MobiSim: A Framework for Simulation of Mobility Models in Mobile Ad-Hoc Networks

S. M. Mousavi, H. R. Rabiee, M. Moshref, A. Dabirmoghaddam

Abstract—**A Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes forming a self-configuring network without using any existing infrastructure. Since MANETs are not currently deployed on a large scale, research in this area is mostly simulation based. Among other simulation parameters, the mobility model plays a very important role in determining the protocol performance in MANET. Thus, it is essential to study and analyze various mobility models and their effect on MANET protocols. In this paper we introduce a new framework for simulation of mobility models in mobile Ad-Hoc networks. This simulator can generate mobility traces in various mobility models. The mobility traces can be customized for different network simulators using XML and text output formats. User friendly graphical interface and batch processing ability makes our simulator one of the most efficient and useful mobility simulators in this field of research. We also propose some new features and parameters in mobility models to make the behavior of our simulator supported mobility models more similar to real world mobile node motions and fix some problems in last proposed methods to generate mobility models.**

Key Words— **Mobile Ad-Hoc Networks, Mobility Models, Mobility Simulator.**

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a group of mobile wireless nodes working together to form a network. Such networks can exist without a fixed infrastructure working in an autonomous manner and every mobile device has a maximum transmission power which determines the maximum transmission range of the device. As nodes are mobile, the link connection between two devices can break depending on the spatial orientation of nodes. Mobile ad-hoc networks have numerous applications in sensor networks, disaster relief systems and military operations. Some of the network constraints in mobile ad-hoc networks are limited bandwidth, low battery power of nodes, and frequent link unreliability due to mobility [1].

In order to thoroughly simulate a new protocol for an Ad-Hoc network, it is imperative to use a mobility model that accurately represents the mobile nodes that will eventually utilize the given protocol. Only in this type of scenario it is possible to determine whether or not the proposed protocol will be useful when implemented. Currently, there are two types of mobility models used in the simulation of networks: traces and synthetic models. Traces are those mobility patterns that are observed in real life systems. Traces provide accurate information, especially when they involve a large number of participants and an appropriately long observation period. However, new ad-hoc network environments are not easily modeled if traces have not yet been created. In this type of situation it is necessary to use synthetic models. Synthetic models attempt to realistically represent the behaviors of mobile nodes without the use of traces.

The mobility model is designed to describe the movement pattern of mobile users, and how their location, velocity and acceleration change over time. Since mobility patterns may play a significant role in determining the protocol performance, it is desirable for mobility models to emulate the movement pattern of targeted real life applications in a reasonable way. Various researchers proposed different kinds of mobility models, attempting to capture various characteristics of mobility and represent mobility in a somewhat 'realistic' fashion. Much of the current research has focused on the so-called synthetic mobility models that are not trace-driven.

A mobility model should attempt to mimic the movements of real mobile nodes. Changes in speed and direction must occur and they must occur in reasonable time slots. For example, we would not want mobile nodes to travel in straight lines at constant speeds throughout the course of the entire simulation because real mobile nodes would not travel in such a restricted manner.

Mobility pattern of the Mobile Ad Hoc Network, in many previous studies, was assumed to be Random Waypoint because of its relatively simple implementation and analysis. However, in the future, MANETs are expected to be deployed in various different scenarios and applications having complex node mobility and connectivity dynamics. For example, in a MANET on a battlefield, the movement of the soldiers will be influenced by the commander. In a city-wide MANET, the node movement is restricted by obstacles or maps. The node mobility characteristics are very application specific [2,3].

In this paper, we introduce a framework to simulate several synthetic mobility models that have been proposed for the performance evaluation of Ad-Hoc network protocols.

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MobiSim Simulator [4] is a Java Based Software used to generate mobility traces in various mobility models.

The rest of the paper is organized as follows: Section 2 presents our mobility simulator structure and a brief introduction to its Features. In section 3 we introduce our mobility simulator supported mobility models and explain our proposed schemes to make the mobility models more similar to motion behavior of real world mobile nodes. And finally in section 4 we discuss the conclusion and future works.

II. MobiSim Structure

An overview on the mobility simulator structure is shown in figure 1. The mobility simulator general workflow is:

1- Simulation Runner fetches simulation configurations from properties and XML files.

2- Creates corresponding models, maps and simulation objects.

3- If it was *batch simulation* it sets parameters according to variables and runs each simulation for *run Number* times.

4- In each simulation first the model initializes position of nodes.

5- In each time slot the model updates position of nodes. So each model only should initialize and update position of nodes.

Also some additional methods have been considered in "Model" class to enable models to change the order of node's location updating and the painting mechanism and trace outputs data. Traces can be written in plain text or XML, on a file or on a network socket.

Figure 2 shows MobiSim main activities in batch simulation as an activity diagram.

