AODV, DSDV, DSR Performance Analysis with TCP Reno, TCP New Reno, TCP Vegas on Mobile Ad-hoc Networks using NS2

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ABSTRACT
A Mobile Ad-hoc Network (MANET) is considered an autonomous collection of wireless mobile nodes that are capable of communicating with each other without the use of a network infrastructure or any centralized Administration. MANETs have a wide range of applications from military to search and rescue operations during disaster. In the research work, Mobile Ad-hoc Network protocols like AODV, DSDV and DSR protocol performance analysis are investigated with TCP Reno, TCP new Reno and TCP Vegas using NS2. The Analysis of TCP variants is based on these performance metrics: Average End-to-End delay, Packet Delivery Fraction, Packet Loss, Routing Overhead and Convergence Time. These metrics will be calculated by varying the node coverage area. In additional to this metrics convergence time is also calculated. Convergence Time is defined as the time between Link Breakage and its Recovery. This analysis will be useful in determining the most suitable routing protocols and the TCP variants that can perform more efficiently and robustly in a Mobile Ad-hoc Network.

Keywords
MANET, Performance metrics, AODV, DSR, DSDV, TCP Reno, New Reno, Vegas.

1. INTRODUCTION
The routing protocols in the MANET are traditional networks, however routing protocols deals with the various challenges which is only because of the nodes mobility which more prone to the errors as compared to the wired networks.

Due to the dynamic mobility and routing between the mobile nodes, routes between the mobile nodes sometimes disappear and again back which resulted into the MANET routing mechanism more complicated as compared to the wired network. To finding the optimal communication route from source to destination is only basic and main goal of routing in MANET. Optimal path considers the other network factors as well such as latency, jitter, network overhead, throughput, communication cost and power in order to communicate between the source and destination without failure.

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 are considered 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 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, versions of TCP called TCP variants were developed especially for wireless ad hoc networks to provide reliable communication.

There are different network layer protocols for route discovery and maintenance in MANET but, the issue is the selection of suitable coupling of TCP variant over MANET routing protocol to provide reliable communication.

Figure 1: Mobile Ad-Hoc Network (MANET)

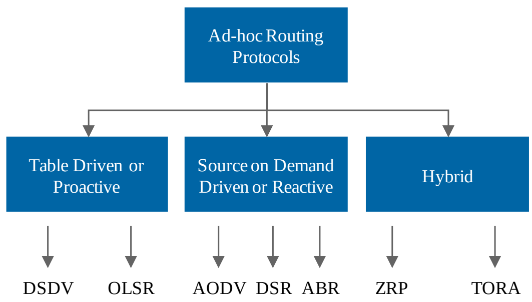

Figure 2: Classification of MANET routing protocols

2. OVERVIEW OF ROUTING PROTOCOLS

2.1 Destination Sequenced Distance Vector (DSDV)

DSDV is one of the most well known table-driven routing algorithms for MANETs. [7] The DSDV routing algorithm is based on the number of hops to reach to the destination, sequence number of the classical. Data packets are transmitted between the nodes using routing tables stored at each node. The protocol has three main attributes: to avoid loops, to resolve the "count to infinity" problem, and to reduce high routing overhead. Each and every mobile node maintains a routing table with all available destinations along with some more information [4].

2.1.1 Advantages of DSDV

DSDV was one of the early algorithms available. It is quite suitable for creating ad hoc networks with small number of nodes.

2.1.2 Disadvantages of DSDV

DSDV requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle.

Whenever the topology of the network changes, a new sequence number is necessary before the network re-converges; thus, DSDV is not suitable for highly dynamic networks.

2.2 Ad-hoc On-demand Distance Vector (AODV)

Reactive protocols discover routes when it's required. If a node wishes to communicate with another node, it checks with its previous information for a valid route to the destination [2]. If one route is found, the node uses that route for communication with the destination node. If route is not found, the source node starts a route discovery process by RREQ, to which either the destination node or one of the intermediate nodes sends a reply back to the source node with a valid route [5]. Less amount of information (mostly fixed packet size) is stored into routing packet unlike DSR routing protocol. [6]. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV. AODV is capable of both unicast and multicast routing.

