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Virtual Explorer: a Path Prediction Algorithm for Intelligent Transport Systems

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Abstract

Mobile user tracking is an important issue in wireless Network. Spatial data is used for location based services and to support traffic management. Traffic management is an important problem faced by the local authorities where they try to manage efficiently all the information gathered for traffic control. For that location and movement determination are important. This paper proposes Virtual Explorer system that detects the movement of mobile user, analyses the information collected about him and predicts his destination only by measuring the signal received from his mobile phone. If some interruption is presented in the path to the destination a notification message is sent to him to inform him about that or to propose an alternative path. This paper proposesα-path prediction algorithm that predicts the future location of the mobile user based on the user's history movement. We expect that our system help in reducing congestion on the principal roads and help in reducing the number of cars that reach certain point in the case of accident. In addition, our system can help the police to keep track the pedestrian only by collecting information from his mobile phone.

Keywords: traffic management, path prediction, location based detection, received signal strength

1. Introduction

Intelligent transport system refers to the use of information and communication technologies on the transport infrastructure. Traffic management is an important problem faced in most of the crowded cities, in particular in the absence of information system or advanced transport infrastructure that supports the high traffic load in the critical hours of the day.

Mobile phone is becoming now a necessary part of our life, our business. Companies relay on the information collected from mobile phone to run their application. Using mobile phone as information center improve the performance and the quality of service offered from telecommunication companies. Today, there are only a few mobile phone companies offering mobile phone tracking based only on the GSM network capability. Using GPS for position determination is more accurate than GSM network. However, GPS consumes large amount of power and only works well when mobile phone is exposed to a view of the sky. Consequently, using GPS for location detection reduces significantly the standby time of the mobile phone.

Virtual Explorer (VE) is location based detection system that uses the features offered from the cellular network, to collect information about the location of mobile user, to be used in detecting his path in order to provide him new services. It is a hybrid system that detects the mobility model under fixed infrastructure. In VE, the passenger (mobile terminal) is a passive one, where is used the signal received from his mobile phone to identify his movement pattern. Our goal in proposing VE is to find a technique that reduces the traffic on the crowded roads, and to provide safety for the passengers in some dangerous cases. Currently, car navigator systems which uses GPS system succeeds commercially[GPS], new mobile phone (smart phone) with GPS receiver also can help in collecting information about the traffic on the road. However, the high cost of navigator, and the needs of accurate and detailed digital map make the use of navigator is unpractical in the country where a digital map about the road is not available. Accuracy of mobile phone tracking varies with the size of the cell coverage which varies from 200 meters to several kilometers. Because mobile phone tracking is a new technology and composes of several technologies integrated together. So, it needs a cooperation from all parts (user, telecommunication companies, transportation companies, and it Departments) participating in the system to produce a completely integrated system.

About the user, he must sign an agreement that allows the telecommunication company to collect information about his movement and to be used only in providing him new services. The telecommunication companies must

ensure the privacy of information collected about the user and to provide him new services. The transportation companies are responsible of providing the telecommunication companies the name and the number of each location.
Using the mobile phone as transmitter reduces the cost of network communication without the need of additional hardware on the user's car. Our work consists on adding a new function to the central base station (referred as MSC in figure.2) that allows it to keep track any user. Our system is composed on three main components are:
-Mobile terminal (A_i): is a mobile user equipped with cellular phone (active).
-Fixed base station(F_{ij}):that is a base station situated in different locations on the road has the role of sensing the access of mobile terminal in his area, identifies it and sends the information to the correspondent Mobile Telephone Switching Center (MSC).
-Mobile Telephone Switching Center (MSC) it provides link between the cellular network and public switched telecommunication network, (Figure.2).Its role consists of collecting information from different F_{ij} about the mobile terminals, analyzes this data, and predicts the mobile terminal destination. it is denoted as C (Arwa Zabian 2011).