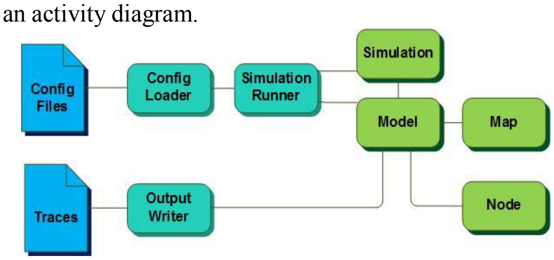

Figure 1: MobiSim general structure

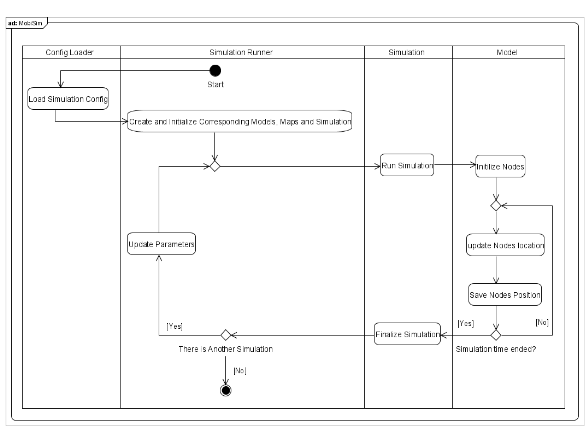

Figure 2: Activity Diagram of MobiSim main activities in batch simulation

Graphical simulation also has a similar workflow. In order to create graphical forms to manipulate maps, models, and simulation parameters we implemented a component that automatically gets these parameters and creates appropriate UI forms. So the process of implementing new models became more simple and independent from UI. The following list shows information that one can get about each node in the simulation in each time slot from the trace files:

Node number.

Position (x,y,z).

Speed: node's speed in current time slot.

Direction Angle: Direction Angle of node's movement in current time slot.

Transition: defined by a source and destination point.

Start time: start time of current transition.

End time: expected finish time of current transition.

Pause time: planned pause time for current transition.

Transition speed: planned speed for current transition.

Source: source point position.

Destination: destination point position.

Movement time: time that the node expected to move to reach destination position.

Transition length: distance between source and destination point position.

The GUI can present some of these properties including destination node and transition.

A. *Simulator features*

Current section lists some of the most important features of MobiSim:

Graphical simulation (Animation).

Input XML configuration files (map and Model configurations).

Batch simulation to run several simulations with several variable parameters .

Graphical batch simulation scenario creator module.

Output formats (plain text, XML).

Customized outputs for network simulators like NS2, Glomosim, OMNET++, …

Robust framework to add new models easily.

Trace viewer module to graphically view traces and create footprint of generated traces.

Ability to zoom and change speed in graphical mode.

Ability to generate several traces with different columns of data.

Ability to show and change attributes of models and nodes graphical mode simulation.

8 implemented mobility model and 6 maps.

III. Supported Mobility Models

In this section we try to briefly introduce the implemented mobility models and explain their parameters, algorithm and properties and also explain our innovative proposed schemes to make behavior of mobility models more similar to real world motion of mobile nodes.

A. *Random Waypoint*

The Random Waypoint Model was first proposed by

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Johnson and Maltz [5]. Soon, it became a 'benchmark' mobility model to evaluate the MANET routing protocols, because of its simplicity and wide availability.

The implementation of this mobility model is as follows: as the simulation starts, each mobile node randomly selects one location in the simulation field as the destination. It then travels towards this destination with constant velocity chosen uniformly and randomly from $[0, V_{Max}]$, where the parameter V_{Max} is the maximum allowable velocity for every mobile node [6]. The velocity and direction of a node are chosen independently of other nodes. Upon reaching the destination, the node stops for a duration defined by the 'pause time' parameter. If $T_{Pause} = 0$, this leads to continuous mobility. After this duration, it again chooses another random destination in the simulation field and moves towards it. The whole process is repeated again and again until the simulation ends [3].

We used MobiSim to generate mobility traces for Random Waypoint Mobility Models. Node Spatial Distribution of Random Waypoint Mobility Model with 20 mobile nodes in 500m*500m simulation area, average speed=20m/s, and maximum pause time=10s, for simulation time=100000sec is shown in figure 3.

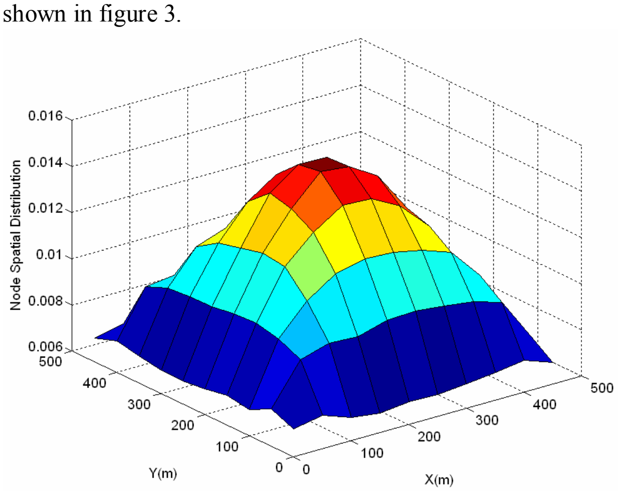

Figure 3: Spatial Node Distribution in Random Waypoint Mobility Model

As we can see in figure 3 spatial node distribution in Random Waypoint is non-uniform and the node density is maximum at the center region, whereas the node density is almost zero around the boundary of simulation area. This phenomenon is called non-uniform spatial distribution problem in random waypoint.

