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Mobile User Motion Detection and Traffic Road Management

Arwa Zabian[1*]

[1]*Department of Computer Science, Jadara University, Jordan.*

Author's contribution

The sole author designed, analyzed and interprets and prepared the manuscript.

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ABSTRACT

The vision of next generation networks is to offer a real time services such that traffic situation on the major or minor roads. While 3G networks are based on wide area cell concept, 4G will be a hybrid network that use wide area network with Ad-hoc network. In this paper we propose two algorithms, the first algorithm describes how information is disseminate in our system Virtual Explore (VE). VE is a motion detection system that able to predict the mobile user destination. The second algorithm is α-path prediction algorithm that predicts the destination of mobile user based on his previous movements, we expect that our proposed system will reduce the traffic rate between (40-50%) in the case of accidents or in the congested locations. Our analytical results show that the prediction accuracy in our work will vary from 20-40% if we maintains a prediction correctness in the range 40-50%. Considering our goal the prediction accuracy is considered a good results in comparison with other works in the same context.

Keywords: Received signal strength; path prediction; motion detection; traffic management; information dissemination.

**Corresponding author: E-mail: arwa@jadara.edu.jo;*

1. INTRODUCTION

Next generation networks will employ hybrid network architectures using both cellular and Ad-hoc network concept.

Determining the location of mobile terminals relies on the cellular network infrastructure and protocols to provide a reliable and accurate estimate of mobile terminals position without the need of global positioning system GPS [1] or any other positioning system [2,3,4]. Using GPS for localizing the mobile terminal is an interested option for high end applications but is not well suited for all contexts. For example, in the dense urban area where some time satellites are not visible from the mobile terminal or in the country where a few information about the transport infrastructure is available, it is necessary to find another methods to localize the mobile terminal.

Due to the importance of mobile phone in our life, it is necessary to provide a new services that make the user life more comfortable, this is the main idea behind proposing our system. It consists on providing the user a real time information about the traffic road to help in traffic management.

Our system detects and observes the movement of mobile user on the urban roads to predict with high accuracy his destination. In this paper, we propose a virtual explorer system that is hybrid system that collects information about the movement model of mobile user, analyses it, and try to predict his destination in order to give him correct information about the roads followed by him until arriving at destination. People are more likely to pass less time on the roads, sometimes the path from home to work takes longer time than expected due to interruptions, accidents, bad roads situation due to weather conditions. Knowing in precedence the condition of the road can help in providing alternative path that makes the user more satisfied. Our proposed system is composed on three parts are: mobile user (that is a passive one) where it is used the signal received from his mobile phone to define his location. Fixed base station located on the side of the road has the role to sense the entrance of mobile terminal his area and it determines his location and it calculates his velocity, and sends the information to central base station. CBS (Central Base Station) is the third components of our system have the role to predict the user destination and to provide him an alternative path if necessary.

So, our work is divided into three parts are user identification, distanceestimationand path prediction. Our system to work correctly information must be disseminate between base stations and central base station, for that it is necessary to provide a routing mechanism that route the information with low cost and high speed. The rest of this paper is organized as follow: section.2 contains description of our system and its components.Section.3, explains how VE works, user identification and distance estimation mechanisms. Section 4, presents our α –path prediction algorithm. Section .5, contains our analytical results. Then, some previous works and finally conclusion and future works.

2. SYSTEM DESCRIPTION

Our proposed system is called Virtual Explorer, it is composed of three main components are: mobile terminal, base station and MSC (Mobile Telephone Switching Center).

2.1 Mobile Terminal

Mobile terminal that represents the user that holds mobile phone denoted as A_i.It refers to physical terminal 3G mobile phone GSM with frequency 900-2100 Mhz. When the mobile phone starts working, a handshaking is done between the mobile unit and the MSC center to identify it and to assign to it the channel on which it can transmit. When the mobile terminal moves from one location to another, a handshaking is done with the base stations of the visited cells to maintain the communication during the handoff process. In VE, the mobile phone can be only in active state.

2.2 Base Station

Base station is a fixed station in a mobile cellular system used for radio communications with mobile units. They consist of radio channels, transmitter and receiver antenna mounted on a tower. Denoted as F_{ij} where i indicates its number and j indicates the company to which it belongs (MSC).

