Performance evaluation of TCP and UDP over FSR, DSR and ZRP in MANETs

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***Abstract*—No infrastructure, no centralized administration and self-configuration are the main characteristics of MANETs. The primary motivation of MANET deployment is to increase portability, mobility and flexibility. However, this mobility causes an unpredictable change in topology and makes routing more difficult. In this report we will show our conducted study with AODV (reactive), DSDV (proactive) and ZRP (hybrid) routing protocols. The performance of TCP and UDP over FSR (proactive), AODV (reactive) and ZRP (hybrid) routing protocols have been evaluated by analyzing the affects of changing network parameters such as, node speed and pause time on three performance metrics: throughput, average end-to- end delay and packet delivery ratio in GloMoSim. Our simulation results show that DSR gives better performance in all designed simulation models. Performance of FSR, ZRP is found average.**

Keywords- *TCP;UDP; MANET; Throughput; Average End-to-End delay; Packet Delivery Ratio*

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a self-configuring network that is formed and deformed on the fly by a collection of mobile nodes without the help of any prior infra-structure or centralized management. These networks are characterized as infrastructure less, mobile, autonomous, multi-hopped, self-administered, and having dynamic topology. Nodes within each other's radio range communicate directly via wireless links, while those that are far apart use other nodes as relays in a multi-hop routing fashion.

As mobile ad hoc networks are characterized by a multi-hop network topology that can change frequently due to mobility. Efficient routing protocols are needed to establish communication paths between nodes, without causing excessive control traffic overhead or computational burden on the devices. The routing protocols may generally be categorized as: Proactive, Reactive and Hybrid Routing protocols. Proactive protocol solutions exchange routing control information periodically and on topological changes. Reactive routing protocols only set up routes to nodes they communicate with and these routes are kept alive as long as they are needed. Hybrid routing protocols are proposed to combine the merits of both proactive and reactive routing protocols and overcome their shortcomings. Normally, hybrid routing protocols for mobile ad hoc networks exploit hierarchical network architectures.

Though there exist comparison of so many routing protocols, here FSR (proactive), DSR (reactive) and ZRP (hybrid) are considered for evaluating the performance of both TCP and UDP over MANETs.

II. RELATED WORK

Most recently, Ashish K. et al [4] evaluated AODV, FSR and ZRP for Scalable Networks. They performed simulations with the following two different scenarios for the performance evaluation of AODV, FSR and ZRP routing protocol.
(i). Network designed using random waypoint mobility model with different pause time.
(ii). Network designed using random waypoint mobility model with variable number of nodes.

Performance of AODV, FSR and ZRP routing protocol is evaluated with respect to four performance metrics such as average end to end delay, packet delivery ratio, throughput and average jitter. AODV shows best performance when compared with FSR and ZRP in terms of packet delivery ratio and throughput. AODV delivers more than 60 percent of all CBR packets when network is presented as a function of pause time and delivers more than 80 percent of all CBR packets when network is presented as a number of nodes.

Sree Ranga Raju, et al [5] compared the performance of DSR, AODV and ZRP, especially focusing on ZRP and the impact of some of its most important attributes to the network performance. They found that the performance of ZRP was not up to the task and it performed poorly throughout all the simulation sequences.

Ayyaswamy Kathirvel, et al [6] compared the performance of DSR, AODV, FSR and ZRP with respect to propagation model. Reactive routing protocols (AODV and DSR) have got good packet delivery ratio. When compared with proactive and hybrid routing protocols, hybrid routing protocol have got next higher packet delivery ratio. Similarly reactive routing protocols have got less delay and jitter.

S. Satish, et al [7] compared the performance of DSR, AODV, FSR and ZRP routing protocols for mobile Ad-hoc networks is presented as a function of pause time. Performance of these routing protocols is evaluated with respect to four performance metrics such as average end to end delay, packet delivery ratio, throughput and average jitter. According to our simulation results, DSR shows best performance than AODV, FSR and ZRP in terms of packet delivery ratio and throughput as a function of pause time. FSR show lowest end-to-end delay and ZRP has less average jittering than DSR, AODV and FSR.

III. OVERVIEW OF MANET ROUTING PROTOCOLS

Due to different routing techniques, mobile Ad Hoc protocols can be classified in to proactive (table-driven), reactive (on-demand) and hybrid (mix features of proactive and reactive routing). The following section further describes these routing techniques and routing protocols.

