A CONCEPTUAL STUDY OF MOBILITY MODELS IN MANET

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***Abstract*—In general, a Mobile Ad hoc Network (MANET) is a self configuring network of mobile nodes connected by wireless links to form an arbitrary topology without the use of existing infrastructure.**

In mobile ad hoc network, simulation plays an important role in determining the network characteristics and measuring performance. On the other hand, unrealistic simulation conditions may be misleading, instead of being explanatory.

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. In this paper, we provide survey and classification of existing mobility models. We also discuss various mobility models that exhibit the characteristics of temporal dependency, spatial dependency and geographic constraints. Hence, we attempt to provide an overview of the analysis of mobility modeling.

***Keywords*: Mobility Model; Mobile Ad hoc Network.**

Introduction: A mobile adhoc network (MANET) is an autonomous, infrastructure-less, self-configuring and self-healing system of mobile nodes connected by wireless links. The nodes are free to move about randomly and may join or leave the network at their will.

The nodes in an ad hoc network move according to various patterns are needed in
simulation in order to evaluate system and protocol performance. Unlike the wiring networks, the unique characteristics of mobile ad hoc networks pose a number of nontrivial challenges to security design, such as open peer-to-peer network architecture, shared wireless medium, stringent resource constraints and highly dynamic network topology [1].

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. Figure 1 shows the classification of mobility model.

Mobility model is classified into entity mobility and group mobility. In this paper mobility models used are: random way point mobility model, column mobility model and reference point group mobility model. Random way point mobility models come under the entity mobility model and other two come in group mobility model. These mobility models are described below:

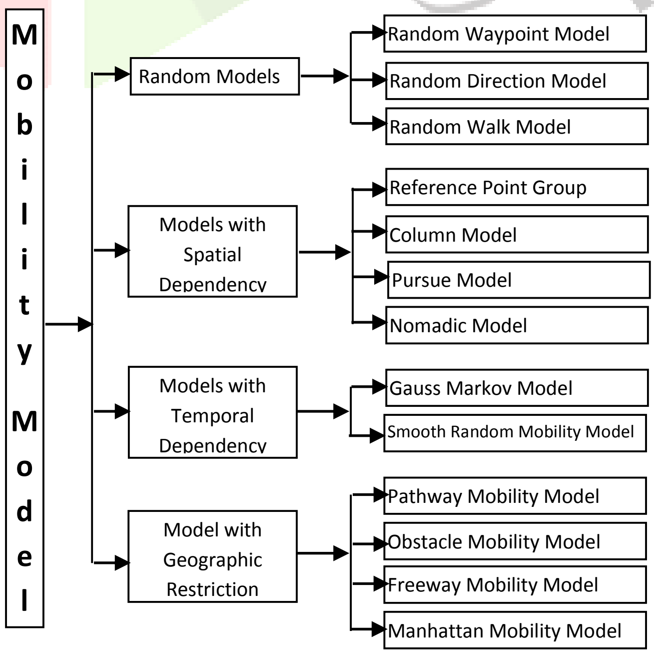

Figure 1: Classification of Mobility Models

RANDOM BASED MOBILITY MODEL

A. Random way point mobility model

The Random Waypoint Model was first proposed by Johnson and Maltz[2]. Soon, it became a 'benchmark' mobility model to evaluate the MANET routing protocols, because of its simplicity and wide availability. In this model, the position of each node is randomly selected within a fixed area and after that moves to the selected position in linear form with random speed. This movement has to stop by a certain period called pause time before starting the next movement.

The pause time is determined by model initialization and its speed is uniformly distributed between [Min Speed, Max Speed]. The Random Waypoint Mobility Model is the most widely used mobility model. Many researchers use it to compare the performance of various mobile ad hoc network routing protocols. This model includes pause times between changes in direction and/or speed. Using the waypoint mobility model, each node starts the simulation by remaining stationary for pause-time seconds. Then, it randomly chooses a destination in the simulation area and moves towards that destination at a speed uniformly chosen between zero and maximum speed and so on. When the node reaches the selected destination, it halts again for pause-time, selects another destination and starts to move towards the new destination.