2.2.1 Advantages of AODV

In AODV, route discovery process is in on demand, which is more efficient in dynamic nature of mobile ad-hoc network.

2.2.2 Disadvantages

Due to on demand manner, it won't check route in periodic interval so transmission of data after discover the rote is taking some more delay, but due to dynamic nature of network this delay is not considerable.

2.3 Dynamic Source Routing (DSR)

Dynamic source routing protocol (DSR) is an on-demand protocol designed to restrict the bandwidth consumed by control packets in ad hoc wireless networks by eliminating the periodic table-update messages required in the table-driven approach. Using DSR, there is no need for administration or existing network infrastructure and the network is completely self-configured and self-organized. It is not table driven like AODV but it has on-demand characteristics and based on source routing .The source routing is a technique in which the source of the packet determines the complete sequence of nodes through which to forward the data packets. The source routing has the advantage that there is no need to maintain the routing information by the intermediate hops .Due to routing decision of source it is different from link-state routing and table driven routing [1].

The DSR protocol has route discovery and route maintenance mechanisms that work together in the ad-hoc network.

2.3.1 Route Discovery

Is the mechanism in which source node wish to send a packet to destination, it first check, the route cache to ensure whether the route information already exist or not. If it has the route information which is not expired, it will utilize this route to send data packet, otherwise it will initiate the route discovery by broadcasting a route request. This route request packet consist of a unique "request id", address of source and destination node.

2.3.2 Route Maintenance;

Mechanism is used to detect the network topology when originating or forwarding a packet to destination. During the transmission each node is responsible to detect, if its next hop has broken.

2.3.3 Advantages of DSR

This protocol uses a reactive approach which eliminates the need to periodically flood the network with table update messages which are required in a table-driven approach.

In a reactive (on-demand) approach such as this, a route is established only when it is required and hence the need to find routes to all other nodes in the network as required by the table-driven approach is eliminated. The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead.

2.3.4 Disadvantages of DSR

The disadvantage of this protocol is that the route maintenance mechanism does not locally repair a broken link.

The connection setup delay is higher than in table-driven protocols. Even though the protocol performs well in static and low-mobility environments, the performance degrades rapidly with increasing mobility.

Routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

3. TCP

3.1 TCP Reno

The Reno TCP implementation retained the enhancements to Tahoe, but changed the Fast Retransmit operation to include Fast Recovery [Jac90]. This algorithm prevents the communication path from going empty after Fast Retransmit, because of that avoiding the need to Slow-Start to re-fill it after a single packet loss.TCP Reno can manage a loss of at most one packet from a single window of data.

In Reno, the sender' s usable window becomes *min(awin, cwnd+ndup)* where *awin* is the receiver' s advertised window, cwnd is the sender' s congestion window, and *ndup* is maintained at 0 until the number of dup ACKs reaches *tcprexmtthresh*, thenceforth tracks the number of duplicate ACKs. Thus, during Fast Recovery the sender "inflates" its window by the number of dup ACKs it has received, accordant with the observation that each dup ACK indicates some packet has been removed from the network and is now cached at the receiver after entering.

3.2 TCP Vegas

TCP Vegas was proposed by Brakmo et al [3]. TCP Vegas detects congestion at an incipient stage based on increasing Round-Trip Time (RTT) values of the packets in the connection unlike other flavors like Reno, New Reno, etc., which detect congestion only after it has actually happened via packet drops. It has a very different congestion control algorithm compared to New Tahoe. TCP Vegas [10] in general controls its segment flow rate based on its estimate of the available network bandwidth. Among the many new features implemented in TCP Vegas, the most important difference between it and TCP Tahoe lies in its bandwidth estimation scheme. Studies on TCP Vegas have shown that Vegas achieve higher efficiency than Tahoe, causes fewer packet retransmissions

Slow-start

```
W_init ← 1;
delta ← (W/RTTmin-W/RTT)*RTTmin;
for each ack
   if (delta < gamma) then
      W ← W+1;
   else
        enter Congestion Avoidance
   end if
```

Congestion Avoidance

```
delta ← (W/RTTmin-W/RTT)*RTTmin;
for each ack
   if (delta < alpha) then
      W ← W+1/W;
   else if (delta > beta) then
      W ← W-1; (only execute once in a RTT)
   else
   W ← W;
   end if
```

Fast Retransmit

```
   if (dup_ACKs)
   retransmit the lost packet
    W ← W/2;
   enter Congestion Avoidance
end if
```

3.3 TCP New Reno:

TCP New Reno defined by RFC 3782, advances retransmission during the fast recovery phase of TCP Reno. while fast recovery for every duplicate ACK that is returned to TCP New Reno, a new not sent packet from the end of the congestion window is sent, to keep the transmit window as full.

