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Review Paper

A Classification and Mobility Metrics of Various Mobility Models

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Abstract

In wireless network research, simulation plays an important role in determining the network characteristics and measuring performance. The results of simulative performance evaluation relies on models used in the network. Since wireless networks consist of or at least contain mobile devices, the mobility model used has a decisive impact. However, in common performance evaluations mainly simple random-based models are used. In this study, we first provide a survey and a categorization of existing mobility models in the literature. In the paper, we present classification of various mobility models. We also define various kinds of mobility metrices using mobisim simulator.

Keywords: Mobility models, mobility metrics, networks, mobisim.

Introduction

The communication systems used in disaster area scenarios need to be as reliable as possible, the performance of these systems has to be evaluated. Field-tests in manoeuvres may be the preferred evaluation method. However, they are expensive, as sufficient hardware is needed. Furthermore, the results concerning some characteristics are limited. Thus, especially for the evaluation of algorithms and protocols, simulation is an alternative. Naturally, the results of simulative performance evaluation strongly depend on the models used. Since networks consist of mobile devices, the mobility model used has a decisive impact. However, in common performance evaluations mainly simple randombased models are used. In the not-too-distant future, travelling vehicles will be able to communicate while forming ephemeral, rapidly changing ad hoc networks[1].

In the paper our aim will be to give a performance evaluation of various mobility models and metrices using mobisim. The individual nodes and there movement characteristics need to be modeled. In this paper we will focus on models that realize the movement of individual nodes. In the literature there are already some surveys on mobility models[2, 3]. However, these surveys are quite old or miss a lot of specific models.

Furthermore, there is no review concerning the requirements for tactical scenarios. Thus, in this paper we will give a performance existing mobility models and classify these models.

Related work

In the past, understand contact patterns of mobile nodes. This section reviews some related work in the literature on these various parameters used in mobisim simulator and generate various kinds of traces. Added highlights the input and output parameters using mobisim simulator.

In the mobisim simulator, first uses input parameters. After then, Output traces are produced. These traces used in Evaluation of without power and with power. After that, various kinds of matrices generated from these evaluation parameters.

All the mobility models use various kinds of input parameters. Some of these defined below: i. max simulation time, ii. Maxspeed, iii. Memoryfactor, iv. Minspeed, v. random amplitude.

The best value of memory factor between 0 to 1 and random amplitude between 0 and 2.

All the mobility models generate various kinds of metrices. Some of these defined below: i. Spatial dependency, ii. Relative speed, iii. Repetive behavior, iv. Location distribution variance, v. Average distance, vi. Avg life time, vii. Disconnection ratio%, viii. Neighborhood instability, ix. Network diameter, x. 1Way node degree, xi. 2Way node degree, xii. Clustering coefficient.

Furthermore, as mobile scenarios take place in areas of destruction, obstacles might be encountered. Smaller ones may be ignored, because they only have little impact on the movement. However, larger ones such as, walls, houses, etc. will have a certain impact on movements.

However, these trace based studies are based on current penetration of wireless technologies and usage behaviors. Moreover, they might not be an accurate reflection of real contact patterns since they are based on the interactions between only a small subset of the population.

The researchers have developed simple and reasonable mobility models which have been used to characterize the performance of wireless ad hoc networks. Mobility models such as the Random Way-point and the Random Direction model are commonly studied in ad hoc networking research. In these models however, nodes are typically assumed to move independently. This assumption results in intercontact times that are exponential in nature.

Finally, especially in mobile communication systems, it is quite common that units leave the scenario, while others join later on. In military scenarios there may be fatalities, and in civil protection scenarios there may be units that take patients to hospital. When some units leave the scenario, typically others are requisitioned.

As a conclusion, the analysis yields the following main dependencies: i. Temporal, ii. Spatial, iii. Geographical.

The following sections present existing mobility models and examine which models meet these dependencies.

Classification

In general, the mobility models can be classified according to the different behaviour of models that are considered.

Random Models: There are neither dependencies nor any other restriction modeled. (e.g., Random-walk).