B. Random Direction

The Random Direction model based on similar intuition is proposed by Royer, Melliar-Smith and Moser [7]. This model is able to overcome the non-uniform spatial distribution problem. Instead of selecting a random destination within the simulation field, in the Random Direction model the node randomly and uniformly chooses a direction by which to move along until it reaches the boundary. After the node reaches the boundary of the simulation field it stops with a pause time T, then it randomly and uniformly chooses another direction to travel. This way, the nodes are uniformly distributed within the simulation field [2,3].

Node Spatial Distribution of Random Direction Mobility Model with 20 mobile nodes in 500m*500m simulation area, average speed=20m/s, and maximum pause time=10s, for simulation time=100000sec is shown in figure 4.

As we can see spatial node distribution in the simulation field is uniform. In comparison to spatial node distribution shown in figure 3, Random Direction model does not have non-uniform spatial distribution problem.

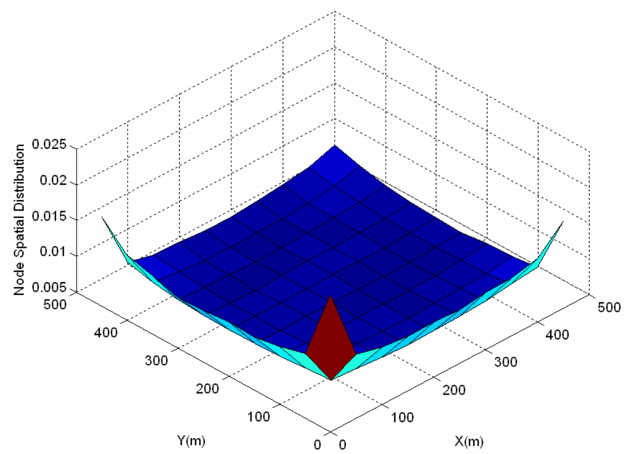

Figure 4: Spatial Node Distribution in Random Direction Mobility Model

C. Random Walk

The Random Walk model was originally proposed to emulate the unpredictable movement of particles in physics. It is also referred to as the Brownian Motion. Because some mobile nodes are believed to move in an unexpected way, Random Walk mobility model is proposed to mimic their movement behavior [3]. The Random Walk model has similarities with the Random Waypoint model because the node movement has strong randomness in both models. We can think the Random Walk model as the specific Random Waypoint model with zero pause time.

However, in the Random Walk model, the nodes change their speed and direction at each time interval. For every new interval t, each node randomly and uniformly chooses its new direction $\theta(t)$ from $(0, 2\pi]$. In similar way, the new speed follows a uniform distribution from $[0, V_{Max}]$. Therefore, during time interval t, the node moves with the velocity vector $(v(t)\cos(\theta(t), v(t)\sin(\theta(t)))$. If the node moves according to the above rules and reaches the boundary of simulation field, the leaving node is bounced back to the simulation field with the angle of $\theta(t)$ or $\pi - \theta(t)$, respectively. This effect is called border effect [8] or reflection rule.

Node Spatial Distribution of Random Walk Mobility Model with 20 mobile nodes in 500m*500m simulation area, average speed=20m/s, for simulation time=100000sec is shown in figure 5. As we can see spatial node distribution in the simulation field is uniform.

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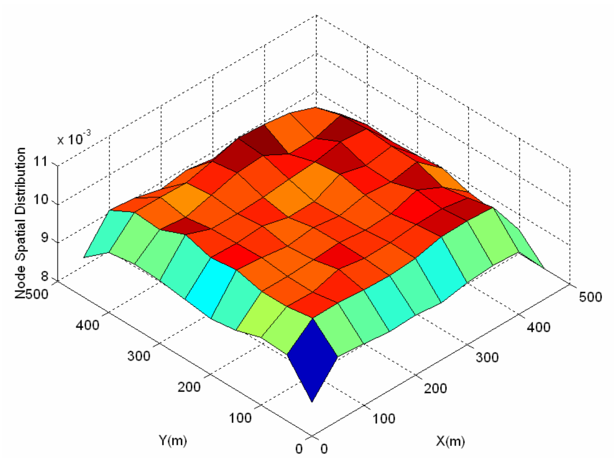

Figure 5: Spatial Node Distribution in Random Walk Mobility Model

D. *Freeway*

This model is proposed to emulate the motion behavior of mobile nodes on a freeway [3]. The freeway map used in our simulations is shown in Figure 6.

