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A Performance Review of Intra and Inter-Group MANET Routing Protocols under Varying Speed of Nodes

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ABSTRACT

Mobile Ad-hoc Networks (MANETs) are a cluster of self-organizing and self-governing wireless nodes without any backbone infrastructure and centralized administration. The various nodes in MANET move randomly, and this node mobility may pose challenges on the performance of routing protocols. In this paper, an Intra and intergroup performance review of various MANET routing protocols are performed under varying speed of nodes. The routing protocols included in this study are reactive, proactive, and hybrid protocols. This performance review is done using the NS2 simulator and random waypoint model. The routing protocols performance is assessed through standard performance measure metrics including packet delivery ratio, throughput, routing overhead and end to end delivery with varying speed of nodes. The simulations result shows that there is no significant impact of varying speed of nodes on standard performance evaluation metrics.

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1. INTRODUCTION

With the development of cutting edge technology enabled powerful portable devices and availability of cost effective wireless communication, mobile ad-hoc networks (MANETs) are gaining popularity. MANETs are deploying for different applications ranging from military to natural disaster management. Mobile Ad Hoc Networks (MANETs) connects wireless mobile nodes which have an arbitrary motion which makes the topology unpredictable [1],[2]. It is self-organizing and self-configuring and can be deployed without any wired base stations or infrastructure support. The mobile nodes act as hosts and also as routers to send the data across the networks.

A MANET is a collection of free mobile nodes such as laptops, smartphones, tablet PC, etc. It has many characteristics. In MANETs, there is no central server and nodes themselves are responsible for communicating with other nodes to carry out network operations such as on-demand routing[3]. Nodes are free to move anywhere whenever and wherever they want, and they are also free to change their speeds [4]. Therefore, the network topology changes randomly and at uncertain times. Nodes can send messages to other nodes which are not in range or nor directly connected with the help of intermediate nodes [5].

MANET has many advantages. It is scalable as it supports the addition of more mobile nodes in the network. The information can be accessed irrespective of the geographic position of nodes [5]. The use of mobile nodes results in many connection failures. The routing protocols are designed to handle these situations [6]. MANETs are fault tolerant. The main advantage is that the nodes do not need wireless routers to connect to the internet[7].Therefore, it reduces the cost of deploying a router and affordable than a traditional network and MANETs are installed quickly as it does not require any infrastructure or previous installation [4].

As the number of portable devices and wireless communication is increasing, the ad-hoc network is gaining priority and is having an increase in a number of applications [8]. It is robust and reliable which is used to maintain the network in war zones (between soldiers, their vehicles and military headquarter) natural disasters, etc. The information related to situational awareness is passed in the network may be used in an emergency or in a rescue operation by various rescue teams to communicate with each other through small handhelds as there is no established communication infrastructure and it must be deployed quickly. They can be used as an autonomous network used to connect various devices at home [9]. Regardless of the interesting and useful applications of MANET, it also has to face few challenges [10]. It can suffer from both Passive and active attacks and various vulnerabilities. Passive attacks are checking routing traffic and getting valuable information. Active attacks are injecting certain packets with an aim to affect the network. Wired links have more capacity than the wireless links. The error rates increase in the wireless link by attenuation and interference. Nodes cannot have the infinite time of operation as their battery gets exhausted. Unlike wired networks, nodes in MANET cannot be addressed using the position of the node as the nodes are mobile. MANET has a dynamic network which makes it difficult to route the information [4], [10].

The routing protocols are required whenever the source needs to send packets to the destination. There are many routing protocols which have been proposed for the mobile ad hoc network. There classification as shown in Figure 1. Flat routing protocols assign the same role to all the participating nodes whereas in Hierarchical routing different roles are assigned to the network nodes [11]. Flat routing is further classified into proactive and reactive routing protocols. Proactive protocol maintains an up-to-date routing table which contains the routing information for every node in the network by periodically sending control messages between the nodes. In Reactive protocols, routes are discovered only when a source wants to send some packets to the destination. The hybrid protocol used the advantages of both proactive and reactive routing protocols and was made to overpower their weaknesses. Routing is first done through proactive protocols which then activate few nodes which do reactive flooding [12].

Various routing protocols have been considered for the comparative study which includes proactive, reactive and hybrid protocols. Proactive protocols used are DSDV, OLSR, and FSR. Reactive protocols used are AODV, DSR, and AOMDV. Hybrid protocols used is ZRP.

