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A Comparison of TCP Performance over Routing Protocols for Mobile Ad Hoc Networks

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Abstract

Sometimes there is no infrastructure in the network, then mobile ad hoc network is the best choice which is also less costly and easily deployable as in comparison. In such networks, in order to make them reliable and secure one need to analyze the routing mechanisms which are called as the MANET routing protocols. In the research, we have to do the investigation of mobile ad hoc network protocols like ad hoc on demand routing protocol (AODV), destination sequence distance vector (DSDV) protocol using the different TCP types like TCP Reno, TCP Vegas and TCP NJ-plus. Our Analysis of the variants of TCP is based on three performance metrics: TCP Throughput, Average End- to -End delay and Packet Delivery Fraction. This analysis will be useful in determining the better variant among TCP Protocols to ensure better data transfer, speed, and reliability and congestion control.

Keywords

AODV, DSDV, Congestion Control and TCP Variants, TCP-NJ Plus, Ad-hoc Network, Reactive and proactive Protocols.

I. Introduction

Ad hoc network is a temporary network connection for a specific purpose (such as transferring data from one computer to another) in wireless networks. It is self organizing networks, which all end nodes are act as routers or data user. It improves the efficiency of fixed and mobile internet access and enables new applications for public. A Mobile Ad hoc Networks (MANET) consists of a set of mobile hosts within the communication range and exchange data among themselves without using any pre-existing infrastructure. MANET nodes are typically distinguished by their limited power, processing and memory resources as well as high degree of mobility. In such networks, the wireless mobile nodes may dynamically enter the network as well as leave the network. Due to the limited transmission range of wireless network nodes, multiple hops are usually needed for a node to exchange information to other node. Due to mobility the communication paths are changing very frequently and hence network packets are not at all affected or even not changing the packet optimality and its uniformity. There are mainly three categories of the mobile routing protocols such as proactive, reactive and hybrid routing protocols as shown following figure 1. There are many protocols which we are considering for the investigation and evaluation in the mobile ad hoc networks. But each of these routing protocols is focused on the certain aspects of simulation results. Some of the other issues like, the behavior of selected protocol in MANET environment where there are no mobility constraints on nodes, advantages and disadvantages in collaboration with corresponding MANET routing protocols and quality of service. TCP is not well suited for wireless networks especially in MANET; the performance of TCP degrades significantly due to the heavy packet and connection losses. To overcome the problems of reliability, different versions of TCP called TCP variants were developed especially for wireless ad hoc networks to provide reliable communication. There are various routing protocols for route discovery and configurations in MANET but, the problem is the selection of suitable coupling of TCP variant over MANET routing protocol to provide reliable communication.

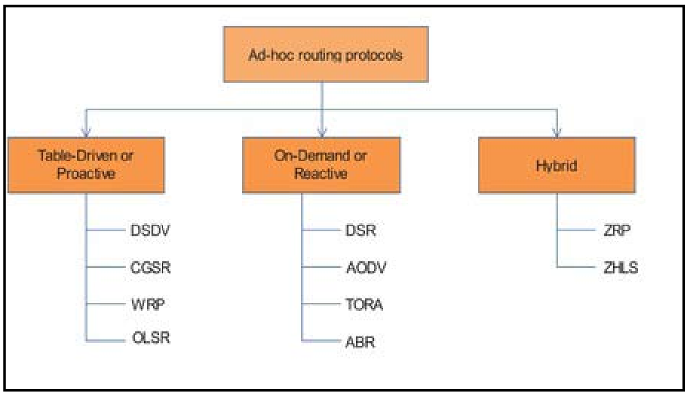

Fig. 1: Classification of MANET Routing Protocols

II. Problem Identification

In addition to non-congestion losses due to transmission errors, recently, the studies show that packet reordering is not a rare event in WMNs [2, 3] and it plays an important role in\ the packet transmission. Packet reordering is the network behavior where the relative order of the packets is altered when these packets are transported in the network. In WMNs, packet reordering may happen due to link-layer retransmissions, route fluttering, inherent parallelism in routers, router forwarding lulls etc. When the sender receives three successive duplicate acknowledgments (dupacks) caused by non-congestion loss and packet reordering, TCP sender assumes that a packet has been lost due to network congestion and reduces the size of congestion window (cwnd) unnecessarily. Furthermore, if the dupacks cause due to packet reordering, the sender not only reduce the congestion window size but also trigger spurious retransmission of packets and hence wasting bandwidth. Several loss differentiation algorithms [4-8] are proposed to improve the performance of TCP over wireless networks.