For each and every ACK that provides partial progress in the sequence space, sender assumes that the ACK points to a new hole and the next packet beyond the ACK sequence number is sent.

4. TCP OVER MANET

As a result of the improvement of wireless technology and the proliferation of handheld wireless terminals, now a day's have witnessed an ever-increasing popularity of wireless communication, ranging from wireless WLAN and WWANs to MANETs. In WLANs (e.g., the Wi-Fi technology) in WWANs (e.g. 2.5G/3G/4G cellular networks), mobile station communicate with an access point or a base station that connected to the wired networks. Patently, only one hop wireless link is needed for communications between a mobile host and a stationary host in wired networks. In counterpoint, there no fixed infrastructure such as base stations or access points a MANET. All nodes in a MANET are capable of moving independently and functioning as a router that discovers and maintains routes and forwards packets to other nodes. Thus, mobile ad-hoc networks are multi-hop wireless networks by nature.

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. Each TCP sender maintains a running average of the estimated round trip delay and the average deviation derived from it. Lost 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.

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

As TCP performance disintegrates more seriously in ad hoc networks compared to cellular networks or WLANs, then divide wireless networks into two large groups: first 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 MANET [8], given these wireless specific issues, considerable research has been carried out and many schemes have been suggested. As the research in this area is still active and many difficulties are still wide open.

5. PARAMETERS

5.1 Packet Delivery Fraction

Packet delivery fraction is the defined as number of packets successfully transmitted between source and destination.

*PDR = (Total number of Packets received/Total number of Packets sent)*100*

The greater value of packet delivery ratio means the better performance of the protocol.

5.2 End to End Delay

Time duration between packet received and sending time is called as End to End delay.

$EED = \sum (\text{arrive time} - \text{send time}) / \sum \text{Number of connections}$

The lower value of end to end delay means the better performance of the protocol

5.3 Routing Overhead
Number of extra packets such as routing packets called as Routing Overhead.

5.4 Convergence Time
Time duration between route failure and route recovery is called as convergence time. Convergence time has been defined as the time between detection of an interface being down, and the time when the new routing information is available. [10]

6. PERFORMANCE EVALUATION
Simulation is performed by using NS2 tool [9]. In this paper simulation is done with various network environments given as bellow table.

Table 1. Simulation parameters

Parameter name	Parameter value
Area	500 X 500, 700 X 700, 1600 X 1600
Coverage area	86m , 230m, 410m
Routing protocol	AODV, DSR, DSDV
Transport protocol	TCP--- Reno, New Reno, Vegas
No. of nodes	8, 10, 50, 100, 200
Speed	5 m/s, 10m/s, 20m/s
MAC	MAC/802.11

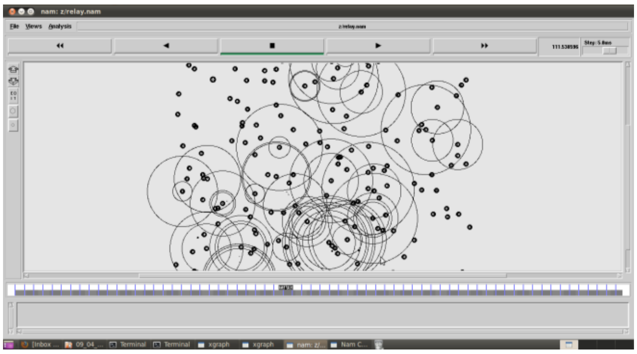

Figure 3: NAM simulation window

6.1 Packet Delivery Fraction (Nodes)
In this paper comparison of different routing protocols in different network environment is analyzed. Simulation result for packet delivery ratio is shown in the following graphs, TCP New Reno is mostly providing high performance with DSR and AODV but not in DSDV

