Simulation Based Performance Comparison of Community Model, GFMM, RPGM, Manhattan Model and RWP-SS Mobility Models in MANET

Gowrishankar.S, SubirKumarSarkar,
Department of Electronics and Telecommunication Engineering, Jadavpur University, Kolkata 700032, West Bengal, India.
gowrishankarsnath@acm.org
sksarkar@etce.jdvu.ac.in

T.G.Basavaraju,
Department of Computer Science and Engineering, National Institute of Technology, Surathkal 575025, Mangalore, Karnataka, India.
basavaraju@nitk.ac.in

Abstract—**A characteristic feature of ad hoc networks is the infrastructure less and seamless connectivity of the wireless mobile nodes. Mobility plays an important role in the connectivity of these nodes. In this paper a performance comparison of five important mobility models; Community Model, Group Force Mobility Model (GFMM), Reference Point Group Mobility (RPGM), Manhattan Mobility Model and Random Waypoint-Steady State (RWP-SS) Mobility Model has been analyzed. Community Model, GFMM and RPGM Mobility Models are pure group mobility models, while Manhattan Mobility Model can be considered as a pseudo Group Mobility Model. We have included RWP-SS to give a whole picture of how group mobility models stand against a random model like RWP-SS. From our analysis we deduce that group mobility models hold inherent advantage over mobility models like Random Waypoint models. Among the group mobility models, Community model has good performance when compared to other mobility models. Energy Consumption of these mobility models has also been analyzed. Various Metrics like Packet Delivery Ratio, Average Network Delay, Network Throughput, Routing Overhead and Number of Hops have been considered. The results obtained in our paper colligates with the theoretical results in [20]. We also claim that our work is the first to compare these five different mobility models together.**

Keywords-Mobility Models, MANET, Performance Comparison, Group Model, Simulations

I. INTRODUCTION

Today Ubiquitous computing is the buzzword and it has reached a stage where it has become a routine to use the ubiquitous devices as part of our every day life. Portable devices are expected to move from one geographic location to other locations. These geographic locations may include various obstacles in their path. So, mobility is the central theme in the connectivity of these wireless devices. Mobile ad hoc networks provides the principality behind these ubiquitous computing. Mobile Ad hoc networks do not have any centralized administration. All the nodes in an ad hoc network are autonomously connected in a dynamic manner.

In ad hoc networks, the topology changes very frequently due to the mobility of the nodes. Mobility plays a very important role in the performance of the routing protocol and hence the underlying mobility model should be carefully selected for optimum performance.

The *main contribution of this paper* is that we have made a substantial effort to study the performance of various group mobility models like Community model, GFMM, RPGM, a pseudo group mobility model like Manhattan model and a random mobility model like RWP-SS. *To the best of our knowledge, no work has been reported that compares and studies the performance of all these Mobility Models in a single research paper*.

The rest of the paper is organized as follows. Section two presents related work, a description of various mobility models and the energy model is given in section three, various simulation parameters is discussed in section four, simulation results are provided in the fifth section and we finally conclude the paper.

II. RELATED WORK

The authors of [1] have considered various synthetic entity mobility models and group mobility models. Under synthetic entity mobility models they have given a detailed description of seven different mobility models: Random Walk Mobility Model, Random Waypoint Mobility Model, Random Direction Mobility Model, A Boundless Simulation Area Mobility Model, Gauss-Markov Mobility Model. Five group mobility models discussed are Exponential Correlated Random Mobility Model, Column Mobility Model, Nomadic Mobility Model, Pursue Mobility Model and Reference Point Group Mobility Model. The authors have also discussed the importance of selecting the underlying mobility model. The authors have simulated the results of four different mobility models. The authors conclude that the Random Way Point Mobility Model has the highest PDR and lowest end to end delay.

Fan Bai and Ahmed Helmy have conducted another survey paper of the various mobility models in the ad hoc networks [2]. The authors categorize the various mobility models in to random models, Mobility Models with Temporal Dependency, Mobility Models with Spatial Dependency and Mobility Models with Geographic Restrictions and they have discussed various mobility models under each category.