Reactive routing protocol: also called on-demand routing protocols. In on-demand routing, routes are only created and maintained when needed. Route discovery mechanism is used to find path. Path to the destination remains maintained until no longer needed or become inaccessible. AODV and DSR fall into this category.

Proactive routing protocol: also called table-driven protocols. Such protocols keep updated routing information at each node in the network. DSDV, FSR, OLSR and WRP fall into this category.

Hybrid routing protocols: these routing protocols have the features of both proactive and reactive routing. An example of such protocol is ZRP.

Based on the above stated routing strategies a variety of routing protocols have been developed so far. As far as the scope of this paper is concern, FSR, DSR and ZRP have been considered for simulation.

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A. Fisheye State Routing

Fisheye State Routing (FSR) [4] protocol is a proactive (table driven) ad hoc routing protocol and its mechanisms are based on the Link State Routing protocol used in wired networks. FSR is an implicit hierarchical routing protocol. It reduces the routing update overhead in large networks by using a fisheye technique. Fisheye has the ability to see objects the better when they are nearer to its focal point that means each node maintains accurate information about near nodes and not so accurate about faraway nodes. The scope of fisheye is defined as the set of nodes that can be reached within a given number of hops. The number of levels and the radius of each scope will depend on the size of the network. Entries corresponding to nodes within the smaller scope are propagated to the neighbors with the highest frequency and the exchanges in smaller scopes are more frequent than in larger. That makes the topology information about near nodes more precise than the information about far away nodes. FSR minimized the consumed bandwidth as the link state update packets that are exchanged only among neighboring nodes and it manages to reduce the message size of the topology information due to removal of topology information concerned far-away nodes. Even if a node doesn't have accurate information about far away nodes, the packets will be routed correctly because the route information becomes more and more accurate as the packet gets closer to the destination. This means that FSR scales well to large mobile ad hoc networks as the overhead is controlled and supports high rates of mobility.

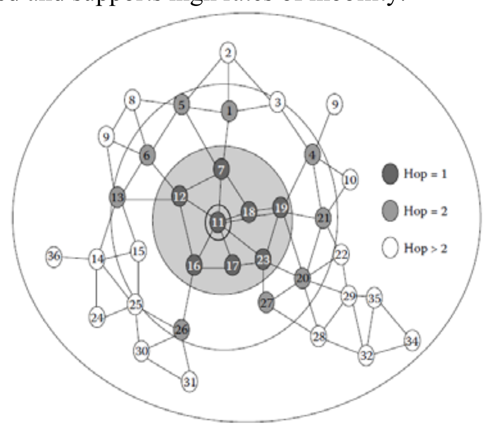

Figure 1 Fisheye Scope

Figure 1 illustrates how the fisheye technique is applied to a MANET. When the size of a network increases, sending update messages may potentially consume the bandwidth. FSR uses the fisheye technique to reduce the size of the update message without affecting routing. In the figure, three fisheye scopes are defined with respect to the focal point, node 11.

B. Dynamic Source Routing

The Dynamic Source Routing protocol is composed of two main mechanisms to allow the discovery and maintenance of source routes in the ad hoc networks.

Route Discovery: It is the mechanism by which a source node to send a packet to a destination node, obtains a source route to the destination. Route discovery is used only when the source node attempts to send a packet to a destination and does not already know a route to that destination.

Route Maintenance

Route maintenance can be accomplished by two different processes:

- Hop-by-hop acknowledgement at the data link layer
- End-to-end acknowledgements

Hop-by-hop acknowledgement at the data link layer allows an early detection and retransmission of lost or corrupt packets. If the data link layer determines a fatal transmission error (for example, because the maximum number of retransmissions is exceeded), a ***route error*** packet is being sent back to the sender of the packet.

*C. Zone **Routing Protocol (ZRP)***

In a mobile ad-hoc network, it can be assumed that most of the communication takes place between nodes close to each other. The Zone Routing Protocol (ZRP) takes advantage of this fact and divides the entire network into overlapping zones of variable size. It uses proactive protocols for finding zone neighbors (instantly sending *hello* messages) as well as reactive protocols for routing purposes between different zones (a route is only established if needed). Each node may define its own zone size, whereby the zone size is defined as number of hops to the zone perimeter. For instance, the zone size may depend on signal strength, available power, reliability of different nodes etc. While ZRP is not a very distinct protocol, it provides a framework for other protocols.