Table 2. Packet delivery fraction

Protocol Name	TCP Variant	50 Nodes	100 Nodes	200 Nodes
AODV	Reno	94.99	97.56	100.00
DSDV	Reno	98.31	96.14	96.31
DSR	Reno	99.56	99.55	99.41
AODV	New Reno	95.50	95.85	94.97
DSDV	New Reno	97.90	96.37	95.81
DSR	New Reno	98.92	99.11	99.76
AODV	Vegas	98.83	99.80	99.69
DSDV	Vegas	95.93	98.31	95.13
DSR	Vegas	99.87	99.98	99.82

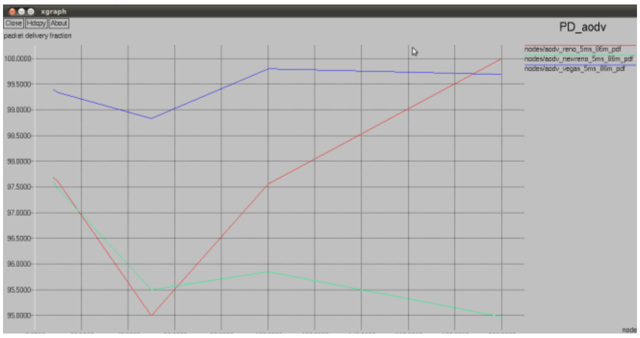

Figure 4: Packet delivery fraction with AODV (varying nodes)

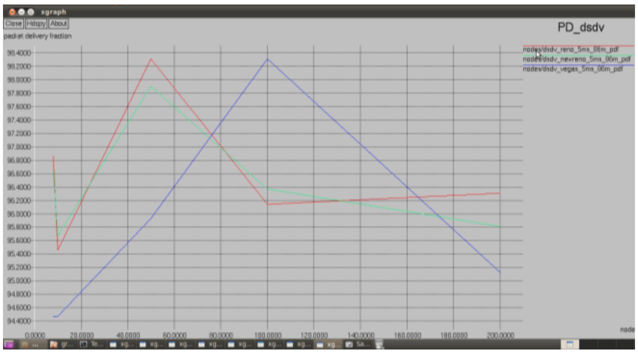

Figure 5: Packet delivery fraction with DSDV (varying nodes)

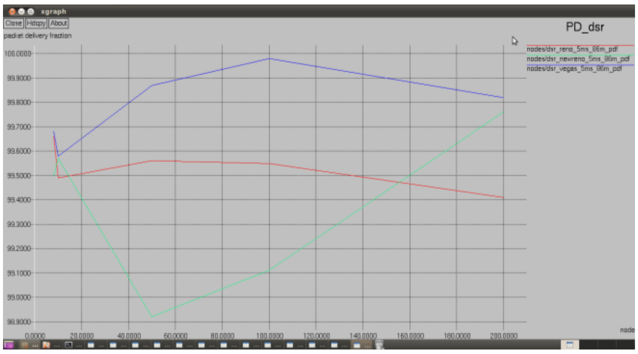

Figure 6: Packet delivery fraction with DSR (varying nodes)

In next comparison, node coverage area is used. In this result also TCP New Reno is better than remaining TCP protocols.

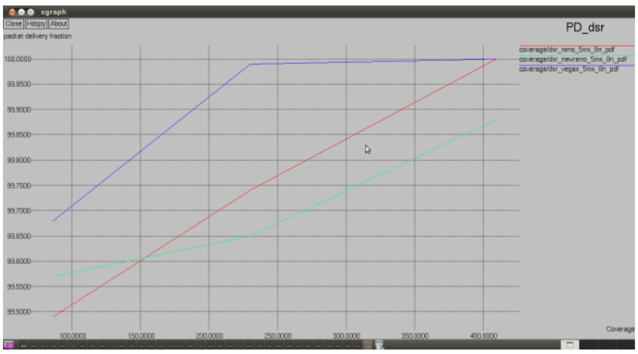

Figure 7: Packet delivery fraction with DSR (varying node coverage area)