This model can be used in exchanging traffic status or tracking a vehicle on a freeway.

In this model we use maps. There are several freeways on the map and each freeway has lanes in both directions. The differences between Random Waypoint and Freeway are the following:

(a) Each mobile node is restricted to its lane on the freeway.

(b) The velocity of mobile node is temporally dependent on its previous velocity.

(c) If two mobile nodes on the same freeway lane are within the safety distance (SD), the velocity of the following node cannot exceed the velocity of preceding node.

The inter-node and intra-node relationships involved are:

If node j is ahead of node i in its lane then:

$$\begin{aligned} &|\vec{V}_i(t+1)| = |\vec{V}_i(t)| + random()*|\vec{a}_i(t)| \\ &\forall i, \forall j, \forall t, D_{i,j}(t) \le SD \Rightarrow |\vec{V}_i(t)| \le |\vec{V}_j(t)| \end{aligned} \quad (1)$$

Due to the above relationships, the Freeway mobility pattern is expected to have spatial dependence and high temporal dependence. It also imposes strict geographic restrictions on the node movement by not allowing a node to change its lane.

In our proposed simulation scheme the model has 4 new parameters. This new parameters make our simulation scheme more similar to real world motion of cars in a freeway.

1- *Max acceleration* which specifies the maximum acceleration that a node can have in a time slot.

2- *Fixed acceleration:* it's a Boolean parameter that specifies whether a node should have fixed acceleration in each transition or not.

3- *Positive speed ratio:* if the node can change its acceleration in each transition, its acceleration will be random. So this parameter specifies the weight of positive acceleration to negative one.

The model's map also has its special parameters that follow:

1- Points to make the freeway Map,

2- Number of lanes in each direction.

3- Horizontal space between lanes,

4- Horizontal space between lanes in opposite direction.

Node Spatial Distribution of Freeway Mobility Model with 20 mobile nodes in 500m*500m simulation area and average speed=20m/s, for simulation time=100000sec is shown in figure 7.

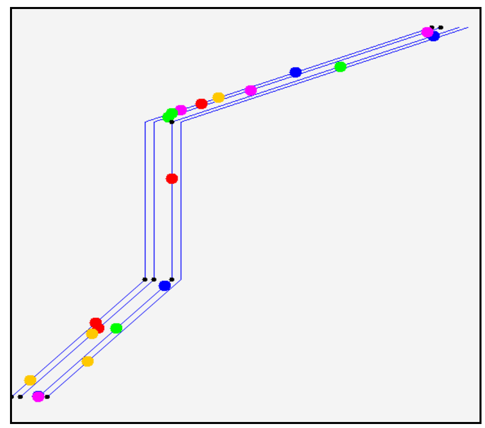

Figure 6: Freeway Mobility Model Map

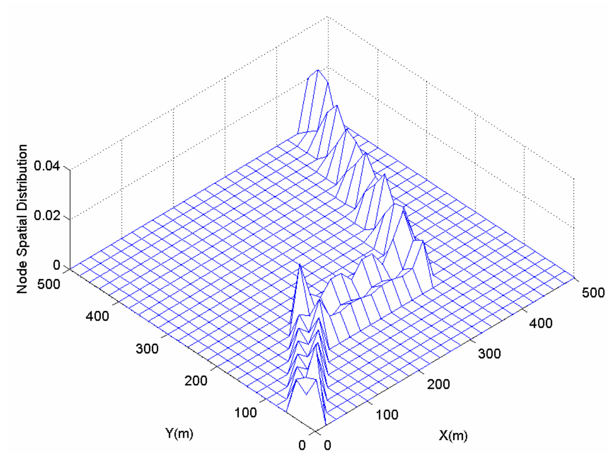

Figure 7: Spatial Node Distribution in Freeway Mobility Model

E. *Manhattan*

The Manhattan mobility model usually used to emulate the movement pattern of mobile nodes on streets defined by maps. It can be useful in modeling movement in an urban area where a pervasive computing service between portable devices is provided [3].

Maps are used in this model too. The map is composed of a number of horizontal and vertical streets. Each street has two lanes for each direction (north and south direction for vertical streets, east and west for horizontal streets). The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection of a horizontal and a

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vertical street, the mobile node can turn left, right or go straight. This choice is probabilistic: the probability of moving on the same street is 0.5, the probability of turning left is 0.25 and the probability of turning right is 0.25. The velocity of a mobile node at a time slot is dependent on its velocity at the previous time slot. Also, a node's velocity is restricted by the velocity of the node preceding it on the same lane of the street. The inter-node and intra-node relationships involved are the same as in the Freeway model. Thus, the Manhattan mobility model is also expected to have high spatial dependence and high temporal dependence. It too imposes geographic restrictions on node mobility. However, it differs from the Freeway model in giving a node some freedom to change its direction.