Random Variant Models: The actual movement of a node is influenced by the movement of the past. (e.g., Gauss-Markov).

Group Models: The movement of a node is influenced by the nodes around it. (e.g., Reference-point-group).

Geographic Models: The area in which the node is allowed to move is restricted. (e.g., Freeway).

Social Models: A social relationship between nodes is realized. (e.g., CMM).

Random models: Random-waypoint mobility model often used in the last years (especially in performance evaluation of ad hoc networks). It is a simple stochastic model in which a node perpetually chooses destinations (waypoints) and moves towards them. In the original model the nodes are distributed randomly over the simulation area[4]. After waiting for a constant pause time, each node chooses a waypoint and moves towards it with a speed chosen from an interval [umin; umax]. After arriving at the waypoint, the node again waits for a constant pause time and chooses the next waypoint. In it is proposed to also choose the pause time from an interval [pmin; pmax][5]. The different random variants are mostly chosen uniformly distributed.

In the last years, there were several studies that analyze the random-waypoint model with respect to implicit (unwanted) assumptions and characteristics. As the nodes are initially distributed randomly, it takes some time until the nodes reach a stationary distribution[6]. Thus, a long enough initial period should be discarded. In it is shown that the average velocity is decreasing over simulation time if vmin = 0[7]. Thus, vmin >0 and pmax < ∞ should be chosen. Furthermore, in several publications it was shown that the nodes cumulate in the middle of the simulation area[8, 9, 10].

A distribution and movement of the nodes across the entire simulation area does not fit to the characteristics of most realistic movements. There are extensions which add attraction points to this model in order to generate more realistic non-equally distributed mobility[9]. The probability that a node selects an attraction point or a point in an attraction area as next waypoint is larger than the choice of other points. The nodes visit some points more frequently than others. Hence, they still move across the complete simulation area. The clustered-mobility model is motivated by disaster areas and uses a similar approach[11]. The difference is that the attraction of a point depends on the amount of nodes nearby. This implies that the areas of higher density variated concerning the intensity and position. Further approaches like the random-direction model, random-border model, and the modified-random-direction model also result in fully random movement with different node density distributions[9, 12].

All random-based models result in random movement across the complete simulation area. The models are quite simple to implement, but the only characteristics of a tactical scenario that is realized are the optimal paths. However, at least heterogeneous velocity may be integrated quite easily.

Random variant models: The nodes suddenly may change speed or direction, using one of the models of the previous section. This is quite unrealistic considering aspects like acceleration and deceleration. The models presented in this section are random variant models by using temporal dependencies.

The smooth-random model is a more detailed approach[2,13]. The nodes are classified concerning their maximum velocity, preferred velocity, maximum acceleration and deceleration. New velocities and directions are calculated based on these parameters and the current ones. Velocity and direction may also be chosen in correlation to each other. By doing so, more realistic movements like deceleration before a change of direction may be realized.

In the Gauss-Markov model velocity and direction of the future time interval t+1 depend on the current values time interval t. Initially for each node position, velocity, and direction are chosen uniformly distributed. The movement of each node is variated after an interval dt. The new values are chosen based on a first-order autoregressive process. Further details can be found in[14].

By using mobisim simulator, one of these models and realizing the temporal dependencies the movements of the nodes become smoother concerning direction and velocity.

Group models: Nodes may move together in groups. Thus, the movement of one node may influence the movement of others around him.

One approach to realizing spatial dependence is the use of reference points. The reference-point-group-mobility model (RPGM) models the movement of groups of nodes[15]. The movement of the groups is modeled according to an arbitrary mobility model. The movement of the nodes inside a group is realized using a reference point for each node. The actual position of a node is a random movement vector added to the position of his reference point. The absolute positions of the reference points do change according to the arbitrary mobility model, but the relative positions of the reference points inside a group do not change. Hence, the spatial dependence is realized using the reference points.

In a variance of the model called structured-group-mobility model is proposed[16]. In this model there is no random movement vector. The nodes of a group move in a fixed non-changing formation. The formations are motivated by fire-fighter, police, and tanks. In literature there are also found several other variances of the RPGM model, e.g., column model, pursue model, nomadic-community model[3,17].