The base stations are situated on beside of the road, have the role of sensing the access of the mobile terminal in their area, identify it and send the related information to the correspondent MSC. In cities, each base station has a range up to 0.5-5 miles (0.8-8km). All the base stations are connected to telephone exchange switches of the cellular company. In cellular system each mobile switching center serves cellular system of 50-100 cells. Base stations are supported by interconnection to each other and to the Public Switching Telephone Networks (PTSN) via Mobile Telecommunication Switching Center (MSC), Fig. 1.

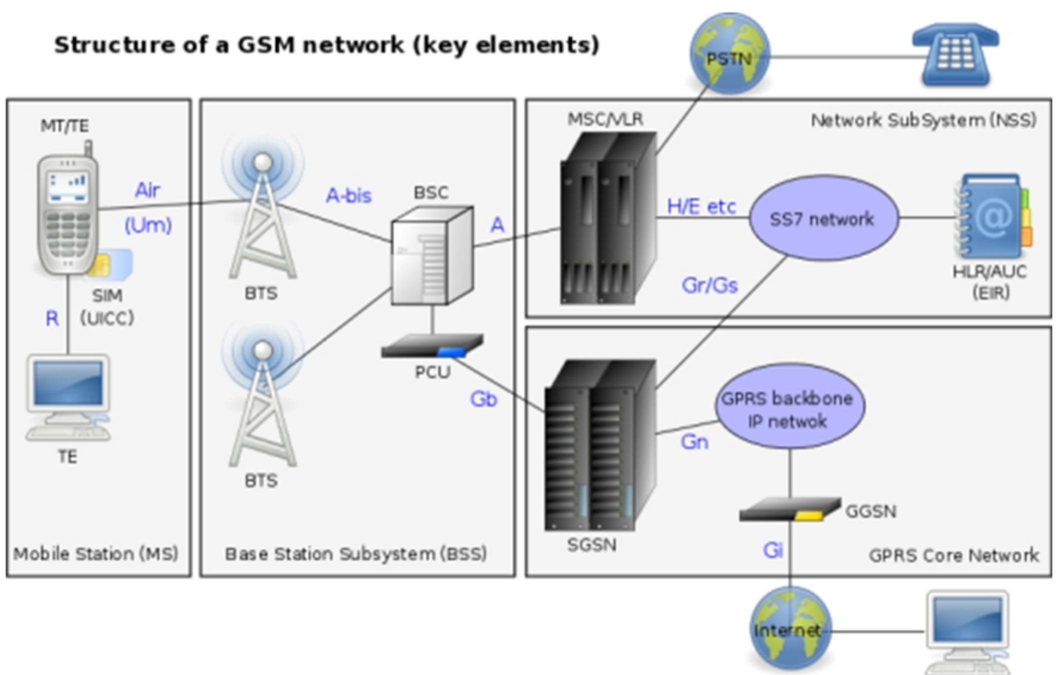

Fig. 1. Structure of GSM network

•Mobile Telephone Switching Center (MSC)

It provides links between the cellular network (composed from Mobile Terminal MT, Base Station BTS) and Public Switched Telecommunication Network (PTSN), Fig. 1. It is an information station responsible about collecting, analyzing and distributing information to/from all the system components. So, has the role to predictthe path of the mobileuserto provide him a service and information about the road situation.

Our system provides the implementation of prediction algorithm that takes the information received from the BS's as input and produces the destination as output. Denoted as Cj.
MTSC supports four databases:

1. Home Location Register Data Base (HLR): that stores information permanent and temporary about each of the subscribers that belongs it (Fig. 2).
2. Visitor Location Register Data Base (VLR): it maintains information about subscribers that are currently physically in the region covered by the switching center. It records if the subscriber is active, and manage the call coming by identifying the both caller and receiver and identify their locations and the area covered them (Fig. 2) [5].
3. Authentication Center Data Base (AUC).
4. Equipment Identity Register Data Base (ETR).