The track of nodes in Random waypoint
model is showed in Figure1

Random Waypoint mobility model [3, 4] is used in many papers. It is a simple and straight forward stochastic model that describes the movements of mobile nodes in a given area as follows: firstly, a node randomly chooses a destination point in the given area Z, the destination points are independent and distributed at complete random on Z. Secondly, the node randomly chooses a speed from [Vmin, Vmax] . The speed is ultimately distributed at random in min max [V ,V] . Then the node moves at

Figure1. Track of node in Random Waypoint model speed on a straight line to the destination point. Once
arriving at the destination point, the node randomly chooses a pause time p T from ,max [0,] p T
. After waiting p T time, the node will chose a new destination point and speed, move at a constant speed to the new destination point, and so on. The track of nodes in Random waypoint model is showed in Figure1.

Advantages

- The most common use mobility model, because of its simplicity.
- A building block for developing a variety of mobility models.

Disadvantages

- Lack of regular movement modeling.
- Exhibits speed decay.
- Exhibits density wave.
- Memory-less movement behaviors (a common problem for all random waypoint variations).

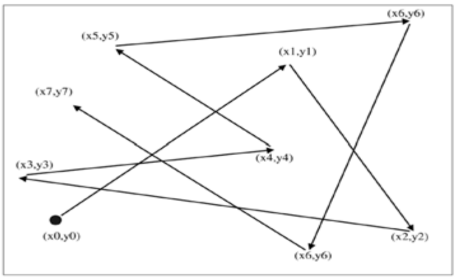

Figure 2: Node movement in the Random Waypoint Model

B. Random walk mobility model

In this mobility model mobile host moves from current location to new location by choosing randomly direction and speed from the predefined ranges between min speed and max speed. Since many entities move in unpredictable ways, the Random Walk Mobility Model was developed to mimic this erratic movement [5]. In this kind of mobility model, a mobile node randomly chooses a direction and speed to move from its current location to a new location. The speed and direction are chosen from pre-defined ranges, [minimum speed, maximum speed] and [0, 2π] respectively. If a mobile node reaches a simulation boundary, it bounces off the simulation border with an angle determined by the incoming direction. The node then continues along this new path. The Random Walk Mobility Model is widely used [5], and it is a memory less mobility pattern because it does not have any knowledge concerning its past locations and speed values. The current direction and speed of the node are independent of its past direction and speed [6]. This model may generate unrealistic movements such as sudden stops and sharp turns.

Advantages

- The simplest model to implement.
- Generates unpredictable movements enabling a long-running simulation to consider all locations and node interactions.

Disadvantages
- Unrealistic movement patterns
- Sharp and sudden turns.
- Wrapping not observed in real applications.

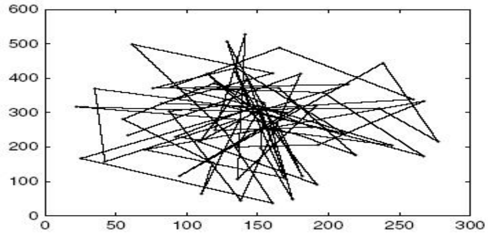

Figure 3: Node movement in the Random Walk Model

C. Random Direction Mobility Model

In the case of Random Direction Mobility Model, a node chooses a random direction uniformly within the range [0, 2π]. The velocity is also chosen uniformly from within the range [minspeed, maxspeed]. Node then moves in the chosen direction until it arrives at the boundary of the simulation area. At this point the node pauses for a specified pause time and again selects a new direction from within the range [0, π]. Since the node is on the boundary of the simulation area, the direction is limited to π.

Advantages
- A variation of the random waypoint without drawback of density wave.
- Uniform distribution of chosen routes.

