A two-tier mobility generator for wireless simulations

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I. Introduction

While it is crucial to test and evaluate protocol implementations in a real testbed environment, simulations are still commonly used as a first step in any protocol development for wireless network research. One of the most important parameters in simulating wireless ad-hoc networks is the node mobility. It is important to use a realistic mobility model so that results from the simulation correctly reflect the real-world performance. Several mobility models have been developed for MANET simulations such as Random Walk and Random Waypoint [4]. By virtue of their simplicity in implementation and analysis, these models allow researchers and modellers to compare the results generated by different protocols in simulations. However, one notable drawback among these models is that the movement patterns they create are not necessarily comparable to true real world movements.

In real world, it is common that different transportation modes are used (e.g. walking, driving, flying, etc) depending on the distances of the trips. Different types of transportation modes have their own sets of characteristics. Thus, the mobility patterns of people typically vary greatly according to the type of transportation they are using. For example, on a college campus, the movement of an individual is typically confined by the walkways that interconnect different campus buildings. But when a person travels from one campus to another, his mobility patterns will be affected by factors such as the roads that connect the two campuses and the type of vehicle he is using (e.g. motorcycle will be less affected by the traffic jam than a car). In such a context, a model that only captures one single type of mobility pattern might not be sufficient.

In this paper, we propose a multi-tier mobility model to create more realistic movements in the simulation. In this model, each tier characterizes a different mobility pattern introduced by the use of a different transportation mode. In addition, based on such a model, we implement a parameterized mobility generator to generate realistic synthetic mobility traces for ns-2 simulations.

II. A Two-Tier Mobility Model

In real world, individual movements are affected by the geographical distance of the trip. The distance of the trip, in turn, typically decides the type of transportation to be used.

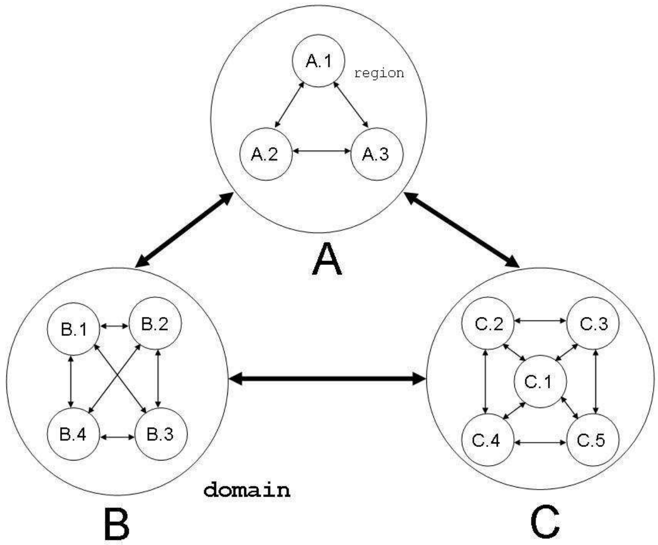


Fig. 1. A multi-tier mobility model

For a shorter distance, people normally adopt a transportation mechanism which has a lower speed but better flexibility in movement (such as walking, biking). On the other hand, for a longer distance, people typically have to rely on transportations which have a higher speed but are more constrained in movement (e.g cars are typically confined by the road topology and the traffic condition). Another observation of human behavior is that people tend to follow certain routine during a day. In particular, people tend to spend most of their time staying in places (which we refer to as "regions" in this paper) which are relatively close to each other (e.g. in walking distance, such as different classrooms in a college campus, different offices in a corporation building, different shops in a shopping mall, etc). Finally, human movements typically exhibit certain temporal and spatial localities (such as rush hours, lunch crowd, etc.) [5]. In other words, people tend to move to certain places at certain times.

In this paper, we refer an area that consists of a set of regions as a "domain" and the inter-region movements inside a domain as "micro-mobility". People also travel between domains from time to time by adopting a transportation with a higher mobility (such as cars, buses, etc). We refer the inter-domain travel as “macro-mobility’. As illustrated in Figure 1, A, B and C are three domains. People tend to spend most of their time travelling between regions (such as A.1, A.2 and A.3) within the same domain but could also travel between domains by adopting a faster transportation mode.

