Sensor Nodes Based Group Mobility Model (SN-GM) for MANET

Deepali Jain, Ashish Payal, Umang Singh

Abstract— Mobile ad hoc network is an autonomous system of mobile nodes connected by wireless links without any infrastructure support. Mobility of nodes in MANET is defined as entity based or group based. Entity mobility is designed to simulate the movement of each individual. Group mobility model are designed to simulate the movement of nodes in a group. Many of the application of mobile ad hoc networks are based on group mobility for example disaster recovery, battlefield situation, people visiting fair and search and rescue operation. Group mobility also introduces the concept of two or more subgroups moving individually. In this paper we propose a new group mobility model. In the proposed model there are number of groups that can move within the simulation area, and there are some individual static nodes, scattered in the area concerned, to report one group activity to other group. They might be think of as forwarding nodes or sensor nodes. Nodes in the same group move with same average velocity in the simulation area. As a part of discussion we will simulate our proposed group mobility model namely Sensor Nodes based Group Mobility Model (SN-GM) and evaluate the performance of routing protocol namely Ad Hoc On-Demand Distance Vector Routing protocol (AODV) and Dynamic Source Routing (DSR).

Index Terms— Ad Hoc Networks, AODV, DSR, Group Mobility, Sensor nodes

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1 INTRODUCTION

MOBILE Ad hoc Network (MANET) [1] is an autonomous system of mobile nodes connected by wireless links without any infrastructure support. Each node operates not only as an end-system, but also it serves as a router to forward packets. The nodes in the formed network are free to move about and organize themselves into a network. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic.

Node mobility is one of the inherent characteristics of mobile ad hoc networks. Mobility models play a significant role in the development of MANETs and are used for analyzing the performance of ad hoc network protocols [2]. We can divide mobility of nodes in MANET into two categories; one is entity mobility model and another is group mobility model [3]. Entity mobility is designed to simulate the movement of each individual. Random Walk Mobility model [4] and the Random Waypoint Mobility model [5] most popular entity mobility model.

Group mobility model are designed to simulate the group movement. Reference Point Group Mobility Model [6], Reference region Group mobility model [7] and Virtual Track Based Group Mobility Model [8], are some popular group mobility model.

Many of the application of mobile ad hoc networks are based on group mobility for example disaster recovery, battlefield situation, people visiting fair and search and rescue operation. The common characteristic of these applications is that mobile nodes can be organized in the unit of groups. Group mobility also introduces the concept of two or more subgroups moving individually.

As there can be number of subgroups, nodes in different groups wish to communicate, to share information with each other. But if these groups are at a distance with each other, there is possibility that they would not be connected with each other and the information they like to share will be lost in between.

Among the entire existing group mobility model, some of them cannot simulate the inherent group characteristics, i.e., group partitions and group mergers which are very common in most practical group mobility related scenarios. Some of the group mobility model can only be applied to specific scenarios where predefined path for group movement has been given, and some model has not taken into consideration of the fact that when there are number of groups, connectivity can be lost when these groups are moving in different direction.

In this paper we propose a new group mobility model namely Sensor Nodes Based Group Mobility (SN-GM) Model, which will address the above concerned issues. In the proposed model there are some static nodes, scattered in the area concerned to report one group activity to other group. They might be think of as forwarding nodes or sensor nodes.

It has been observed previously that performance of the rout-

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- *Deepali Jain is currently pursuing masters degree program inInformation Technology from inSchool of Information & Communication Technology, Guru Gobind singh IndraPrastha University, Delhi, India. E-mail: deepali_08@yahoo.com*
- *AshishPayal is currently at the post of Assistant Professor inSchool of Information & Communication Technology, Guru Gobind singh IndraPrastha University, Delhi, India. E-mail: ashish.ipu@gmail.com*
- *UmangSingh is currently at the post of Assistant Professor Institute of Technology & Science, Ghaziabad, India. E-mail: umangsingh@its.edu.in*

ing protocols depends on the mobility pattern of nodes [9],[10],[11],[12]. In this paper, taking node mobility as per our proposed model, we will evaluate and compare the performance of well-known on demand network routing protocols using NS2 [13], namely Ad Hoc On-demand Distance Vector Routing (AODV) [14] and DSR [15] taking the performance metrics Packet Delivery Ratio (PDR), average end-to-end delay (EED) and Normalized Routing Load per data packet sent (NRL).