However, these algorithms have no mechanism to detect and differentiate non-congestion losses from packet reordering.

TCPs inability to distinguish non-congestion loss from packet reordering may causes unnecessary retransmissions, slow down the growth of cwnd and reduces the efficiency of the receiving TCP. As a result, it is an important issue of TCP to guide the TCP sender for triggering the congestion control algorithms properly by distinguishing non-congestion losses from packet reordering in addition to network congestion when the sender receives three dupacks.

III. Proposed Work

In this project our main goal is to improve the performance of TCP by distinguishing non-congestion losses from packet reordering over MANET. We designed and investigated a new TCP scheme called TCP NJ-Plus, which is capable of reducing the unnecessary retransmissions and reduction of the size of cwnd by detecting and differentiating non congestion losses from packet reordering over MANET. Mainly, our proposed solution has three mechanisms. First, detection of non-congestion losses and packet reordering from network congestion loss. Second, detection of non congestion losses from packet reordering and third, congestion control algorithms of TCP NJ-plus. We evaluated TCP NJ-Plus with other TCP schemes such as TCP-Reno and TCP-Vegas and compared the end-to-end throughput and fairness performance through extensive simulations using NS2. Simulation results show that TCP NJ-Plus has significant improvement over other TCP variants.

IV. Literature Review

As we know that MANET stands for the Mobile Ad hoc Network which is rapidly growing, deployable, on demand self configuring network.

- This is network with no infrastructure at all.
- Links between the mobile nodes are wireless only.
- Topology is not fixed rather it can be dynamic and also network nodes are mobile.
- Since the communication mobile nodes possibly when out of range; nodes must needed to relay traffic.
- It can be a self network or may be connected to other external networks such as internet.

Following figure 2 shows the usage of MANET in the military applications and figure 3 shows the basic network structure for the MANET.

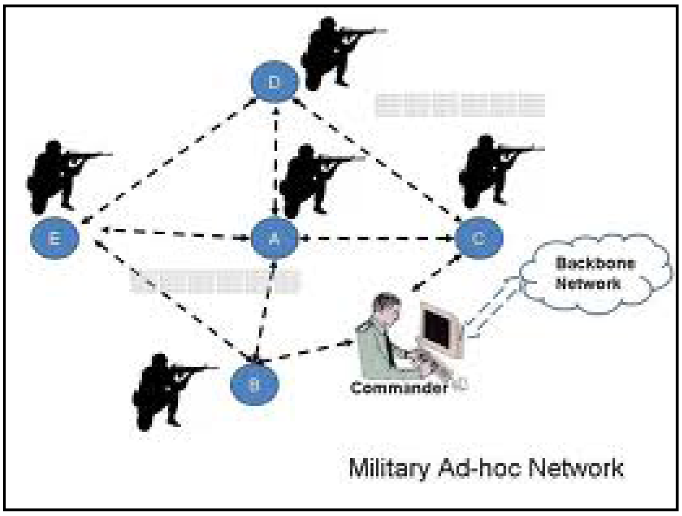

Fig. 2 : MANET Example in Military

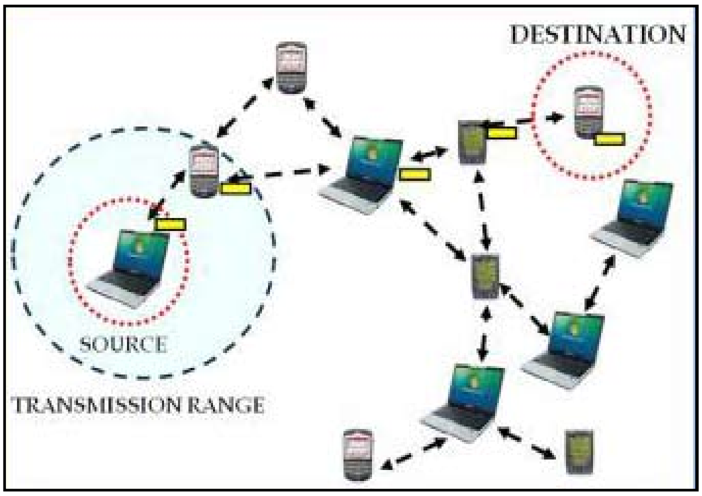

Fig. 3: MANET network structure

1. AODV: Ad-hoc On-Demand Distance Vector Routing

This is one ad hoc routing protocol which is somewhat different from the DSR protocol in working and has the following procedure to follow:

RREQ - A route request message is transmitted by a node requiring a route to a node. As an optimization AODV uses an expanding ring technique when flooding these messages.

