Improved Zone Routing Protocol with Reliability and Security using QualNet Network Simulator

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Abstract- ***Zone Routing Protocol is a hybrid routing protocol in MANET. In real life scenario some links in MANET are unreliable due to interfering signals from neighboring network, ambient noise in the system and jamming signal from malicious nodes. These types of links are not accounted for in ZRP resulting in lower throughput, higher end-to-end delay and jitter. Furthermore zone radius is fixed in ZRP resulting in frequent zone switching for highly mobile nodes thereby increasing the control and maintenance overhead. Furthermore in ZRP border casting is used which does not guarantees shortest routing path and as consequence MZRP was developed which uses broadcasting and guarantees shortest path but with no path reliability and fixed zonal radius. We propose modified secure and efficient version of the MZRP coined as M^2ZRP which takes into account the link SNR value as a measure of its reliability and security and also introduces the concept of variable zone radius. QualNet network simulator is used to evaluate the performance of M^2ZRP over ZRP and MZRP in two different network scenarios consisting of 50 and 80 mobile nodes respectively considering two different mobility models i.e. Random Way Point (RWP) and Group mobility model (GM). Results indicate a considerable improvement in throughput, end-to-end delay and jitter with enhanced reliability and security.***

Keywords **– MANET, ZRP, IARP, IERP, BRP, MZRP, M^2ZRP, RWP, SNR, GPS, Group Mobility, Proactive Routing, Reactive Routing, Hybrid Routing, Throughput, Jitter, End-to-End Delay.**

1. MANET.

A Mobile Ad Hoc Network (MANET) [11] consists of independent mobile nodes which communicate with each other over wireless radio links in an infrastructure less setup. The nodes generate their own data packets and forward others i.e. they act both as terminal and router. The routes between the nodes changes rapidly due to node mobility. So dynamic on demand routing protocols are needed in most of the application areas of MANET. They must be capable of handling unreliable links due to interference from nearby networks. The malicious nodes or selfish nodes selectively forwards its own traffic while dropping others and also advertises false routes through them. It is desirable for routing protocols to detect and avoid such nodes and further they should be scalable in order to adapt itself with the change in network size (i.e. number of nodes).

1.1. Routing Protocols in MANET.

They are divided into three broad classes namely proactive, reactive and hybrid (combination of proactive and reactive routing) [11]. In proactive or table driven routing protocol every node maintains a routing table containing information of the network topology. The routing table contents changes with time due to the topology change as a result of node mobility. The table size is large as it contains information of all the nodes in the network. DSDV, STAR etc. fall under this category. Reactive/on demand routing protocol dynamically initiates the route discovery process when needed. It is a lazy approach and its main aim is to reduce the size and maintenance overhead of the routing table. DSR, AODV and DYMO are typical examples of this category. Hybrid protocols like ZRP, TORA combine the salient features of both proactive and reactive approach to exploit the advantages of both.

2. Zone Routing Protocol (ZRP).

Zone Routing Protocol (ZRP) [8, 9, 10] defines a network with a number of virtual, overlapping routing zones. For every node there exists a zone with radius k hops i.e. all the nodes within k hop distance from the particular node is an element of that node's routing zone. The nodes on the circumference of a zone i.e. at hop k are referred to as peripheral nodes and other nodes within the zone are coined as interior nodes. ZRP combines two sub-protocols, a proactive routing protocol: Intra Zone Routing Protocol (IARP) [6], used inside routing zones and a reactive routing protocol: Inter Zone Routing Protocol (IERP) [7], used between routing zones. A route to a destination within a node's routing zone is directly established from the routing table of that node by IARP subcomponent of ZRP otherwise the node creates a border casting tree and sends a route request (RREQ) packet to its peripheral nodes containing its own address, destination address and a unique sequence number (Seq_No.) as a part of IERP subcomponent of ZRP. The value of this Seq_No is one more than the previous RREQ for the same source destination pair. Seq_No is used to ensure that the same RREQ(S, D) that was previously received at node I will be rejected if received again at node I. However new RREQ(S, D) will be received and processed at node I because the Seq_No is updated (i.e. incremented by 1). The peripheral nodes again first invoke IARP. If it fails i.e. the destination node is not a member of the routing zone of the peripheral node then the peripheral node initiates the IERP subcomponent of ZRP. The process continues until the destination is reached. The destination node sends a route reply (RREP) on the reverse path back to the source and the intermediate routers make the necessary changes in their routing table thereby establishing the path.