In [3], the authors have considered three mobility models, Pursue mobility model, column mobility model and RPGM-RW mobility models and have studied the effects of these mobility models on the performance of three ad hoc routing protocols, AODV, DSDV and DSR. The authors

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conclude that DSR protocol is having the highest PDR under Pursue and Random Waypoint mobility model and AODV is having lower routing overhead under column and RPGM-RW mobility model.

The authors of [4] have mapped AODV, DSR and TORA routing protocols against Random Waypoint, Random Walk and Pursue mobility models. The above mobility models are simulated using the OPNET simulation tool. The authors have compared these routing protocols under various mobility models by varying the mobility speed and the pause time.

A comparison of Random Waypoint and Gauss-Markov Mobility Model is done in [5], an analysis of DSR and DSDV routing protocols under various mobility models like RPGM, Manhattan mobility, Freeway Mobility is done in [6]. The authors consider throughput as the main metrics and is mapped against number of nodes and mobility speed. A performance comparison of Random Trip mobility models is done by [7].

III. Description of the Mobility Models and Energy Model

In this section we provide an informal description of five different mobility models, which are simulated in this paper.

A. Community Mobility Model

A new social network based model called Community Mobility Model was proposed by [8]. This mobility model can be used to model humans moving in groups or groups of humans which are clustered together. The authors of the community model have evaluated their model by using the real time synthetic mobility traces provided by the Inter Research Laboratory, Cambridge. The Community Model can be conceptualized as below:

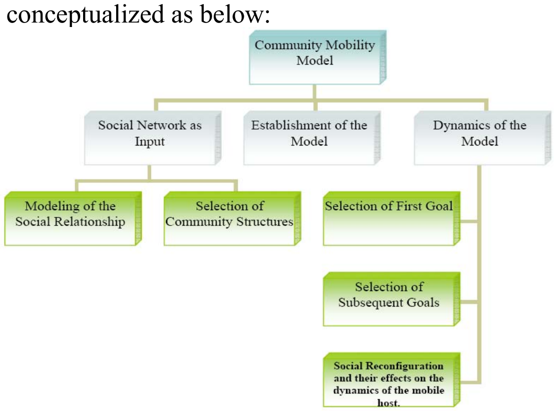

Figure 1. Steps Involved in the Establishment of the Community Mobility Model [ref 8]

The first step in establishing a community model is using the "Social network as input" to the community mobility model. It involves two ways i.e. "modeling of social relationships" and "detection of community structures". Modeling of social relationship can be represented as a weighted graph matrix. If any of the elements in the matrix is greater than the specified threshold value then that element in the graph is set to 1 and if it is less than the threshold value then it is set to 0. A value of 1 represents strong social interaction between the groups and a value of 0 represents no interaction. The concept of 1 and 0 is used to emphasize the relation between any two members of a group or any individuals of the group. The next step is to conceptualize the interaction between groups of a social community network. The authors of the community model have implemented this aspect by considering an algorithm provided by [17]. Groups communicate with each other through "inter community edges" and this concept is called as "betweeness of edges". Once the connection between the individuals in the communities and the interaction between the communities itself is established then the next step is the placement of the communities in a square location on a grid. This can be represented by S_{pq} i.e. "a square in position of p, q". The next step is the dynamics of the mobile host. For mobility, a host from each group or community is selected. For each of the host the first goal is randomly chosen inside the square S_{pq}. Here goal represents the mobility position. The next goal is selected by the "social attractivity". Each host will have a certain attraction for another host representing another square location. When a host is attracted to another host then the community moves from the present square location to the square location of another host to which the present host is attracted. Finally, the mobile host needs to be associated with the mobility dynamics [8].