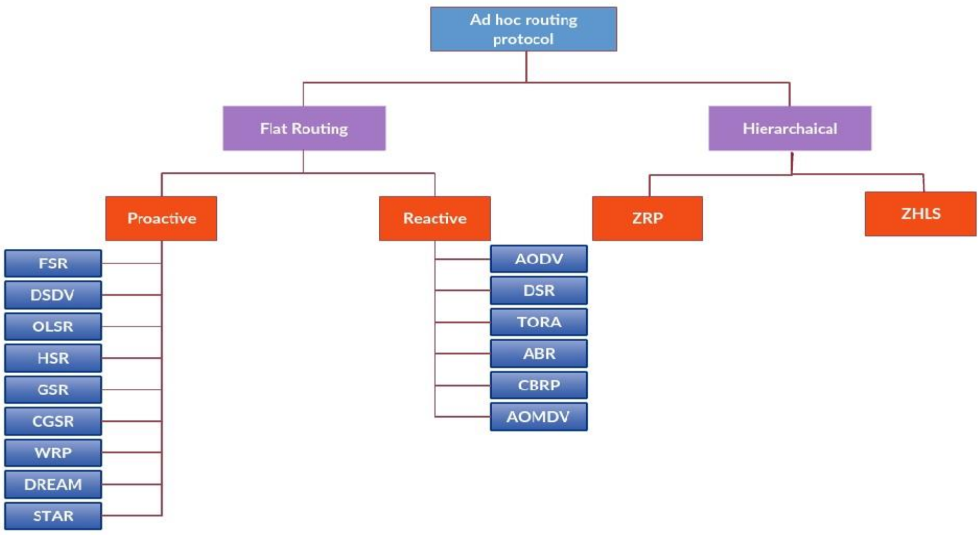

Figure 1. Classification of MANET Routing Protocols

1.1. Destination-Sequenced Distance-Vector Routing (DSDV)

DSDV developed by C. Perkins and P. Bhagwat in 1994, is a proactive protocol, which is based on a Bellman-Ford algorithm. It uses Distance vector routing with sequence number generated by the destination that solves the problem of a routing loop. Each mobile node that forms the network maintains an updated routing table that stores information about all the destinations and their hop counts required reaching those destinations [13].

1.2. Destination Sequence Routing (DSR)

DSR is a reactive protocol. It uses the principle of source routing. It uses two mechanism route discovery and route maintenance. By route discovery, the source sends packets to the destination and obtains the full path to it by flooding the network with route requests (RREQ). Nodes can reply to the RREQ by sending route reply (RREP) by unicasting it back to its source. Hence, full address is stored as a path in the data packet. The route maintenance is used to check if the network topology has changed [14].

1.3. Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV [15] is a reactive routing protocol. It uses the mechanism of route discovery and route maintenance of DSR and the approach of sequence numbers and periodic updates from DSDV [16]. The source node floods the network with route request packet (RREQs) which then floods to their neighbors. This process continues till the destination is reached or an intermediate node, with a route to the destination, is reached. They then send route reply (RREP) back to the source which tells the source the path to the destination [15].

1.4. Fisheye State Routing (FSR)

FSR is a proactive routing protocol. It uses "Fisheye" technique. The nodes have accurate information about the nearby nodes as compared to far away nodes. Any update in the topology is also propagated more frequently to the nearby nodes than the far away nodes which reduce the routing overhead [17].

1.5. Optimized Link State Routing (OLSR)

OLSR is a proactive protocol. It reduces the retransmission in the same region. Nodes exchange HELLO messages with their neighbors to maintain information and determine one hop neighbor and its two-hop neighbors. Each node chooses set of nodes as multipoint relays (MPR) to covers all the nodes which are two hops away and sends the topological information through MPRs selectors only instead of broadcasting it to its entire neighbor [18].

1.6. Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV)

AOMDV is considered as an expansion of AODV which is used to calculate multiple loop-free, link disjoint paths, and node disjoint paths. When the source wants a route to the destination, it broadcasts RREQ packets and gets multiple RREPs from the intermediate nodes. It stores all the routes to the destination, unlike AODV which stores the best path. All these routes are linked disjoint means that there are no common links between the paths, whereas node disjoint means that there are no common nodes among paths [19].