For realizing group mobility, the RPGM model seems to be the better approach, as with an appropriate choice of parameters relative positions of nodes inside the groups can be modeled explicitly. Using the RPGM model, beside the characteristic of group movement, other characteristics may be realized by using an appropriate model for the reference points.

Geographic models: For many scenarios it is unrealistic to assume that the nodes are allowed to move across the entire simulation area by considering temporal and spatial dependencies. There are very different approaches to restrict the nodes movement to certain parts of the simulation area.

A further approach to restrict the movement area geographically is to use information from road maps. In the context of the UMTS standardization, the so-called Manhattan-grid model was specified. The simulation area is divided into squared blocks. Nodes are modeled as pedestrians moving on the vertices of the streets squares. Initially the nodes are randomly distributed on the streets. Each node chooses a direction and a velocity. If a node reaches a corner, the node changes direction with a certain probability. The velocity is changed over time. The random-waypoint-city model realizes vehicular traffic in urban environments[18]. Therefore, road maps including speed information and crossroads are retrieved. A node chooses a destination on the streets similar to the random-waypoint model and chooses a route after an arbitrary metric of smallest travel time. At the crossroads delays are modeled according to the amount of roads. Furthermore, an equal distribution of the nodes throughout the simulation area is realized. In two further models are described which realize mobility models (e.g., random-waypoint) on graphs based on road maps[19].

One possibility of modeling simulation areas with obstacles is to determine the movement paths or areas using Voronoi-diagrams. This approach was first introduced with the obstacle mobility model[20, 21]. In this model, the edges of the buildings such as, campus are used as an input to calculate a Voronoi-diagram. The movement graph consists of the Voronoi-diagram and additional vertices. These vertices are the intersection of the edges of the Voronoi-diagram and the edges of the obstacles. They model entrances to obstacles such as, buildings. The movement on the graph is realized similarly to the graph-based model. By using Voronoi-diagrams, the paths are modelled equidistant from all obstacles. Furthermore, even for a campus network it is a strong assumption that all streets are built equidistant from all buildings and all nodes move in the middle of the street. In the approach is extended to realize buildings and streets more realistically[22]. In the Voronoi mobility model movement, paths are refined to movement areas. The nodes choose their destinations inside these areas. The movement using this model is more realistic, as streets and buildings are realized more precisely. However, there is still no movement on optimal paths.

Another approach is to divide the simulation area in subareas and to use in them arbitrary mobility models. The area-graph-based mobility model tries to realize clusters with higher node density and paths in between with lower node density[23]. The clusters are regarded as vertices of the area graph while the paths are regarded as edges. A probability of weight is assigned to each edge. A node moves inside the cluster for a randomly chosen time according to the random-waypoint model. After this time, he chooses one path according to probabilities at the edges. Next, the node moves on the path to the next area. A similar approach is used in CosMos[24]. The simulation area is subdivided into non-overlapping zones. In each zone the nodes move according to an arbitrary mobility model. The transition between the zones is realized similarly to the area graph based mobility model using transition probabilities. If a node is chosen to change the zone, he moves to a handover area and switches to the other mobility model.

A quite intuitive approach is to manage the allowed paths in a movement graph. The graph-based mobility model realizes a graph whose vertices are the possible destinations and whose edges are the allowed paths[25]. Based on this graph a random waypoint approach is used. The nodes initially start at a random position on the graph, choose a destination (vertex), move there at random velocity, and choose the next destination and velocity.

Another approach that is using graphs is the weighted-waypoint mobility model[26]. The vertices of the graph are specific areas of classroom, cafe, etc. The nodes choose destinations inside these areas. The directed edges of the graph contain probabilities of choosing a destination in the directed area depending on the current area. Having chosen a waypoint, the nodes move there on the direct way similar to the random-waypoint model. Compared to the graph-based model, the movement is not restricted to distinct paths.