B. Group Force Mobility Model

The Group Force Mobility Model (GFMM) is proposed in [9]. The GFMM is based on the concept of attraction and repulsion of mobile nodes. The GFMM can be easily applied to human groups. The authors of GFMM compare these mobility models with RPGM by taking into considerations of the various metrics proposed in the IMPORTANT framework. There is repulsion among human nodes to avoid collision among themselves and to other obstacles in their path, while attraction is used to reach the destination. The GFMM introduces a novel concept called "loose group" and "tight group". A group is called as loose group if the distance between the hosts range from 0 to 15 m or > 15 m, while a group can be considered as a tight group if the distance is in between 0 to 5 m. The repulsive force or the exponential force denoted by Exppdf(x, μ) decreases as the nodes move apart farther. The attractive force is represented by three different models and the exponential force is subtracted from these three different attractive force models. The three different attractive force models are (The equations (1), (2) and (3) are from [9]):

1) *Chi Squared group force model*

$$\bar{f}_{ij} = A_{ij}\left[\frac{\bar{r}_i - \bar{r}_j}{d_{ij}}\right]x \qquad (1)$$

[Exppdf(x, μ) – chi2pdf(x, μ)]

2) *Rayleigh Group force model*

$$\bar{f}_{ij} = A_{ij}\left[\frac{\bar{r}_i - \bar{r}_j}{d_{ij}}\right]x \qquad . (2)$$

[Exppdf(x, μ) – Rayleighpdf(x, B)]

3) Fisher-Snedecor or F group force model

$$\bar{f}_{ij} = A_{ij}\left[\frac{\bar{r}_i - \bar{r}_j}{d_{ij}}\right]x \qquad (3)$$

[Exppdf(x, μ) – Fpdf(x, v_1, v_2)]
Aij and B are the simulation specific constants.
V1 v2 are positive integers.
X exists in the interval [0 ∞]

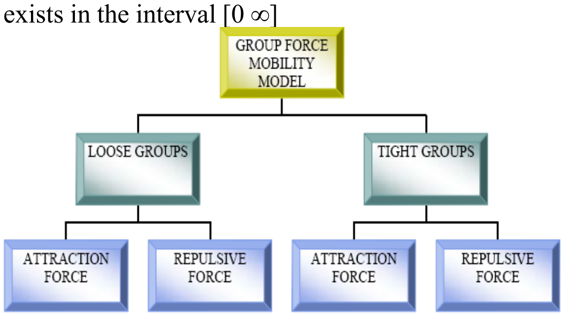

Figure 2. Steps Involved in the Establishment of the Group Force Mobility Model (GFMM) [ref 9]

C. *Reference Point Group Mobility Model*

The Reference Point Group Mobility (RPGM) Model is a popular group mobility model proposed in [10]. There is random selection of a leader for the group in the RPGM mobility model. The authors call this step as selecting "logical center". This group leader is used to set the speed, position and direction of the group. All the nodes in the group follow this leader even though they have their own individual random motion behavior. The group leader selects a random destination or "checkpoint" and moves towards that "checkpoint" or destination at a given speed. New destination is selected using the motion path given to each group. This motion path is calculated using the checkpoints [11, 18].

D. *Manhattan Mobility Model*

In Manhattan model, street maps are used for generating node mobility. The street map consists of vertical streets and horizontal streets and the intersection of these streets. A node is placed randomly in any of these streets during the initial simulation time. A node can move in a vertical direction or in horizontal direction. When it reaches a street intersection, then the subsequent street (i.e. straight or left or right) chosen probabilistically. If a node wants to move in the same direction then the node has 50% chance of continuing in the same direction or 25% chance of turning to the east/north or 25% chance of turning to the west/south. The mobile node speed is dependent on the direction of the previous movement [11, 19].