1.7. Zone Routing Protocol (ZRP)

ZRP is a hybrid protocol. It combines the benefits of both proactive and reactive protocols. A routing zone is specified for every node. ZRP has three units namely, Intrazone zone routing protocol (IARP), Interzone Routing Protocol (IERP) and Bordercast Resolution Protocol (BRP). Each unit works independently of the other unit. IARP is used within the zone, nodes inside the zone behave proactively, and each node in the zone has an updated routing table to the destinations within the zone [20]. IERP is used when the destination is not available within the zone. It depends on BRP in which border nodes perform on-demand routing to search for the nodes residing outside the source node zone [21].

In this paper, an Intra and Intercomparison have been done between above described proactive, reactive and hybrid protocols by varying speed of the mobile nodes under standard performance metrics. The rest of the paper is organized as follows. Section 2 gives a brief description of related work. Section 3 proposes the performance metrics used. Section 4 tells about the simulated experiment and results for setting up the environment in NS2. Section 5 presents the result analysis of the study, which are the graphical results of all the experiments. Section 6 presents the result discussion. Finally, the conclusion of the study and the future work is presented in section 7.

2. RELATED WORK

In literature, different studies related to the simulated performance of MANET routing protocols had been reported. Some noteworthy related contributions are discussed in this section. In [3], AODV is analyzed in a network consisting various intensity of unidirectional links against three mobility models, Gauss-Markov, Reference Point Group Mobility (RPGM), and Manhattan, which are widely used in the MANET research community. They have shown the impact of mobility models on routing protocols simulation output. They have also presented a new performance metric called probability of route connectivity, which measures the success rate of route established in a network. A high probability indicates that a particular routing protocol is reliable and efficient regarding routes establishment.

In [22], authors have compared DSR and DSDV based on four mobility scenarios: Random Waypoint, Group Mobility, Freeway and Manhattan models. Protocol varies widely across different mobility models, and hence the study results from one model cannot be applied to another model. They proved that DSR gave better performance for highly mobile networks than DSDV.

In [23]-[24], comparative study of AODV, DSR and DSDV have been carried out using mobility models such as reference point group Mobility (RPGM), random waypoint (RW), Gauss-Markov (GM) and Manhattan Grid (MG) in NS2. The results show that relative ranking of routing protocols vary depending upon mobility model used, and it also depends on speed. DSDV showed the most stable performance; AODV shows the best performance with RPGM. DSR shows the best performance with RW model.

In [25], authors have compared reactive (AODV, DSR) and proactive (OLSR) protocol under CBR traffic with different network conditions. They concluded that OLSR showed better performance regarding packet delivery and end-to-end delay. DSR performs poorly in stressful scenarios where AODV is more desirable in a stressful environment. The proactive protocol has higher routing overhead as compared to reactive protocols. OLSR outperforms the reactive protocols at higher speed even though it has high routing overhead.

In [26], authors have compared AODV and DSDV at a different number of nodes and varying speed between 25m/s, 35m/s, and 50m/s. AODV shows higher efficiency and performance under high mobility than DSDV. In [27], a comparative study has been done between AODV, DSR, and DSDV. They concluded that AODV performed better regarding packet loss and DSDV regarding throughput. AODV outperforms DSDV and DSR in high mobility environment, and AODV adapts itself to changes. However in this article inter and intra-group performance of MANET routing protocols is evaluated using all the key performance measures.

3. PERFORMANCE METRICS

The performance metric is the criteria with which the performance of various routing protocols is compared in the given environment [23]. In NS2, the awk file is used to calculate it, which is run on the trace file generated. There are many performances metric. The standard performance metrics used for comparison are:

3.1. Packet Delivery Ratio (PDR)

Packet delivery ratio is the ratio of data packets received by the final destinations to those generated by the sources. The greater value of packet delivery ratio means the better performance of the protocol.

$$PDR = \frac{\sum Number\ of\ packets\ received\ at\ destination}{\sum Number\ of\ packets\ send\ by\ node} \tag{1}$$

3.2. Throughput (THP)

Throughput is the average rate of packets successfully sent to their final destination per unit time.

$$THP(kbps) = \frac{packet\ size * receive * 8.0}{1000 * (end_{time} - start_{time})} \tag{2}$$

The packet size is the size of a packet used in Application layer in bytes. The numerator is the total number of bits received. The value is divided by 1000 and difference of end time which is the end time of simulation and the start time which is the start time of simulation to get the throughput in kbps.