In proposed simulation scheme for Freeway and Manhattan in [3] they did not describe the nodes behavior when it reaches the simulation boundaries. In our simulation method when a node reaches boundaries of the simulation area it chooses the opposite lane and turns back on the opposite lane. This can solve the simulation boundary problem. The Manhattan map used in our simulations is shown in Figure 8.

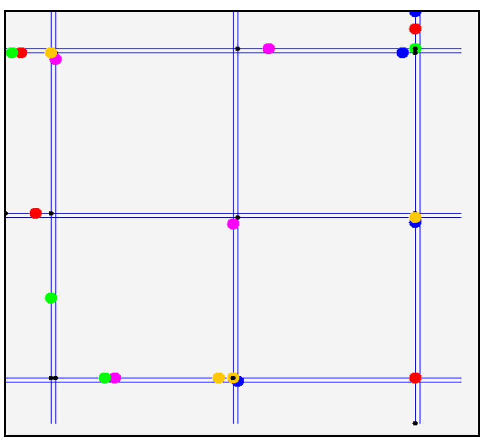

Figure 8: Manhattan Mobility Model Map

Node Spatial Distribution of Manhattan Model with 20 mobile nodes in 500m*500m simulation area and average speed=20m/s, for simulation time=100000sec is shown in figure 9.

As we can see spatial node distribution in the simulation field is not uniform and we have much more node density in intersections in comparison with lanes. In our proposed scheme, modes in this mobility model stop for a random pause time between zero and a specified maximum pause time in intersections and choose another destination so the node density in intersections is much more. We added this pause time to Manhattan Model to simulate behavior of cars in intersections due to the traffic lights and pedestrian crossings.

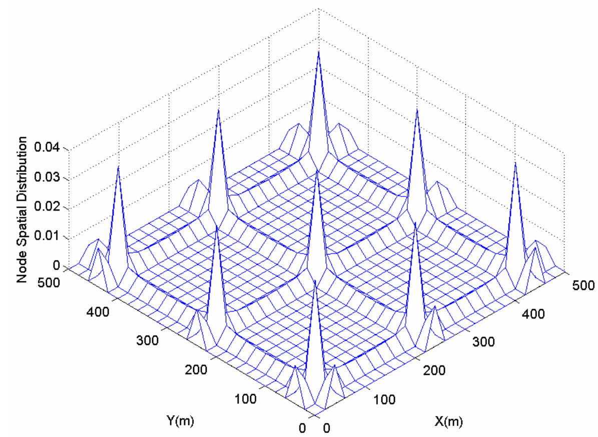

Figure 9: Spatial Node Distribution in Manhattan Mobility Model

F. Gauss-Markov

The Gauss-Markov Mobility Model was designed to adapt to different levels of randomness via one tuning parameter [9]. Initially each MN is assigned a current speed and direction. At fixed intervals of time *n*; node's movement occurs by updating the speed and direction of each mobile node. Specifically, the value of speed and direction at the *nth* instance is calculated based upon the value of speed and direction at the $(n-1)^{st}$ instance and a random variable using the following equation:

$$
\begin{aligned}
s_n &= as_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha)^2}\, s_{x_{n-1}} \\
d_n &= ad_{n-1} + (1-\alpha)\bar{d} + \sqrt{(1-\alpha)^2}\, d_{x_{n-1}}
\end{aligned} \tag{2}
$$

Where s_n and d_n are the new speed and direction of the mobile node at time interval *n*; α, where $0 \le \alpha \le 1$, is the tuning parameter used to vary the randomness; $\bar{s}$ and $\bar{d}$ are constants representing the mean value of speed and direction as $n \to \infty$; s_{n-1} and d_{n-1} are random variables from a Gaussian distribution. Totally random values or Brownian motion are obtained by setting $\alpha = 0$ and linear motion is obtained by setting $\alpha = 1$ [9]. Intermediate levels of randomness are obtained by varying the value of α between 0 and 1.

At each time interval the next location is calculated based on the current location, speed, and direction of movement. Specifically, at time interval *n*, an Mobile node's position is given by the equations:

$$
\begin{aligned}
x_n &= x_{n-1} + s_{n-1}\cos d_{n-1} \\
y_n &= y_{n-1} + s_{n-1}\sin d_{n-1}
\end{aligned} \tag{3}
$$

Where (x_n, y_n) and (x_{n-1}, y_{n-1}) are the *x* and *y* coordinates of the mobile node's position at the n^{th} and $(n-1)^{st}$ time intervals, respectively, and s_{n-1} and d_{n-1} are the speed and direction of the mobile node, respectively, at the $(n-1)^{st}$ time interval [2].

