A Novel Mobility Model for Mobile Ad Hoc Networks

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Abstract. In this paper, we investigate mobility models in mobile ad hoc networks (MANETs) and propose a novel mobility model for mobile ad hoc nodes with intelligence. The proposed model named Attracting Group Mobility (AGM) Model means mobile node moving from one attracting point to another. Compared to the traditional mobility models, the proposed model has intelligent property. Once a reference point is full, mobile nodes can't enter even they are attracted and the mobile nodes already in the reference point may leave it with a probability. Besides, mobile nodes have inertia that moving speed and direction have only a small variation. Moreover, inhomogeneity is discussed in this paper. Simulation results show that the proposed mobility model can also be a method of generating inhomogeneity distribution.

Keywords: Mobile ad hoc networks, mobility model, inhomogeneity.

1 Introduction

Mobile ad hoc networks (MANETs) are growing at a very fast rate, and are likely to continue in the future. How to effectively mimic moving behaviors of mobile nodes in a real environment is a challenging issue. Besides, the evolution of improved designs and new systems will always depend on the ability to predict MANETs performance using simulation methods [1].

The challenging of building an effective mobility model has motivated many researchers to propose mobility models and use them in their simulation. For instance, random waypoint (RWP) model [2-3] and random direction (RD) model [4] are most commonly used mobility models. They all have sharp turn, and base on random distribution. Small world in motion (SWIM) [5] presents a small world in motion, a mobility model that can be set by setting just a few parameters. Semi-Markov Smooth (SMS) model [6] can avoid average speed decay problem and always maintains a uniform spatial node distribution.

Existing mobility models aimed at mobile nodes without life. However, nowadays many mobile nodes are set on people or animals such as cows and sheep. So, the social behavior should be taken into account. Existing random mobility models have their limitations such as totally random mobile nodes and no prediction which don't accord with life's law of motion. Our intelligent group mobility model just hits it.

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Moreover, people and animals have intelligence; they can be attracted such as applicants being attracted by recruitment table, people on the square being attracted by performance, animals being attracted by food and drinking water. Even if there is no physical attraction source, people and animals may form some group by themselves. But if a group is too crowded, people and animals may feel ill and leave out. Thus, this paper proposes a novel group mobility model, named as Attracting Group Mobility Model, aimed at the characteristic of such mobile nodes.

The remainder of the paper is organized as follows: Section II briefly discusses the related work of mobility models. In Section III, we describe our group mobility model in details. Section IV describes the defined inhomogeneity measure with equations and derives the inhomogeneity's upper bound of the proposed mobility model. Section V shows a case study of using the model to simulate some properties such as inhomogeneity. And finally in Section VI, we summarize this work and point some issues for further research.

2 Related Work

There were already many models used to describe the movement of mobile nodes in MANETs [7]. In general, classic mobility models could be categorized into entity mobility models and group mobility models. The two most commonly used entity models were the RWP model and the RD model.

According to the RWP model, the movement of a mobile node can be described by a stochastic process. At first, the initial position (x, y) of a mobile node was chosen uniformly over the simulation area, that is x and y were uniformly distributed over $[0, X_{max}]$ and $[0, Y_{max}]$, respectively. For each time state, a node selected a destination inside the simulation area and moved at a constant speed v toward the destination, in which v was uniformly chosen over $[V_{min}, V_{max}]$. When the destination was reached, the node stayed there for a pause time. Later, the node chose the new destination and speed, and started the new movement. The shortcoming of RWP model were that it had sharp turn and based on random distribution.

According to the RD model [8], a mobile node moved with a certain speed which was chosen from a uniform distribution for a selected direction. After certain time which was selected, it paused for a certain period and then started over.

SWIM [5] presented small world in motion, a mobility model for MANETs. SWIM was relatively simple, was easily set by just setting a few parameters. SWIM was proved to generate traces that look real, and it could provide an accurate estimation of forwarding protocols in real mobile ad hoc networks.