Every RREQ carries a time to live (TTL) value that states for how many hops this message should be forwarded. This value is set to a predefined value at the first transmission and increased at retransmissions. Retransmissions occur if no replies are received. Data packets waiting to be transmitted (i.e. the packets that initiated the RREQ). Every node maintains two separate counters: a node sequence number and a broadcast_ id.

RREP- A route reply message is unicasted back to the originator of a RREQ if the receiver is either the node using the requested address, or it has a valid route to the requested address. The reason one can unicast the message back, is that every route forwarding a RREQ caches a route back to the originator.

RERR - Nodes monitor the link status of next hops in active routes. When a link breakage in an active route is detected, a RERR message is used to notify other nodes of the loss of the link. In order to enable this reporting mechanism, each node keeps a ―precursor list'', containing the IP address for each its neighbors that are likely to use it as a next hop towards each destination.

2. DSDV: Destination Sequence Distance Vector

DSDV is one of the most well known table-driven routing algorithms for MANETs. The DSDV routing algorithm is based on the classical Bellman-Ford Routing Algorithm (BFRA) with certain improvement [3]. Every mobile station maintains a routing table with all available destinations along with information like next hop, the number of hops to reach to the destination, sequence number of the destination originated by the destination node, etc. DSDV uses both periodic and triggered routing updates to maintain table consistency. Triggered routing updates are used when network topology changes are detected, so that routing information is propagated as quickly as possible.

Full dump packets carry all available routing information and may require multiple Network Protocol Data Units (NPDU); incremental packets carry only information changed since the last full dump and should fit in one NPDU in order to decrease the amount of traffic generated. Mobile nodes cause broken links

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when they move from place to place.

3. TCP over MANET

As a result of the advancement of wireless technology and the proliferation of handheld wireless terminals, recent years have witnessed an ever-increasing popularity of wireless networks, ranging from wireless Local Area Networks (WLANs) and wireless wide-area networks (WWANs) to mobile ad hoc networks (MANETs). In WLANs (e.g., the Wi-Fi technology) or in WWANs (e.g. 2.5G/3G/4G cellular networks), mobile hosts communicate with an access point or a base station that is connected to the wired networks. Obviously, only one hop wireless link is needed for communications between a mobile host and a stationary host in wired networks. In contrast, there is no fixed infrastructure such as base stations or access points in a MANET. Each node in a MANET is capable of moving independently and functioning as a router that discovers and maintains routes and forwards packets to other nodes. Thus,

MANETs are multi-hop wireless networks by nature.

Note that MANETs may be connected at the edges to the wired Internet. Transmission control protocol (TCP) is a transport layer protocol which provides reliable end to end data delivery between end hosts in traditional wired network environment. In TCP, reliability is achieved by retransmitting lost packets. Thus, each TCP sender maintains a running average of the estimated round trip delay and the average deviation derived from it. Packets will be retransmitted if the sender receives no acknowledgment within a certain timeout interval (e.g., the sum of smoothed round trip delay and four times the average deviation) or receives duplicate acknowledgments. Due to the inherent reliability of wired networks, there is an implicit assumption made by TCP that any packet loss is due to congestion. To reduce congestion, TCP will invoke its congestion control mechanisms whenever any packet loss is detected. Since TCP is well tuned, it has become the de facto transport protocol in the Internet that supports many applications such as web access, file transfer and email. Due to its wide use in the Internet, it is desirable that TCP remains in use to provide reliable data transfer services for communications within wireless networks and for those across wireless networks and the wired Internet. It is thus crucial that TCP performs well over all kinds of wireless networks in order for the wired Internet to extend to the wireless world.

Unfortunately, wired networks and wireless networks are significantly different in terms of bandwidth, propagation delay, and link reliability. The implication of the difference is that packet losses are no longer mainly due to network congestion; they may well be due to some wireless specific reasons. As a matter of fact, in wireless LANs or cellular networks, most packet losses are due to high bit error rate in wireless channels and handoffs between two cells, while in mobile ad hoc networks, most packet losses are due to medium contention and route breakages, as well as radio channel errors. Therefore, although TCP performs well in wired networks, it will suffer from serious performance degradation in wireless a network if it misinterprets such non congestion related losses as a sign of congestion and consequently invokes congestion control and avoidance procedures, as confirmed through analysis and extensive simulations carried out.

