

An Approach to Mobility Prediction in Mobile Environments

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Abstract

Mobility prediction is one of the most critical research areas in wireless network. At the network level, accurate node mobility prediction may be critical to tasks such as call admission control, reservation of network resources, pre-configuration of services and QoS provisioning. At the application level, user mobility prediction in combination with user's profile may provide the user with enhanced location-based wireless services such as route guidance, local traffic information and on-line advertising. In this paper, an approach for predicting the next inter-cell movement of a mobile user in wireless network is presented. The future location of a mobile user is predicted based on the user's movement history. User mobility patterns are mined from the history of mobile user trajectories. And then mobility rules are extracted from these patterns. Finally, mobility predictions are accomplished by using these rules.

1. Introduction

A personal communication system (PCS) allows mobile users to move from one location to another location since these systems are based on the notion of wireless access. In mobile system each mobile user is associated with Home Location Register (HLR) which stores up-to-date location of the mobile users. These logs accumulate as large database, in which data mining technique is applied to find the frequently followed location. Mobility of the users in PCSs gives rise to the problem of mobility management. Mobility management in mobile computing environments covers the methods for storing and updating the location information of mobile users who are served by the system.

A hot topic in mobility management research field is mobility prediction. Mobility prediction can be defined as the prediction of a mobile user's next movement where the mobile user is traveling between the cells of a PCS or GSM network. The predicted movement can then be used to increase the efficiency of PCSs. By using the predicted movement, the system can effectively allocate resources to the most probable-to-move cells instead of blindly allocating excessive resources in the cell-neighborhood of a mobile user.

If each mobile node's future location and network topology changes can be predicted accurately enough, then route reconstruction can be done prior to topology changes without overburdening the network with a large number of control packets. Thus, services are pre-connected and pre-assigned at the mobile node's new location before the node moves into the new location. The end user receives immediately services at the new location, almost as efficiently as at the previous location. Therefore, the employment of mobility prediction techniques is very crucial in the design of efficient routing schemes.

The rest of this paper is organized as follows. In the next section, we discuss the related papers with our work. In section 3, we present overview of mobility rules mining. And then we describe mobility prediction strategy using data mining approach in section 4. And then we describe the proposed system in section 5. Finally, we conclude our paper.

2. Related Work

Different mobility prediction algorithms have been proposed in the literature to cope with user mobility in different wireless and mobile networks.

Markov chain models have been widely used in order to estimate the probability of an object's movements from one region or state to another at next time period. Hoyoung Jeung, Heng Tao Shen, and Xiaofang Zhou [2] proposed trajectory pattern mining using hidden Markov models. In the paper, they introduced a novel approach which takes advantages of the effectiveness of space-partitioning methods. Moreover, an activity based mobility prediction strategy using Markov modeling for wireless networks is proposed by R.V. Mathivaruni and V.Vaidehi [6].

Neural network models are also applied to predict next locations of mobile user [3][7]. Shiang-Chun Liou and Yueh-Min Huang [7] used that model for their research. In the work of Lyes Dekar and Hamamache Kheddouci, a cluster based mobility prediction technique is used [4].

Furthermore, data mining approaches are also proposed in [1][9][3]. Khan Yavas and et.al presented a new algorithm for predicting the next inter-cell movement of a mobile user in a Personal Communication Systems network. In the paper of

Luis Otavio Alvares and et.al., meaningful patterns can only be extracted from trajectories if the geographic space where trajectories are located is considered [5]. And then, incremental data mining algorithms for Mobility Prediction of Mobile Users are proposed by U. Sakthi and R.S. Bhuvaneshwaran [9].

Many works have been presented in the literature to support mobility prediction. Some use Markov model, others use data mining algorithms and a few just use cluster and neural network.

3. Mobility Rules Mining

In location-based services, data mining is used to reveal patterns of services and provide prediction of location. A sequential mining approach for the location prediction is used to allocate resources in a PCS network.

The mobile users move from one location to another location in a wireless PCS network. The movement of mobile user is called as User Actual Path (UAP) which have the form $UAP = \langle l_1, l_2, \dots, l_n \rangle$, where n is the number of locations followed by the mobile user and l_k represents k th location in the movement path. The frequently followed trajectory is named as User Mobility Pattern (UMP) which is used to generate mobility rules.

Let $UAP = \langle l_1, l_2, \dots, l_n \rangle$ be the set of locations. A database DB is a set of mobile user records, where each record contains set of locations. Frequent locations are mined from UAPs in the database. Mobility rules are generated from the mobility patterns which is in the form of $A \rightarrow B$ having global confidence c if $c\%$ of records in DB that contain A followed by B. Mobility rule $A \rightarrow B$ represents the mobile users current location is A then he/she will move to location B.

4. Rule Based Mobility Prediction Strategy

Mobility prediction strategy based on mobility rules mining consists of three phases: user mobility pattern mining, mobility rules extraction from mobility patterns and mobility prediction.

4.1 Mining User Mobility Patterns

User mobility pattern (UMP) is a sequence of neighboring cells in the coverage region network. The consecutive cells of a UMP should be neighbors because the users cannot travel between non neighbor cells. In order to mine the user mobility patterns (UMPs) from user actual paths (UAPs), sequential pattern mining can be used. Sequential pattern mining has been previously used and examined in various research domains such as web log mining. In

that work, sequential pattern mining is used to mine the access patterns of a user who visits the pages of web sites. This method assumes the web pages to be the nodes and the links between these pages to be the edges of an unweighted directed graph, G. Then, sequential pattern mining is applied to web logs by considering G.