3.3. End-to-End (E2E) Delay

End-to-end delay is the average amount of time taken a delay of packets from the time the source sent it to the time it was received at the destination. It includes the time spent in the packet queue, forwarding delays, propagation delay and the time taken to make retransmission if the packet is lost, etc. [23], [7].

$$E2E = \frac{\sum arrive_{time} - send_{time}}{\sum Number\ of\ connections} \tag{3}$$

3.4. Routing Overhead (RO)

Routing overhead is the number of additional information used for a transmission of data divided by the total of bytes for the complete transmission[28]. In NS2, it is calculated using trace file by dividing the total number of routing packets by the total number of data packets received.

$$RO = \frac{\sum Routing\ packets}{\sum Packets\ received} \tag{4}$$

4. SIMULATED EXPERIMENT AND RESULTS

This section describes the software used and the parameters set in NS2.Ubuntu 15.04 with 4GB RAM, 1TB disk space, and Intel Core i5 Processor are used for this study. There are several simulators available for network simulation tools including OMNET++[29], QualNet[30], OPNET and NS2[31]. NS2 is preferred over others as it is open-source and many nonprofit groups contribute many packages that can be used [32]. In this comparative analysis, NS2.35 is used as a simulator. Graphs are plotted using LibreOffice Calc. NS2 is an object-oriented simulator written in C++ and has OTcl (Object Oriented Tool command language) as its frontend. If components have to be developed, then both Tcl (Tool command language) and C++ has to be used [32].

Table 1, shows all the simulation parameters with their corresponding values. The Tcl code for all the protocols was written to set the network environment. Some papers support the parameter values set in NS2 [32]. There are three radio propagation models- FreeSpace, TwoRayGound, Shadowing. For this study, TwoRayGound radio propagation model is used as there is a limitation in NS2 that sender and receiver have to be at the same height. This model gives more accurate prediction at a long distance than the free space model [33], and it gives better results for routing protocol than Shadowing[34]. TCP/FTP is preferred over UDP/CBR [35] as the performance metrics, such as throughput, packet delivery ratio and average end to end delay gives better results with TCP/FTP traffic. Therefore, TCP/FTP is used to generate traffic source.

In [21], it has been showing that ZRP demonstrated an extraordinarily low packet delivery ratio and throughput when the mobility of nodes is high. With the increase in a number of nodes, the routing load also increases with the Zone Radius. If The zone radius is kept in the range, 2-4 then it shows the higher throughput. On the other hand, average end to end delay is least at high Zone Radius. Hence, Zone radius as 2 has been selected for ZRP to get best results.

Table 1. Parameter values for simulation.

Parameter	Values
Platform	Ubuntu 15.04
Simulator	NS-2.35
Antenna	Antenna / Omni Antenna
Link layer type	LL
Simulation area	500m*400m
Mobile nodes	20
Mac layer type	802.11/Mac
Packet size	500 bytes
Traffic source	TCP
Channel	Wireless
Radio propagation model	TwoRayGround wave
Variable speed	10,20,30,40 m/s

5. RESULT ANALYSIS

In this section, comparison of various reactive, proactive and hybrid protocols is made by throughput, packet delivery ratio, an average end to end delay and routing overhead and the result is shown in the form of graphs. Seven protocols have been compared by varying speed of mobile nodes that take the value 10, 20, 30 and 40. For this experiment, some nodes are kept constant to 20 nodes.

5.1. Comparative performance of proactive protocols

This section compares the proactive protocols which are DSDV, OLSR, and FSR based on performance metrics discussed above. In the graphs for proactive protocols, from Figure 2, it has been observed that throughput has a very slight variation with changing speed. FSR has the maximum throughput value approximately 659kbps among all the proactive protocols considered while OLSR shows the least value of throughput value approximately 649kbps. From Figure 3, it can check that there is no change in packet delivery ratio with speed. It remains constant throughout. FSR has the maximum packet delivery ratio with approx. 98.7% packets delivered.

OLSR has the least value of approx. 91% of packet delivery ratio. Figure 4, shows that End to end delay varies very slightly with speed. FSR shows a disadvantage here by having the maximum end to end delay, and OLSR has the least value. Figure 5, shows that routing overhead remains constant with speed variation. OLSR has the maximum routing overhead with value 0.16. DSDV has the least routing overhead value 0.028. FSR has the value of 0.069 which is subtle as compared to OLSR but greater than DSDV.

