Improving Mobile Networks based on Social Mobility modeling

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***Abstract*—Wireless networks growing popularity coupled with a wide availability of wireless-enabled personal devices is today the basis for user-centric Internet architectures to evolve. Central to this new paradigm of *user-centricity* is the fact that today the Internet end-user exhibits a highly nomadic behavior, where most of the portable devices are carried by humans. The thesis proposed relates to the recent trend of social mobility modeling as a way to improve mobile network operation. The work is focused on the analysis of social mobility models and how to propose new models having in mind an overall network optimization due to the possibility to predict adequately node movement on mobile networks.**

***Index Terms*—wireless networks, social mobility models, human movement.**

I. Introduction

WIRELESS mobile networking has presented many challenges to the research community, especially in evaluating and analyzing the performance of protocols and applications. Internet users today exhibit a highly dynamic roaming profile, hopping between different wireless hotspots. According to some studies [1], [2], not only is such hopping frequent, but it is also based on human movement routines, e.g. person moving between home and work regularly. It is today well known that the movement patterns of Internet users impact the patterns of the devices they carry or own and hence, impact on the overall network operation. Moreover, today the majority of portable devices are carried by their owners; this implies that the movement these devices exhibit is strongly affected by the interests of humans to socialize [3]. When a node moves it may be useful to consider adequate resource in its next position; if a node is moving quickly, it may affect routing on the network depending on the timing of its association to nodes surrounding it. Many resources in wireless networks can be best used if it is possible to provide an efficient human mobility modeling.

Modeling of node movement from an individual or from an aggregate perspective [4] is today a wide research field, which combines real-world experience (e.g. traces) together with analytical aspects to derive mobility models that can track and mimic some aspects of human behavior. The most recent work related to such attempt relies on social mobility models that provide an analytical modeling of social strength between nodes, i.e., a cost for the association between nodes which is a representation of some form of social relation, e.g., social attractiveness [5], [3], [6] between nodes or towards locations. Such models are highly relevant, given that, they are closest to what realistic traces exhibit. But, being a new field of work, there are a few gaps [7] that have not been addressed yet.

In order to model realistic social movement, we need to understand the needs of humans, but also understand how to relate these needs in space and time. A concrete and realistic example on how shared interests relate to human movement and as consequence, how they affect network operation, can be provided by considering an end-user on its regular Saturday routine, walking to its preferred coffee-shop. Humans can decide what to do at any time, then, imagining that along his/her path to the coffee-shop he/she meets a friend and decides to change its route, opting to visit a new coffee-shop. A realistic mobility model should be able to model this behavior, considering in this case, the interest of this user to its friend (maybe this user has a higher attractiveness with its friend).

Our motivation is in the fact that; mobility modeling is often and in most cases perceived as a way to assist network simulations. However, by capturing properties of realistic environments, mobility modeling can assist different aspects of network operation, such as: handover, resource management, routing, and even a better autonomic deployment of connectivity models mainly due to the possibility of the location prediction. Out of the several applicability scenarios of mobility modeling, our focus is to consider node movement estimation and hence assist in location prediction, i.e., to track the future location of nodes, given that, often and in terms of network self-organization, mobility is treated as a secondary aspect. But, in user-centric environments, mobility is a key feature given that roaming is one of the main properties of such environments.

The remainder document is organized as follows. Section 2 covers related work concerning mobility models. Section 3 provides a discussion on mobility models. Initial results are showed in Section 4. Section 5 presents some conclusions.

II. A review of Human Mobility

A number of approaches have been dealing with measurement of accurate node mobility. In this section, we highlight the most important mobility models based on social relationship and that are closest to reality.

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The Community based Mobility Model (CMM) [3] was one of the first mobility models built that considers the social relationship among individuals. CMM is a synthetic mobility model founded on social network theory. This model defines the users movement based upon a social attractiveness function. In other words, nodes move towards other nodes or other communities based upon probabilities and taking into account the strength social association between nodes. There are some works that propose improvements to CMM ([8], [5]), however, there are key aspects that these models cannot provide. For instance, they do not take into consideration pauses or the needs to change their direction on the fly.

The Self-similar Least Action Walk (SLAW) mobility model [9] is one of the most complete mobility models in the sense that it contains several properties that are left aside on other models, such as: pause time; intercontact time; attraction by the popular places and preference of people to move around in their own confined area. However, the notion of pause time is in an artificial way, by providing an average pause time to ensure that a whole trip completes in 12 hours. Moreover, the nodes define the future position and can not change their direction until reach to destination.

A human mobility model based on heterogeneous centrality and overlapping community structure in social networks is proposed by Yang et. all. [10], where the nodes movement is based on three components: establishment of overlapping community structure and heterogeneous local degree; mapping communities into geographical zones; and driving individual motion. The authors use the local (number o nodes in contact within its community) and global (number of communities that a node belongs) popularity to specify where a node can stay in a specific instant of time. The communities are mapped in a geographical zones; and the nodes select their goal according to their associated cell (e.g. a cell defined at the beginning) during a specific period in time. Then, when a new period starts, the community structure and the corresponding zones, change.