3. Modified Zone Routing Protocol (MZRP).

In Modified Zone Routing Protocol (MZRP), Ghosh et al. [1] modified the IERP route discovery process of ZRP so that a node broadcasts the RREQ packets in its immediate neighborhood and the process continues until the RREQ reaches the destination node. Here the intermediate nodes like ZRP add its own address to the header field in RREQ before broadcasting to its neighborhood so that the RREQ's reaching the destination node have the entire path from the source to the destination stored in its header. When the destination receives the RREQ it sends a route reply packet (RREP) to the source node through the selected reverse path and thereby establishing the route from the source to the destination. The route found out in ZRP using BRP during the route discovery phase may not be the shortest. If the destination is unavailable within a nodal zone then peripheral nodes are searched for that zone and RREQ are multicast to them which takes a considerable amount of time. But MZRP always finds out the shortest route between two nodes belonging to different zones by broadcasting RREQ without searching for peripheral nodes. It contributes to reduction in searching time and control packet overhead leading to improvement in overall network throughput, end-to-end delay and jitter in comparison with ZRP.

4. Mobility Models.

Mobility model [14] emulates the real life movement of mobile nodes with respect to their location, velocity and direction of motion as a function of time. It should accurately predict the actual node movement with minimum deviation. MANETs have a wide range of applications with each having its own node movement pattern requiring different mobility models to cater for them. When simulating a MANET protocol for a specific application, it is necessary to choose the proper mobility model for the scenario There are different kinds of mobility models defined in literature but in our work we confine ourselves to Random Way point Mobility (RWP) [4] model and Group Mobility (GM) [5] model.

4.1. Random Way Point Mobility Model.

Random Way Point (RWP) [4] model is a commonly used synthetic model for node mobility in Ad Hoc networks. It is an elementary model which describes the movement pattern of independent nodes in simple terms.

The characteristics of RWP are briefly summarized below:

I. Each node moves along a straight line in a zigzag fashion from one waypoint to the next.

II. The waypoints are uniformly distributed over the deployment area.

III. The node velocities are randomly selected from a given range.

IV. Optionally, the nodes may have so called "thinking times" by which when they reach a waypoint they choose a random pausing time independent of each other before continuing to the next one.

4.2. Group Mobility.

Group Mobility (GM) model divides the whole set of nodes into a number of subsets known as groups based on certain mathematical criteria. The node mobility within a group is random. Different groups move randomly as a unit independent of each other within the deployment area. Group movements are based upon the path traveled by a logical center for the group. It is used to calculate group motion. The motion of the group center completely characterizes the movement of this corresponding group of mobile nodes including their direction and speed. Individual mobile nodes randomly move about their own predefined reference points whose movements depend on the group movement [5].

5. Network Parameters.

There are a number of metrics [15] based on which performance of a routing protocol is evaluated. In our work we have used throughput, end-to-end delay, response time and jitter.

5.1. Throughput.

Throughput is defined as the average data transfer rate in Kbits/sec measured between a source and destination. It is an important QoS in multimedia based applications, video streaming, teleconferencing and others. Throughput is adversely affected due to network congestion and signal interference from other nearby networks.

5.2. End-to-End Delay.

The end-to-end delay [12] is the time taken by a packet to move from source to destination node and is calculated by the elapsed time when a packet is sent by the source node to the time when it is received at the destination node. This includes all possible delays like buffering, queuing and processing at intermediate routers. MAC layer delays are also included in the above. This metric is important in time-critical and real life applications, where fast and timely delivery of messages is crucial.

5.3. Jitter.

Jitter [13] is defined as the variation of a signal's instants from their ideal positions in time i.e. the deviation from the ideal timing of an event. Jitter arises due to the variation of packet delay i.e. the variation in time between packets arriving, caused by network congestion or route changes. For an example, say packets are transmitted to the receiver every 20 ms. Now if the 2nd packet is received 30 ms after the 1st packet, then jitter is −10 ms. This is referred to as dispersion. If the 2nd packet is received 10 ms after the 1st packet, jitter will be +10 ms. This is referred to as clumping. In a communication system, the accumulation of jitter will eventually lead to data errors.