Semi-Markov Smooth model [6] presented a mobility model that had characters such as evenly speed acceleration/deceleration and temporal correlation of velocity. The entire moving process in SMS model was smooth just as in real scenarios. SMS model had no average speed decay problem and could appropriately and flexibly mimic widespread real motion. Besides, SMS model could maintain a uniform spatial node distribution.

In Charge Vector Group mobility model [9], mobile nodes could carry a kind of charge and transit among three states named individual movement, tracking and group movement. And reference point could carry another kind of charge and generate force field to attract mobile nodes. The Charge Vector Group mobility model could simulate motions such as grouping in proposed, individual random movement, aggregating and disaggregating. The model had shown characters in real moving behaviors such as randomness and some orderliness.

3 Proposed Attracting Group Mobility Model

3.1 Mobiles in Real Life

In this section, we propose our group mobility model. There are two mobile states in mobility model. One is individual state; the other is group mobile state. Once captured by a reference point (RP), mobile node begins group mobile state. For instance, recruitment table are put in order and motionless in the recruitment hall. Applicants wander outside the recruitment table. When an applicant is attracted by a recruitment table, and the table is not full, he or she could enter the recruitment table. If a recruitment table is not full, everyone could not leave; on the contrary, if the table is full, everyone's leaving probability is equal. Meanwhile, mobiles in real life also have their inertia. People often move at a certain range of speed and ahead to a certain range of angle. Even they would like to change, they may not change sharply.

3.2 Model Description

In the following, we describe the model's basic characteristics. Consider a scenario of nodes moving in a square area with section blocks. RPs are randomly distributed on lattice points, which are uniformly distributed in the area. The space between lattice points Δ is twice larger than the radius of RP's coverage *R*. We consider a set of mobiles moving around in a given domain. Each mobile node has two mobile states. One is individual state, mobile nodes wandering in the simulation area, we regard it as state 0; the other is group mobile state, mobile nodes moving around RP, we regard it as state 1. Then we get a state transition diagram as Fig.1.

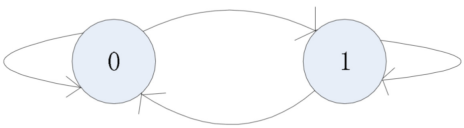


Fig. 1. Markov state transition diagram

The speed and direction of the proposed model are different from RWP model. We get,

$$v_{t+1} = (1-\alpha)v_t + \alpha\Delta v$$

where, v_t denotes the velocity of current time, v_{t+1} denotes the velocity of next time, v_0 denotes the velocity of initial time, $v_0 \sim U(0, V_{\max})$. Δv denotes the increment of velocity, $\Delta v \sim U(0, V_{\max})$. α is a parameter.

$$\theta_{t+1} = \theta_t + \alpha\Delta\theta$$

where θ_t denotes the direction of current time, θ_{t+1} denotes the direction of next time, θ_0 denotes the direction of initial time, $\theta_0 \sim U(-\pi, \pi)$. $\Delta\theta$ denotes the increment of direction, $\Delta\theta \sim U(-\pi, \pi)$.

Regard mobile nodes' mobile state at k time as $T_k \in \{0,1\}$, k=0,1,2,.... Regard the maximum number of mobile node that a RP could tolerance as $N_{\max}$. If a mobile node moves ahead to a RP, and the RP is not full, mobile node transits from state 0 to state 1. Otherwise, mobile node maintains at state 0. If RP's mobile nodes equals to the maximum number of mobile nodes that a RP could tolerance, mobile node is selected according to a departure probability $p_1=1/N_{\max}$ to transit from state 1 to state 0. Otherwise, mobile node maintains at state 1.

4 Defined Inhomogeneity Measure

An objective measure for the inhomogeneity of spatial distributions has defined in the literature [10]. The computation of the inhomogeneity is shown as follow.