2 LITERATURE REVIEW

2.1 Review on Mobility Models in MANETs

Mobility model in MANET has been classified into two main categories [3]: entity mobility model and group mobility model. Entity mobility model are used to describe the mobility of each individual node while group mobility model are used to mimic the movement of group.

2.1.1 Entity based model

Random Walk Mobility model [4] is the most popular entity mobility model. This model is based on the random speed and direction taken by each node. Another important entity mobility model is Random Way point model [5]. In this model, each mobile node chooses a destination in the area and move toward that destination with randomly selected speed which is uniformly distributed in the range of minimum velocity and maximum velocity. After reaching the destination the node may includes pause times between changes in destination and speed. [16],[17],[18] are some other entity mobility models.

2.1.2 Group mobility model

The most popular group mobility model proposed in the literature is Reference Point Group Mobility (RPGM) Model [6]. The RPGM Model is a typical group mobility model. In RPGM model, each node in a group has two components in its movement vector: the individual component and the group component. The individual component is based on the Random Waypoint (RWP) model. A node randomly picks a destination within the group scope and moves towards that destination at a fixed speed. Once the node reaches the destination, it selects another destination point in the concerned area randomly and moves towards it after a pause time. This behavior is repeated for the duration of the simulation. The group component of mobility is shared by all nodes in the same group and is also based on the random waypoint model. In this case, however, the destination is an arbitrary place in the entire system. Because the RPGM model is based on RWP model, it still cannot overcome the shortcomings caused by the characteristics of the RWP model, such as non-uniform network density, and it is not adequate to simulate the group movement in reality, such as split of one group into two or many groups and merger of two or many groups into one group, etc.

In Reference region Group Mobility (RRGM) Model [7], every group is associated with a reference region which is an area that nodes will move towards to a once they arrive, the nodes will move around within the region waiting for the arrival of others. After a reference region has been stationary for some time at an intermediate location, a new location for the reference region will be generated. As such, the reference region moves gradually towards the destination with its path defines the trajectory of the movement of the group. The size of the region is defined based on the node density as given by the user according to the specific scenario. In RRGM, new destinations may be created at times so that if multiple destinations are assigned to a group, this group will be partitioned into a number of smaller subgroups, each with a new reference region associated to a different destination. When a group has reached its destination, the group could merge with another group. But as the Group Partition takes place in RRGM Model, Network connectivity get lost, and two groups have difficulty in communicating with each other as they are moving in different direction.

The Virtual Track Based Group Mobility Model [8] uses some "Switch Stations" to model the dynamics of group mobility. Some switch stations are randomly placed in the field connected via virtual tracks with equal track width. Group moving nodes are moving towards switch stations along the tracks. They split and merge at switch stations. Some nodes in this model are individually moving nodes and static nodes. They are placed and move independently of tracks and switch stations. The problem with the VT based model is that nodes follow a predefined path for group moment. And group partitions and merger take place only at switch stations. [19],[20] are other group mobility model in mobile ad hoc networks.

2.2 Review on Network Routing Protocols

Routing approaches in MANET can be divided into three main categories [21]: Pro-active, Reactive and Hybrid. Below given description of these three approaches.

In pro-active (table-driven) routing protocols, network topology information is maintained by every node in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to destination, it runs an appropriate path-finding algorithm on the topology information it maintains. Examples include DSDV (Highly Dynamic Destination-Sequenced Distance Vector routing protocol) [22] and OLSR (Optimized Link State Routing)[23].