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We changed the specification that discussed in [9] so we do not force away nodes from edges but when they reach the border they reflect using the reflection rule we explained for Random Walk mobility model. The model parameters are memory factor (α), and random amplitude which is represented with σ. If we set the memory factor to 1 the model behavior becomes like Random Walk and if we set it to zero model behavior becomes like Brownian Motion. Figure 10 shows traveling pattern of 5 nodes with $a = 0.1$, $\sigma = 5$ and average speed=20m/s.

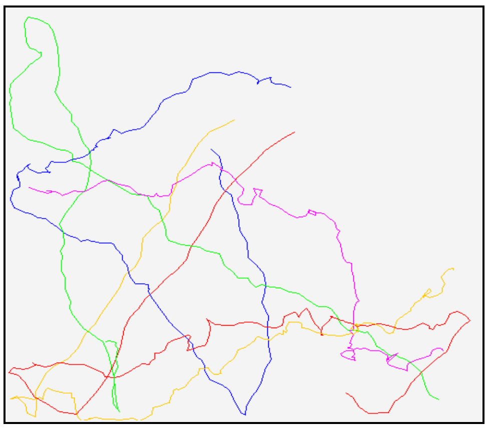

Figure10: Traveling pattern of Mobile Nodes in Gauss-Markov Mobility Model

Node Spatial Distribution of Gauss-Markov Model with 20 mobile nodes in 500m*500m simulation area and average speed=20m/s, for simulation time=100000sec is shown in figure 11.

As we can see the node spatial distribution in this mobility model is similar to Random Walk node spatial distribution.

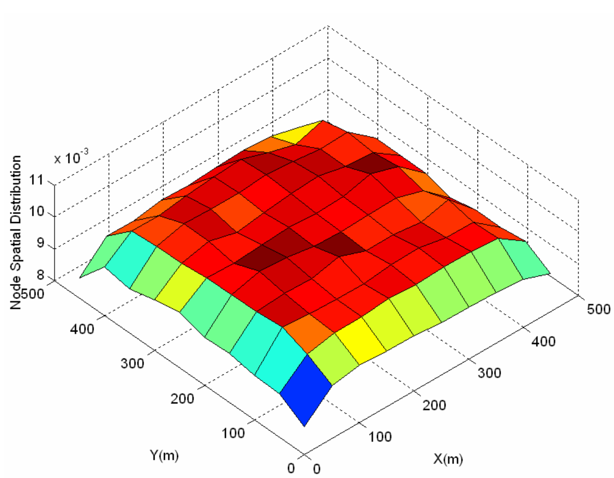

Figure 11: Spatial Node Distribution in Gauss-Markov Mobility Model

G. *Probabilistic Random Walk*

Chiang's mobility model utilizes a probability matrix to determine the position of a particular mobile node in the next time step, which is represented by three different states for position *x* and three different states for position *y* [10]. State 0 represents the current (*x* or *y*) position of a given MOBILE NODE, state 1 represents the mobile node's previous (*x* or *y*) position, and state 2 represents the mobile node's next position. if the mobile node continues to move in the same direction. The probability matrix used is where each entry $p(a,b)$ represents the probability that a mobile node will go from state a to state b. The values within this matrix are used for updates to both the mobile node's *x* and *y* position. In Chiang's simulator each node moves randomly with a preset average speed. The following matrix contains the values Chiang used to calculate x and y movements:

$$P = \begin{bmatrix} p(0,0) & p(0,1) & p(0,2) \\ p(0,1) & p(1,1) & p(1,2) \\ p(0,2) & p(1,2) & p(2,2) \end{bmatrix} \quad (4)$$

These values are illustrated via a flow chart in Figure 12.

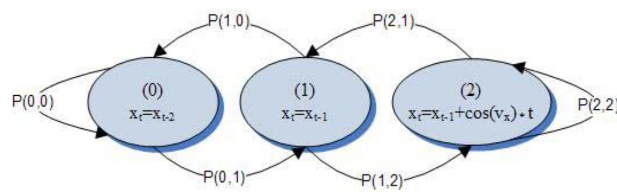

Figure 12: flow chart of the Probabilistic Random Walk model

With the values defined, a mobile node may take a step in any of the four possible directions (i.e., north, south, east, or west) as long as it continues to move. In addition, the probability of the MN continuing to follow the same direction is higher than the probability of the Mobile Node changing directions. Lastly, the values defined prohibit movements between the previous and next positions without passing through the current location. This implementation produces probabilistic rather than purely random movements, which may yield more realistic behaviors. For example, as people complete their daily tasks they tend to continue moving in a semi-constant forward direction. Rarely do we suddenly turn around to retrace our steps, and we almost never take random steps hoping that we may eventually wind up somewhere relevant to our tasks [2].

To force nodes to move in map region, we made an innovative solution. When a node moves outside of region its state will be changed to opposite state, it means if its state is 0, it will be changed to 2 and vice versa. By this technique the node comes back into region, and we can emulate the reflection effect. Obviously the matrix values will be used as parameters of this model.

Figure 13 shows traveling pattern of 5 nodes with average speed=20m/s using probabilistic random walk model.