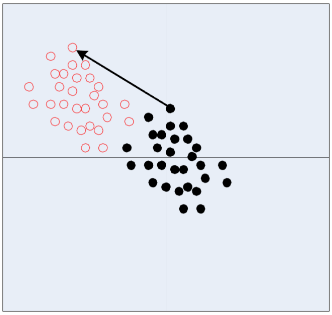


Fig. 2. Offset for a moved cluster

1) Divide the simulation area A into s^2 subareas with the same proportion.

2) Count the numbers of the nodes in each subarea.

3) Compute the expected number of the nodes in each subarea with uniform distribution.

4) Compare the actual numbers of the nodes to the expected number of the nodes, and accumulate the absolute deviation.

5) The weighted sum over all segmentations is calculated yielding the final inhomogeneity value.

6) Consider all possible offsets (x, y) as shown in Fig.2. So that we can achieve the same inhomogeneity value h for distributions which only differ in mirroring, movement and so on.

7) All nodes are moved x length units in horizontal direction and y length units vertically. Offset is picked that maximizes the local deviation for each subdivision. The number of nodes in the ith subarea for a given offset (x, y) is called $m_{i,(x,y)}$.

The measure is normalized on the interval [0,1]. While 0 signifies a optimal grid distribution and 1 signifies absolute inhomogeneity with all nodes at the same position.

$$h(s) = \max_{(x,y)} h_{(x,y)}(s) \tag{1}$$

where,

$$h_{(x,y)}(s) = \frac{1}{2n}\sum_{i=1}^{s^2}\left|m_{i,(x,y)} - \bar{m}(s)\right| \tag{2}$$

The average mobile nodes in each subarea is $\bar{m}(s) = n/s^2$. The subareas can be categorized into those with RP and without RP. So, let S_0 denotes the set of the indexes of the subareas without RPs, and S_1 denotes the set of the indexes of the subareas with RPs.

Assumption 1:

The subarea with RP has $N_{\max}$ mobile nodes at most. That is, $m_{i,(x,y)} = N_{\max}$.

Assumption 2:

The number of mobile nodes in the subarea without RP is less than the average values. That is, $m_{i,(x,y)} < \bar{m}(s), i \in S_0$.

According to equation 1, clearly, the inhomogeneity reaches the maximum value when all the RP located in the center of subareas. Thus, the upper bound of inhomogeneity is as follows:

$$\begin{aligned} h_u(s) &= \frac{1}{2n}\left[\sum_{i\in S_0}\left|m_{i,(x,y)} - \bar{m}(s)\right| + \sum_{i\in S_1}\left|m_{i,(x,y)} - \bar{m}(s)\right|\right] \\ &= \frac{1}{2n}\left[\sum_{i\in S_0}\left(-m_{i,(x,y)} + \bar{m}(s)\right) + \sum_{i\in S_1}\left(N_{\max} - \bar{m}(s)\right)\right] \\ &= N_{RP}\left(\frac{N_{\max}}{n} - \frac{1}{s^2}\right) \end{aligned} \tag{3}$$

Due to the above two assumptions, the upper bound is only a loose bound. However, the following simulation will show that the upper bound has a good approximation.

5 Simulation

Upon above description of the proposed model, in this section, we set up a scenario and simulate it as a case study. Consider a scenario of nodes moving in 100m×100m area with 20×20 section blocks as Fig.3. Circles represent RPs, red stars represent mobile nodes. Such scenario is to simulate mobiles' individual and group mobility in a recruitment hall. There are 20 RPs in the simulation area. They are stationary, as if fixed recruitment table. The RPs are randomly distributed on lattice points, which are uniformly distributed in the simulation area. The space between lattice points is twice larger than the radius of RP's coverage. The radius of RP's coverage is R=2.5m. The maximum number of mobile nodes that a RP can tolerance is N_{max}=20. The parameter α=0.05. The upper bound of inhomogeneity is calculated as 0.75.