As TCP performance deteriorates more seriously in ad hoc networks compared to WLANs or cellular networks, we divide wireless networks into two large groups: one is called one-hop wireless networks that include WLANs and cellular networks and the other is called multi-hop wireless networks that include MANETs.

To understand TCP behavior and improve TCP performance over wireless networks, given these wireless specific challenges, considerable research has been carried out and many schemes have been proposed. As the research in this area is still active and many problems are still wide open, this chapter serves to pinpoint the primary causes for TCP performance degradation over wireless networks, and cover the state of the art in the solution spectrum, in hopes that readers can better understand the problems and hence propose better solutions based on the current ones.

V. Implementation and Details Used

Table: Comparison of the three simulators.

Simulator	Free	Open Source	Programming Lang.
NS-2	Yes	Yes	C++, TCL
GloMoSim	Limited	Yes	Parse
Opnet	No	No	C

After studying this network simulator, for the present network simulation of the AODV, DSR, ZRP and DSDV, the tool called NS2 is most feasible for the use along with the Trace graph tool for the performance measurement calculations and output graphs. NS 2 is selected because of the following advantages of using it:

1. Open Source and free software for the simulations.
2. Easily available for the download and installation.
3. Programming is done in C++.
4. More features implemented for the simulation.

VI. Results and Discussion

In this research methodology, we have to simulate the four MANET routing protocols such as ADOV, DSDV with number nodes 20, 40 and 75 for the TCP variants. In the following section first we have to show the NAM results for each protocol and for each scenario one by one:

1. AODV NAM Simulation Result

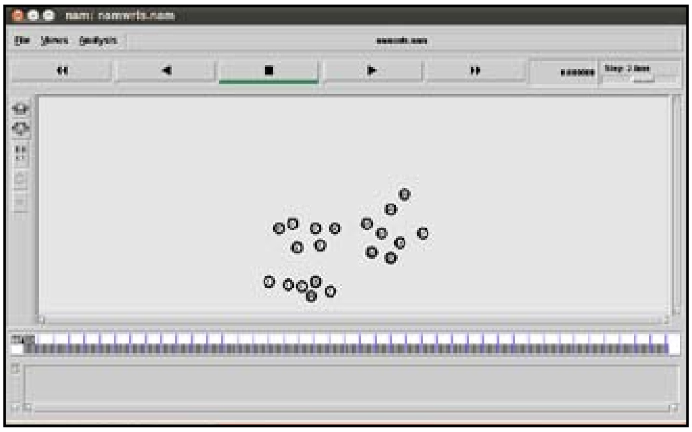

Fig.1 : AODV 20 node NAM Simulation result

2. DSDV NAM Simulation Result

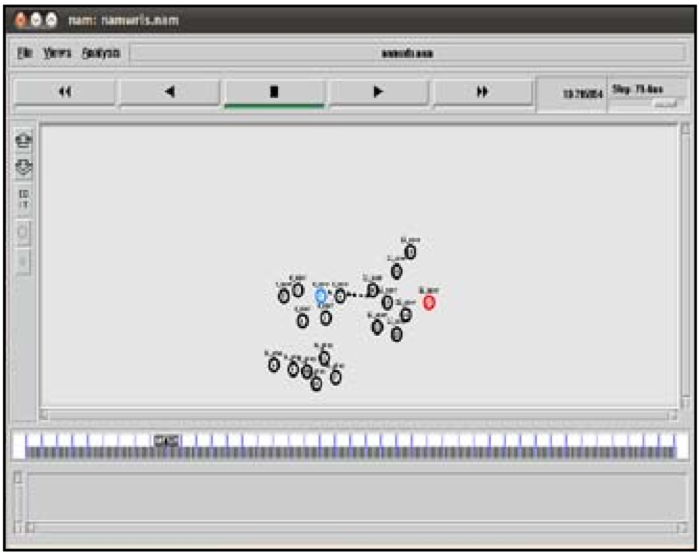

Fig. 2 : DSDV 20 node NAM Simulation result

In the same we got the NAM animation results for various network scenarios considered in this simulation studies. Now below we will present the performance evaluation based on simulated networks along with different TCP variants.