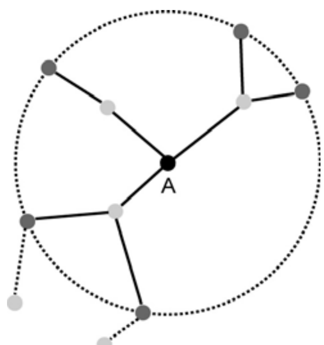

Figure 2. ZRP - Routing Zone of Node A, ρ = 2

First of all, a node needs to discover its neighborhood in order to be able to build a zone and determine the perimeter nodes. In Figure 5, all perimeter nodes are printed in dark gray color –they build the border of A's zone with radius ρ = 2. The detection process is usually accomplished by using the *Neighbor Discovery Protocol* (NDP). Every node periodically sends some ***hello*** messages to its neighbours. If it receives an answer, a point-to-point connection to this node exists. Nodes may be selected by different criteria, be it signal strength, radio frequency, delay etc. The discovery messages are repeated from time to time to keep the map of the neighbors updated.

The routing processes inside a zone are performed by the *Intrazone Routing Protocol* (IARP). This protocol is responsible for determining the routes to the peripheral nodes of a zone. It is generally a proactive protocol. An other type of protocol is used for the communication between different zones. It is called *Interzone Routing Protocol* (IERP) and is only responsible for routing between peripheral zones. A third protocol, the *Bordercast Resolution Protocol* (BRP) is used to optimize the routing process between perimeter nodes. Thus, it is not necessary to flood all peripheral nodes, what makes queries become more efficient. Below, the three protocols are described in more detail.

Intrazone Routing Protocol (IARP): The IARP protocol is used by a node to communicate with the other interior nodes of its zone. An important goal is to support unidirectional links, but not only symmetric links. It occurs very often, that a node A may send data to a node B, but node B cannot reach node A due to interference or low transmission power for example. IARP is limited to the size of the zone ρ. The periodically broadcasted route discovery packets will be initialized with a Time To Live (TTL) field set to $\rho-1$. Every node which forwards the packet will now decrease this field by one until the perimeter is reached. In this case, the TTL field is 0 and the packet will be discarded. This makes sure that an IARP route request will never be forwarded out of a node's zone. As already mentioned, IARP is a proactive, table-driven protocol for the local neighborhood may change rapidly, and changes in the local topology are likely to have a bigger impact on a nodes routing behavior than a change on the other end of the network. Proactive, table driven routing delivers a fast, efficient search of routes to local hosts. Local routes are immediately available. Therefore, every node periodically needs to update the routing information inside the zone. Additionally, local route optimization is performed. This includes the following actions:
• Removal of redundant routes
• Shortening of routes, if a node can be reached with a smaller number of hops
• Detecting of link failures and bypassing them through multiple local hops

*Interzone Routing Protocol (IERP):*The Interzone Routing Protocol is used to communicate between nodes of different zones. It is a reactive protocol and the route discovery process is only initiated on demand. This makes route finding slower, but the delay can be minimized by use of the Bordercast Resolution Protocol. IERP takes advantage of the fact that IARP knows the local configuration of a zone. So a query is not submitted to all local nodes, but only to a node's peripheral nodes. Furthermore, a node does not send a query back to the nodes the request came from, even if they are peripheral nodes.

Bordercast Resolution Protocol (BRP): The Bordercast Resolution Protocol is rather a packet delivery service than a full featured routing protocol. It is used to send routing requests generated by IERP directly to peripheral nodes to increase efficiency. BRP takes advantage of the local map from IARP and creates a bordercast tree of it. The BRP employs special query control mechanisms to steer route requests away from areas of the network that have already been covered by the query. The use of this concept makes it much faster than flooding packets from node to node.

IV. PERFORMANCE METRICS

We have considered three performance metrics, the packet delivery fraction, average end-to-end delay and throughput. All metrics are measured quantitatively. Following is description of each metrics.

Packet Delivery Ratio (PDR): It is ratio of successfully delivered data packets to packets generated by CBR sources. Packets delivery ratio describes how successfully protocol delivers packet from source to destination.