Disadvantages
- Unrealistic movement pattern
- Average distances between mobile nodes are much higher than other models, leading to incorrect results for routing protocols evaluation.

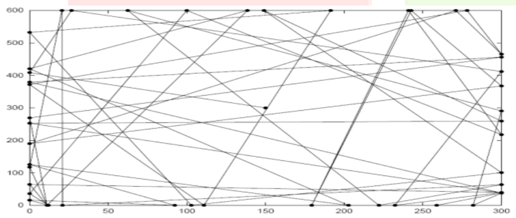

Figure 4: Traveling pattern in Random Direction Mobility Model

<u>MOBILITY MODEL WITH SPATIAL DEPENDENCY</u>

A. Column Mobility Model

The Column Mobility Model represents a set of mobile nodes (e.g., robots) that move in a certain fixed direction. This mobility model can be used in searching and scanning activity, such as destroying mines by military robots.

At time slot t, the mobile node i is to update its reference point RP_i^t by adding an advance vector α to its previous reference point RP_i^{t-1},

Formally,

$$RP_i^t = RP_i^{t-1} + \alpha_i^t$$

where the advance vector α_i^t is the predefined offset used to move the reference grid of node i at time t. After the reference point is updated, the new position of mobile node i is to randomly deviate from the updated reference point by a random vector w_i^t.

Formally,

$$P_i^t = RP_i^t + w_i^t$$

When the mobile node is about to travel beyond the boundary of a simulation field, the movement direction is then flipped 180 degree. Thus, the mobile node is able to move towards the center of simulation field in the new direction.

Figure 5: Node Movement in Column Mobility Model

B. Reference Point Group Mobility Model

The whole group of mobile nodes moves randomly from one location to another. Then, the reference point of each node is determined based on the general movement of this group. Inside of this group, each node can offset some random vector to its predefined reference point. Represents the random motion of a group of mobile nodes as well as the random motion of each individual mobile node within the group.

- Group movements are based upon the path traveled by a logical center of the group.
- Individual MNs randomly move about their own pre-defined reference points.
- The RPGM model uses a group motion vector GM to calculate each MN's new reference point, RP(t +1), at time t +1.
- The length of RM is uniformly distributed within a specified radius centered at RP(t +1) and its direction is uniformly distributed between 0 and 2π.
- Both the movement of the logical center for each group, and the random motion of each individual MN within the group are implemented via the Random Waypoint Mobility Model.
- Individual MNs do not use pause times while the group is moving. Pause times are only used when the group reference point reaches a destination and all group nodes pause for the same period of time.

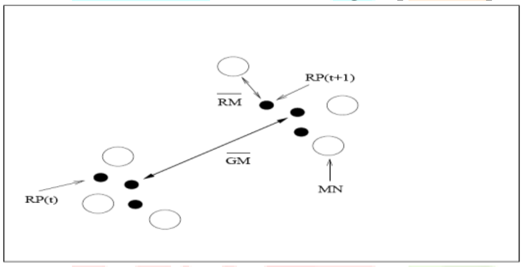

Figure 6: Movement of three nodes using RPGM model

Here, we examined the mobility models with its properties and exhibit different mobility characteristics. We expected that these mobility models behave differently and influence the protocol performance in different ways. Each model has its own unique and specific mobility characteristics. On the basis of characteristics, these are the comparative features of some mobility models in its own category:

2.4. Pursue model

The Pursue Mobility Model emulates scenarios where several nodes attempt to capture single mobile node ahead. This mobility model can be used in target tracking and law enforcement. The node being pursued (target node) moves freely according to the Random Waypoint model by directing the velocity towards the position of the targeted node, the pursuer nodes (seeker nodes) try to intercept the target node.