6.2 End to End Delay (Nodes)

In End to End delay analysis, Reno providing constant delay in different network environment in all the routing protocol. But new Reno is proving less delay in 100 node environment for all routing protocols

Table 3. End to End Delay

Protocol Name	TCP Variant	50 Nodes	100 Nodes	200 Nodes
AODV	Reno	0.25716	0.14315	0.04157
DSDV	Reno	0.39355	0.55613	0.31871
DSR	Reno	0.05034	0.04520	0.05294
AODV	New Reno	0.17241	0.21185	0.18279
DSDV	New Reno	0.31305	0.33109	0.38920
DSR	New Reno	0.03765	0.03775	0.03850
AODV	Vegas	0.12077	0.08192	0.09728
DSDV	Vegas	0.51455	0.19811	0.82829
DSR	Vegas	0.03953	0.03705	0.06106

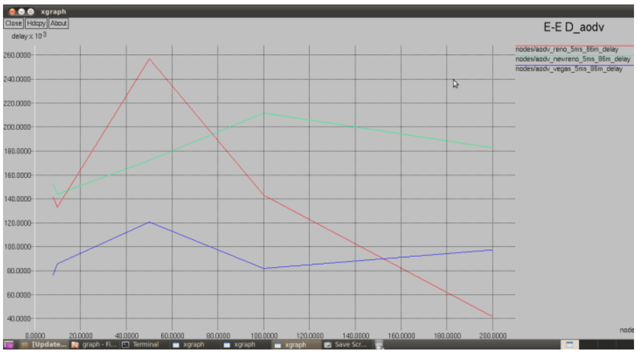

Figure 8: End to End delay with AODV (varying nodes)

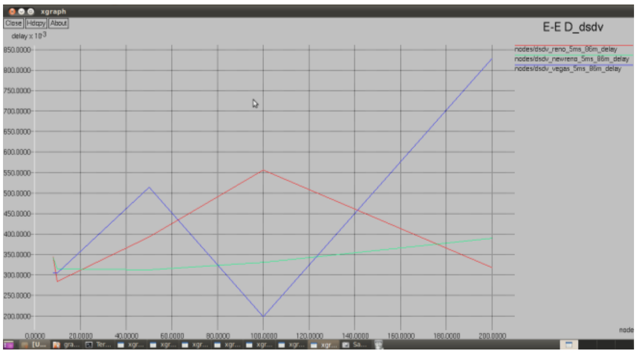

Figure 9: End to End delay with DSDV (varying nodes)

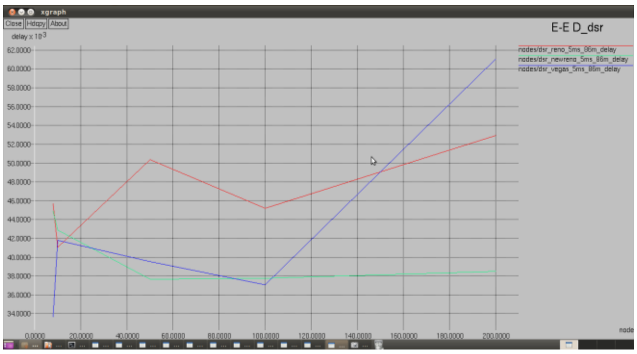

Figure 10: End to End delay with DSR (varying nodes)

6.3 Routing Overhead (Nodes)

In routing overhead total number of routing packets transmitted during simulation. Each hop-wise transmission if a control message by node is counted as one transmission.