PDR = (ΣCBR pkt rec ⁄ ΣCBR pkt sent) * 100

Average end-to-end delay: This performance metric defines all possible delays. There are many factors causing delay in network, such as, queuing delay, buffering during routes discovery, latency and retransmission delay. Lower delay means better performance.

$$\text{Average End-to-End delay} = \frac{1}{N}\sum_{n=1}^{N}(Rn - Sn)$$

Sn = Time, when data packet *n* was sent
Rn = Time, when data packet *n* was received
N = Total number of data packets received

*Throughput***:** It is ratio of the total number of bits received to the total time taken.
Throughput= Total number of bits received / Total time taken
Where total time taken = time at which last packet received – time at which first packet sent.

All performance metrics are analyzed under varying network parameters such as pause time, varying speed.

TABLE I. SIMULATION PARAMETERS

Parameters	Environment
Area	1000m*1000 m
Simulation time	600 sec
Transmission range of a node	251.820 m
Transmission Power	8dBm
Temperature	290.0 K
Node density	100
Routing Protocols	FSR,DSR,ZRP
Mobility model	Random Waypoint mobility model

V. SIMUALTION RESULTS

A. PERFORMANCE EVALUATION OF TCP

This section analyses the performance of TCP over three routing protocols with respect to pause-time model and node speed model.

Pause-time model: As pause time increases, mobility (movement) decreases. When a pause time occurs, node stops for a while and selects another direction to travel. In this model pause time changes from 50s to 250s while other parameters (nodes = 100, speed = 5 m/s, data sending rate = 2Mbps are constant.

Figure 3 shows throughputs for three routing protocols with respect to pause time. DSR shows consistency compared to FSR and ZRP as pause-time increases beyond 50sec. Here relative mobility of nodes is higher at pause-time 50sec compared to others, so occurrence of link failures are more. In Reactive routing protocols, source has to initiate the process of route reestablishment and hence throughput of DSR is slightly lower than throughput of ZRP.

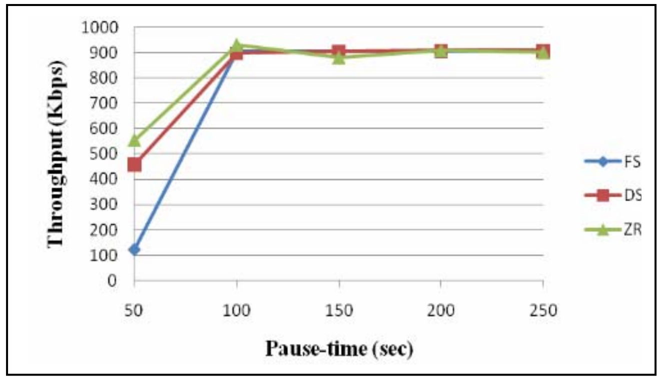

Figure 3. Pause time vs Throughput.

Figure 4 shows Avg. end-to-end delay for three routing protocols with respect to pause time. DSR Routing protocol outperforms all other routing protocols. ZRP uses Interzone Routing Protocol to communicate between nodes of different zones. It is a reactive protocol and the route discovery process is only initiated on demand. Hence delay is relatively more.

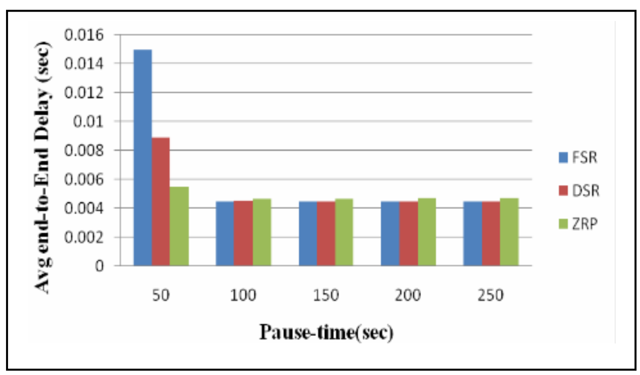

Figure 4. Pause time vs Average End-to-End Delay.

Speed model: Speed of nodes play an important role in mobile Ad Hoc networks. In this model the node's speed changes from 2 m/s to 6 m/s with 50s pause time. Other parameters like sending rate 2Mbps, no. of nodes 100 are kept constant.