Nomadic community model

The Nomadic Mobility Model is to represent the mobility scenarios where a group of nodes move together. This model could be applied in mobile communication in a conference or military application. The whole group of mobile nodes moves randomly from one location to another. Then, the reference point of each node is determined based on the general movement of this group. Inside of this group, each node can offset some random vector to its predefined reference point. The movement in the Nomadic Community Model is sporadic while the movement is more or less constant in Column Mobility Model

MOBILITY MODELS WITH TEMPORAL DEPENDENCY

Mobility of a node may be constrained and limited by the physical laws of acceleration, velocity and rate of change of direction. Hence, the current velocity of a mobile node may depend on its previous velocity. Thus the velocities of single node at different time slots are 'correlated'. We call this mobility characteristic the Temporal Dependency of velocity.

However, the memory less nature of Random Walk model, Random Waypoint model and other variants render them inadequate to capture this temporal dependency behavior. As a result, various mobility models considering temporal dependency are proposed. Gauss-Markov Mobility Model and Smooth Random Mobility Model are described in details. Finally, we briefly summarize the key characteristic of temporal dependency in Table 1

Gauss-Markov model

In the Gauss-Markov Mobility Model each mobile node is initialized with a speed and direction. By fixed intervals of time movement occurs to updating the speed and direction of each node. To be specific, the value of speed and direction at the nth instance of time is calculated based upon the value of speed and direction at the n - 1st instance and a random variable. Camp et al [6] elaborates the equations for calculating speed and direction in detail.

Manhattan Grid model

The Manhattan mobility model [7] uses a grid road topology. This model is mainly proposed for the movement in urban area, where the streets are in an organized manner and the mobile nodes are allowed to move only in horizontal or vertical direction.

At each intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight with certain probability.

Except the above difference, the inter-node and Intra-node relationships involved in the Manhattan model are very similar to the Freeway model. This model can be used in Mobile Ad-hoc Networks (MANET) and Vehicular Ad-hoc Networks (VANET) simulators.

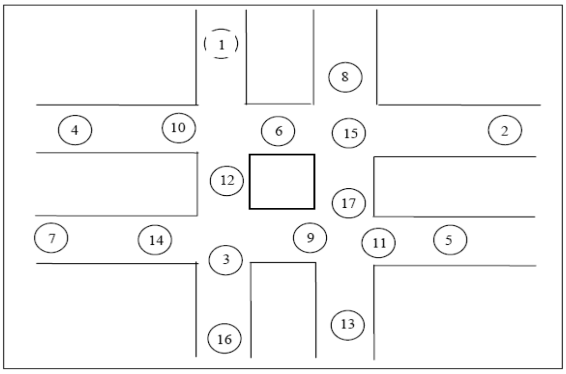

Figure 7 Topography showing the movements of nodes for Manhattan Mobility model

In this Figure 3 shows the sample topography the movement of nodes for Manhattan Mobility Model with seventeen nodes. The map defines the roads along the nodes can move

1.4 Freeway model

The Freeway model emulates the motion behavior of mobile nodes on a Freeway. It can be very well used in exchanging traffic status or tracking a vehicle on a Freeway. This model makes use of use maps. There are several freeways on the map and each freeway has lanes in both directions.

Each mobile node is restricted to its lane on the freeway. The velocity of mobile node is temporally dependent on its previous velocity.

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.

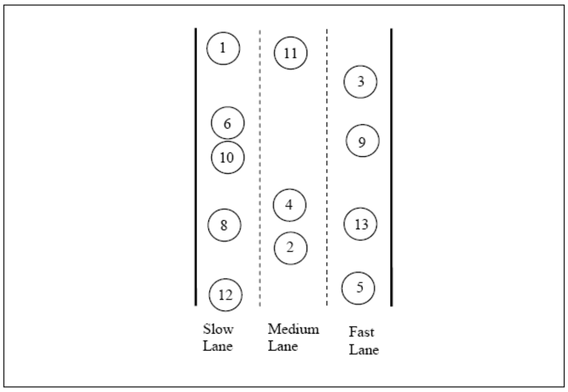

Figure 8 Topography showing the movements of nodes for Freeway Mobility model In this figure 4 shows the topography the movements of nodes for freeway model with twelve nodes. Because of the use of maps, nodes traveling in one line can't move to the