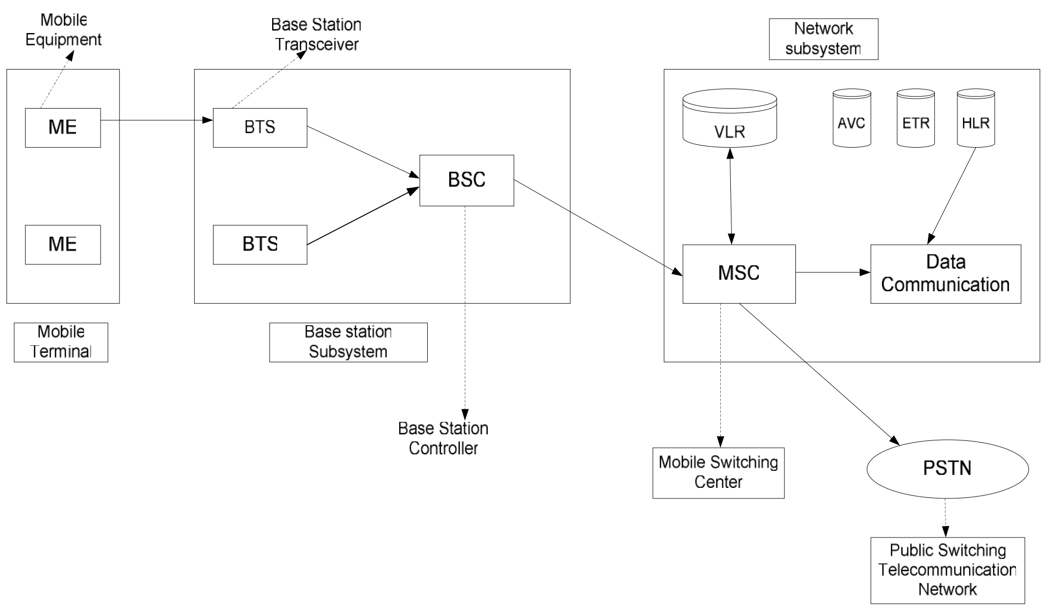

Fig. 2. Mobile Telephone Switching Center (MSC)

3. HOW VIRTUAL EXPLORER WORKS?

VE starts working from the moment on which the user switches on his mobile phone denoted as Ai. During the movement of A_i a handshaking is done with the base station F_{ij}. Based on that, the base station identifies it, calculates its distance using the signal strength received

(RSS) [6,7,8] and it calculates its speed. Its direction is calculated using AOA (Angle of Arriving) technique [8,9,10,11].

We speak about urban roads where the base station has a fixed location.

•At time T_1 the mobile terminal was at distance d from the base station with angle α.

The angle of arriving is calculated as follow: $\cos\alpha = d1/L$ where d is the linear distance to the base station and L is the height of the base station.

•At time T_2 the mobile terminal is becoming in location at distance d_2 and angle α_2. So, its speed is calculated as $v= \Delta d / \Delta T$. α is used to define the direction of the mobile terminal. This information (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.

3.1 Assumptions

- our trackers (mobile phone A_i) is the central element of our system, is in active state
- the base stations is an assistant element
- C_j is the master element
- Both C_j and $F_{ij}$are fixed nodes and the unique mobile elementis A_i.

3.2 Distance Estimation

The distance between the mobile terminal and the base station is estimated using RSSI (Received Signal Strength Indicator). This method does not require additional hardware, but it is based on estimating the distance between two entities (transmitter and receiver) by measuring the signal at the receiving side. RSSI values are not accurate, but can be oscillate due to the effects of fading and environment changes. It depends on the radio transceivers type and on the presence of obstacles. We speak about urban roads where the base stations are situated beside the roads. The distance is estimated given the following relation: $\mathbf{P_{rc} = P_{rt}/ d^{\alpha}}$ where $\mathbf{P_{rc}}$ is the received signal power,$\mathbf{P_{rt}}$ is the transmission power, d is the distance to the base station, and α is path loss coefficient [5].

3.3 User Identification

Each MSC center contains two data bases (as mentioned in section 2) are home location register (HLR) that is a data base that stores permanent information about each of the subscribers that belong to it. And visitor location registers (VLR) that maintains information about subscriber that are currently physically covered by it. When a foreigner user enters the area of the base station a handshaking must be done to ensure to it the connectivity during his staying in the coverage area of the base station, then it is added to the VLR (Fig. 2).