Reactive (On- Demand) protocols find a route on demand by flooding the network with Route Request packets. They do not maintain the network topology information. Hence these protocols do not exchange routing information periodically. Ad-hoc On-demand Distance Vector (AODV) [14] and Dynamic Source Routing (DSR) [15] are examples of Reactive routing protocols.

Hybrid protocol combines the advantages of proactive and of reactive routing. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. The choice for one or the other method requires predetermination for typical cases. ZRP (Zone Routing Protocol) [24] is one of the examples of hybrid routing protocol.

2.2.1 Ad Hoc On Demand Distance Vector Routing (AODV)

In AODV, when a source node desires to send a packet but does not have a valid path to the destination, it initiates a route discovery process to locate the destination by broadcasting a route request (RREQ) message to its neighbors, which then forward the request to their neighbors and so on, until either the destination or an intermediate node with a "fresh enough" route to the destination is located.

Each node that forwards the RREQ creates a reverse route for itself back to the source node. The routing table is updated with the address of the neighbor from which the first copy of the broadcast message is received; thereby the reverse routes are established. Other additional copies of the same RREQ arrived later are discarded.

The destination or any intermediate node with a "fresh enough" route to the destination responds by unicasting a route reply (RREP) packet back to the neighbor from which it first received the RREQ. The RREP is routed back along the reverse path hop-by-hop. The intermediate nodes update their route tables with the node from which the RREP is received as forward route entries. If an intermediate node moves, its upstream neighbors notices it and sends a link failure notification message to all its upstream neighbors to inform them of deletion of that route. The link failure notification message is relayed to the source which will choose to re-initiate a new route discovery process or discard.

2.2.2 Dynamic Source Routing (DSR)

DSR is a source-routed on-demand routing protocol. In DSR, a node maintains route cache containing the source routes that it is aware of and updates entries in the route cache when it learns about new routes. The protocol consists of two major phases: route discovery and route maintenance. The route discovery phase is initiated by broadcasting a route request (RREQ) when the source node does not find a route to the destination in its route cache or if the route has expired. This RREQ contains the address of the destination, along with the source nodes' address and a unique identification number. To limit the number of RREQs propagated, a node processes the RREQ only if it has not already seen it before. Each node receiving the RREQ checks whether it knows of a route to the destination. If it does not, it adds its own address to the route record of the packet and then forwards the packet along its outgoing links. A route reply (RREP) is generated when either the destination or an intermediate node with current information about the destination receives the RREQ. In the route maintenance phase, each node transmitting the packet is responsible for confirming that the packet has been received by the next hop along the source route. Hello message is used to maintain the local connectivity of a node. By periodically broadcasting a hello message, a node may determine whether the next hop is within communication range. If no hello message is received, the node returns a route error (RRER) message to the original sender of the packet which can send the packet using another existing route or perform a new route discovery and remove the expired route information from its routing table.

3 DESIGN OF SENSOR NODES BASED GROUP MOBILITY (SN-GM) MODEL

The key idea of proposed model is simulate mobility of mobile nodes and there are some static nodes called sensor nodes that are distributed at strategic location in the area of interest. This mobility model is proposed to mimic the behavior of military operation, where different groups move in the area to achieve the target.

Initially, a group of mobile nodes are deployed in the simulation area taking node density as the parameter as one of the parameter, this area is known as the target area for those nodes. The size of the target area depends on the number of nodes and node density, and there are a number of sensor nodes placed at strategic location in the area.

Next, a target is created and assigned to that group. Assuming that every mobile node has the knowledge of the target, a new target area is created around the target depends on the node density. Each of the node select point in the target area and move toward that point.

Fig. 1 show the behavior of the model with two groups when target has been assigned.

