Social Networks Based Ad Hoc Mobility Models

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1 Introduction

Most current research on mobile ad hoc networks relies on simulations. One of the key points in the design of good simulations is the choice of realistic movement models. Since there is a nearly total absence of realistic data in the public domain, synthetic models for movement pattern generation must be used. However, the most widely used models are currently very simplistic and totally unrealistic.

Our approach is based on a simple consideration: mobile networks are social networks after all, since mobile devices are usually carried by humans. In fact, it is possible to observe that the movement pattern of humans are strongly influenced by the social relationships amongst them. This can be mathematically modelled with a high degree of precision.

In this paper, we outline our current research efforts in designing more realistic mobility models based on the exploitation of recent results in social networks theory. We start from a discussion of the initial model presented in [4] and we analyse several possible refinements of this solution.

2 Background and Motivation

The definition of realistic mobility models is one of the most critical and, at the same time, most difficult aspects of the simulations of applications and systems designed for mobile environments. Currently, there is no publicly available data capturing node movement in real large-scale mobile ad hoc environments. Instead, synthetic models are used, and many such models have been presented in recent years [2]. The most widely used models are based around random individual movement; the simplest, the Random Walk Mobility Model (equivalent to Brownian motion), is used to represent pure random movements of the entities of a system. A slight enhancement of this is the Random Way-Point Mobility Model, in which pauses are introduced between changes in direction or speed.

All synthetic movement models are suspect because there is no means of assessing to what extent they map reality. However, it is not difficult to see that the random mobility models generate behaviour that is most unhuman-like. This last point is key. Mobile devices are usually carried by humans, so the movement of such devices is necessarily based on human decisions and socialisation behaviour. Thus, for example, it is important to model the behaviour of individuals moving in groups and between groups, as is likely in the typical ad hoc networking deployment scenarios of disaster relief teams, platoons of soldiers, etc. In order to capture this type of behaviour, it is necessary to define models for group mobility that are heavily dependent on the structure of the relationships among the people carrying the devices. Existing group mobility models [2] fail to capture this social dimension.

3 Mobility Models Founded on Social Networks Theory

Starting from these considerations, we have been investigating the possible applications of research results in the area of social networks (and, in general, of complex networks).

According to a widely accepted definition, a social network is a set of people or groups of people with some pattern of contact or interaction among them [9]. The first significant quantitative results were presented by Rapoport [8] and his colleagues in the 1950s and 1960s in a series of papers in which they analysed the statistics of epidemic diffusion in populations characterised by different social structures.

In the same period, a renewed interest in graph theory led to the definition of the so-called random graphs by Paul Erdős and Alfred Rényi [3]. These theoretical studies were applied to many disciplines including biology, ecology, linguistics and sociology. This was the beginning of the complex networks research area, investigating properties such as their topology, average diameter and degree of connectivity, as well as the presence of clusters.

In recent years, many analytical models of real networks have been proposed and interesting experiments have been conducted to assess the validity of these theories. In particular, the application of complex network theory to the analysis of social networks has been investigated by many researchers in order to verify the properties predicted by theoretical models. One of the most interesting approaches is the so-called small world model proposed by Watts and Strogatz [10]. Excellent reviews of the recent progress in complex and social networks analysis may be found in [1] and [6].

We believe that these recent results in social network theory can be used to design more realistic mobility models for mobile ad hoc research. We now present the principles and the basic concepts of the design of mobility models founded on social networks research, focussing in particular on the recent progresses and the refinements of the model presented in [4]. First of all, we represent a social network using a *weighted* graph, by defining the weights associated with each edge of the network to model the strength of the direct interactions between individuals. In this case, interactions are said to be direct if they take place between people who are colocated. It is our explicit assumption that these weights, which are expressed as a measure of the strength of social ties, can also be read as a measure of the likelihood of geographic colocation, though the relationship between these quantities is not necessarily a simple one, as it will become apparent.

We model the degree of social interaction between two people using values in a given range. It is worth noting that these indicators are *not* a measure of the subjective importance of the relationships, such as family ties or friendships. An example of strong social interaction may be the case of two colleagues sharing the same office.

There are many possible ways of generating these weights and, more in general, the structure of the entire network. For example, it is possible to generate the social networks using random distributions (as in [4]), or reflecting very precise structures such small-world or scale free networks using algorithms such as those described in [1] and [6].

After the generation of the social network, it is possible to detect the presence of communities in the network using for example the method proposed by Newman [7]. These communities are placed in the simulation area. A group (or cloud) area is associated with each group of hosts. Each group area is defined using a geometric shape.

A host belonging to a group moves inside the corresponding group area towards a goal (i.e, a point randomly chosen in the group space). Clouds of hosts also move towards randomly chosen goals in the simulation space. Therefore, the movements of each host is given by the composition of its speed and that of the cloud it belongs to. After reaching a goal, each host may choose its new goal in the same cloud area or inside another area. This choice depends on its tendency to stay within a group of people (i.e., its *sociability*) and the *attractivity* of each group of hosts. The sociability of a host is calculated by considering its relationships with the other nodes in the system. The attractivity of a cloud of hosts is calculated by evaluating the strength of the relationships between the host and the members of that cloud. A host will join the cloud that exterts the greatest attractivity. By analogy, this mechanism is similar to the gravitational or the electro-magnetic attractivity phenomena.

4 Future Work

The social based abstraction seems to have a lot of potential for verification of mobile systems. We plan to use different social networks for different intervals of time to represent the fact that social relationships have different relative importance during the day and/or the week. For example, during working hours, the relationships with colleagues assume a primary importance, whereas in the evening, family ties usually have a stronger influence on the movement patterns of people (i.e., after work, people usually go home to stay with their relatives). We also plan to refine the model by allowing the definition of obstacles (like buildings, etc.) within the simulation environment.

We are also studying possible refinements and applications of the model presented in this paper. In particular, we plan to use it in our current investigation on efficient adaptive routing protocols and systems (especially in terms of the use of the available resources) for mobile ad hoc networks [5].

Moreover, we are also interested in evaluating the degree of approximation of the reality of our model comparing the generated movement patterns with real traces.

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