Towards a Social Mobility Model

Leila Harfouche  
CNAM – CEDRIC  
Paris, France  
Email: leila.harfouche@cnam.fr

Selma Boumerdassi  
CNAM – CEDRIC  
Paris, France  
Email: selma.boumerdassi@cnam.fr

Éric Renault  
Institut Télécom – Télécom SudParis  
Évry, France  
Email: eric.renault@it-sudparis.eu

Abstract—Mobility models are used in the network simulation area to reproduce the typical behaviour of nodes. If lots of mobility models have been proposed in the literature, very few are taking into account the social behaviour of users. In this paper, we propose a modelling framework to introduce social behaviours into existing mobility models so as to evaluate their impact on network performance. An example illustrates the paper by introducing social attraction points into the Manhattan mobility model.

Keywords-component: Mobility model, Social network, Manhattan.

I. INTRODUCTION

Works on mobile ad hoc networks mainly depends on simulations, which rely on realistic movement models. Thus, mobility modelling has a critical role for the specific domain of mobile networks and many surveys on mobility models for MANETs for both research and simulation have been presented in recent years [1,2,3].

Some mobility models like Random Way Point, Random Walk, Manhattan or Gauss-Markov are extensively used to perform simulations. However, if most of them allow to uniformly distribute nodes in the simulation area, this is not the typical behaviour of users. In one hand, the movement of humans is strongly affected by their need to socialise with others. On the other hand, humans may have some habits and interests. Group mobility models focus on the relationship between individuals of the same group but fail to catch more social behaviour of individuals and groups. In order to capture these types of behaviours within a network, it is necessary to define models that are depending on the relationships between the people moving in it and the relationship between people and their environment. As a result, it is important to consider the influence of social behaviour in synthetic mobility models if we want to get closest to more realistic models.

This paper proposes to introduce social behaviours into existing mobility models so as to evaluate their impact on network performance. In order to illustrate this purpose, the Manhattan mobility model has been used in which we introduced our proposal to create a new Social Manhattan mobility model.

A typical use of the Social Manhattan mobility model is a conference or exhibition centre where several attraction points are visited by attendees. During the exhibition or the conference, the intrinsic attractive value of the different spots varies has some activities may occur at specific periods, leading to massive movement of people in the area. A similar case is a shopping centre where people are moving from one shop to another depending on their personal will and the known reputation of the stores, especially during a sold period.

The article is organized as follows: Sec. II presents some related works including the most famous mobility models and others related to the group behaviour of users. The next section describes how to introduce social behaviours into mobility models which is illustrated in Sec. IV with the presentation of our Social Manhattan mobility model. Finally, Sec. V discusses some performance evaluation.

II. RELATED WORKS

Mobility models may be divided into two categories [3]: trace based mobility models rely on the accurate information about the mobility traces of users that can be provided by an telecommunication operator for example; synthetic mobility models rely on mathematical models that try to capture various mobility characteristics and describe node motion within a given space. In this latter case, the nodes motion can be completely randomized or more realistic.

Since there is a lack of realistic data in the public domain, and obtaining real mobility traces is a major challenge, synthetic mobility models have become de facto widely used in mobile network simulations. For the purpose of development easiness, current synthetic mobility model implementations are very simplistic rather than based on soundness of foundation.

First, synthetic mobility models are based on individual movement. The most widely used such models are based on random motion; the simplest model of this category is the Random Walk mobility model (RW) [4,5], it is equivalent to a Brownian motion. A slight improvement of this model is Random Way Point mobility model (RWP) and its different variants [1,6,7], it introduces pauses between changes in directions and/or speeds. However, it is very improbable that these kinds of movement occur in real life. Thus, more realistic individual mobility models had to be introduced. For example, in Gauss-Markov mobility model (GM) [8], the values of speed and direction follow a markovien process which allows the nodes to move gently and continuously. Since mobile devices are usually transported by humans, the Manhattan mobility model [9], uses a grid road topology to simulate a movement in an urban area.

Since the movement of such devices is necessarily based on human decisions and behaviour, it is important to model the social behaviour of humans. People may have some interest points or travel together. Group movement and individual
moving of the nodes in a group are modelled in group mobility models. The Reference Point Mobility Group Model (RPGM) [10], represents the random motion of a group of mobile nodes as well as the random motion of each individual node within the group. Other models such as Pursue mobility model [11,12] and Column mobility model [13] are derived from the RPGM, they differ by the manner that the mobile nodes moves around their reference point.