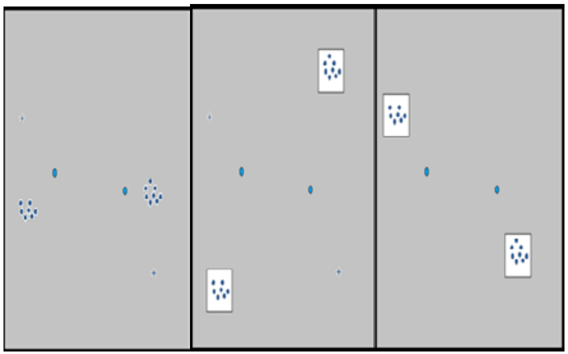

Fig. 1 Mobility of groups in SN-GM Model

Fig. 1(a) shows the rectangular area as the initial target area for the group of mobile nodes, and two static sensor nodes, shown by '◊' are strategically placed within the simulation area. A target is shown by the '+' sign. In Fig. 1(b), both groups are moving toward their respective target. Fig. 1(c) shows that all the mobile nodes reached the target area.

The velocity that each group member travels with, namely *v*, is varied by:

$$v = v_0 + rand() \times v_0 \qquad (1)$$

Here v_0 is a pre-defined average velocity of mobile nodes of that group, and the random seed *rand* () returns a random value within the range of (-0.1, +0.1).

4 ANALYTICAL MODEL

The performance metrics which will be used in the simulation include the *Packet Delivery Ratio (PDR)*, the *Normalized Routing Load* (*NRL*) *and Average end-to-end delay (EED).*

Packet Delivery Ratio (PDR) reflects the percentage of data packets that can be successfully delivered, which is an important metric to evaluate the efficiency of a network. *PDR* is calculated as the ratio of the number of data packets delivered to the destinations to those generated by the sources.

Normalized Routing Load (*NRL*) refers to the amount of routing packets required to set up and maintain routes in order to deliver data packets and it is then normalized by every data packet sent to indicate the average overhead spent in order to deliver a data packet. To calculate the NRL we calculate the sum of all the control packets incurred during simulation, which is then normalized by the total number of data packet sent. The control packets include *route request, route reply* initiated by intermediate nodes and by destinations separately, and *route error messages*.

End-to-end delay (EED) measures the average time spent in the period when a packet is successfully sent from the source to the destination. This includes all possible delays caused by buffering during route discovery, queuing at the interface queue, retransmission delays at the MAC layer, propagation delay and transmission delay.

5 SIMULATION SCENERIO

The simulation studies are carried out using NS2. Rectangular area of 1500m * 1500m has been taken for simulation of battlefield situation. For mobile nodes, node density is fixed at 300 nodes / KM square for each group. Static sensor nodes are placed strategically in the simulation area. Radio propagation range of each node is 250 meters with channel capacities of 20Kbits/s. 20 sender receiver pair are designated randomly to conform only inter group communication and each source can generate constant bit traffic (CBR) traffic of 512 bytes data packets per second.

Simulation time has been taken as 500 sec. Each group has its own average speed. Average speed is taken as 10 m/s for each individual group. Each scenario is repeated for 20 times and the average values are finally presented in the simulation result. Simulation studies are carried out by varying the number of static sensor nodes and number of groups.

TABLE 1

NETWORK ENVIRONMENT CONFIGURATION

PARAMETER	VALUES
Terrain size	1500 meters * 1500 meters
Radio propagation range	250 meters
Channel capacity	20k bits/sec
Cbr traffic	512 bytes/sec
Simulation time	500 sec
Average node velocity(*v*)	10 m/s
Node density for group of mobile nodes(ρ)	300 nodes/km square

5.1 Experimental Settings- Investigation on number of static sensor nodes

In this scenario, there are three groups of 15 nodes each in different location. Different simulation scenario has been generated by varying the number of static sensor nodes from 1 to 17 to investigate its impact on network performance. All three groups move in the simulation area with each individual node having average velocity of 10 m/s.

5.2 Experimental Settings- Investigation on number of groups

In this scenario, there are 9 static sensor nodes deployed in the simulation area. Simulation scenario has been generated by varying the number of groups from 2 to 10 to investigate its impact on network performance. All the groups move in the simulation area with each individual node having average velocity of 10 m/s. Total number of mobile nodes has been taken as 50. When two groups are there, each group has 25 nodes. When four groups are there each group has 12 or 13 nodes likewise.