2. How Virtual Explorer works?

VE starts working from the moment on which the user switches on his mobile phone. During the movement of A_i a handshaking is done with the base station $\mathbf{F_{ij}}$. Based on that, the base station identifies its (ID), calculates its distance using the Received Signal Strength (RSS) (Hofman (2001), HajarBarani(2010), Yilin Zhao(2000)), and it calculates its speed. Its direction is calculated using AOA (Angle of Arriving) technique (HajarBarani(2010), Benslimane(2005), Savvides.A(2001), Russel.S(2003)).
The distance to base station is calculated based on the signal received from the mobile phone that is calculated given the following equation :

$$P_r = P_t \left(\frac{\lambda^2}{(4\pi d)^2}\right) \qquad (1)$$

where P_r is the received power that can be measured by the base station
P_t is the transmission power
λ is the wave length each telecommunication company uses a well defined wave length for communication
d is the distance between the transmitter and the base station .

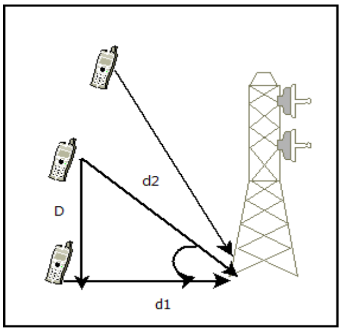

Figure.1: the difference in distance to the base station

So, from figure .1 is calculated the velocity as follow :
$V= D/ \Delta T$ (2)
Where D is the difference in distance to the base station . And ΔT is the time difference.
We speak about urban roads where the base station has a fixed location.
• At time T1 the mobile terminal were at distance d1 from the base station with angle α_1.
At time T2 the mobile terminal is becoming in location at distance d2 and angle α_2 .
α is used to define the direction of the mobile terminal.
The information about the user (ID, v, α, T) is sent to the MSC, that is used with the references from other BSs, to predict the destination of the mobile user.

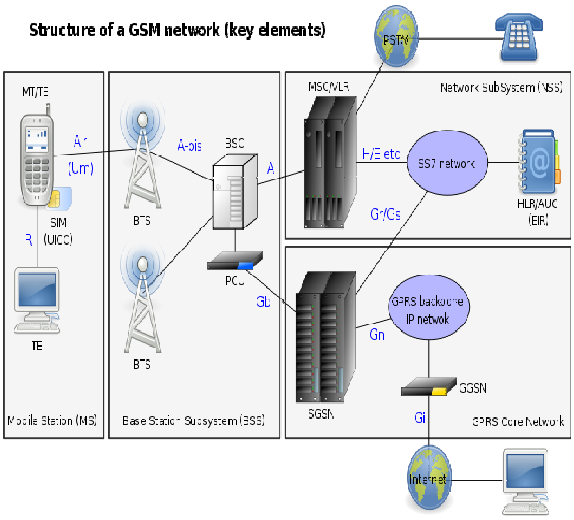

Figure .2:Mobile Telephone Switching Center

Assumptions:

– Our trackers (mobile phone A_i) is the central element of our system
– The base stations is an assistant element
– $\mathbf{C_j}$ is the master element
– Both $\mathbf{C_j}$ and $\mathbf{F_{ij}}$ are fixed nodes and the unique mobile element is A_i.

The idea behind proposing Virtual Explorer is to provide the user new services. In the country where the transport infrastructure does not provide the user with some information like traffic information on the road (interruptions, congestion), or weather conditions. In section.4, it is shown the results of survey done in Jordan about the importance of the system for traffic congestion and about the facilities offered from the system when travelling on the interior and exterior roads.

The work in our system can be divided into three parts: first part consists on identifying the mobile user location, that is the role of the fixed base station, that uses the strength of signal received from the mobile phone of the user (RSS) to determine his distance to it. Measuring the strength of this signal in different locations in the coverage area in different time can determine with good accuracy the mobile user velocity V and its direction α .

The second part is the routing of the information collected from the base station to the nearest central base station C_j. The information collected about the mobile system must be disseminated to the correspondent MSC. When the base station collects information about a home subscriber, it routes this information to its MSC. If the user is a visitor, so the information collected must be routed by a way of MSCs or by a way of the other nodes in the network to the correspondent MSC. So, we need an efficient routing algorithm that can find the best path to the correspondent MSC in short time, in a manner that the MSC predicts his path and provides him a service before he had travelled long distance .