Social network theory is recently widely used in the field of mobility modelling. For example, Musolesi and al. [14] uses a social network to generate a mobility model for ad hoc networks which focused on the mobility of a group of individuals. Borrel and al. [15] proposed a mobility model in which nodes are following attraction points. Mathematical foundations and progress in complex and social networks analysis may be found in [16] and [17].

III. Social Mobility Model

The choice of a mobility model for simulations has a significant impact on the performance evaluation of mobile networks. As users have a social behavior when using mobile network facilities, it is important to find new method to take into account this typical behavior.

The social behavior of users is usually oriented according to a specific characteristic. For example:

- If users are sharing the same application like a distributed game, they behave is application oriented. In this case, there is no constraint related to localization and users movements are not necessary linked.
- If mobiles are localized in the same area and are attracted by one or several places like metro stations, a conference center, etc. the behavior is social-point oriented. Here, localization constraints and mobile movements are generally linked.
- If people are following one individual of the group like a guide tour, the behaviour is individual oriented: In such a case, localization constraints and mobile movements are linked.

Therefore, in order to be appropriate, different mobility models have to be used when simulating such social behaviours. For example, a random model can be used for an application-oriented simulation. However, the same random model would not suit for an individual-oriented one.

To simulate this specific behaviour, the mobility model has to introduce some characteristic points in the simulated area. Each point is affected a social value that represents the relative social value computed by the users. As a result, these social values are varying in time.

This copes with the effective gregarious behavior of people that usually think a location is attractive when everybody around says it is attractive.

Let $S_t(i)$ be the social value of attraction point $i$. The set of social values is normalized in order to make sure values are not diverting. At initialization, social values are chosen according to different data and/or parameters like a probe, reputation, etc. In the scope of a simulation, initial social values can be chosen randomly using any probability laws. Initial social values can be expressed as follows:

$$
\sum_i S_{t=0}(i) = 1 \quad \forall i
$$

Then, the social value of a social attraction point is updated taking into account the relative attractive value of this point for all nodes in the network. Mobiles in this model can choose to visit the nearest social attraction point, the furthest, or a random one (as a function of its popularity).

First, each node computes a relative social coefficient for all attraction points. Let $c_t(i, n)$ be the relative social coefficient of attraction point $i$ for node $n$ at time $t$. At time $t + \Delta t$, the relative social coefficient for attraction point $i$ is a function of the social value of attraction point $i$ at time $t$ and any other suitable values, i.e:

$$
c_{t+\Delta t}(i, n) = f_1(S_t(i), \ldots)
$$

A good example consists in taking into account the distance between the node and the attraction point, considering that the closer the attraction point, the more attractive this attraction point. Let $d_t(n, i)$ denotes the distance between node $n$ and attraction point $i$ at time $t$, $f_1$ can then be expressed as follows:

$$
f_1 = \frac{S_t(i)}{d_{t+\Delta t}(n, i)}
$$

The second step consists in normalizing the relative social coefficients so that their sum at each node is equal to 1. Let $s_t(i, n)$ be the relative social value of attraction point $i$ for node $n$ at time $t$. $a_t(i, n)$ is defined by:

$$
s_{t+\Delta t}(i, n) = \frac{c_{t+\Delta t}(i, n)}{\sum_i c_{t+\Delta t}(i, n)}
$$

Then, the new social value can be computed for all attraction points taking into account the relative social values computed by each node.

In a similar way as for the computation of relative social values, a social coefficient is defined. Let $C_t(i)$ be the social coefficient for attraction point $i$ at time $t$. Social coefficients have to take several characteristics into account, especially the relative social values computed by all nodes or a subset of the nodes. The general definition for $C_t(i)$ is given by:

$$
C_{t+\Delta t}(i) = f_2(s_{t+\Delta t}(i, n)w(n), \ldots)
$$

However, other characteristics may be included here. For example, nodes may have a different weight depending upon their associated class. This is typically the case for a guided tour where the guide usually has an important role and visitors are mainly following him/her. Let $w(n)$ be the weight of node $n$. All weights are normalized so that their sum is equal to 1. If all nodes have the same weight, all $w(n)$ are equal to the inverse of the number of nodes and $w(n)$ can be removed.
Another example consists in limiting the impact of an attraction point regarding the others so that all can live, but it can also be used to represent some social behaviour like jealousy. For the first case, a maximum can be introduced like in a low-pass filter; for the second case, the attractive coefficient can increase according to the relative attractive values up to a given threshold, and decrease afterwards. There are lots of famous functions that match this behaviour like second-degree denominator rational functions or second-order differential equations. For the purpose of simplicity, we decided to limit the impact of attraction points as a function of the mean social value. Let \( N \) be the number of attraction points in the network and \( k \) the maximum acceptable factor for an attraction point as a function of the mean social value. The social coefficient including both examples can be expressed by:

\[
f_2 = \sum_n w(n) \min \left( s_{t+\Delta}(i, n), \frac{k}{N} \right)
\]