Figure 5 shows Throughput for FSR, DSR and ZRP with respect to node speed. As speed increases, number of route failures will be more. In DSR, each node maintains a route cache that contains the source routes learned by the node. Hence DSR has high throughput compared to other routing protocols.

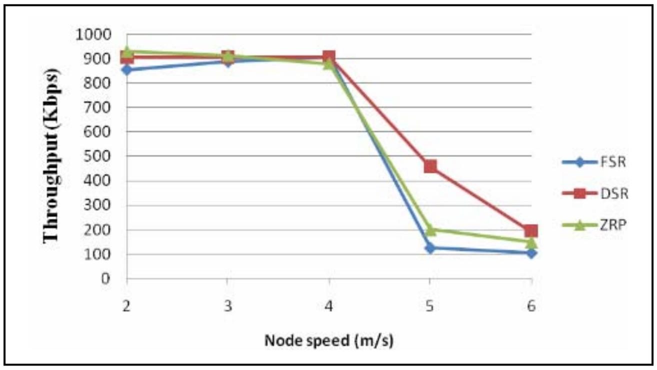

Figure 5. Node speed vs Throughput.

Figure 6 shows Average end-to-end delay for FSR, DSR and ZRP with respect to node speed. It shows that the average end-to-end delay increases as speed increases. Proactive protocol (FSR) solutions exchange routing control information periodically and on topological changes. Hence Average end-to-end delay is more for FSR.

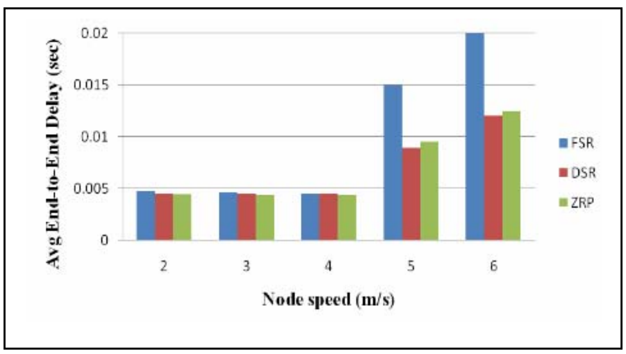

Figure 6. Node speed vs Average end-to-end delay.

B. PERFORMANCE EVALUATION OF UDP

This section analyses the performance of UDP over three routing protocols based on testing models.

Pause-time model: As pause time increases, mobility (movement) decreases. When a pause time occurs, node stops for a while and selects another direction to travel. In this model pause time changes from 0s to 250s while other parameters (nodes = 100, speed = 25 m/s, data sending rate = 2Mbps and CBR flows = continuous) are constant.

Figure 7 shows throughputs for FSR, DSR and ZRP with respect to pause time. DSR outperforms over FSR and ZRP. In ZRP, IARP route request will never be forwarded out of a node's zone. As mobility increases, throughput of ZRP gradually decreases.

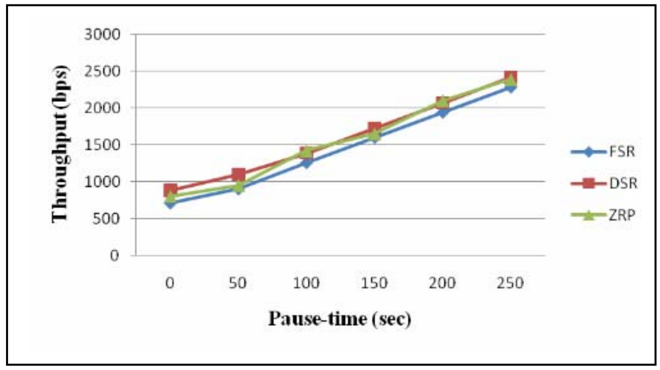

Figure 7. Pause time vs Throughput.

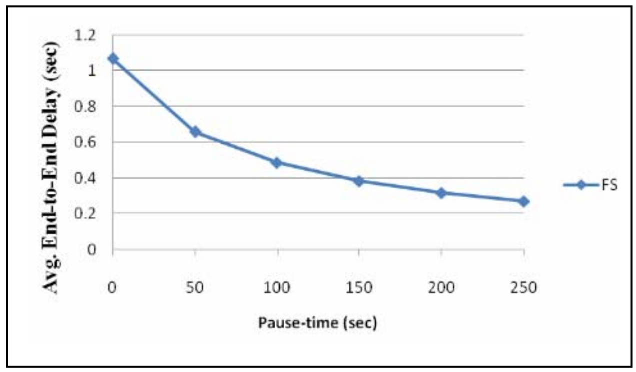

Figure 8. Pause time vs Average end-to-end delay.