E. *Random Waypoint Mobility Model-Steady State (RWP-SS)*

While considering the Random Waypoint Mobility Model for simulation, a dissimilar mobility pattern is observed during the initial mobility duration and at the later stage of the simulation. In literature, to avoid the mentioned situation, many of the papers follow a procedure where the initial few seconds are discarded and then it is assumed that the remaining seconds of the simulation are assumed to have a similar pattern. But this method is too crude, as it can not be told at which point the dissimilar pattern starts or stops. To overcome this problem the authors of [12] have proposed the Random Way Point-Steady State Mobility Model (RWP-SS). "The initial speed and the stationary distribution location are sampled" to overcome the problem of discarding the initial simulation data. The RWP-SS without pause is given by

$$F^{-1}(u) = \frac{S_1^u}{S_0^{u-1}} \qquad (4)$$

Here S is the initial speed chosen uniformly over (0, 1) and F-1 (u) is the inverse of the cumulative distribution function. RWP-SS with pause is given by

$$H_0(p) = \frac{\int_0^p [1-H(t)]dt}{E(p)} \qquad (5)$$

Where, H(p) is the cumulative distribution function, E(p) is the expected length of a pause. (The equations (4) and (5) are from [12])

F. *Energy Model*

For transmission and receiving of energy can be modeled as "$E_{(ptx/rcv)} = i * v * t_p$ Joules", where i is the current value, v is the voltage and t_p is the time taken to transmit or receive the packet [13, 14]. The transmission power and receiving power values of 0.0271 W and 0.0135 W are considered, which are same as in [15].

IV. SIMULATION ENRIVONMENT

Simulations are performed using Network Simulator NS-2 [16]. The simulated values of the radio network interface card are based on the 914MHz Lucent WaveLan direct sequence spread spectrum radio model. This model has a bit rate of 2 Mbps and a radio transmission range of 250m. The IEEE 802.11 distributed coordinated function with CSMA/CA is used as the underlying MAC protocol. Interface Queue (IFQ) value of 70 is used to queue the routing and data packets.

Following metrics have been selected for evaluating the mobility models:

Packet Delivery Ratio: It is defined as

$$\frac{\sum \text{Number of Received Data Packets}}{\sum \text{Number of Sent Data Packets}}$$

Average Network Delay: It is defined as

$$\frac{\sum(\text{Time packet arrive @dest} - \text{Time packet sent @source})}{\text{Total Number of Connection Pairs}}$$

Throughput of the network: Throughput is defined as

$$\frac{\sum \text{Node Throughputs of Data Transmission}}{\text{Total Number of Nodes}}$$

Routing Overhead: It is defined as

$$\frac{\sum \left[\text{MAC}\left(\text{Control}_{\text{pkt}}\right)_{\text{sentsize}} + \text{MAC}\left(\text{Control}_{\text{pkt}}\right)_{\text{fwdSize}}\right]}{\Delta T_{\text{sim}}}$$

Average Hop Count: It is defined as

$$\frac{\sum CBRnumFwds}{\sum CBRrecv}$$

The various simulation parameters used in the simulation are provided in Table 1.

TABLE I. SIMULATION PARAMETERS

Simulator	NS2
Simulation Time	500s
Simulation Area	1000 x 1000 m
Number of Nodes	30
Transmission Range	250 m
Mobility Model	Community Model, GFMM, RPGM, Manhattan Model, RWP-SS
Maximum Speed	5, 10, 15, 20, 25 (m/s)
Pause Time	10 s
CBR Sources	15
Data Payload	512 Bytes
Traffic Rate	5 packets/sec

V. RESULT ANALYSIS

Each of the group mobility models is mapped against the mobility speed. The mobility speed is varied from 5 m/s to 25 m/s in steps 5. All the simulations were run independently and their results were averaged over at 5 different seeds. AODV routing protocol is used as the underlying routing protocol for simulation. Each of the group mobility models needed different configurations in their file. In Community mobility model, as discussed in section 3.1 various communities need to communicate with each other. This is done using a parameter called "rewiring probability". The value of this parameter was set at 0.1. The number of rows and columns was set at 3. In GFMM, three different force mobility models to form loose or tight groups among the nodes were proposed. For our simulation we have chosen Fisher-Snedecor or F group force mobility model. For the number of groups parameter, a value of three was used, so we could have ten nodes in each group. For RPGM and Manhattan Model, the IMPORTANT [11] framework was used to generate the mobility files. For RPGM, the number of groups was specified as three and that amounts to ten nodes in each group. The same maps that were supplied with the source code were used to generate the mobility files. For Manhattan Model, the horizontal and vertical parameters were set at 3 and the number of lanes per street was set at 2. RWP-SS did not have much configuration to do as it has fewer parameters.