3.4 Information Dissemination in Virtual Explorer

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 entities must be done. So, each node must work as router. For that, it creates itsrouting 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 $\mathbf{C_j}$, the cost of communication between two nodes varies given the MSCs that belong to it.Two nodes that belongs the same $\mathbf{C_j}$ communicate to each other with cost 0, if the two nodes belong to different $\mathbf{C_j}$ the cost of communication will be 1 (the cost of communication is a cost assigned to the link between nodes).

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 $\mathbf{C_j}$. 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) , 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 [12].

3.5 Algorithm Description

VE can be represented by a graph G=(V,E) where V is a set of nodes represent the base stations $\mathbf{F_{ij}}$ or MSC ($\mathbf{C_j}$) and E is a set of bidirectional links between the nodes of the graph.

3.6 Neighbors Discovering Phase

Each $\mathbf{F_{ij}}$ when start working, it broadcasts a hello message to discover its neighbors and set a time out t. t is the time needed to a radio waves to travel a distance equal to the transmission range. If the time out is ended without any receiving answer. $\mathbf{F_{ij}}$ waits another time t and restart the discovering process until an answer message is coming from one neighbor. $\mathbf{F_{ij}}$ inserts the identities of the nodes that have sent an answer message in a list called neighborhood list. Used later for the construction and the update of the routing table Fig. 3.

3.7 Network Construction Phase

In this phase each node creates its routing table that is used to forward the information to the appropriate $\mathbf{C_j}$. All the neighbors nodes are considered in the range and can communicate to them directly, but the cost of communication is vary based on the $\mathbf{C_j}$ to which they belong. To the link between the nodes that belong the same $\mathbf{C_j}$ is assigned a value 0, and a value 1 is assigned to the link between the nodes that belong different $\mathbf{C_j}$s. After setting up the link with neighbors, each node creates its routing table.

Each node exchange its routing table with their neighbors and so constructs the path, and the cost to reach Cj (Fig. 4).