Our system to be able to provide the proposed service a communication between its components(fixed base station, central base station) must be done. So, each node must work as router to route the information to the correspondent CBS . For that, each node creates its routing table in which is inserted all its neighbors by which it can communicate directly. The information stored in the routing table are: the node ID of the direct neighbor, link cost to reach Cj. The cost of communication between two nodes varies given the MSCs that belong to it. Cost 0 means the base stations belong the same C_j , and cost 1 means communication done between base stations belong different C_j . For example, from figure.3, the routing table of the node F_{22} contain the following information :

Table.1: the routing table of node F_{22}

node	Cost
F_{21}	0
F_{31}	1
F_{11}	1
F_{14}	1

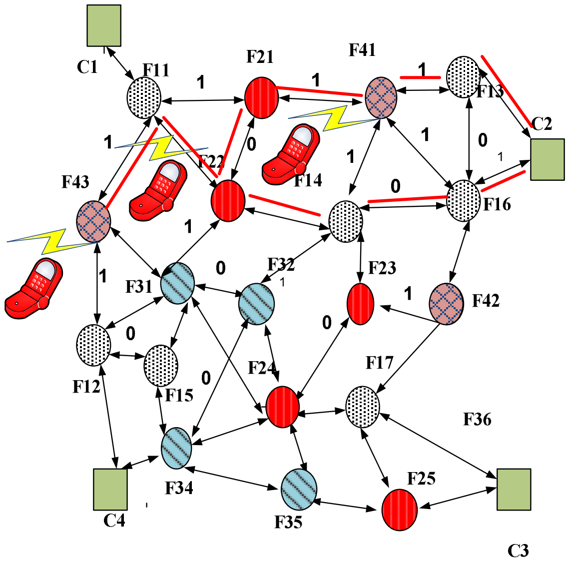

Figure.3: how Virtual explorer works

Then, it is used A* search algorithm to calculate the short distance from any source to any destination. The best path is considered that is done with less number of hops and within base stations that belongs the same Cj .
A* uses a best first search and find the least cost path from any initial node to one goal node. It uses a function f(n) that represents the path cost function $f(n)= g(n)+h(n)$ (3)
f(n) represents the total cost of the path and that is calculated from the routing table . g(n) is the cost to reach the initial node. h(n) is the cheapest cost from n to the goal (Russel.S (2003)). Form figure.3, if F_{11} want to reach F_{16} by a way of F_{22} the cost to reach the initial node F_{12} is equal 1 and that is g(n).
F_{22} searches about the least cost path to reach F_{16} it has the following possibilities :

- F_{22} , F_{14} , F_{16} with cost 1 two hops
- F_{22} , F_{21}, F_{41} , F_{16} with cost 2 three hops
- F_{22} , F_{21} , F_{41} , F_{14} , F_{16} with cost 2 four hops

So the least cost is the first one .
F(n) calculated from equation 3 is equal to 2.
Third part of our system, that is the main goal of this paper, is to predict the destination of the mobile user and to provide him an alternative path in the case of interruption or traffic presented in his path. The rest of this paper is organized as follow: Section.3, introduces our proposed path prediction algorithm. Section 4, presents questionnaire results. Section.5, provides some of the techniques proposed for path prediction. And finally conclusion and future works.

3. α-Path Prediction Algorithm:

We propose a path prediction algorithm that is based on Mobile Motion Prediction algorithms (Alexander Marlevi (1994), A. Bttacharya(1999)), that predicts the future location of a mobile user according to his movement history pattern. The MMP algorithms are based on the fact that everyone has some degree of regularity in his/ her movement that consists of a random and regular movement. While we speak about user that moves on urban roads, some regularity in the user movement is due to the topology of the roads. The random movement is represented in the choices tacked on the minor roads. So, all the random movement on the urban roads can be reduced to regular movement.
Our work considers the user's movement only regular movement defined by the urban roads maps.
An important parameter used to express the regularity of the user's movement is called

Degree of Regularity $D_R = N_s / N$ (4)

D_R is an important parameter in our work, it helps in increasing the prediction accuracy. N_s is a counter that counts the number of states that matching on the path (the states are considered a well defined indications on the road).
N represents the total number of states considered to define the path with high precision. Generally, the description of a path between two nodes is described by a set of indications between the two points. The urban

roads can be considered as a graph G with N nodes. Where nodes are indications on the path , and the links between such nodes are the urban roads, figure (5,6).

