovery.

Figure 5: MANET Eight Nodes Simulation

4.0 RESULTS AND ANALYSIS

In this section, the throughput of each variant of TCP and to find out which variant outperformed with what type of routing protocol was discussed. To achieve clear analysis, each scenario was considered separately, starting from the three node scenario, to five node scenario and finally to eight node scenario of the proposed FUTO MANET which was explained in details.

Table 1: Throughput Comparison of 3, 5 And 8 Nodes

3 nodes		5 nodes		8 nodes	
trput	time	trput	time	trput	time

	175	5	175	5	170	5
	175	10	130	5	125	5
AODV	155	5	155	0	150	5
DSR	720	5	700	5	575	5
TORA	470	10	400	5	350	5
Aodv	80	5	75	0	70	5
DSR	160	40	160	40	170	40
TORA	180	30	175	30	170	30
AODV	220	30	155	30	150	50
DSR						
TORA						

Eight Nodes Scenario

Different protocols evaluated in this scenario are listed in Table 1. Like other scenarios depending on the number of clients, eight simultaneous connections have established with a fixed source to download a file of the same size over each connection.

Table 2: Detail of TCP Variants and Routing Protocol for Eight Nodes Scenario.

THROUGHPUT/DELAY/CONGESTION WINDOW MEASUREMENT				
Stages	TCP Variants	Protocol	Number of nodes	Speed of Nodes m/s
A	New Reno	AODV	8	10
		DSR	8	10
		TORA	8	10
B	Reno	AODV	8	10
		DSR	8	10
		TORA	8	10
C	Tahoe	AODV	8	10
		DSR	8	10
		TORA	8	10

Throughput Analysis

From figure 6, we conclude that the graph behaviour remains the same and the assumption made for figure 4 are also acknowledgeable. Further we observe that the AODV have the highest throughput in all the three scenarios compared to the DSR and TORA. A small change has been observed in the number of data packets when nodes are increased to 8 in figure 6. The highest number of data packets is reduced from approximately 700 to 575 (9.8%) which means that if more nodes are added in MANET, throughput will reduce.

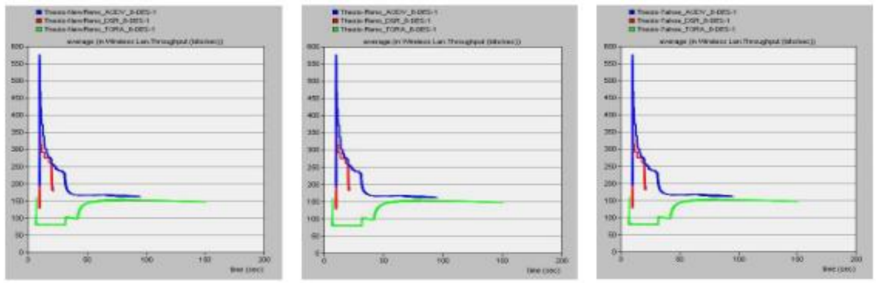


Figure 6: Throughput Comparison in Eight Nodes Scenario

It has been concluded that throughput performance of DSR and TORA are minutely affected with increase in the number of nodes and due to mobility. In general, MANET could have dynamic number of nodes connectivity in mobility, so it is important to realize that when the number of nodes is higher, DSR and TORA would be avoided. AODV has better throughput performance shown in all three figures as compared to DSR and TORA and is the best solution for MANET. However simulation results for AODV with respect to New Reno, Reno and Tahoe depict that throughput is the same in all the cases, so our proposed solution in this case uses New Reno as it offers multiple packet loss recovery.

CONCLUSION

In order to enhance MANET in FUTO from the coverage of three departments to eight departments which supposed to lead to loss of throughput with TCP because it is not originally designed for mobile Ad Hoc Network (MANET) but for fixed network (wired network), a comprehensive TCP performance evaluation study is presented to evaluate the nature of the TCP performance in different scenarios with variable amount of payload and number of nodes. Three different routing protocols; Temporally ordered routing algorithm (TORA), Dynamic source routing (DSR) and Ad hoc on demand distance vector (AODV) are evaluated with three different TCP variants (Tahoe, Reno and New Reno) using traffic of three different packet sizes, 512, 1000, 1500 bytes each, all of them being tested in three different scenarios having 3, 5 and 8 nodes (representing 3, 5 and 8 departments).The challenge in this work is to determine which TCP variant and routing protocol work better with regards to throughput and multiple data recovery when there is increase in departments.

From simulation, when the number of nodes is higher, AODV yielded better throughput performance than DSR and TORA, and when AODV was used with New Reno it offered multiple data recovery better than when used with Tahoe and Reno. Therefore AODV and New Reno are best selected for MANET enhancement in FUTO. A further step was taken developing another AODV (NE AODV) that works with energy and load level of the nodes in FUTO MANET to increase the effect of the selected New Reno TCP.

REFERENCES

1. Holland, G., and Vaidya, N. (1999), "Analysis of TCP Performance over Mobile Ad hoc. Networks", *5th Annual International Conference on Mobile Computing and Networking,* Vol. 2, No. 4, pp. 12 - 23.
2. Prasanthi, S., and Sang-Hwa, C. (2010), "An Efficient Algorithm for the Performance of TCP Over Multi-hop Wireless Mesh Network," *Institute of Electrical and Electronics Engineering Magazine, Vol.10, No. 2, pp. 609 - 615.*
3. Chlamatac, I., and Conti, M. (2003), "Mobile Ad-hoc Networking", *Imperative and Challenges in Ad hoc Networks, Vol. 1, No.1, pp. 13 - 24.*
4. Ramraton, A., Lockande G. and Logendra, K. (2012), "Congestion Control Through Bandwidth Estimation Mechanism in MANET", *International Journal of Applied Information Systems, Vol. 2, No. 4, pp. 41-48.*
5. Krag, T. and Sebastian, B. (2004), "Wireless Mesh Networking", *O' Reilly Wireless Development Center, Vol. 2, No. 14, pp. 1-14.*
6. Wang, F. and Zhang, Y. (2010), "A Mobile Ad-hoc Network", *Journal of Computing and Information Technology, Vol. 16, No. 3, pp. 233-243.*
7. Ramly, El. and Magdy, M. (2015), "Improving TCP Congestion Control for Networks", *International Journal of Computer Applications, Vol. 122, No.14, pp. 23-27.*