5.4. Response Time.

It is the time interval between the first packet sent from CBR client and received in CBR server. It is same as the end-to-end delay except here we are concerned only with the first packet. In some situations the delivery of the first data packet sent might be of interest. For example, if a sensor network is deployed as some kind of warning system, delivery of the very first packet could be important. So response time must be minimized in those cases.

6. Proposed Work.

In our work we have incorporated two features namely variable routing zone radius and link reliability to the existing ZRP and MZRP protocols and have coined the new method as M^2ZRP which exhibits a better performance in throughput, delay and jitter. We have considered two scenarios with random node placement and different mobility models namely Random Waypoint and Group Mobility.

6.1. Variable Routing Zone Radius.

In traditional ZRP and MZRP the radius for all zones are fixed and they never change during the protocol execution. So whenever velocity of a particular node increases it leaves its current zone and enters into other zone leading to a change in zonal members of different zones. For frequent node velocity change this addition/deletion of zonal members are rapid. This considerably increases the overhead related to zone maintenance i.e. updating the information of member nodes of a zone in the routing table of the zone's central node. As a consequence throughput decreases while increasing end-to-end delay and jitter. To reduce this overhead in M^2ZRP we propose a variable routing zone radius proportional to the velocity of a node. The motivation behind this in the reasoning that the routing zone members of a low mobility node changes slowly in comparison to a high mobility node. So making the zone radius proportional to the node velocity results in a less frequent change in zonal members which in turn leads to low overhead for routing table maintenance for central zonal nodes. Node velocity can be measured by GPS (Global Positioning System).

6.2. Link Reliability.

Wireless links are subjected to interference from nodes in nearby networks and also malicious nodes as a result their bandwidth decreases significantly. It affects the throughput of all the paths which passes through the link. In ZRP and MZRP we do not take into account link reliability. As a remedial solution in our work, the RREQ packet includes an additional field, ROUTE_SNR, to store SNR value of the path so far traversed by the RREQ packet. If any non destination node receives the RREQ packet then it rebroadcasts the packet after updating the ROUTE_SNR field with the SNR feedback from the physical layer. On the other hand when the destination node receives a RREQ then it compares the SNR value associated with each possible path between the source destination contained in the RREQ and selects the path with maximum ROUTE_SNR field value subject to the constraint of it being greater than a predefined threshold ($SNR_{Threshold}$=10dB in our method). This path is expected to give maximum throughput, minimum delay and jitter [2] as its interference level is less and offers greater bandwidth in comparison to the other path alternatives.

6.3. Algorithm for M^2ZRP.

We propose algorithms for determining variable zone radius and routing path reliability respectively.

6.3.1. Algorithm for Variable Zone Radius.

Input: Network Topology, Node Velocity **V** for node **N**.

Output: Zonal Radius **K** for node **N**.

Terminology Used.

S : Source node, **D** : Destination node, **I** : Intermediate node, **RREQ(S, D)**: Route request packet for source-destination node pair S and D, **Seq_No**(**RREQ**(**S, D**)): Sequence Number generated by node S for route request packet for destination D. This value is one more than the previous route request for the same source destination pair, **Prev_Seq_No(S, I, D)**: Sequence Number of previous RREQ(S, D) received at node I, **K**: Zone radius, **V**: Velocity of a node in **mps** (Meter per second).

BEGIN PROCESS

IF ((**RREQ(S, D**)) received at (**I ≠ D)** && (**Seq_No** (**RREQ(S, D)**)) > **Prev_Seq_No(S, I, D)**) **then**

I. If 0 ≤ **V ≤ 5** then set **K = 2 hops.**
II. If 5 < **V ≤ 10** then set **K = 3 hops.**
III. If 10 < **V ≤ 15** then set **K = 4 hops.**
IV. If 15 < **V ≤ 20** then set **K = 5 hops.**

END IF

END PROCESS

Here we have limited ourselves to four velocity ranges.