Finally, after normalization, the new social value for the attraction points is given by:

\[
S_{t+\Delta}(i) = \frac{C_{t+\Delta}(i)}{\sum_i C_{t+\Delta}(i)}
\]

The update of social values and coefficients may occur at different period of time. Some examples, but this is not limiting, are: 1) updates are performed regularly, i.e. \( \Delta \) in this case is constant and 2) updates are performed on demand when nodes need to compute their relative social values to choose a new social attraction point to visit (\( \Delta \) in this case is not constant). If this choice has no impact on the model, it may have some on the performance evaluation.

IV. SOCIAL MANHATTAN

The concept of social behaviour can be introduced in most existing mobility models. In order to illustrate this work, the social behaviour of users has been applied to the Manhattan mobility model. The choice was mainly conducted by the popularity of this model regarding the others (note that this choice follows a social behaviour based on the reputation of mobility models and should probably be the focus of some researches).

This enhanced version of the Manhattan mobility model is called Social Manhattan. The original model was introduced to represent a city area with a predefined road structure. Thus, the area is composed of horizontal and vertical lanes and nodes can change their direction randomly, but only at cross-points. In the Social Manhattan mobility model, the same area characteristics are kept and some social attraction points have been added (as shown in Fig. 1). Nodes move along both vertical and horizontal lanes in the direction of a selected social attraction point as described in the previous section.

V. EVALUATION

In order to evaluate our proposal, we performed some simulations to compare our Social Manhattan mobility model to the original Manhattan and Random Way Point. The NS-2 simulator was used as it allows to specify a large variety of parameters. As we wanted to avoid as much as possible to get into a very specific configuration, we decided to use the most generic ones. Table I presents the most important parameters that have been used for our simulations.

<table>
<thead>
<tr>
<th>Simulator</th>
<th>NS-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC layer</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Transmission range</td>
<td>250 m</td>
</tr>
<tr>
<td>Simulation area</td>
<td>1000 m × 1000 m</td>
</tr>
<tr>
<td>Simulation duration</td>
<td>600 s</td>
</tr>
<tr>
<td>Number of mobile nodes</td>
<td>50</td>
</tr>
<tr>
<td>Number of social attraction points</td>
<td>16</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>AODV [18]</td>
</tr>
</tbody>
</table>

The evaluation of the impact of the Social Manhattan mobility model has been performed using three metrics, the average end-to-end delay, the average delay and the average routing overhead, as a function of the nodes motion, the number of connections and the network density (see Fig. 2 to 6).

A. Impact on the average end-to-end delay

The average end-to-end delay for the Social Manhattan mobility model is lower than both the Random Way Point and Manhattan as nodes are grouped around social attraction points which lead to a shorter connection path.

B. Impact on the average packet delivery ratio

The average packet delivery ratio for Social Manhattan is lower than the one of the two other mobility models for the same reason as for the end-to-end delay, i.e. most nodes are grouped around social attraction points. This leads to a very high density of nodes around social attraction points and a...
very low density in between. Thus, the connectivity from one node to another in between social attraction points cannot be ensured.

C. Impact on the routing overhead

As a reactive routing protocol, AODV does not need to build a path to all the destinations. Paths are discovered on demand and the grouping effect involved by the Social Manhattan mobility model limits the search in the close neighbourhood of the node.

In a more global point of view, the same grouping effect involved by the Social Manhattan mobility model has a positive impact on the end-to-end delay and the routing overhead, and a negative impact on the packet delivery ratio. This will have to be taken into account for the future development of network protocols coping with social behavior aspects.

VI. CONCLUSION

This article presents how to introduce social behaviours into mobility models. As an example, we created a social Manhattan mobility model which an augmented Manhattan mobility model that includes social attraction point that is attraction point which popularity varies over time.

Over time many characteristics have been introduced in networks for the purpose of routing, path discovery... However, some of them were based on hypothetical assumptions with few relations to realities which do not enhance the global quality of the network. At the opposite the social behaviour of the users is a reality and taking into account this behaviour aspect into network protocols should lead to better performance.

SHORT BIBLIOGRAPHY

Fig. 6. Effect on routing overhead.