In this approach, a directed graph is used to represent the cells in the coverage region. A sample coverage region is shown in figure 1 and the corresponding graph G is illustrated in figure 2. The algorithm for UMP mining is presented in figure 3.

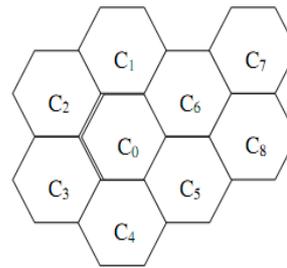


Figure 1. A sample coverage region

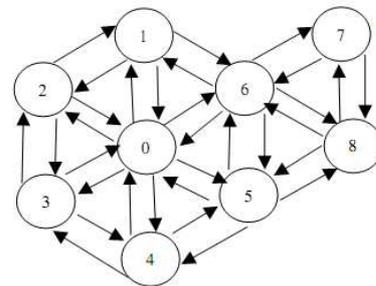


Figure 2. A directed graph G corresponding of the sample coverage region shown in figure 1

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UMPmining()
Input:  Moving paths of mobile users UAP in the
        database DB
        Minimum value for support, supp(min)
        Coverage Region Graph G
Output: User Mobility Patterns UMPs
K=1
While length k large pattern exists
For each UAP a ∈ DB
    Find the subsequence of UAP and put it in S
    For each subsequence s ∈ S
        Calculate the support count
        (s.count)
    End for
End for

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Choose the candidates where s.count >= supp(min)
Add these length k large patterns to the set of all
large patterns
Generate length (K+1) candidate patterns using the
graph G
k=k+1
End While
Return all large patterns

```

Figure 3. UMP Mining Algorithm

The UMP mining algorithm terminates with the set of large candidates. A sample result of the UMP mining algorithm is shown in Table 1.

Pattern	Support
<0>	4
<2>	2
<4,0>	1.5
<4,5>	2.5
<0,5>	1.5
<2,0>	1.33
<3,4,0>	1.5
<3,4,5>	1.5

Table 1. Sample results of UMP mining algorithm

4.2 Mobility Rules Extraction

In this phase, mobility rules are generated from which the next user movements are predicted. Having the UMPs mined in the previous phase, we can now produce the set of the mobility rules from these UMPs. Moreover, when these rules are generated, a confidence value is calculated for each rule. For a mobility rule $R : c_1, c_2, \dots, c_i \rightarrow c_{i+1}, \dots, c_{ki}$, the confidence is determined by using the following formula:

$$confidence(R) = \frac{\langle c_1, c_2, \dots, c_k \rangle \cdot count}{\langle c_1, c_2, \dots, c_{i-1} \rangle \cdot count} \times 100$$

Example mobility rules and confidence values for the UMPs are given in table 2.

Rule	Confidence
<2> → <0>	66.6
<4> → <0>	50
<4> → <5>	83.3
<3,4> → <0>	75
<3> → <4,0>	50
<3,4> → <5>	75
<3> → <4,5>	50

Table 2. Sample Mobility Rules

4.3 Mobility Prediction

Mobility Prediction is the last phase of mobility prediction strategy. In this phase, the next movement of the mobile user is predicted. In mobile environment, next location of mobile users is predicted using mobility rule and current location of the mobile user. For example, currently the mobile user is in location 4. Matching rules $\langle 4 \rangle \rightarrow \langle 0 \rangle$ and $\langle 4 \rangle \rightarrow \langle 5 \rangle$ are generated. The match value is calculated by summing up the support value of the UMP and confidence of the rule for each predicted location and stored in resultant array. Resultant array contains two values $[(0, 50), (5, 83.3)]$. If $m = 1$, then the location 5 will be predicted as next location. If $m = 2$, then the locations 0 and 5 are the predicted as next locations.

5. The proposed Approach

Existing works have mainly focused on the cells of the coverage region, while the semantics and the background geographic information has rarely been addressed. We claim that meaningful patterns can only be extracted from trajectories if the geographic space where trajectories are located is considered. Therefore, there is an increasing necessity for a more meaningful representation of trajectories, as well as their relationships with the geographic space. An example which expresses such necessity is shown in Fig. 4. In Fig. 4 (left) we can visualize a set of trajectories, from which not much information can be extracted. In Fig. 4 (right) we have the same trajectories over the geographic space, where we can visually infer information like the geographic location (Paris) and the intersection of trajectories with the Eiffel tower and hotels.

In order to capture and model mobility pattern relationships, data mining techniques play an essential role. With attention to this, a combining approach with background geographic information will accomplish more accurate predictions.

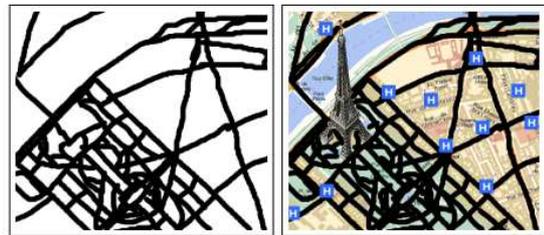


Figure 4. (left) trajectories and (right) trajectories with geographic information

6. Conclusion

In this paper, data mining approach for mobility prediction is presented. The algorithm is

based on mining the mobility patterns of user, forming mobility rules from these patterns, and finally predicting a mobile user's next movements by using the mobility rules. Through accurate prediction of mobile user movements, our algorithm will enable the system to allocate resources to users in an efficient manner, thus leading to an improvement in resource utilization and a reduction in the latency in accessing the resources.

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