6.3.2. Algorithm for Routing Path Reliability.

Input: Network Topology**, Link SNR, S, D.**

Output: Routing path between **S** and **D** having highest **ROUTE_SNR.**

Terminology Used.

RREP (D, S): Route Reply packet for destination-source node pair D and S, **ROUTE_SNR**: Minimum SNR value of a link in the route, **$SNR_{Threshold}$:** Minimum acceptable value of SNR of a link assumed to be ≥ 10dBm.

BEGIN PROCESS

IF ((**RREQ(S, D**)) received at **I (I ≠ D**) & (**Seq_No** (**RREQ(S, D)**)) > **Prev_Seq_No(S, I, D)**) **then**

Step 1. Among all **RREQ(S, D)** select the one that has highest **ROUTE_SNR.**

Step 2. Calculate **SNR** of all the links from physical layer at node **I** except **RREQ(S, D)** arrival link.

Step 3. Update **ROUTE_SNR** field of **RREQ(S, D)** for all possible link to be forwarded from **I**.

Step 4. RREQ(S, D) packets having **ROUTE_SNR** ≥ **$SNR_{Threshold}$** are forwarded from **I**.

END IF

ELSE //[i.e. **I = D]** but (Seq_No(RREQ(S, D))) > //Prev_Seq_No(S, I, D))

Step 1. Among all **RREQ (S, D)** select the one that has highest **ROUTE_SNR.**
Step 2. Send **RREP (D, S)** using that path.
END ELSE
END PROCESS

7. Simulation Environment and Results.

We have considered two different network scenarios with one having 50 nodes and the other having 80 nodes randomly deployed over the deployment region. QualNet 4.5 network simulator is used to extensively simulate the above mentioned topologies. User Datagram Protocol (UDP) is used as the transport layer protocol and Constant Bit Rate (CBR) data traffic is applied between source and destination as the application layer protocol. We have considered a deployment area of 1500m X 1500m with 50 and 80 nodes randomly distributed over the said deployment area in the first and second scenario respectively. In the first scenario 7 different CBR traffics are applied between 7 different source destination pairs namely (1, 39), (4, 37), (18, 11), (45, 27), (36, 13), (42, 40) and (16, 22) respectively as depicted in figure 1. In the second scenario 8 different CBR traffics are applied between 8 different source destination pairs namely (1, 57), (77, 79), (41, 30), (6, 9), (53, 65), (32, 25), (80, 68) and (22, 49) respectively as shown in figure 2. In both the scenarios Random Waypoint (RWP) and Group mobility (GM) node mobility models are considered separately. Table 1 lists different simulation parameters considered in our work.

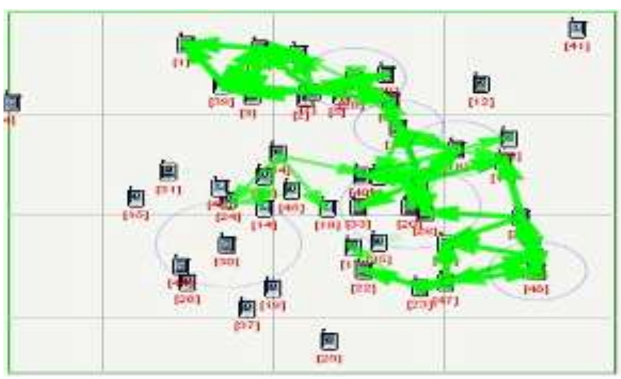

Figure 1. First Network scenario comprising of randomly deployed 50 nodes with 7 different source destination pairs.

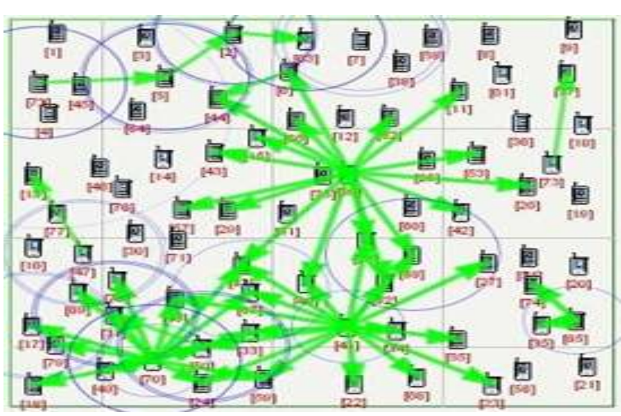

Figure 2. Second network scenario comprising of randomly deployed 80 nodes with 8 different source destination pairs.