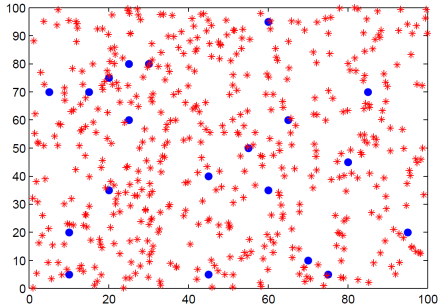
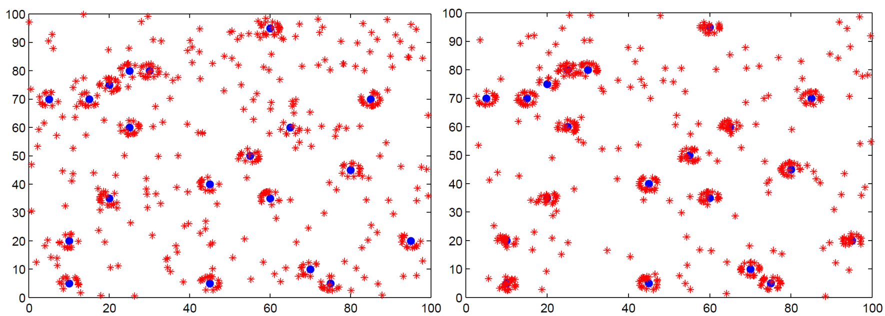


Fig. 3. Initial spatial node distribution of mobile nodes

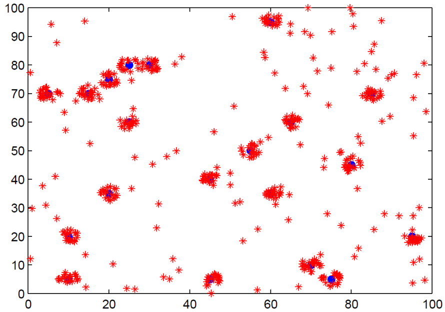
5.1 Distribution of Mobile Nodes

In the simulation area, there distributed many mobile nodes. We first analyze the impact of the moving parameters on the node distribution. Many parameters affect the node distribution such as the number of mobile nodes, the number of RPs, the velocity of mobile nodes, mobile times of mobile nodes, the coverage of the RP, maximum number of mobile nodes in RP's coverage and so on. In the experiments, it is performed with a varying maximum speed of mobile nodes. For the number of nodes n=500, Fig.4a, Fig. 4b and Fig. 4c show how the node distribution changes if we increase maximum speed of mobile nodes from 0.5m/s (Fig.4a) over 1m/s (Fig.4b) to 2m/s (Fig.4c). In the recruitment hall, someone moves fast like running; someone moves slowly like watching advertisement while walking. From the process of simulation, we know that the higher the maximum speed of mobile nodes is, the more clustered the simulation picture is.



(a) n=500, V_{max}=0.5m/s (b) n=500, V_{max}=1m/s

Fig. 4. Spatial node distribution after 300 seconds simulation



(c) n=500, V_{max}=2m/s

Fig. 4. *(Continued)*

5.2 The Moving Trace of a Single Mobile Node

Single mobile node has two mobile states in the simulation. One is cruise state outside RP, the other is captured state inside RP. A mobile node may be captured by a RP, and then leave it. After moving for a while, it may be captured by another RP. Fig.5 shows the moving trace of a single mobile node with V_{max}=1m/s. From the figure, we can see that the node begins moving in cruise state. Then it encounters boundary and rebounds to the simulation area at once. Afterward, it is captured by a RP located in (85,70) and then it releases from the RP. It encounters boundary again, and rebounds to the simulation area. After rebounding, the mobile node moves in cruise state for a while and is finally captured by another RP located in (30,80). Clearly, the trace of the proposed model is more accord with the law of life's motion than that of RWP model.