Pathway model:

One simple way to integrate geographic constraints into the mobility model is to restrict the node movement to the pathways in the map. The map is predefined in the simulation field. Tian, Hahner and Becker et al [8] utilize a random graph to model the map of city. This graph can be either randomly generated or carefully defined based on certain map of a real city. The vertices of the graph represent the buildings of the city, and the edges model the streets and freeways between those buildings. Initially, the nodes are placed randomly on the edge. Then for each node a destination is randomly chosen and the node moves towards this destination through the shortest path along the edges.

Upon arrival, the node pauses for T pause time and again chooses a new destination for the next movement. This procedure is repeated until the end of simulation.

Unlike the Random Waypoint model where the nodes can move freely, the mobile nodes in this model are only allowed to travel on the pathways. However, since the destination of each motion phase is randomly chosen, a certain level of randomness still exists for this model. So, in this graph based mobility model, the nodes are traveling in a pseudo-random fashion on the pathways. Similarly, in the Freeway mobility model and
Manhattan mobility model [9], the movement of mobile node is also restricted to the pathway in the simulation field. Fig.9 illustrates the maps used for Freeway, Manhattan and Pathway Models.

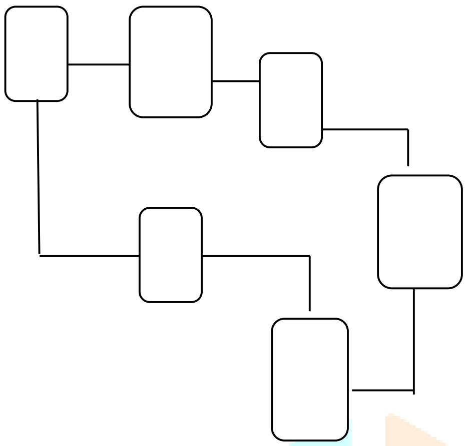

Fig 9: The pathway graphs used in the Freeway, Manhattan and Pathway Model

Obstacle mobility model:
Another geographic constraint playing an important role in mobility modeling includes the obstacles in the simulation field.
To avoid the obstacles on the way, the mobile node is required to change its trajectory. Therefore, obstacles do affect the movement behavior of mobile nodes. Moreover, the obstacles also impact the way radio propagates. For example, for the indoor environment, typically, the radio system could not propagate the signal through obstacles without severe attenuation.
Johansson, Larsson and Hedman et al [10]
develop three realistic mobility scenarios to
depict the movement of mobile users in real
life, including

1. Conference scenario consisted of 50 people attending a conference. Most of them are static and a small number of people are moving with low mobility.
2. Event Coverage scenario where a group of highly mobile people or vehicles are modeled.
Those mobile nodes are frequently changing their positions.
3. Disaster Relief scenarios where some nodes move very fast and others move very slowly.

Jardosh, Belding-Royer and Almeroth et al [11] also investigate the impact of obstacles on mobility modeling in details. After considering the effects of obstacles into the mobility model, both the movement trajectories and the radio propagation of mobile nodes are

IMPORTANCE OF CHOOSING A
MOBILITY MODEL
In this section, I illustrate that the choice of a mobility model can have a significant effect on the performance and investigation of a network protocols. In summary, if a group mobility model is desired, we recommend using the Reference Point Group Mobility Model with appropriate parameters. If an entity mobility model is desired, I recommend using either the Random waypoint Mobility Model, the Random Walk Mobility Model

Table 1: Comparison of Mobility Models between Temporal Dependency and Spatial Dependency