i). Throughput

Throughput is the ratio of total amount packets the receiver will receive from the source of the data within the specified time frame. End to end delay for the packet transmission is most important metrics for the throughput performance of the routing protocols. Along with the routing protocols in the wireless networks for the performance analysis the routing agents are also needs to consider routing agents such as TCP (NJ-plus), TCP Reno and TCP Vegas which are investigated in this research work with two well know routing protocols such as AODV and DSDV. Along with the delay, there some other factors which are also affect the performance of the network throughput such as routing overhead, network size and bandwidth. Thus throughput calculates the fraction of the channel capacity which is used in order to transfer the important information.

In this thesis, AODV and DSDV protocols are simulated with different routing TCP agents such as TCP NJ-plus, TCP Reno, TCP Vegas for the different number of mobile nodes and networks sizes. We measured the throughput of every scenario using the AWK scripts. Following tables and graphs are\ showing the average throughput performance for AODV and DSDV with TCP-Reno, TCP-Vegas and TCP NJ-plus.

Protocol Name	TCP Variant	20-Nodes	40-Nodes	75-Nodes
AODV	RENO	202.80	296.97	205.70
DSDV	RENO	262.80	302.95	245.58
AODV	VEGAS	241.39	316.43	216.18
DSDV	VEGAS	302.03	334.27	275.48
AODV	NJPLUS	279.05	320.95	247.6
DSDV	NJPLUS	321.49	342.72	289.5

Based on these readings we prepared following performance comparison graphs for throughput performance: Following are the graphs for each scenario with different routing protocols and different routing agents: Here measurement of the throughput is calculated by calculating the throughput of receiving the packets versus total simulation time.