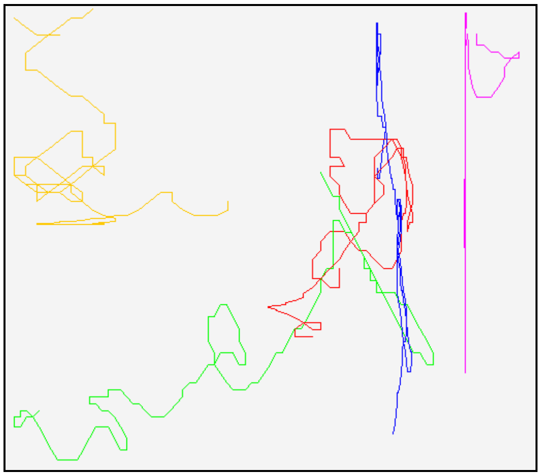

Figure 13: Traveling pattern of Mobile Node s in Probabilistic Random Walk Mobility model

Node Spatial Distribution of Probabilistic Random walk Model with 20 mobile nodes in 500m*500m simulation area and average speed=20m/s, for simulation time=100000sec is shown in figure 14.

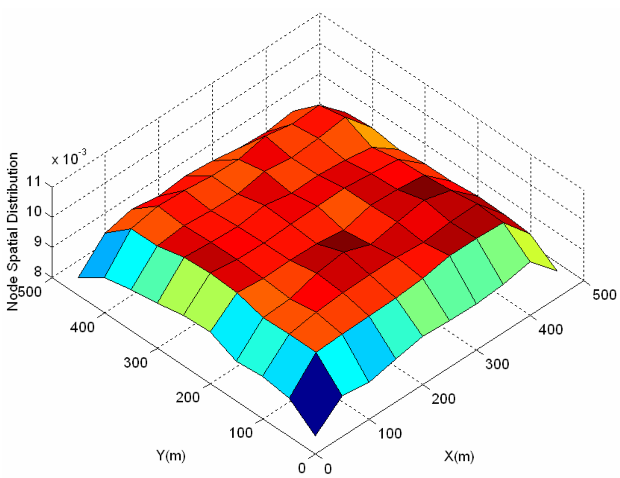

Figure 14: Spatial Node Distribution in Probabilistic Random Walk Mobility Model

H. Reference Point Group Model

In line with the observation that the mobile nodes in MANET tend to coordinate their movement, the Reference Point Group Mobility (RPGM) Model is proposed in [11]. One example of such mobility is that a number of soldiers may move together in a group or platoon. Another example is during disaster relief where various rescue crews (e.g., firemen, policemen and medical assistants) form different groups and work cooperatively.

In the RPGM model, each group has a center, which is either a logical center or a group leader node. For the sake of simplicity, we assume that the center is the group leader. Thus, each group is composed of one leader and a number of members. The movement of the group leader determines the mobility behavior of the entire group. Initially, each member of the group is uniformly distributed in the neighborhood of the group leader. Subsequently, at each instant, each node has a speed and direction that is derived by randomly deviating from that of the group leader. The movement in group mobility can be characterized as follows:

$$\begin{cases} |V_{member}(t)| = |V_{leader}(t)| + random() * SDR * \max speed \\ \theta_{member}(t) = \theta_{leader}(t) + random() * ADR * \max angle \end{cases} \quad (5)$$

SDR is the Speed Deviation Ratio and ADR is the Angle Deviation Ratio. SDR and ADR are used to control the deviation of the velocity (magnitude and direction) of group members from that of the leader. So model parameters will be ADR, SDR, initial distance (members initial distance from the leader node), and group size which determines number of group nodes [3].

We used Random Walk Mobility Model for motion behavior of leader node in each group.

We also proposed a scheme to protect nodes to pass the simulation regions. When the leader node reaches simulation region it reflects using reflection rule we explained in Random Walk Mobility Model and Group member nodes are bounded to simulation region.

Figure 15 shows traveling pattern of 2 groups with 5 nodes with average speed=20m/s, SDR=0.05, ADR=0.05, using RPGM Mobility Model.

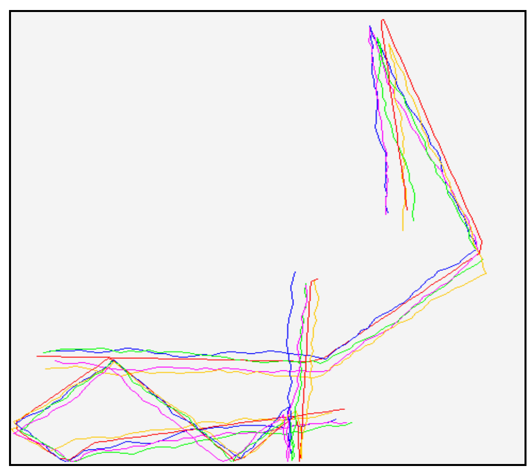

Figure 15: Traveling pattern of Mobile Nodes in RPGM Mobility Model

Node Spatial Distribution of RPGM Mobility Model with 2 groups with 10 mobile nodes in 500m*500m simulation area and average speed=20m/s, for simulation time=100000sec is shown in figure 16.