The packet delivery ration of Community Model has the highest packet delivery ratio when compared with other models (fig 3). At 25 m/s the PDR of Community model and GFMM are comparable. The delivery ratio of all the mobility models decrease as the mobility speed is increased. The delivery ratio RWP-SS and Manhattan model are comparable. The Community Model and the GFMM maintain at 90th percentile range even at higher speed, while the other mobility models reduce to 80th percentile range.

The average network delay of RWP-SS is the highest and it remains at 0.23 no matter at what speed the nodes are moving. As mobility increases an extensive link break is observed in the network. A decrease and increase pattern is observed for the Community Mobility model. There is less delay up to 15 m/s, but as the mobility speed increases then the delay increases indicating congestion in the network (fig 4).

Results from fig 5 suggest that the throughput performance decreases when the node mobility speed is increased. Community model is having the highest throughput of 949 bits/sec when operating at a mobile speed of 5 m/s. The throughput of all the mobility models decrease as the mobility speed is increased. Our results adhere to the analytical results obtained in [20], which states that the "throughput decreases when the transmission range of various mobile nodes cross with each other". In a group mobility model since the mobile nodes move strictly in a group there might be clash of transmission range of various mobile nodes.

From fig 6, the routing overhead of group based mobility models is less than RWP-SS. But, as the mobility speed increases the overhead of group mobility comes to the vicinity of RWP-SS. In Community model and GFMM all the nodes are very much packet together in the neighborhood, so there is no need for frequent route discovery with in a group. At high mobility the nodes move frequently and there is a large chance that many of the nodes get out of the transmission range. This increases the probability of traffic among various inter group mobile nodes as there is a need to find the nodes for transmission resulting in more overhead.

The average hop count (fig 7) of RPGM is less than all the other mobility models. In RPGM the nodes are grouped together tightly and have less hop count. The number of hops in Community model and Manhattan model is more or less equal. This was expected because Community model needs rows and columns parameters to be specified and Manhattan model has various horizontal and vertical streets for mobility. This explains the same hop count of Community model and Manhattan model.

The energy consumed is the amount of energy consumed by all the nodes at the end of the simulation. Manhattan model consumes more energy due to less link duration and high spatial dependence of velocity among the nodes. Another generalized reason many be due to high mobility, which results in frequent break up of routes and changes in topology. Here, it is assumed that all the nodes have same energy level at the beginning of the simulation. We saw a peculiar situation where even though RWP-SS has more routing overhead, the energy consumption is less. This might be due to some nodes which might not move with the same speed as other nodes in RWP-SS, while all the nodes in a group mobility model needs to move in the group (fig 8).