According to the authors A. Mei and J. Stefa, a good mobility model should be simple and predict well the performance of networking protocols on real mobile networks [11]. Considering this, the authors developped a simple model based mainly on a observation: People go more often to places not very far from their home and where they can meet a lot of people. SWIM assigns to each node a *home cell* (cell chosen at the beginning), then the node assigns to each possible destination a weight, which decreases with the distance from home. When a node reaches its destination, it communicates with every node that is in the same cell, building a map of the area, considering the weight for each cell. The node chooses its destination randomly and proportionally with its weight. The nodes speed is based on the distance, but remains always constant.

The Sociological Interaction Mobility for Population Simulation (SIMPS) model has been proposed [12], where nodes move according to two important features: the social interaction level, which means the personal status (e.g., age and social class); and the social interaction needs; which means the need of individuals to make acquaintances. The authors show that these two components can be translated into a coherent set of behaviors, called *sociostation*. The nodes movement occurs based on these two definitions, where a node is attracted by acquaintances, in order to so*cialize*; or a node is repulsed by strangers, in order to *isolate*. The problem here, is that pauses still are not considered and users can not change its direction.

III. Discussion on Social Mobility Modeling

This Section provides terminologies and a debate on how to model an adequate social mobility model, assuming that nodes are carried or owned by humans and hence, devices exhibit properties similar to the ones that we observe in humans.

A *node* is here denoted as a wireless enabled device. The mobility features that capture a node movement in mobility models are a node's *speed, direction* and also *acceleration*. The *pause time* is related to the time period that it is in a specific position, i.e., the interval of time when the node's speed is zero or close to zero. *Obstacles* are denoted as places that a node can not stay (e.g. building or another node). *Change direction* is the ability of a node change its goal during the movement.

These terminologies are used to assist in the comparison between different models. Table I, includes several parameters that are considered to be key to build the necessary grounds for a realistic mobility model. The parameters chosen have derived both from the analysed related work as well as from our own experimental understanding of the work available.

Conclusions to draw from this analysis are that social mobility models do seem to have some capacity to be a solid grounds for mobility modeling and hence for mechanisms that attempt to estimate node movement. A second conclusion relates to the fact that some relevant parameters seem to be either missing or have been too simplified. Of particular relevance we believe to be the following gaps; Pause time, when considered, is normally provided in an aggregate way and is not representative of what occurs in reality; Obstacles are never considered; Speed is normally considered to be uniform; and changes during movement are never considered.

IV. Initial Results

Our work started by providing an adequate proposal for the modeling of individual pause time. This parameter is one of the most relevant in terms of mobility, given that it is the basis for the development of communities and of connectivity models. Our proposal for tracking the dynamics of pause time on social mobility models is a reflection of the following line of thought: if a node has a higher social attractiveness for a specific target, then it normally spends more time on this target. A measure of social attractiveness is therefore an adequate factor to consider as basis for a function capable of dynamically define pause

TABLE I
COMPARISON OF THE MAIN PROPERTIES OF MOBILITY MODELS.

Model	Pause Time	Direction change	Speed/acceleration	Obstacles
SIMPS	No	No	Uniformly chosen	No
HHW	Based on a power law distribution.	No	Uniformly chosen	No
SWIM	Based on a truncated power law.	No	Proportional to the distance.	No
Collision avoidance [6]	Based on social factors.	No	Uniformly chosen [1-4 m/s]	Yes
Gesomo [13]	No	No	Based on the group speed.	No
CMM	No	No	Uniformly chosen	No
HCMM	No	No	Uniformly chosen	No
URM	No	No	Cumulative, depends on all nodes' speed	No
SLAW	Partially (aggregate average)	No	Uniformly chosen	No

time, from a node perspective, being the underlying assumption the fact that humans tend to pause more time closer to nodes to whom they exhibit stronger affinities.

In order to evaluate our proposal for pause time, we implemented our function in the CMM model [3] and we did a comparison based on two realistic scenarios. Here, we show only the results related to University Campus (NCSU). These are sets that have been collected based on GPS receivers, which logged data every 10 seconds. The traces are available through the CRAWDAD website [14] and the scenarios have also been previously used and described [1] by Lee et al.

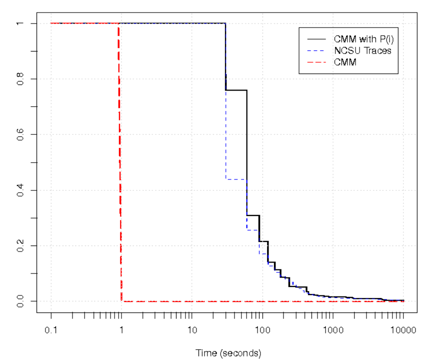

Fig. 1. Results obtained for the NCSU scenario in seconds.

Figure 1 shows the results obtained for CMM, for CMM with $P(i)$ (pause time function), as well as for the NCSU traces, where the X axis represents the pause time and the Y axis holds the *ccdf* representation of the probability of occurrence of the different pause times. The CMM behavior observable in Figure 1 is justified due to the fact that CMM does not track pauses; when a node reaches its target cell, it stays there just the time interval required to compute another target. While when looking at CMM with $P(i)$ then there is a clear improvement, being the achieved results quite close to reality.

V. CONCLUSIONS AND FUTURE WORK

A brief conclusion is that; social mobility models are able to estimate the human behavior. However, some gaps still are missed, such as; pause time, obstacle detection and change direction during the movement. Our first proposal was develop a pause time function considering the relationship among individuals. The future work is targeting at studying how we can provide the change direction on the nodes movement.

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