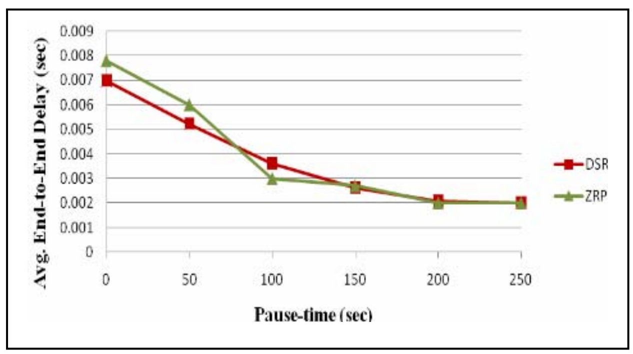

Figure 9. Pause time vs Average end-to-end delay

Figure 8 and Figure 9 show Avg. end-to-end delay for FSR, DSR and ZRP with respect to pause time. FSR shows relatively higher end-to-end delay because as the network size grows large, a "graded" frequency update plan must be used across multiple scopes to keep the overhead low. Clearly, this consumes a considerable amount of bandwidth when the network size becomes large. End-to-end delay in DSR consistently decreases as network is getting stabilized.

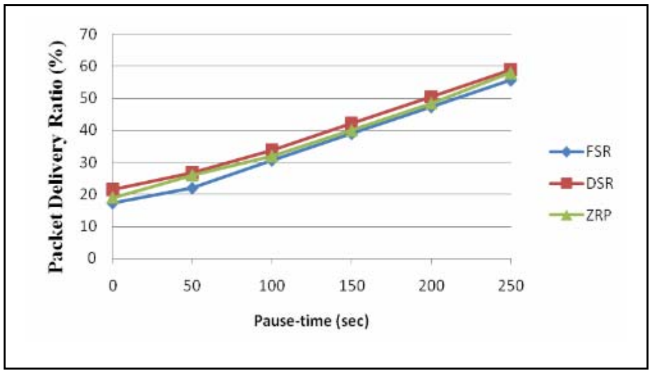

Figure 10. Pause time vs Packet Delivery Ratio

Figure 10 shows Packet delivery ratio for FSR, DSR and ZRP with respect to pause time. As pause-time increases, network stability also increases. Hence, all three routing protocols show consistent improvement in delivering packets.

Speed model: Speed of nodes play an important role in mobile Ad Hoc networks. In this model the node's speed changes from 10 m/s to 50 m/s with 25s pause time. Other parameters like sending rate 2Mbps, no. of nodes 100, and CBR flows continuous are kept constant.

Figure 11 shows Throughput for FSR, DSR and ZRP routing protocols with respect to node speed. As speed increases, number of route failures will be more. Compared to FSR protocol, less control overhead is a distinct advantage of DSR protocol. Thus, DSR protocol has better scalability than FSR. Hence DSR has high throughput compared to other routing protocols.

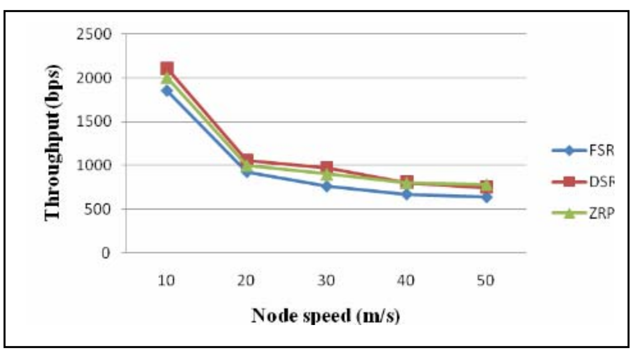

Figure 11. Node speed vs Throughput.