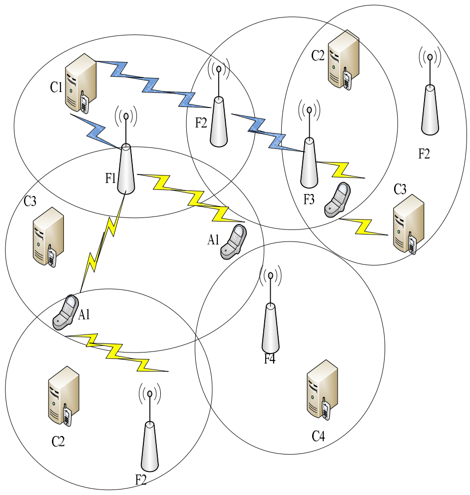

Figure.4:Virtual Explorer System

α-PPA maintains information about the previous movements of the user and this information is stored in an array multidimensional N[i][j] (flowchart in figure.5), and is updated periodically given the information received from the base stations.

The information about the user (ID) is stored in a hash table. The user that travels on the same path each day has a regular movement and its destination can be predicted quickly. Generally, when people go to work, they follow the same path every day, the presence of interruption or accident on the path can create unexpected delay. Our system can help in minimizing the delay in such cases.

α-PPA works based on the information received from the base station that is (ID, V, α, T). Where ID indicates the user ID that can be his phone number or the number of his SIM card number. Local users can be identified quickly by the HLR (Home Location Register) data base stored in the MSC (Arwa Zabian (2011)). However, visited users need a registration during which is identified his phone number or his SIM card number. V indicates the user velocity calculated by the base station given two measurements in the same range. T is the time on which the user is located in a given location near the base station. α define the direction.

The MSC recognizes the information received in only the following two states: new user or registered one. New user that means the ID is not presented in the hash table (referred ID=0 in the flowchart). And registered one means information about him has been received from another base station previously and this information is stored in a location in the hash table (ID=1 in the flowchart).

Notification:

- Each information received about one user, must occupy a location in the hash table denoted as X_i. n is the size of the hash table i=0…..n
- Ns[i] represents the states that matches with the registered states, for each new matching state Ns is incremented by 1.
- β Indicates the location of the mobile user, considering that the location of the base stations are fixed.

3.1. Algorithm Description :

1. Read information (user ID) received from the base station. If ID=0 that means a new user (Visited one) and he haven't an information in hash table . so h(ID) is calculated to define its location in the hash table .
2. "Path Prediction Procedure"

Path Prediction Procedure

3. At the beginning N_s =0
4. Read indication (β). If the (β =0) is a new one, store it in the N[i][j] table. Increment the counter Ns by 1.
5. Step 4 is repeated until having a good information needed to define the path with high accuracy (Ns >=4). Then is calculated the degree of regular from equation 4.
6. If D_R< 1 the references are not sufficient , it needs more references and the algorithm turn to the step 4
7. If D_R=1 the references are sufficient and the path can be predicted .

8. If Dr>1 the references are sufficient and the path can be defined with high precision.
9. Turn to step 1.

3.2 prediction Procedure

This procedure assigns a weight to each node that is the probability of state S to be accessed after S-1. Each time a prediction success, the probability is increased. If another user arrives at node S-1 the next step can be the node with high probability. For example, in figure.1, to go from source to destination (A to B), each node that takes the path A-C-H-I has two probabilities to continue with L-J path orA-C-H-I N-F-O-F path.
To both L and N is assigned a probability counter that start from 0. If the user follows L, its counter is incremented by 1. When another user wants to go from A to B and passes on I, it is predicted with high probability that will follow L.

system utility

the main goal of our proposed system is to provide the user a new serviced on his mobile phone. Since the mobile phone today is becoming more than simple phone used to make or receive calls.