Social models: In mobile networks, devices are usually carried by humans, so the movement of such devices is necessarily based on human decisions and social behavior. These models are usually trace based, i.e., they are generally founded or evaluated by means of real traces.

The modeling of these relationships and their implications to human mobility is of paramount importance to test protocols and systems that exploit the underlying social structure, such as socially-aware delay tolerant forwarding protocols.

An approach to realize spatial dependence is to found on social networks. The social-network-founded mobility model bases on interaction indicators for all pairs of nodes - the larger an interaction indicator, the larger the probability of a social relationship, the smaller the geographic distance[27]. Initially the nodes are grouped in clouds according to their interaction indicator. The clouds as well as the nodes inside the clouds move according to a random waypoint model, where the waypoints are chosen according to the interaction indicators as well. In this approach is reinvented as community-based mobility model. Furthermore, the interaction indicators are modified over time.

Conclusion

Finally, we want to discuss performance are realized and which approaches mobile model scenarios. Summary of the survey and performance analysis that was provided (table 1). In the table for each model the dependencies considered are shown. A “Y” means “explicitly modeled”, while a “(Y)” means “not modeled but can be easily extended”. For example Temporary dependency not considered in Reference-point-group model. However, it is quite easy to extend the models supporting temporary dependency for nodes. Others may be easily extended using an approach like the area-graph-based model. Group movement may be easily integrated in other models using the reference point approach.

The temporary, spatial and geographical dependencies are considered in some specific models. However, beside the disaster area model there is no model that considers combinations of all of them. This scenario may also be used for the performance evaluation of communication systems for military usage. There are valuable first realizations of specific scenarios, such as, the platoon scenario. However, in the future new scalable models for military scenarios should be invented. Furthermore, the characteristics of these, and, within this, the impact on existing performance evaluation results should be examined.

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Table – 1
A classification of various mobility models

Model	Random	Random Variant	Group	Geographic	Social	Dependencies		
						Temporal	Spatial	Geographical
Random-walk	Y	---	---	---	---	---	---	---
Random-waypoint	Y	---	---	---	---	---	---	---
Random-direction	Y	---	---	---	---	---	---	---
Clustered-mobility	Y	---	---	---	---	---	(Y)	---
Levy Walk	Y	---	---	---	---	---	---	---
Random-border-model	Y	---	---	---	---	---	---	---
Gauss-Markov	---	Y	---	---	---	---	---	---
Smooth-random	---	Y	---	---	---	---	---	---
Semi Markov Smooth	---	Y	---	---	---	---	---	---
Reference-point-group	---	---	Y	---	---	(Y)	Y	(Y)
Structured-group	---	---	Y	---	---	---	Y	---
Social-network-founded	---	---	Y	---	---	---	Y	---
Community-based	---	---	Y	---	---	---	Y	---
User-oriented-meta-model	---	---	Y	Y	---	Y	Y	Y
Platoon	---	---	Y	Y	---	---	Y	Y
Disaster-area-model	---	---	Y	Y	---	---	Y	Y
Column	---	---	Y	---	---	---	---	---
Pursue	---	---	Y	---	---	---	---	---
Nomadic Community	---	---	Y	---	---	---	---	---
Exponential Correlated	---	---	Y	---	---	---	---	---
Row	---	---	Y	---	---	---	---	---
Graph-based	---	---	---	Y	---	---	---	Y
Weighted-waypoint	---	---	---	Y	---	---	---	Y
Obstacle	---	---	---	Y	---	---	---	Y
Voronoi	---	---	---	Y	---	---	---	Y
Area-graph-based	---	---	---	Y	---	---	---	Y
CosMos	---	---	---	Y	---	---	---	Y
Manhattan-grid	---	---	---	Y	---	---	---	Y
Random-waypoint-city	---	---	---	Y	---	---	---	Y
Graph-random-waypoint	---	---	---	Y	---	---	---	Y
Graph-random-walk	---	---	---	Y	---	---	---	Y
CMM	---	---	---	---	Y	---	---	---
Orbit	---	---	---	---	Y	---	---	---
Slaw	---	---	---	---	Y	---	---	---