In this paper, we develop a two-tier empirical model that incorporates micro-mobility and macro-mobility based on experimental data collected from two sources. Not that any model derived from experimental data is limited by that data set. Clearly, our model will be limited by the traces we use. Nonetheless, our model can offer network researchers an additional tool other than simple models like Random Waypoint models.

The first set of data comes from a study of personal travel behavior held by US Department of Transportation in Lexington, Kentucky [2]. In this project, GPS devices are mounted on the cars of the subjects to automatically record travel information. The data sample comprised 100 households with an average 3 vehicles in each household. The study was conducted for a duration of one week. The second set of data was collected from the Dartmouth College campus WiFi network, which recorded the time and identity of over 500 wireless cells visited by more than 6000 users over a period of 2 years [1], [3].

We design an empirical two-tier mobility model based on these data. Specifically, we used Lexington data and Dartmouth data to characterize the macro-mobility and micro-mobility of the users respectively. While these data have some limitations for our purposes. they are the best available to us at present. Our model consists of the following parameters at each tier.

- original spatial distribution of the users
- preference of inter-region vs. inter-domain movement
- user departure rate from the origination
- selected destination
- preferred path
- trip length
- user arrival rate to the destination
- user residence time in one particular region

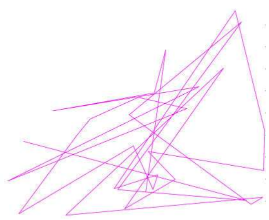
One observation we make from these experimental data is that different transportation mode can introduce different movement patterns. For example, we find that while the distribution of selected destination in Dartmouth data can be characterized by Log-normal distribution ($m = 0.9397$ and $v = 0.8130$), the same parameter is fitted better by Weibull distribution ($a = 10.1753$,$c = 0.658$) in Lexington traces.

III. Evaluation

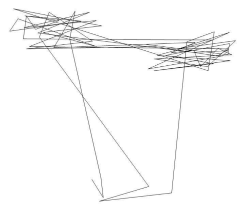
We have implemented a mobility generator based on our model. As shown in Figure 2(a) and Figure 2(b), the two-tier mobility model exhibits a strong spatial locality as compared to Random Waypoint model where the movements of nodes are more uniformly distributed in space. We are currently trying to understand the impact of our mobility model on the performance of ad hoc routing protocols via ns-2 simulations. Specifically, we evaluate the following metrics:

- Node Density: Average number of neighbors per node
- Path duration: The duration for which a path is available between one pair of nodes
- Data delivery rate: number of data packets successfully received by the destination
- Control packet overhead: number of control packet generated by the routing protocol
- End-to-end delay: end-to-end transmission time for data packets

In our simulations, the maximum node transmission range is 250m. The propagation model is the two-ray reflection model. IEEE 802.11 DCF is used for the MAC layer and the link bandwidth is 2Mbps. Each data point is an average six simulation runs.



(a) Travelling pattern of an mobile node using Random Waypoint Model



(b) Travelling pattern of an mobile node using Two-tier Model

Fig. 2. Travelling pattern of a mobile node using different mobility models

As shown in Figure 3, the number of neighbors per node is greater for two-tier model since two-tier model exhibit a higher clustering of nodes as shown in Figure 2(b).

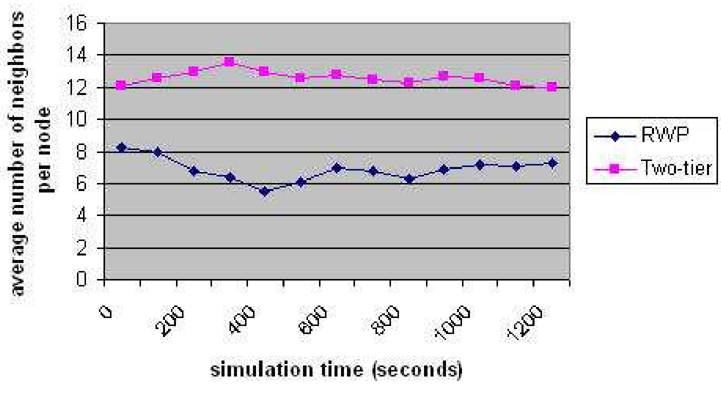


Fig. 3. Node Density

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