Table 1: Simulation Parameters

Parameter	**Value**
Area	1500m X 1500m
Data Rate	4 Mbps
Packet Size	1024 bytes
Mobility Model	Random Way Point, Group Mobility
Physical Layer Radio Type	IEEE802.11b, Abstract
MAC Protocol	IEEE 802.11
Antenna Model	Omni directional
Temperature	290 K
SNR Threshold	10 dBm
Receive Sensitivity	-50 dBm
Transmission Power	25 dBm
Number of Mobility Group	3

7.1. Throughput.

We have measured end to end throughput in Kbits/sec and the simulation results indicate that M^2ZRP produces a significant improvement in throughput over both the scenarios considering RWP and GM mobility models with respect to ZRP and MZRP protocols. The results are shown in table 2 and 3 as well as in figure 3 and 7. The results are indicative of the fact that M^2ZRP considers links having SNR value above a given threshold which results in links having less interference from other networks and higher bandwidth in comparison to the other two protocols.

Table 2: Comparison of Throughput (Kbits/sec) using RWP Mobility

	ZRP	**MZRP**	**M^2ZRP**
50 nodes	27.900	28.100	29.425
80 nodes	18.45	21.50	30.80

Table 3: Comparison of Throughput (Kbits/sec) using GM

	ZRP	**MZRP**	**M^2ZRP**
50 nodes	4.4	21.5	29.1
80 nodes	4.4	33.6	45.9

7.2. End-to-End Delay.

M^2ZRP exhibits low end-to-end delay for every source destination pair and on the average as well because the zone radius is varied in proportion to the velocity of the mobile nodes. As a result the number of routing zones and zone switching of nodes are minimized and as a consequence there is a reduction in the total number of times IARP and IERP are applied during the route discovery phase resulting in a lower end-to-end delay. The results are shown in table 4 and 5 and as well as in figure 4 and 8 respectively.

Table 4: Comparison of Average End-to-End Delay (in µsec) using RWP Mobility

	ZRP	**MZRP**	**M^2ZRP**
50 nodes	6.457	2.628	0.815
80 nodes	24.875	13.216	9.175

Table 5: Comparison of Average End-to-End Delay (in µsec) using GM

	ZRP	**MZRP**	**M^2ZRP**
50 nodes	4.571	1.536	0.846
80 nodes	4.062	1.925	0.939

7.3. Jitter.

In M^2ZRP links with low interference and high stability are used to deliver data packets. Also routing path congestion is reduced and consequently the time gap between the transmissions of consecutive packets is reduced and becomes more or less constant. As a cumulative result of all the above factors the average jitter decreases and the results are shown in table 6 and 7 and as well as in figure 5 and 9 respectively.

Table 6: Comparison of Average Jitter (in µsec) using RWP Mobility

	ZRP	MZRP	M^2ZRP
50 nodes	0.9557	0.5837	0.2174
80 nodes	3.2250	2.4731	1.8750

Table 7: Comparison of Average Jitter (in µsec) using GM

	ZRP	MZRP	M^2ZRP
50 nodes	0.4571	0.2571	0.0658
80 nodes	3.3375	2.1642	1.9129

7.4. Response Time.

Response time decreases in our method due to the low average end-to-end delay. The results are shown in table 8 and 9 and as well as in figure 6 and 10 respectively.

