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Mobility prediction in mobile ad hoc networks using neural learning machines☆

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ABSTRACT

Recent advances in wireless and mobile computing have paved the way for an unprecedented demand growth for mobile services and applications. These services and applications communicate and exchange information using wireless local area networks (WLANs) and mobile ad hoc networks (MANETs). However, new design challenges emerge due to the error-proneness, self-organization and mobility nature of these networks. This paper proposes a neural learning-based solution to the problems associated with the mobility of MANET nodes where future changes in the network topology are efficiently predicted. Using synthetic and real-world mobility traces, the proposed predictor does not only outperform existing mobility prediction algorithms but achieves accuracy scores higher by an order of magnitude. The attained accuracy enables the proposed mobility predictor to improve the overall quality of service in MANETs.

1. Introduction

Mobile ad hoc networks (MANETs) represent self-organizing and self-configuring multi-hop wireless networks with no centralized control where wireless connection and spontaneous interaction take place between mobile nodes in a highly dynamic manner. In the last decade, MANETs have been successfully deployed in both civilian and military environments [1,2]. Their ability to self-organize and self-adapt, without the need for an underlying infrastructure, contributed to their rapid deployment in non-conventional scenarios such as disaster recovery. All MANET nodes have similar functionalities and capabilities with free mobility and future locations usually unknown. These nodes can forward packets and maintain routes while having limited communication range. Therefore, these packets are forwarded in multi-hops from source to destination involving a number of intermediate nodes in a *cooperation mode*. In this mode, global positioning systems (GPS) continuously provide location data of the user nodes to the MANET control system. However, this flexibility in infrastructure requirements engenders issues and problems not known in traditional wireless networks. These issues are specifically addressed by scheduling [3], topology control [4] and routing [5] modules and sub-systems. Efficient scheduling, topology control and routing modules rely on accurate and reliable mobility prediction mechanisms. The goal of this paper is two-fold: 1) to develop a *soft mobility predictor* using neural learning machines, and 2) to demonstrate the superiority of the "*predictive*" formulation of future node locations where the inherent interaction between the node mobility patterns is captured and modeled more accurately.

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The rest of the paper is organized as follows: A review of standard mobility models, widely used in MANETs, is provided in Section 2. Current mobility prediction techniques are surveyed therein and the importance of mobility prediction is emphasized too. Section 3 gives a brief outline of the multilayer perceptron (MLP) and extreme learning machine (ELM) models where the rationale behind the machine learning formulation of mobility prediction is provided. A detailed description of the proposed mobility predictor is given too along with an outline of the design approach. In Section 4, we present an overview of the adopted experimental design/setup and synthetic/real mobility traces used in the simulation experiments. This section concludes with a summary of the performance measures used to assess the prediction accuracy. A Detailed analysis and discussion of the prediction results are given in Section 5 where the effects of various design parameters on the prediction accuracy are thoroughly investigated. Moreover, the generalization capability of the new predictor is illustrated using mixed (synthetic) and real-world mobility traces. Finally, the paper concludes with Section 6 where conclusions are drawn and possible future extensions outlined.

2. Review of mobility models and prediction techniques

2.1. Mobility models

Node mobility models and mechanisms greatly impact the performance of mobile networks in general and MANETs in particular. These models describe the node movement pattern in terms of location, velocity and direction change with respect to time. Also, they should be able to capture the movement pattern of targeted real life applications in a realistic way. Every mobility model is characterized by specific mathematical representations that are appropriate to one particular mobility scenario. In this paper, we restrict our attention to the following mobility models:

1. Manhattan grid.
2. Random way point.
3. Random walk.
4. Vehicular (*Citymob* model [6] based on a modified version of the Krauß model [7,8]).
5. Gauss–Markov.
6. Smooth random.

A brief review of the above mobility models is given below. Mobility traces resulting from these models and real-world mobility scenarios are used in Section 5 to assess the performance of the proposed mobility predictor.

2.1.1. Manhattan grid mobility model

The Manhattan grid model was introduced by the European Telecommunications Standards Institute (ETSI) as a choice standard for the mobility procedures in the universal mobile telecommunications system (UMTS) [9]. In this model, mobile nodes are allowed to move only in pre-defined paths given a fixed number of blocks between the paths. In simulations scenarios, a user parameter presets the minimum speed of the mobile nodes. This option ensures that the node speed does not get very close to 0 and does not end up in slow motion over long periods in the simulation grid. Also, a random pause parameter can be defined to ensure that the mobile while being in the slow motion mode. This mobility model represents a *memoryless* pattern where the next move is totally independent from the previous one [10]. Fig. 1 shows a Manhattan simulation grid where 2-by-3 blocks are placed between the node paths.

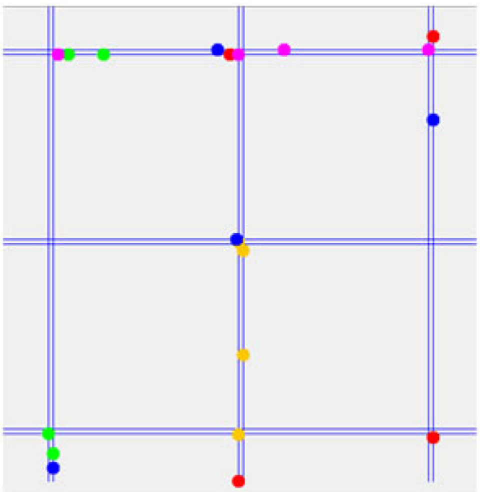

Fig. 1. Manhattan grid mobility model [11].