6 RESULTS AND ANALYSIS

6.1 Varying the number of static sensor nodes

Fig. 2 presents the results which show how the packet delivery ratio varies with the number of static sensor nodes.

As illustrated in Fig. 2, the trends of packet delivery ratio for AODV and DSR increase as the number of static node increases. Since source-destination pair is placed in different groups respectively for inter-group communications, they may not be connected initially if the sources cannot find routes to their destinations, which may be due to long distance beyond the transmission range or the lack of intermediate nodes in between. When the number of static sensor nodes increases, those previously disconnected source-destination pairs which are placed in different group would possibly get connected. Hence packet delivery ratio increases as the static sensor nodes increases. However if we compare the performance of AODV and DSR, AODV yields more packet delivery ratio as compared to DSR, because of the fact that AODV reacts faster than DSR when the network topology changes, as AODV only keep one route entry and DSR keep multiple route entries.

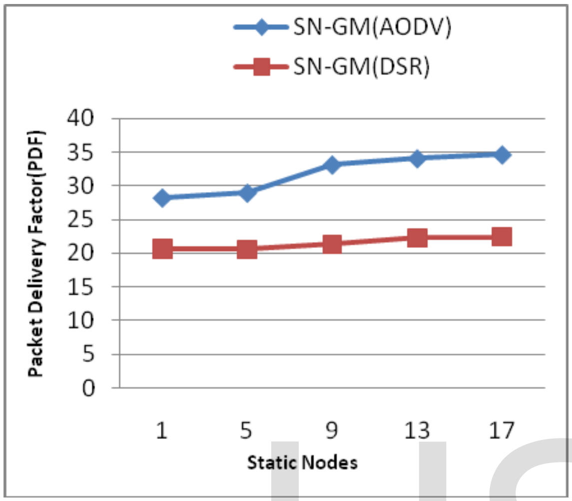

Fig. 2 Packet delivery ratio vs. Number of static nodes

As illustrated in Fig. 2, the trends of packet delivery ratio for AODV and DSR increase as the number of static node increases. Since source-destination pair is placed in different groups respectively for inter-group communications, they may not be connected initially if the sources cannot find routes to their destinations, which may be due to long distance beyond the transmission range or the lack of intermediate nodes in between. When the number of static sensor nodes increases, those previously disconnected source-destination pairs which are placed in different group would possibly get connected. Hence packet delivery ratio increases as the static sensor nodes increases. However if we compare the performance of AODV and DSR, AODV yields more packet delivery ratio as compared to DSR, because of the fact that AODV reacts faster than DSR when the network topology changes, as AODV only keep one route entry and DSR keep multiple route entries.

Fig. 3 present the result which shows how Normalized routing load varies with varies with number of static sensor nodes. As the number of static nodes increases normalized routing load increases for AODV and DSR. This is due to the fact that after certain number of attempts when the route between sender and receiver has not been established, source drop the route discovery process. When the numbers of static nodes are fewer, nodes in different group are disconnected, route request has not been forwarded further and source reaches the threshold to establish the route, hence result in less number of normalized routing loads. As the number of static nodes increases, nodes are connected with nodes in different group, and due to group mobility, increase in the number of normalized routing load.

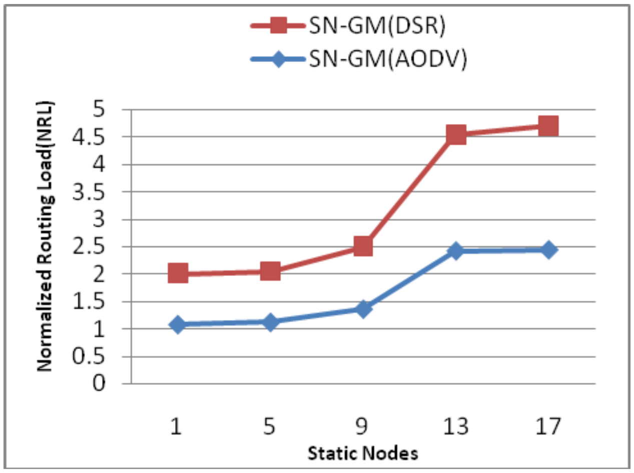

Fig. 3: Normalized routing load vs. Number of static nodes

DSR is having more routing overhead than AODV. It agrees with the earlier discussion that DSR maintain multiple routing entries while AODV maintain only single route entry.