Table 8: Comparison of Response Time (in sec) using RWP Mobility

	ZRP	MZRP	M^2ZRP
50 nodes	11.00	1.03	0.80
80 nodes	14.20	1.25	1.02

Table 9: Comparison of Response Time (in sec) using GM

	ZRP	MZRP	M^2ZRP
50 nodes	11.00	1.02	0.85
80 nodes	11.00	1.02	0.70

8. Conclusion and Future Scope.

The simulation results indicate that M^2ZRP performs better than both ZRP and MZRP considering both RWP and GM mobility models. Furthermore it avoids noisy links by choosing the Route Request (RREQ) packets having highest SNR value which enhances link reliability and system throughput while at the same time reducing end-to-end delay and jitter with respect to ZRP and MZRP. As future work attempt may be made to reduce the control packets during the route discovery phase which will reduce network congestion and also energy consumption per node will be reduced leading to higher average network lifetime. The detection and isolation of malicious node may be incorporated in the routing protocol to increase system security. In our work, we have considered only RWP and GM mobility model with random node placement strategy. The other mobility models such as Random Walk, Gauss-Markov, Pedestrian, Manhattan and others might be considered with different node placement strategies such as grid etc.

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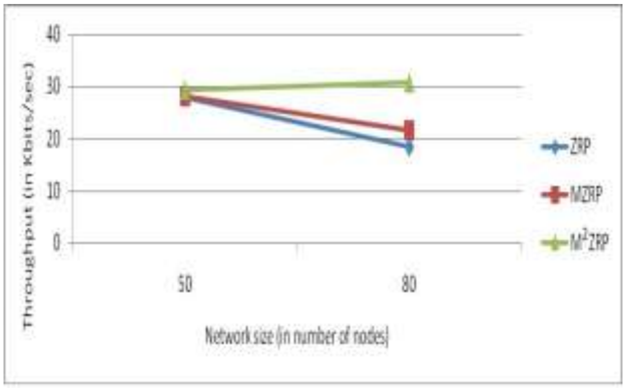

Figure 3: Throughput comparison using Random Way Point (RWP) node mobility model.

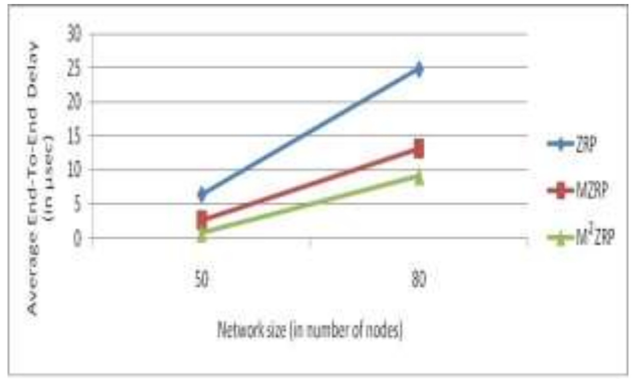

Figure 4: Average End-To-End Delay comparison using Random Way Point (RWP) node mobility model.

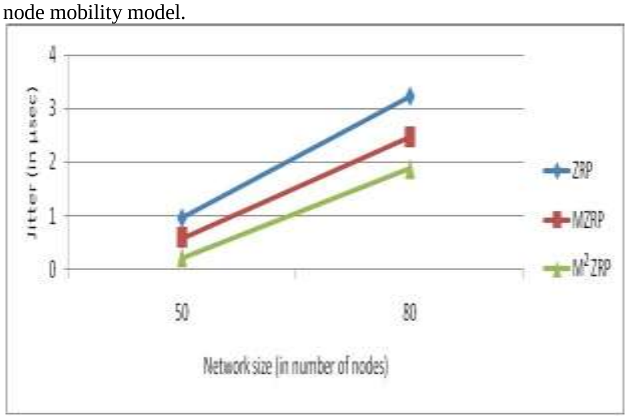

Figure 5: Average Jitter comparison using Random Way Point (RWP) node mobility model.

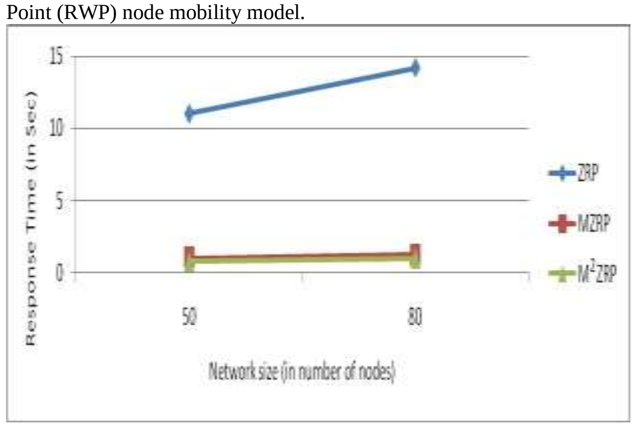

Figure 6: Response Time comparison using Random Way Point (RWP) node mobility model.