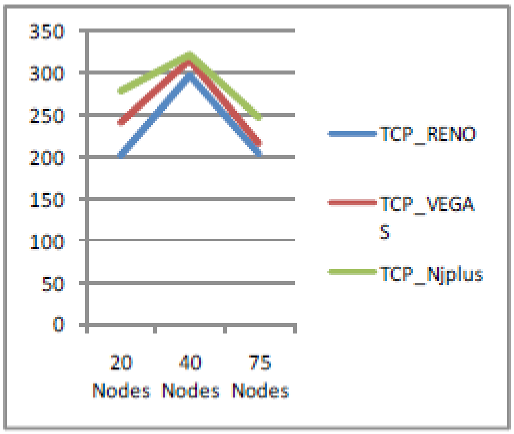

Fig. 3 : AODV-Throughput Performance vs. Network Scenario

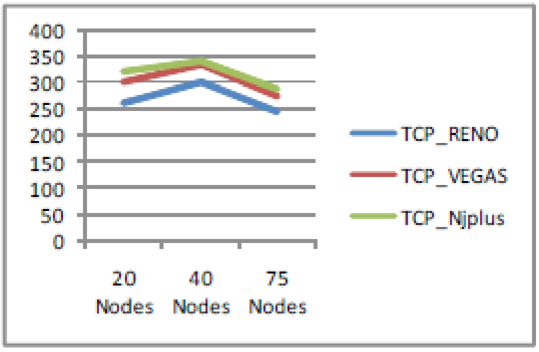

Fig. 4 : DSDV-Throughput Performance vs. Network Scenario

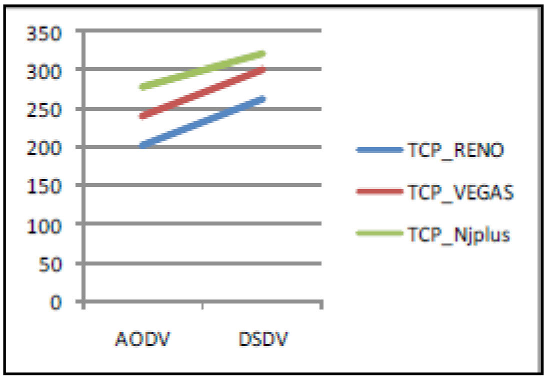

Fig. 5 : AODV-DSDV-20 nodes-Throughput Performance vs. TCP Variants

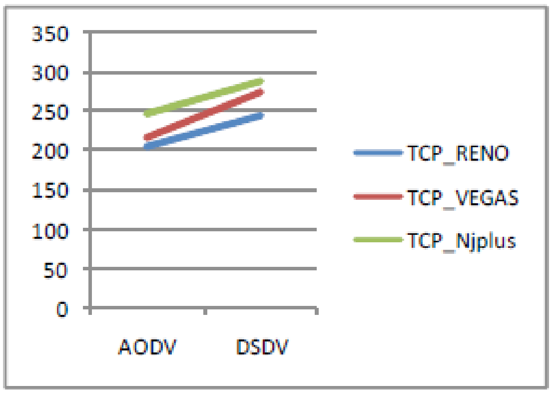

Fig. 6 : AODV-DSDV-75 nodes-Throughput Performance vs. TCP Variants

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Here the figure VI.3 and VI.4 showing that throughput performance against varying number of mobile nodes for three TCP variants. From the graphs it's showing that for both AODV and DSDV routing protocols the TCP variant NJ-plus outperforms the existing TCP variants.

On the other side, next figures VI.5 and VI.6 showing that DSDV is outperforming the AODV protocol in all scenarios and for all TCP variants. The investigation of the TCP agents on the routing protocols such as AODV and DSDV doest affects that much but the it shows the with which TCP agent, this protocols gives the higher throughput.

ii). End-to-End Delay

This one more performance metrics which we calculated here for all the TCP variants with the both routing protocols AODV and DSDV with different network scenarios. Following table shows the average end to end delay for this cases which will explain the performance effects of TCP variants with AODV and DSDV network routing protocols: We measured the average end to end delay of every scenario using the AWK scripts. Following tables and graphs are showing the average delay performance for AODV and DSDV with TCP-Reno, TCP-Vegas and TCP-NJ-plus.

Protocol Name	TCP Variant	20-Nodes	40-Nodes	75-Nodes
AODV	RENO	498	281.56	373.41
DSDV	RENO	477.1	202.58	204.8
AODV	VEGAS	98.94	77.6	104.6
DSDV	VEGAS	87.98	42.03	34.44
AODV	NJPLUS	97.50	73.97	102.7
DSDV	NJPLUS	86	41.9	32.45

