Chapter 8

The Accuracy of Location Prediction Algorithms Based on Markovian Mobility Models

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ABSTRACT

The efficient dimensioning of cellular wireless access networks depends highly on the accuracy of the underlying mathematical models of user distribution and traffic estimations. The optimal placement/deployment of e.g. UMTS, IEEE 802.16 WiMAX base stations or IEEE 802.11 WLAN access points is based on user distribution and traffic characteristics in the service area. In this paper we focus on the tradeoff between the accuracy and the complexity of the mathematical models used to describe user movements in the network. We propose a novel Markov chain based model capable of utilizing user's movement history thus providing more accurate results than other models in the literature. The new model is applicable in real-life scenarios, because it relies on information effectively available in cellular networks (e.g. handover history). The complexity of the proposed model is analyzed, and the accuracy is justified by means of simulation.

1 INTRODUCTION

Random Walk Mobility model is often used in network planning and in analyzing network algorithms, because of its simplicity (Jardosh, Belding-Royer, Almeroth, & Suri, 2003; Zonoozi, & Dassanayake, 1997). On the other hand this very simple model presumes unrealistic conditions, like uniform user distribution in the mobile network.

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However, in real-life networks, geographical characteristics, such as streets and parks influence the cell residence time (dwell time) and movement directions of users in the network, and result in a non-uniform user density. While these models are appropriate for mathematical analysis, easy to use in simulations and for trace-generation, they fail to capture important characteristics of mobility patterns in specific environments, e.g. time variance, location dependence, unique speed and dwell-time distributions, etc. (Yoon, Noble, Liu, & Kim, 2006; Camp, Boleng, & Davies, 2002; Wong, & Leung, 2000).

User movements in a cellular network can be described as a time-series of radio cells the user visited (Chellappa, Jennings, & Shenoy, 2003). The handover event of active connections (e.g. cell boundary crossing) is recorded in the network management system's logs, thus the information can be extracted from the management system of cellular mobile networks, such as GSM/GPRS/UMTS networks. The users movements are described by the dwell-time and outgoing probabilities (the probability of a user leaving for each neighboring cell). These parameters can be calculated for each cell based on the time-series of visited cells of the users. However, in some cases, these two parameters – dwell-time and outgoing probabilities – are not enough to capture all the information in the time-series of user movements. In many situations, the outgoing probabilities are correlated with the incoming direction of the users, so the movement contains memory.

We introduce a precise Markov mobility model based on these information, to capture the additional information contained in the user location traces. Our goal is to provide a synthetic model capable of capturing the unique properties of specific locations, e.g. urban areas, such as crowded parks, one-way streets etc.

The results are applicable for location based services, network dimensioning and more effective Call Admission Control algorithms can be applied in order to ensure user's satisfaction and optimal resource usage in cellular wireless mobile networks (Fongen, Larsen, Ghinea, Taylor, & Tacha Serif, 2003; Michaelis, & Wietfeld, 2006).

In this paper we introduce a Markov chain based mobility model with enhanced memory states, and compare the performance with a memoryless traditional Random Walk model. The models are able to capture the typical movement and cell dwell time patterns in arbitrary shaped mobile cell clusters.

2 RANDOM WALK MODEL IMPROVEMENTS

Our work is based on the utilization of time-series of mobile users' movement patterns in cellular mobile networks. In our work we assume that there is a given trace of a mobile service provider's network history. This dataset consists of all signals that were transferred in the network in the examined time interval. Beside many other network parameters and properties, two main information sets can be recovered:

- the cell-path that each user visited before
- the time intervals users have spent in each cell

The series of visited cells is crucial to analyze the similarities in the users' motion. Based on the motion patterns of the terminals amongst the cells, we can describe some drifts of the users' motion in a given cell or point. A drift may be caused by geographical or infrastructural objects (like highways, etc.) or some time-dependent circumstances (like mass events, concert, football matches, etc.) (Jardosh, Belding-Royer, Almeroth, & Suri, 2003; McDonald, & Znati, 2000).

From a mathematical point of view, the drift of the motion can be interpreted as different transition probabilities from one cell to another. A probability-vector can be defined for each cell that describes the probabilities of moving from

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