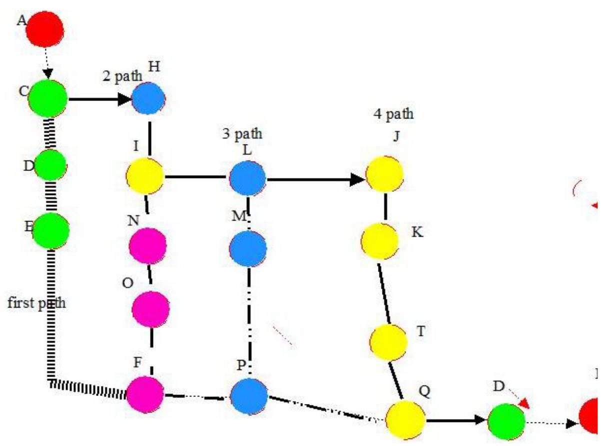

Figure .5: graph that represents the possible paths from Porta Lucca (pisa) to National Museom

Figure.6: Pisa (Italy) Map

For that, it was necessary to poll the opinions of the people in our country (Jordan) about the utility of the system in their daily life. A questionnaire is distributed in Irbid city (Jordan), and a random sample of users with different age (18-45) , different cultural background (PhD, Master and BC degree), different use of transport means (private car, public transportation) is selected.

Our questionnaire where used to evaluate the following parameters :

- the importance of mobile phone in the daily life
- the importance of our service
- the importance of such system in a country like Jordan where no transport information system exist or no electrical signs that indicate the state of traffic on the roads exist.
- The importance of the system in solving the traffic problems on the main roads in the peak hours ("7- 9 am", "1.30- 5.30 pm").

Table .2, shows the results obtained after analyzing the questionnaire based on the previous parameters. Our results confirm the importance of the system in a country like Jordan where 69.23% of our sample state that no such system exist and no electrical signs is presented on the roads in the country studied . reading the data presented in table .2 , it is clear the importance of our system as a service provided to reduce the traffic and to solve the congestion roads problem.

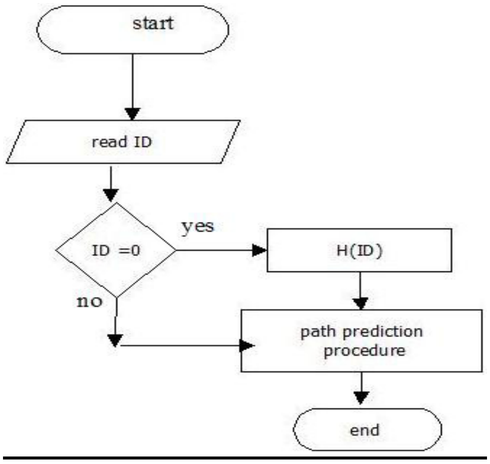

Figure.7: Path Prediction Algorithm

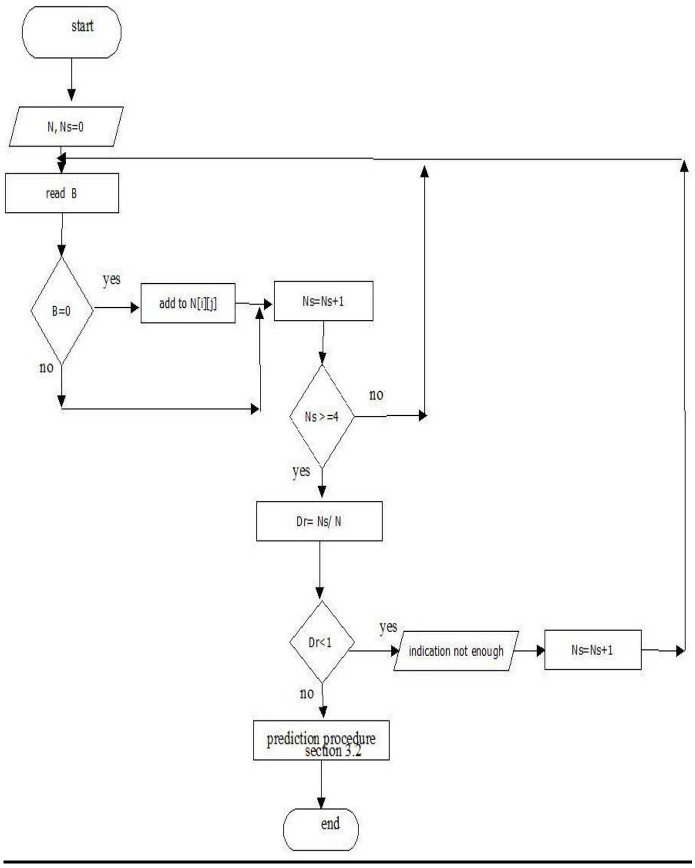

Figure.8 : Path Prediction Procedure

Table 2: questionnaire results

Question	Very high degree	High degree	Middle degree	Never
Exists some electrical signs on the roads that indicate the traffic situation	7.69	15.4	7.69	69.23
Importance of mobile phone	46.15	38.46	15.38	---
Importance of our service	15.38	53.84	23.0	7.69
Does the system solve some of traffic problems	23.00	61.53	15.38	-----