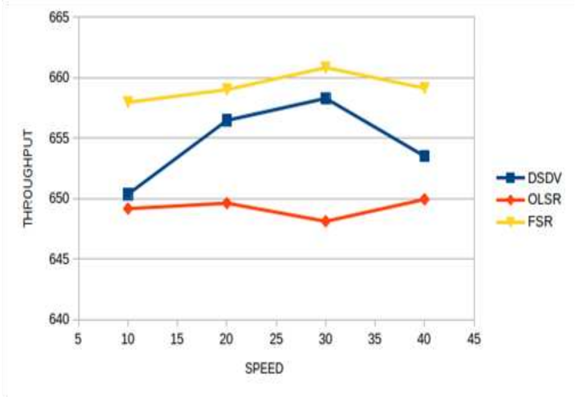

Figure 2. Throughput vs. Speed

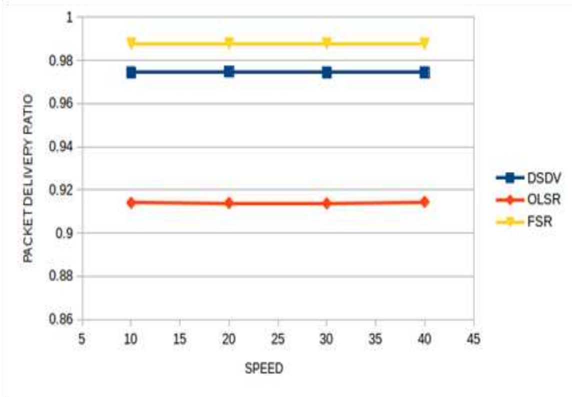

Figure 3. Packet Delivery Ratio vs. Speed

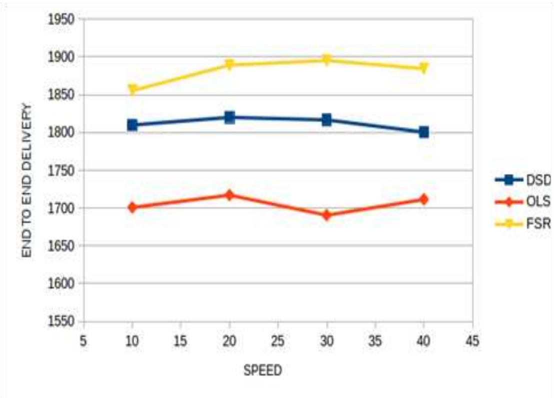

Figure 4. End to End Delay vs. Speed

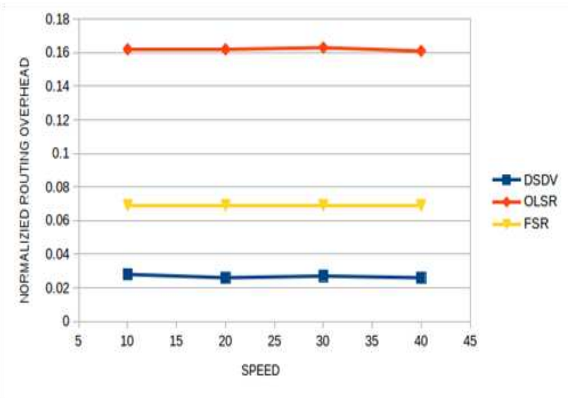

Figure 5. Routing overhead vs. Speed

5.2. Comparative Performance of Reactive Protocols

In this section, the comparison is made between reactive protocols among AODV, DSR, and AOMDV.From Figure 6, it can be observed that AODV has the highest throughput among all the reactive protocols considered. It has a value of almost 680kbps. AOMDV has the least throughput among them. From Figure 7, it can be checked that AODV and DSR vary slightly with speed. From Figure 8, AOMDV shows higher end to end delay as compared to AODV and DSR. In Figure 9, it can be discovered that routing overhead of AOMDV is enormous as compared to AODV and DSR with a value 0.26 whereas AODV and DSR have small routing overhead of 0.04.