As we can see the node spatial distribution is similar to Random Walk Mobility Model because the leader node in each node travels with Random Walk Mobility Model.

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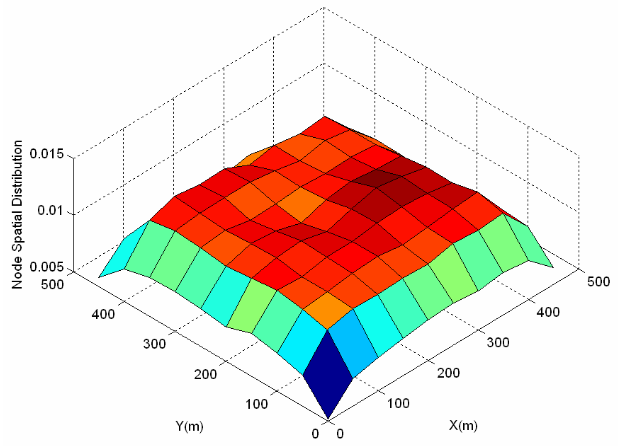

Figure 16: Spatial Node Distribution in RPGM Mobility Model

IV. CONCLUSION AND FUTURE WORKS

In this paper we introduced a powerful java based mobility simulator which can be used to generate mobility traces in various mobility models with customized configuration. This simulator can be used to generate mobility traces to be used in different network simulators which do not support mobility generation for mobile Ad-Hoc networks. User friendly graphical user interface can help the users view and analyze behavior of mobile nodes in each mobility model. Output traces of this simulator can be generated in plain Text and XML formats which can be easily used by different network simulators.

For the future works we are working on the simulator to support more mobility models like: Obstacle, Pathway, Smooth Random, Column, Nomadic Community, Pursue and other mobility models discussed in literature and also to propose new features for our implemented mobility models to make them more similar to motion behavior of real world mobile nodes.

We are working on our simulator to make it capable to simulate special moving entities like pedestrians, cars and animals to be used in other research purposes like Robotics and Intelligent Transportation Systems.

We are also working on a new software called Mobility Analyzer which can be used to analyze mobility traces and recognize their mobility patterns using learning based pattern recognition methods.

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REFERENCES

[1] C. Siva Ram Murthy and B.S. Manoj, Ad Hoc Wireless Networks: Architectures and Protocols, Prentice Hall, 2004.

[2] Tracy Camp, Jeff Boleng, Vanessa Davis, A Survey of Mobility Models for Ad Hoc Network Research, Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile AdHoc Networking: Research, Trends and Applications, vol 2, no 5, pp. 483-502, 2002.

[3] Fan Bai, Narayanan Sadagopan, Ahmed Helmy, The Important framework for analyzing the Impact of mobility on performance Of Routing Protocols for Adhoc Networks, Elsevier Journal of Ad Hoc Networks, 2003, pp. 383-403.

[4] S. M. Mousavi, M. Moshref, H. R. Rabiee, A.Dabirmoghaddam, "MobiSim: a Framework for Simulation of Mobility Models in Ad-Hoc Networks, http://ce.sharif.edu/~sm_mousavi/mobisim.html

[5] J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols", in Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking(Mobicom98), ACM, October 1998.

[6] L. Breslau, D. Estrin, K. Fall, S. Floyd, J. Heidemann, A. Helmy, P. Huang, S. McCanne, K. Varadhan, Y. Xu, and H. Yu, Advances in network simulation, in IEEE Computer, vol. 33, no. 5, May 2000, pp. 59--67.

[7] E. M. Royer, P. M. Melliar-Smith, and L. E. Moser. An Analysis of the Optimum Node Density for Ad hoc Mobile Networks, in Proceedings of the IEEE International Conference on Communications(ICC), Helsinki, Finland, June 2001.

[8] C. Bettstetter and C. Wagner. The Spatial Node Distribution of the Random Waypoint Mobility Model, in Proc. German Workshop on Mobile Ad-Hoc Networks (WMAN), Ulm, Germany, GI Lecture Notes in Informatics, no. P-11, pp. 41-58, Mar 25-26, 2002.

[9] B. Liang and Z. Haas. Predictive distance-based mobility management for PCS networks. In *Proceedings of the Joint Conference of the IEEE Computer and Communications Societies (INFOCOM)*, March 1999.

[10] C. Chiang. *Wireless Network Multicasting*. PhD thesis, University of California, Los Angeles, 1998.

[11] X. Hong, M. Gerla, G. Pei, and C.-C. Chiang, A group mobility model for ad hoc wireless networks, in Proc. ACM Intern. Workshop on Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWiM), August 1999.

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