Table 4. Routing Overhead

Protocol Name	TCP Variant	50 Nodes	100 Nodes	200 Nodes
AODV	Reno	7130	3261	200
DSDV	Reno	2224	4155	23169
DSR	Reno	3023	2512	9807
AODV	New Reno	6301	8917	16315
DSDV	New Reno	2268	5996	23602
DSR	New Reno	2574	3470	11862
AODV	Vegas	2131	400	2028
DSDV	Vegas	2031	4223	21383
DSR	Vegas	594	433	692

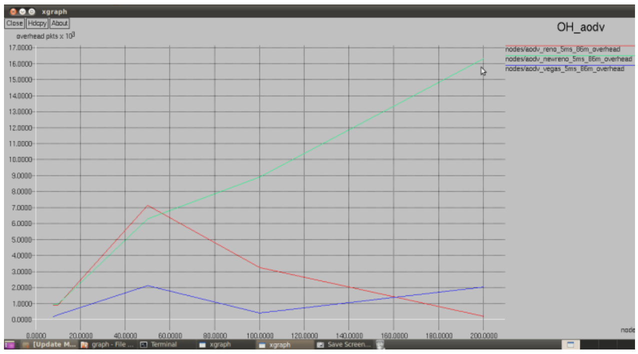

Figure 11: Routing overhead with AODV (varying nodes)

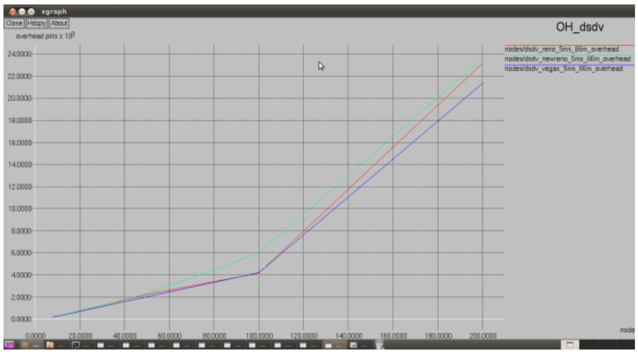

Figure 12: Routing overhead with DSDV (varying nodes)

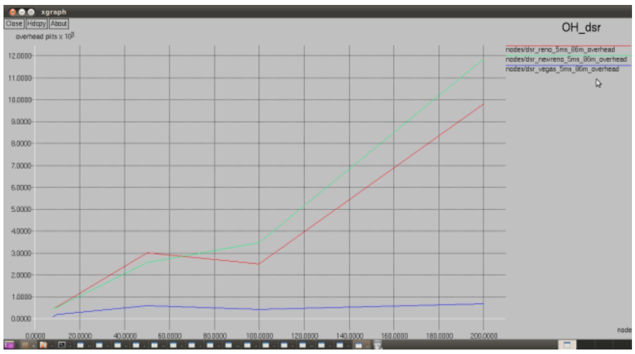

Figure 13: Routing overhead with DSR (varying nodes)

6.4 Convergence Time (Nodes)

Convergence time has been defined as the time between detection of an interface being down, and the time when the new routing information is available. Defines route convergence periods the period that starts when a previously stable route to some destination becomes invalid and ends when the network has obtained a new stable route. Convergence time as the time between a fault detection, and restoration of new, valid, path information. In convergence time analysis, DSR providing less convergence time in most of the cases.

Table 5. Convergence Time

Protocol Name	TCP Variant	50 Nodes	100 Nodes	200 Nodes
AODV	Reno	0.30435	0.46133	0.5344
DSDV	Reno	10.8742	7.08941	65.7214
DSR	Reno	0.49523	0.38165	0.41061
AODV	New Reno	0.58288	0.41436	0.36376
DSDV	New Reno	2.56989	7.63609	4.08506
DSR	New Reno	0.44781	0.27750	0.46964
AODV	Vegas	0.23065	0.41656	0.27972
DSDV	Vegas	25.3348	216.309	161.302
DSR	Vegas	0.17582	0.06593	0.08915

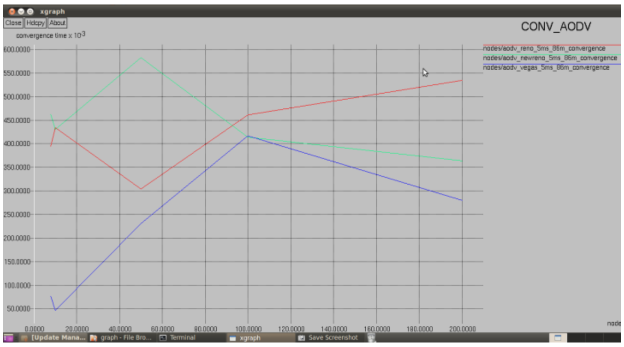

Figure 14: Convergence time with AODV (varying nodes)