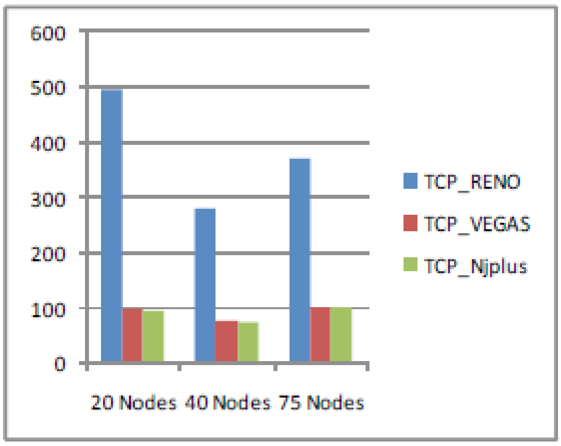

Fig. 7 : AODV-Delay Performance vs. Network Scenario

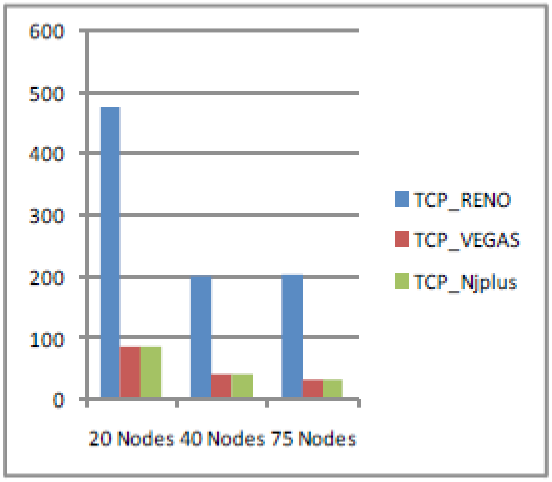

Fig. 8 : DSDV-Delay Performance vs. Network Scenario

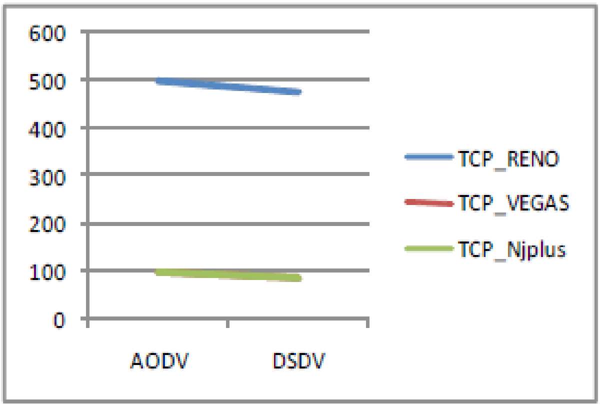

Fig. 9 : AODV-DSDV-20 nodes-Delay Performance vs. TCP Variants

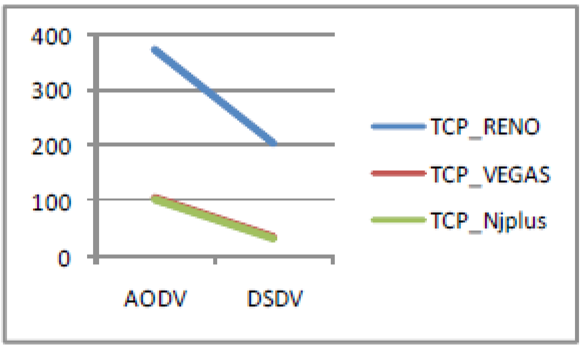

Fig. 10: AODV-DSDV-75 nodes-Delay Performance vs. TCP Variants

Thus above graphs indicate that there is not much benefit of using either of one TCP variants except NJ-plus. Overall performance indicates that TCP NJ-plus performing well in all the conditions most especially with the network scenarios and MANET routing protocol such as DSDV. Overall DSDV protocol and TCP variants performing well together.

iii) Packet Delivery Ratio

This is also one of the major performance metrics which evaluates the performance of routing protocols and TCP variants. Packet delivery ratio is nothing but: PDR: total number of packets generated / total number of packets received. Following table showing the results recorded for PDR.

Protocol Name	TCP Variant	20-Nodes	40-Nodes	75-Nodes
AODV	RENO	98.12	97.5	96.10
DSDV	RENO	98.51	99.4	99.3
AODV	VEGAS	99.24	97.95	98.06
DSDV	VEGAS	99.60	98.73	99.4
AODV	NJPLUS	98.50	98.2	97.80
DSDV	NJPLUS	98.70	99.1	98.00

Based on these readings we prepared following performance comparison graphs for PDR performance: Following are the graphs for each scenario with different routing protocols and different routing agents. PDR is measure in terms of %.