5.3. Comparative Performance of Proactive, Reactive and Hybrid Protocols

In this section, all the protocols i.e. proactive, reactive and hybrid protocols have been evaluated using the standard performance metrics at varying speed. In Figure 10, it may be observed that ZRP has the least throughput among all the protocols considered. This implies a hybrid protocol gives a poor performance as compared to reactive and proactive protocols. Among all, AODV has the maximum throughput. From Figure 11, it can be concluded that ZRP has the least packet delivery ratio showing packet delivery ratio of the hybrid protocol is poor as its design complexity overweighs the performance. FSR and AODV have the highest packet delivery ratio among all the protocols. Figure 12 tells that ZRP has the least end to end delay, and AOMDV has the highest end to end delay among all the protocols considered. Figure 13 shows that ZRP has exceptionally large routing overhead compared to other routing protocols, and DSDV has the least value.

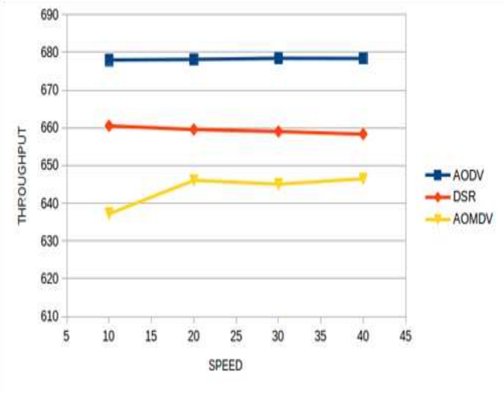

Figure 6. Throughput vs. Speed

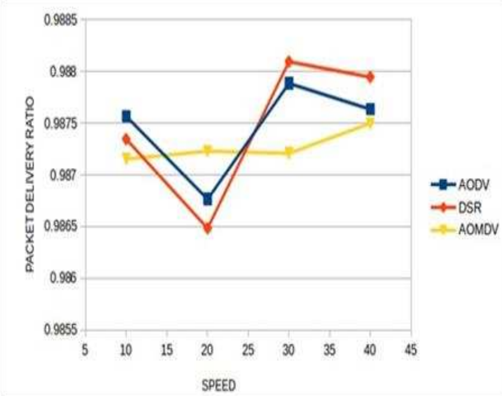

Figure 7. Packet Delivery Ratio vs. Speed

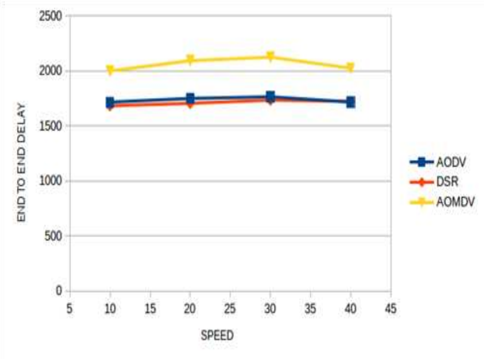

Figure 8. End to End Delay vs. Speed

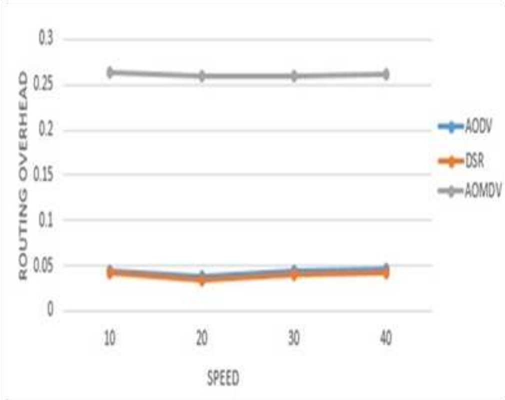

Figure 9. Routing overhead vs. Speed

6. RESULT DISCUSSION

Among all proactive protocols i.e. DSDV, FSR and OLSR, FSR is better regarding throughput and packet delivery ratio as it uses cache mechanism to reduce route discovery mechanism. OLSR has a least end-to-end delay if compared with others as it reduces rebroadcasting by using multicast relays but has a great routing overhead because of the use of source routing mechanism.

All the reactive protocols among which comparative study was done include AODV, DSR, and AOMDV. AODV is better regarding throughput, packet delivery ratio, an end to end delay and routing overhead. AOMDV has a very high routing overhead because of alternate route discovery. The complexity in designing is because of the various procedures used which are IAP, IERP, and BRP. It is also affected by various other parameters like zone radius etc. Hence, Hybrid protocols which were made to combine the advantages of proactive and reactive protocols resulted in an increase in complexity and decrease in its performance.