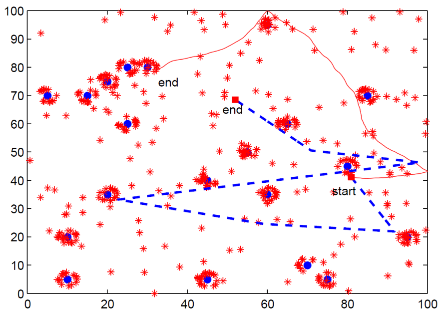
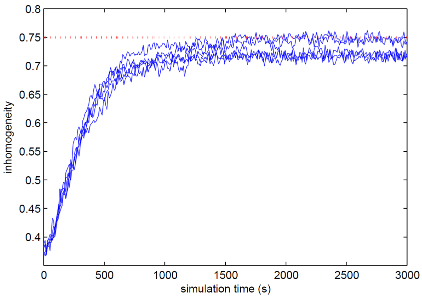


Fig. 5. The moving trace of a single mobile node (solid line denotes the trace of AGM, dot line denotes the trace of RWP)

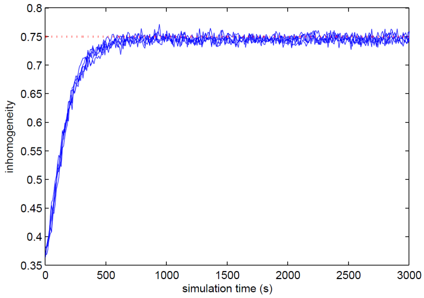
5.3 Measuring Inhomogeneity in Spatial Distribution

In the following simulation, we measure inhomogeneity of mobile nodes using equations. As Fig.6, x axis means simulation time, y axis stands for inhomogeneity.

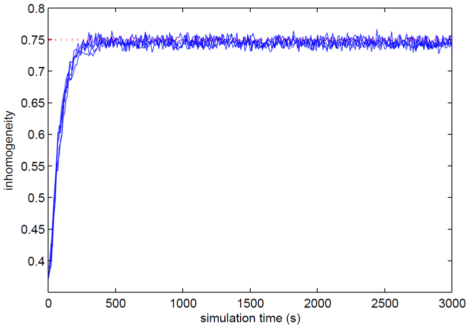
In Fig.6a, as simulation time adding, inhomogeneity grows sharply until 1200 seconds when it reaches a saturation value. After 1200 seconds, inhomogeneity keeps a steady value with small fluctuations. From several simulations in Fig.6a (each line means one time of simulation), we know that the variation rules of inhomogeneity in different times of simulation are more or less the same wherever RP and mobile nodes are, and the final saturation value is 0.75.



(a) n=500, V_{max}=0.5m/s



(b) n=500, V_{max}=1m/s



(c) n=500, V_{max}=2m/s

Fig. 6. Inhomogeneity distribution

The above simulation is done when the number of mobile nodes is 500 and maximum speed of mobile nodes is 0.5m/s. When it is simulated at 1m/s (Fig.6b), and 2m/s (Fig. 6c) for maximum speed of mobile nodes, the variation rules are more or less the same. Except for the the simulation time they get saturation value are different, for 1m/s is approximately 600 seconds, 2m/s is approximately 300 seconds. From the result, we know that the mobile time reaching saturation value is inversely proportional to the maximum speed of mobile nodes. On the other hand, the saturation values are the same for different maximum speed of mobile nodes. From this, we know that the saturation value has no matter with the maximum speed of mobile nodes. Besides, this mobility model can be a method of generating inhomogeneity distribution.

6 Conclusion

In this paper, we propose a novel mobility model for mobile ad hoc nodes with intelligence named Attracting Group Mobility Model. The proposed model takes the social behavior into account. The inhomogeneity's upper bound is derived. What's more, the variation rules of inhomogeneity in different times of simulation are more or less the same wherever RP and mobile nodes are. Meanwhile, we know that the mobile time reaching saturation value is inversely proportional to the maximum speed of mobile nodes. And the saturation value has no matter with the maximum speed of mobile nodes. This paper has just given a novel idea for modeling mobile node with intelligence. However, the performances evaluation of network protocols and routing with the proposed mobility model should be studied deeply in the future.

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