5. Related works:

Traffic management is an important issue from local authorities and they try to manage efficiently all the information gathered for traffic control. Location based services plays an important role because the drivers can be informed immediately in their cars about current situation of the road dangerous points etc….
There are a lot of aspects for traffic management to ensure the road network. For example, cars suddenly stopped on the high way, it is not known what about and when did it happens? If the reason is an accident or something else? For how many kilometers is the line of cars without movement? A motion detection system can predict and answer on the previous questions only by observing the variation of the location of the user with the time.
Usually behavior of a driver can be detected. So, a notification message can be sent to him to inform him about the irregularity in his behavior, or to inform the other drivers next to him. In V. Bharghavan(1997), a location based services system that includes set of requests help the user in keeping information about the road traffic is presented. The system provides interface for the user's requests, the user can use Internet mobile phone or PDA to connect to the system. The system includes an information system that can answer on all the user requests about the road situation, can predict the traffic after a specific time in a specific location in a given direction. It includes also information about accommodation, possibilities, parking place… For that, it uses a data warehouse for integrating, management and data analysis. It is a three tier client server architecture in which the user uses the Bluetooth to define his current position and it uses GPRS protocol to connect to the server in order to retrieve the information needed. In George lie (1994), a path prediction algorithm that uses the history movement to predict the next location to which the user is expected to move is proposed. The information about the history of the user is stored in a profile server and the movement history is stored into mobility profile that represents the mobility pattern of the user. Two steps are followed: the first, when the user is moved from one location to another is used his profile to predict the next locations. If the prediction successes it is calculated the probability to move to the next locations. In the second step, is used the information stored in the user profile to predict and calculate the probability to move to the next locations. A probabilistic prediction algorithm is proposed in George Lie. (1994) , where all the possible behavior happened in a location are stored in a data base, and each base station creates its own function that is based on (T1, prev, next, T2). Where T1 is the time where the behavior happened, prev is the previous event happened at the same location and next is the possible next location. T2 is the time on which the mobileuser reside in the current location, it predicts the next location and the time of residence in such location. In A.Battacharya, and S.K.Das (1999) , Lezi-Update algorithm that uses the update information about registered movement to predict the next movement is proposed. In this algorithm, the user history movement is registered and is updated each time the same user or a new user has made the same movement. The location with high update rate is considered. In George Liu, Gerald Q. Maguire Jr. (1996), a class of Mobile Motion Prediction Algorithms that predict the future location according to movement history pattern is presented. Considering two types of algorithms: Regularity Pattern Detection (RPD) that detects specific pattern of user movement and Motion Prediction Algorithm (MPA) that combines regular information with stochastic information to predict the future location of the user. In the literature, a number of path prediction algorithms that are based on machine learning technology is proposed. In M. Kyriakakos,(2003), a machine learning algorithm that is based on two well established techniques is proposed (S.Hadjiefthmiades (1999) , Neal Patwari (2003).

6. Conclusion and future works:

This paper proposes a path prediction algorithm that helps our proposed system VE (Virtual Explorer) in expecting the kind of movement the user will done in the near future only by reading his history movement. α-path prediction algorithm is implemented in C++ and we still working on finding a best prediction with high accuracy. The proposed system is centralized one, were the MSC is the responsible of predicting the path. But, if the number of user grows the overhead on the MSC will increase. So, we plan to add a distributed system to VE in which the destination or the location can be calculated locally by assigning a new job to each driver or by forming a cluster of drivers that share the same movement and area. In which the leader has the role to calculate the destination of the members of the cluster. Our main idea was to propose a system that requires fewer resources as possible and then finding its utility. If our system successes we expect to develop it to be scalable and easy to implement in any system at any network topology.

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