Fig. 4 illustrates the result of end-to-end delay of data packet delivery for DSR and AODV. End to end delay is calculated on the basis of receive data packets. When there is less number of static nodes, no connection has been established between the source-destination pair, resulting in less number of received packets. Connection has been established when the group are closer to each other. As a result fewer end-to-end delay as compared to when the numbers of static nodes are high.

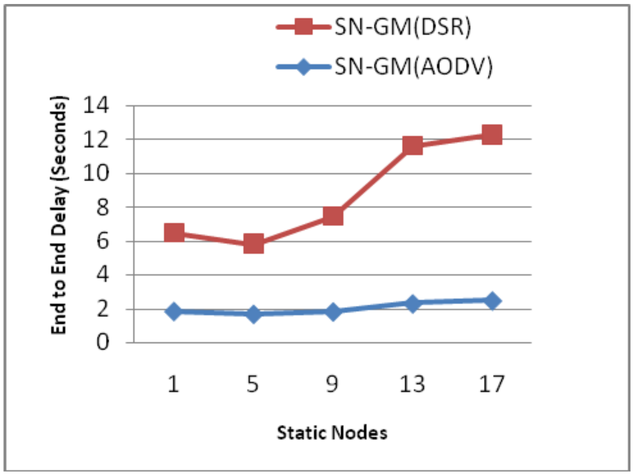

Fig. 4 End-to-end delay vs. Number of static nodes

Again DSR is having very higher end to end delay as compared to AODV because DSR tries every route entry to the destination that are there in the routing entry table. With the dynamic changing topology environment in ad hoc network link disconnection occur very frequently. After trying all entries it start route discovery process with the destination. While AODV maintains only one route entry per destination, it reacts early when the link disconnection detect, and start a new route discovery process, that result in less end-to-end delay as compared to DSR.

6.2 Varying the number of groups

Fig. 5 presents the results which show how the packet delivery ratio varies with the number of groups. As illustrated in Fig. 5, the trends of packet delivery ratio for AODV and DSR increase as the number of group increases. Since source-destination pair is placed in different groups respectively for inter-group communications, they may not be connected initially if the sources cannot find routes to their destinations, which may be due to long distance beyond the transmission range cause of less number of groups. But as the number of group increases, they are scattered in the entire simulation area, hence result in more connectivity between nodes. But after certain point, when the number of groups are 6 or more, packet delivery ratio become almost constant, this is due to the fact that six groups with 9 static nodes covers almost total area to get connected.

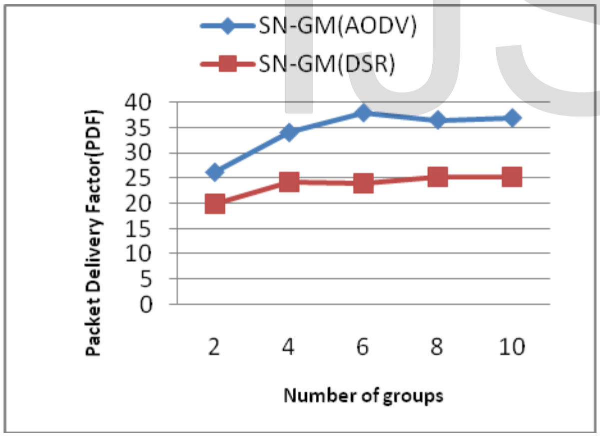

Fig. 5 Packet Delivery Ratio vs. Number of groups

Fig. 6 presents the result which show how Normalized routing load varies with number of groups. As the number of group increases normalized routing load increases. Because we have generated only inter group communication, source destination pair are always taken from different group. Intermediate nodes have no route to the destination as the number of group increases; they forward the request to other nodes and would not be able to reply.