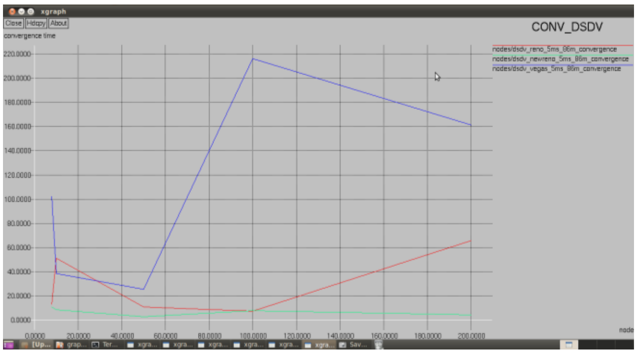

Figure 15: Convergence time with DSDV (varying nodes)

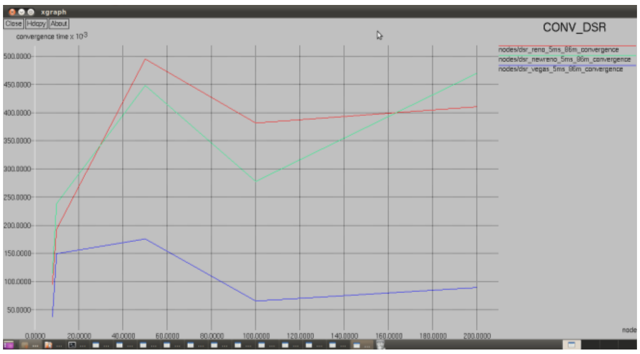

Figure 16: Convergence time with DSR (varying nodes)

7. 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 reactive routing protocols AODV, DSR and proactive routing protocols DSDV are analyzed by varying number of nodes, data connections, of network size. In this research, TCP variant called TCP NEW RENO 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 Packet Delivery Fraction, End to End Delay, Routing Overhead and Convergence Time. Conclusions arrive by showing calculations and graph generations.

In the MANET different protocols have their own advantages and disadvantages which make them different from each other. Here the AODV and DSR protocol is having good performance of TCP variant called NEW RENO. In short we conclude that with TCP variants DSR is protocol is performing best among MANET routing protocols.

The performance of TCP variants varies according to the routing protocols and network scenarios. Among all possibilities, the proposed TCP variant having better performance .TCP NEW RENO outperforms better as compared to other variants.

DSR has performed well compared to all other protocols in terms of delivery ratio while AODV outperformed in terms of average delay. DSR generates lower overhead than AODV while DSDV generates almost constant overhead due to proactive nature. Poor performance of DSR in respect of average delay can be accounted to aggressive use of caching and inability to delete state route. But it seems that caching helps DSR to maintain low overhead. In DSDV, high mobility results in frequent link failures and the overhead involved in updating all the nodes with new routing information compared to AODV and DSR, where the routes are created as and when required. In application oriented metrics such as packet delivery fraction and delay, AODV outperforms DSR in more "stressful" situations (i.e., smaller number of nodes and lower load and/or mobility), with widening performance gaps with increasing stress (e.g., more load, higher mobility). However, DSR consistently generates less routing load than AODV.

8. FUTURE WORK

Dynamic source routing protocol is designed for use in multi-hop wireless ad hoc networks of mobile nodes. DSR uses source routing and does not depend on timer based activities. So it is a fully reactive protocol which initiates a route discovery process only when it has data to send. Though there are some disadvantages of this protocol, it is a robust protocol for use in mobile ad hoc network. Existing works will include the modification to the basic DSR so as to reduce the routing overhead for the performance optimization. Existing work can be extended to various other protocols like TORA.

The performance of such protocols on the performance parameter like standard deviation, energy consumption, etc is analyzed. In this simulation study, large no of nodes are not used and simulation time was 100s. Increasing both of them will increase computational time which was limited due to various reasons. Thus, in future more vigorous simulation are performed so as to gain better understanding of such networks and subsequently helps in development of new protocols or modification in existing protocols.

9. ACKNOWLEDGMENT
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