7. CONCLUSION AND FUTURE WORK

In this paper, a comparative performance review of different MANET routing protocols including proactive (DSDV, OLSR, and FSR), reactive (AODV, AOMDV and DSR) and Hybrid (ZRP) protocols is done. The simulated experiments were performed with increasing speed of mobile nodes from 10m/s to 40m/s. The performance of routing protocols is evaluated using four performance metrics throughput, packet delivery ratio, an end to end delay and routing overhead. It is observed from the simulated results, that there are small variations in the values of performance matrices for all routing protocols.

It is concluded that the variation in performance matrices for different routing protocols with an increase in the mobility of nodes in negligible. In future, it is proposed to evaluate the performance with higher mobility and increasing the load on the network by increasing the nodes and the packet size. The other performance matrices including average jitter etc. may also be used to evaluate the performance of routing protocols.

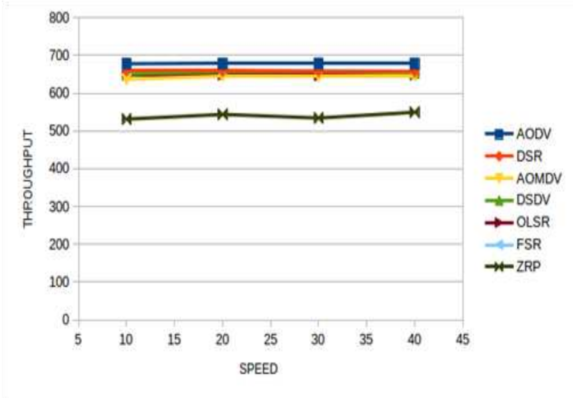

Figure 10. Throughput vs. Speed

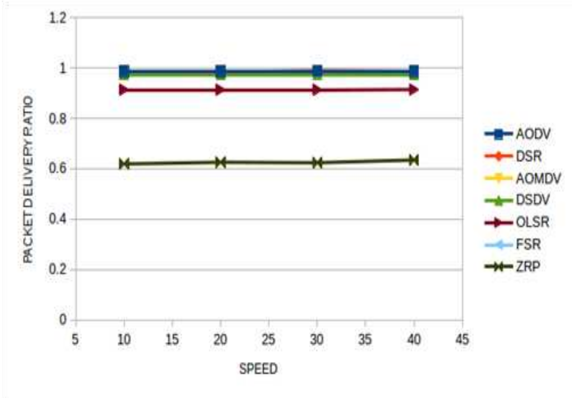

Figure 11. Packet Delivery Ratio vs. Speed

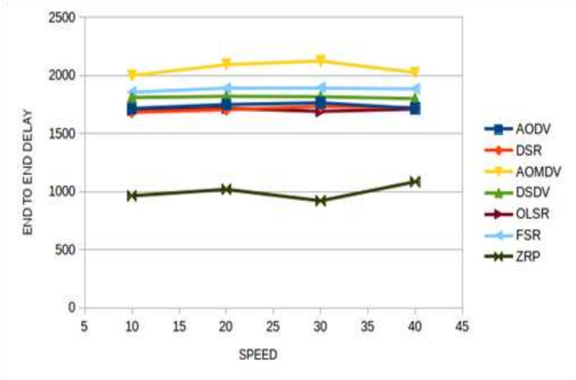

Figure 12. E2E Delay vs. Speed

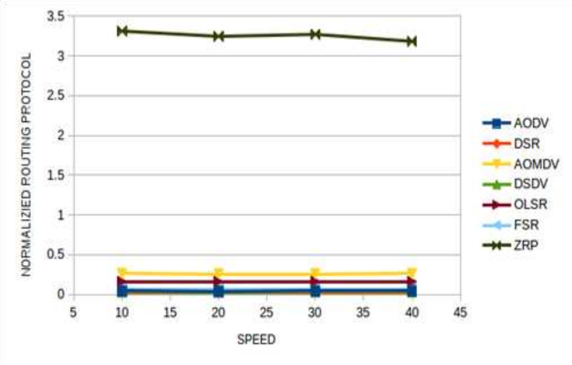

Figure 13. Routing overhead vs. Speed

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