Figure 12 and Figure 13 show differences in Average end-to-end delay for FSR, DSR and ZRP with respect to node speed. It shows that the average end-to-end delay increases as speed increases. Here it is observed that ZRP possesses a constant average end-to-end delay when a node attains speed between 20 to 40 m/sec which shows the behavior of Intra zone protocol as an advantage. FSR shows higher average end-to-end delay among all three routing protocols. DSR does not show relatively much difference once the nodes attain speed of 20 to 50 m/s.

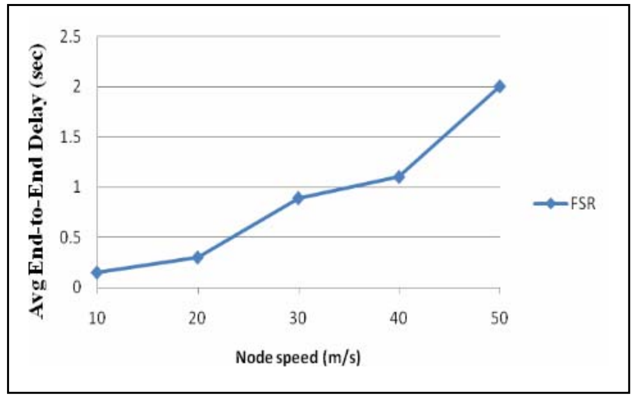

Figure 12 Node speed vs Average end-to-end delay.

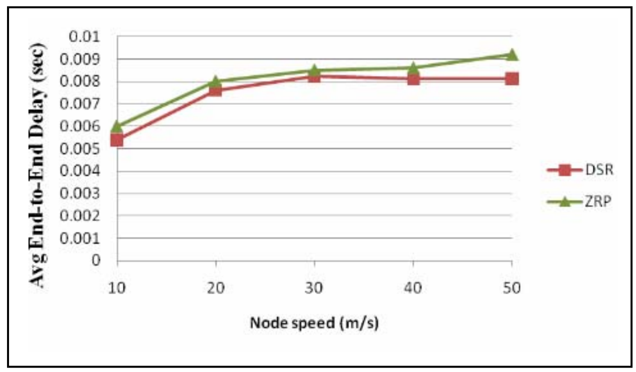

Figure 13 Node speed vs Average end-to-end delay

Figure 14 shows Packet delivery ratio for FSR, DSR and ZRP with respect to node speed. As node speed increases, network stability decreases. Hence, all three routing protocols have shown gradual decrease in delivering packets.

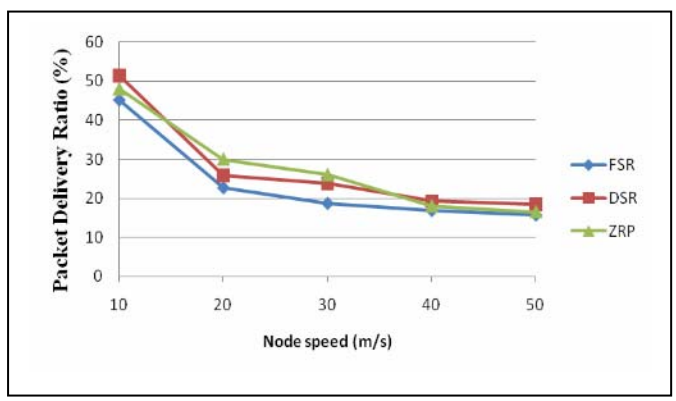

Figure 14 Node speed vs Packet delivery ratio

VI. CONCLUSION AND FUTURE WORK

All three performance metrics namely, Throughput, Average end-to-end delay and Packet delivery ratio have been simulated and evaluated with respect to pause time and node speed over FSR (proactive), DSR (reactive) and ZRP (hybrid) for both TCP and UDP in GloMoSim.

It is observed from the simulation that compared to the proactive routing protocols for mobile ad hoc networks, less control overhead is a distinct advantage of the reactive routing protocols. Thus, DSR (reactive) exhibits better performance over TCP and UDP than FSR (proactive) and ZRP (hybrid) in MANETs.

As the simulation studies were conducted based on Random way point mobility, Zone Routing Protocol (ZRP) has not taken much advantage of Interzone Routing Protocol (IERP) which is responsible for routing between peripheral zones. The performance metrics can also be evaluated and analyzed by considering other mobility models such as Reference Point Group mobility (RPGM), Gauss Markov mobility and Manhattan grid mobility models.

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