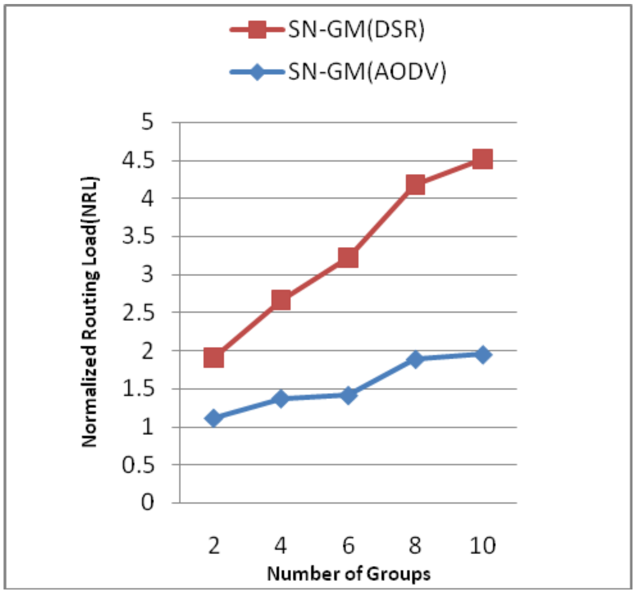

Fig. 6: Packet Delivery Ratio vs. Number of groups

Fig. 7 illustrates the result of end-to-end delay of data packet delivery based on number of groups. Fig. shows that end-to-end delay decreases with increase in number of groups and after certain point it becomes stable. When the numbers of groups are less, they are far apart with each other, but connected with static nodes. So end-to-end delay is high. But as the number of group increases, they cover the entire simulation area with static sensor nodes, and because we have taken only intergroup communication, it might be possible that source destination pair is in nearby group resulting in less end-to-end delay.

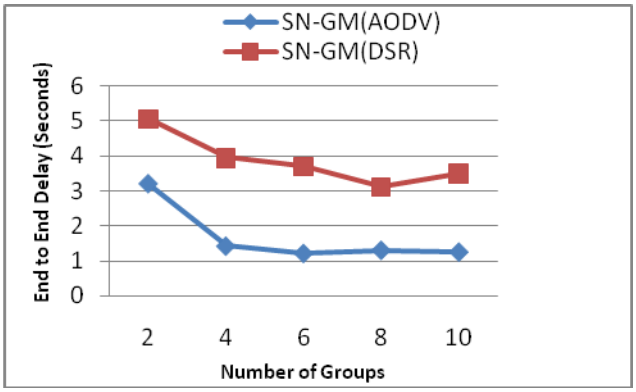

Fig. 7 End-to-end delay vs. Number of groups

7 CONCLUSION

In this paper, we propose novel group mobility model named SN-GM for simulation studies in ad hoc networks. This model can be used to generate group mobility in MANET. By taking the advantage of this model, group mobility in MANET can be realized with good connectivity.

We have compared the performance of two well known reactive routing protocols, AODV and DSR, with generating different network scenarios.

First type of scenario is generated by increasing the number of static nodes, while keeping the number of groups constant to three, having each group fifteen number of nodes. In this scenerio it has been observed that if sufficient numbers of static nodes are there in the simulation area, then we get more connected network as compare to when there are less number of static nodes. But after reaching that optimum level of number of static nodes, performance metrics gives approximately same result if we increase the number of static sensor nodes.

Second type of scenario is generated by varying the number of subgroups while taking the number of static nodes constant at nine. In this type of scenario it has been observed that as the number of subgroup increases connectivity increases. But as the number of subgroups reaches at optimum level, performance metrics shows almost same result for further subgroup division.

Further, for both of the scenerios it has also been observed that AODV shows better result for the performance metrics that we taken for comparison of results as compared to DSR routing protocol.

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