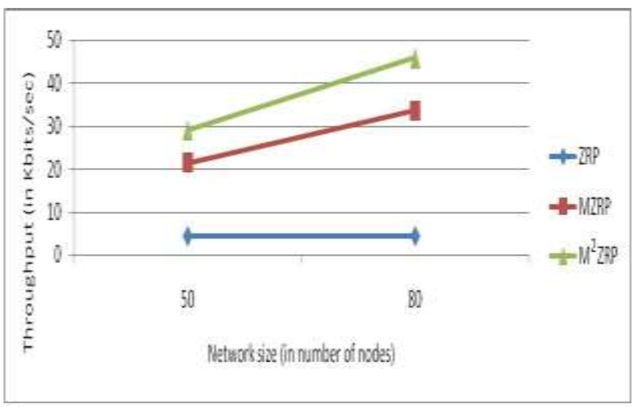

Figure 7: Throughput comparison using Group Mobilty (GM) node mobilty model.

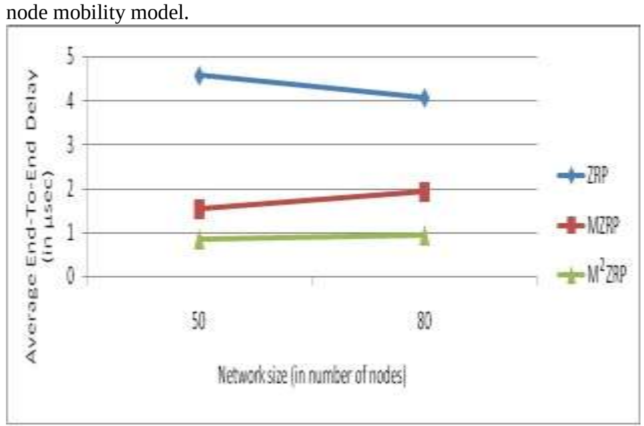

Figure 8: Average End-To-End Delay comparison using Group Mobilty (GM) node mobilty model.

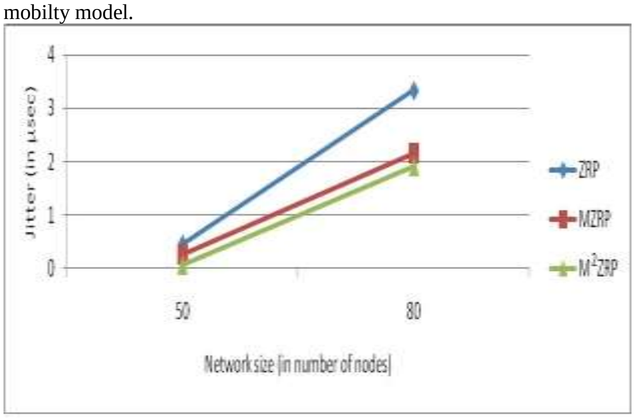

Figure 9: Average Jitter comparison using Group Mobilty (GM) node mobilty model.

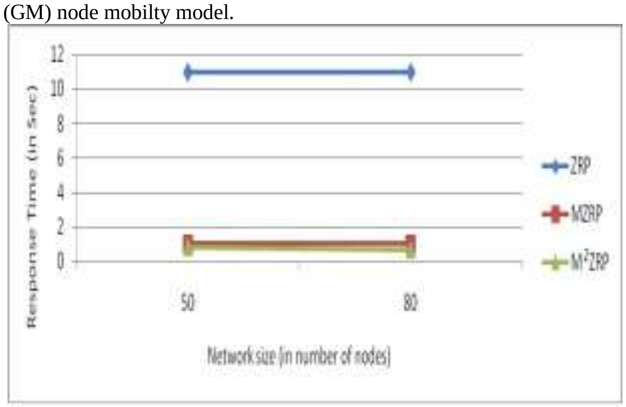

Figure 10: Response Time comparison using Group Mobilty (GM) node mobilty model.