Characteristics ↓ Name→	Random Waypoint Model	Random Walk Model	Reference Point Group Mobility Model	Random Direction Model	Column Mobility Model
Proposed By	Johnson and Maltz.	Karl Pearson.	Hong, G. Pei and C. C. Chiang	Royer, Melliar-Smith & Moser	Sanchez and P. Manzoni
Key Features	Vmax, Tpause are the key factors, where Vmax is the maximum speed and Tpause is the stop time upon reaching the destination.	It is the specific type of Random Waypoint model with Tpause time=0.	Each group has a centre, a logical centre, a group leader and group members. The motion vector of group, Vtgroup and motion vector of a group member i, at time t , named as reference point, RMit are the key factors.	Vmax, Tpause is there, node randomly chooses a direction and moves direction between 0 and 180 degrees.	Same as RPGM, having set of mobile nodes, reference point RPit , along with advance vector of each mobile node i, at time t, αit for referencing the grid property.
Node Distribution Method	Uniform	Uniform	Uniform	Uniform	Uniform
Memory / Memoryless	Memory less	Memory less	Memory	Memory less	Memory
Average Speed	Nodes move at average relative speed between (0, Vmax).	At each interval t, node moves θ(t) from (0,2π)	Nodes move at average relative speed between (0, rmax) and flipped to 0 to 2π degree if reach to boundary line.	Node moves (-π/4, π/4) with probability of 61.4%.	Average relative speed is (0, rmax) and flipped to 180 degree if reach to boundary line.
Distribution Method	Method used is Probability Distribution	Uniform or Gaussian Distribution	Method used is Uniform distribution. Maximum allowed speed is rmax .	Non-uniform spatial node or density wave method is used.	It is the centralized distribution.
Border Effect	It has mean-ergodic property.	It has border-effect property.	No Effect	It affects from border-effect property but also deals with directional affect.	No Effect
Entity/Group Mobility Model	It comes under in Entity mobility model.	It comes under in Entity mobility model.	It comes under in Group mobility model.	It comes under in Entity mobility model.	It comes under in Group mobility model.
Temporal Dependency	It restricts Temporal Dependency.	It restricts Temporal Dependency.	It does not allow Temporal Dependency.	It restricts Temporal Dependency.	It does not allow Temporal Dependency.
Spatial Dependency	No Spatial Dependency is there.	No Spatial Dependency is there.	Spatial Dependency is there.	No Spatial Dependency is there.	Spatial Dependency is there.
Geographic Restrictions	No Geographic Restrictions are there.	No Geographic Restrictions are there.	No Geographic Restrictions are there.	No Geographic Restrictions are there.	No Geographic Restrictions are there.

In above table1 we provide a categorization for various mobility models into several classes based on their specific mobility characteristics. In all Mobility model uniform node distribution is used. Random mobility models are memory less models because they don't have any knowledge concerning its past locations and speed values. Reference point and column mobility used memory to store predefined reference node. For some mobility models, the movement of a mobile node is likely to be affected by its movement history. We refer to this type of mobility model as mobility model with temporal dependency. In some mobility scenarios, the mobile nodes tend to travel in a correlated manner. We refer to such models as mobility models with spatial dependency. Another class is the mobility model with geographic restriction, where the movement of nodes is bounded by streets, freeways or obstacles. We observe that the mobility models may have various properties and exhibit different mobility characteristics. As a consequence, we expected that those mobility models

behave differently and influence the protocol performance in different ways.

The Reference Point Group Mobility Model (RPGM) is a generic method for handling group mobility. An entity (Random) mobility model (or models) needs to be specified to handle both the movement of a group of MNs and the movement of the individual MNs within the group.

CONCLUSION:

Mobility Model plays an important role in wireless network protocols. By studying various mobility models, we attempt to conduct a survey of the mobility modeling and analysis techniques in a thorough and systematic manner. Beside the Random Waypoint model and its variants, many other mobility models with unique characteristics such as temporal dependency, spatial dependency or geographic restriction are discussed. We believe that the set of mobility models included herein reasonably reflect the state-of-art researches and technologies in this field.

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