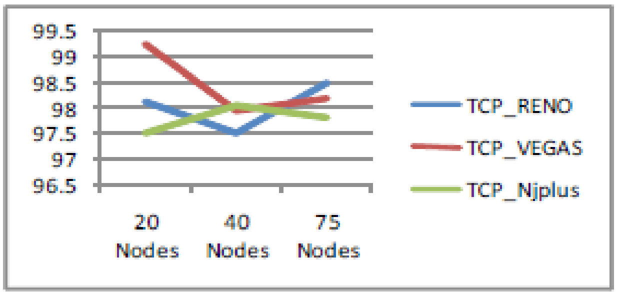

Fig. 11: AODV-PDR Performance vs. Network Scenario

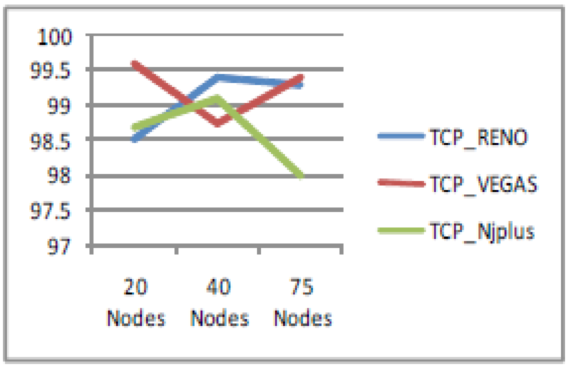

Fig. 12 : DSDV-PDR Performance vs. Network Scenario

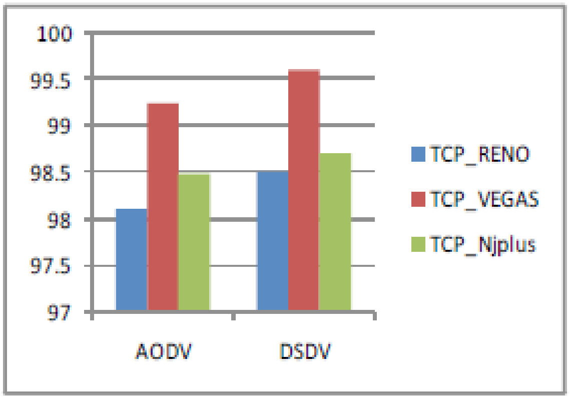

Fig. 13: AODV-DSDV-20 nodes-PDR Performance vs. TCP Variants

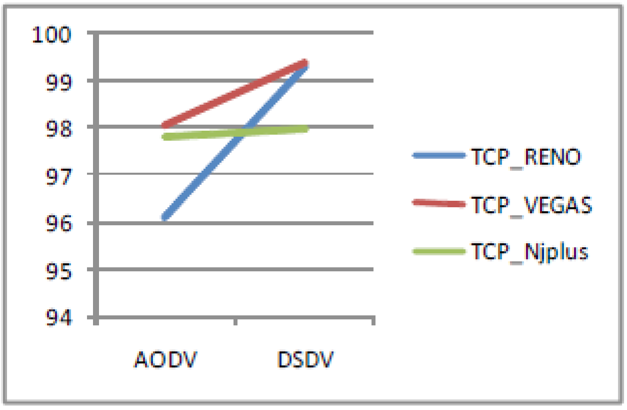

Fig.14 : AODV-DSDV-75 nodes-PDR Performance vs. TCP Variants

From above graphs regarding packet delivery ratio performance, we can say that from figure VI.11 and VI.12, all variants having mixed performance, here in this case proposed approach NJ-plus not able to beat the performance of TCP Vegas and TCP-Reno. From figure VI.11 and VI.12, on an average the performance of TCP-Reno is best.

Coming to the next figures VI.13 and VI.14, the performance of PDR under the DSDV protocol with TCP variants is better as compared to the AODV. From above metrics we compared, the TCP variant called NJ-plus outperforming the existing TCP variants in terms of throughput, delay, off course jitter but having mixed performance in case of PDR. However the TCP variants Vegas and Reno are having very poor performance for delay and throughput. Overall TCP NJ-plus is better for high performance.

On the other side of game, the routing protocols AODV and DSDV, DSDV completely outperforming AODV while working with TCP variants. For all TCP variants the performance of DSDV is better as compared to AODV.

VII. Conclusion

This research work was based on the protocol investigation from the three main categories of MANET routing protocols such proactive routing protocol, reactive routing protocols with different TCP variants. The protocols which we study and analyze are AODV, DSDV from reactive routing protocols and proactive routing protocols respectively with varying the number nodes, data connections, network size. In this research, we proposed efficient TCP variant called TCP NJ-plus which is having aim to outperform the existing TCP variants such as VEGAS and RENO. According to the results which are obtained in the results and discussion section by considering the throughput, delay, packet delivery metrics calculations and graphs generations, following conclusions at which we arrive:

(1) In the MANET different protocols have their own advantages and disadvantages which make them different from each other. Here the AODV and DSDV protocol is having good performance of TCP variant called NJplus, however the performance of DSDV in all scenarios with all TCP variants is better as compared to AODV protocol. In short we conclude that with TCP variants DSDV is protocol is performing best among MANET routing protocols.

(2) The performance of TCP variants varies according to the routing protocols and network scenarios. Among all possibilities, the proposed TCP variant having better

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performance in case of Throughput, delay and jitter as compared to existing TCP variants.

(3) In case of packet delivery ratio, the performance of TCP NJ-plus is little lower as compared to existing TCP variants; however we will keep this further improvement for future work.

VIII. Future Work

So far lots of researches and investigations already carried out in between the different MANET routing protocols by measuring, calculating and comparing the parameters like throughput, delay and jitter for the same. And on the basis of this we have to conclude that which protocol is efficient for use. Our future work is also directed to the same direction in which there will be the introduction of one more performance metrics which needs to be consider for deciding the efficiency of the protocols which is called as convergence times. Convergence time is nothing but the time between the detection of an interface being down and availability of new routing information time.

One more thing, as we discussed detailed types of MANET routing protocols, thus the future work also concentrate on investigation of the remaining MANET routing protocols such geographical based routing protocols, hierarchical based routing protocols, multicast routing protocols and broadcast routing protocols for the future investigation of the MANET routing protocols.

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