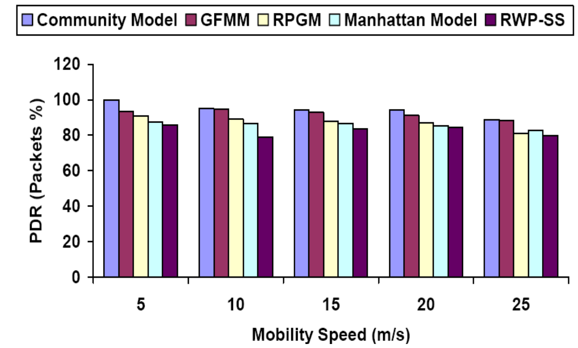

Figure 3. PDR v/s Mobility Speed

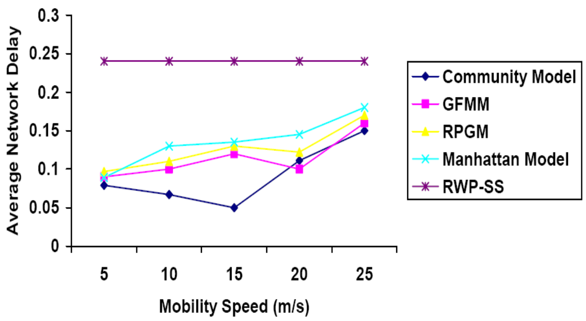

Figure 4. Average Network Delay v/s Moblity Speed

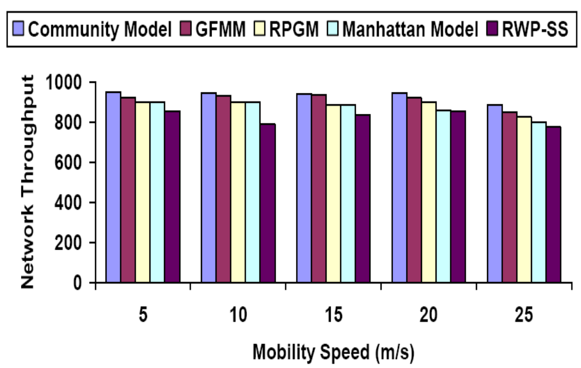

Figure 5. Network Throughput v/s Mobility Speed

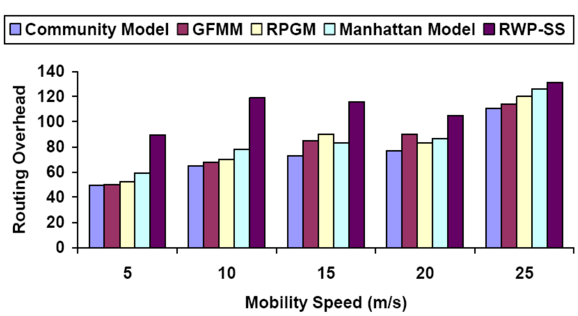

Figure 6. Routing Overhead v/s Mobility Speed

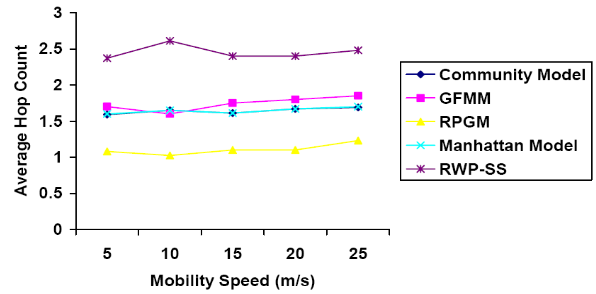

Figure 7. Routing Overhead v/s Mobility Speed

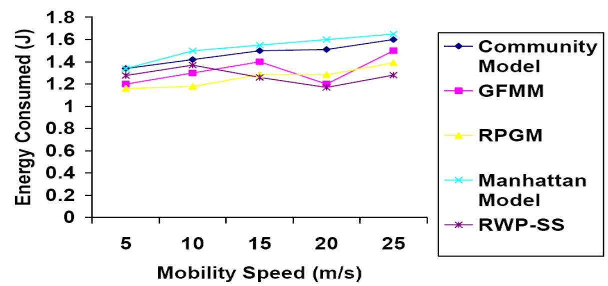

Figure 8. Energy Consumed v/s Mobility Speed

VI. CONCLUSION

In this paper we have provided a comprehensive analysis of the impact of mobility speed on the performance of various mobility models. The simulation experiments were carried out for a medium sized network of 30 nodes. Among all the mobility models the Community mobility model had overall performance advantage over other group mobility models. It has to be seen how these mobility models fare against different routing protocols in various scenarios like traffic, number of nodes, number of connections and at various transmission range. Since different mobility models have different performance level, we can conclude that a mobility model should be selected based on the type of application scenario. Our future work is to propose a new mobility model that takes into considerations the features described by various mobility models.

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