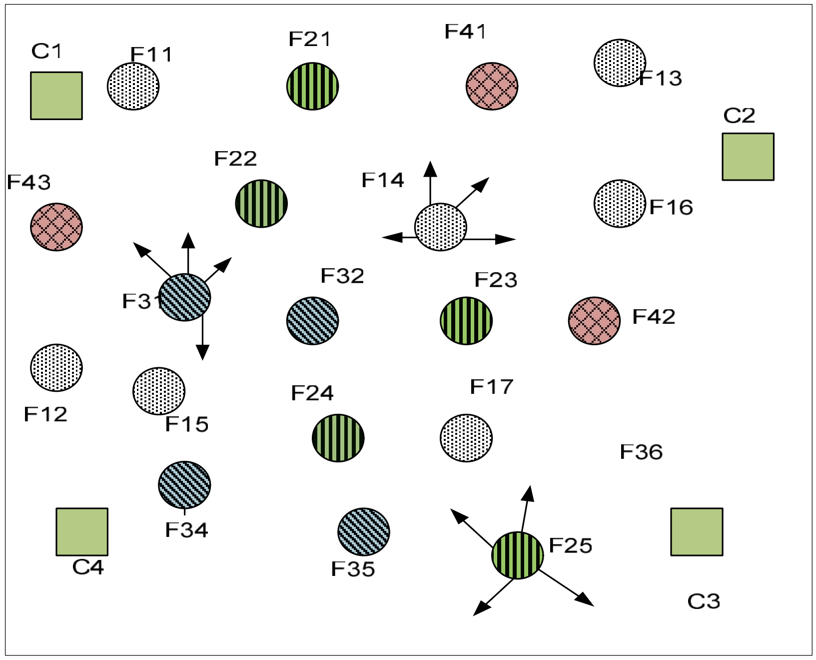

Fig. 3. Neighbor discovering phase

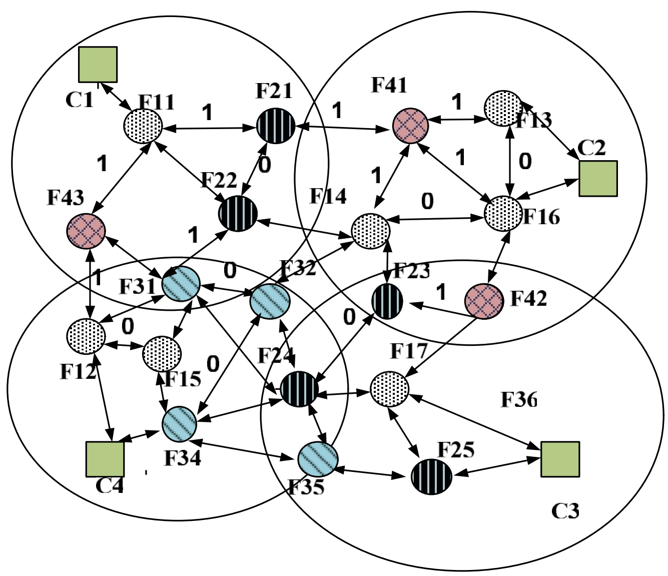

Fig. 4. Network construction phase

Example:

Considering A_i is a mobile terminal that moves from one area to another as in Fig. 5, when A_i enter the area of F43, it senses its presence and identifies it that belong to C_2. So, F43 search in its routing table about the best path to C_2.

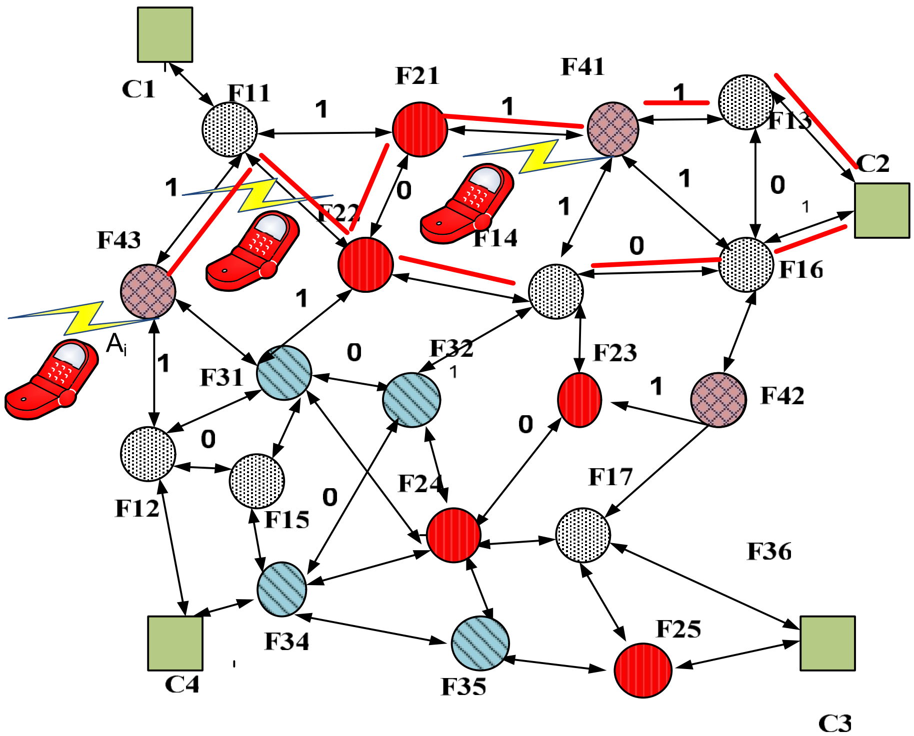

Fig. 5. Example of motion detection in virtual explorer

As is viewed in Fig. 5 two possible paths are presented. The first is by a way of F_{11} (F_{11}, F_{21},F_{41},F_{13},C_2) with cost 5 and the second is by a way of F_{22} (F_{11},F_{22},F_{14},F_{16},C_2) with cost 4. The cost is calculated as follow:

f(n)= g(n) + h(n)
g(n) is the cost to reach F22 that is 2
h(n) is the cheapest cost from F22 to C_2 that is 2

So, it is chosen the second path f(n)=4.

During the movement of $A_{i,}$ C_2 receives more information about it from different base stations presented in the path. Based on this information, it can calculate the mobile user's velocity and its destination.if some interruption is presented in his path a notification message is sent to A_i.

4. 〈-PATH PREDICTION ALGORITHM

We propose a path prediction algorithm that is based on Mobile Motion Prediction algorithms [13,14], it 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

4.1 Degree of Regularity $D_R = N_s / N$ (1)

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, Figs. 6 and 7.

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 Figs.8 and 9 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 [5]. 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).

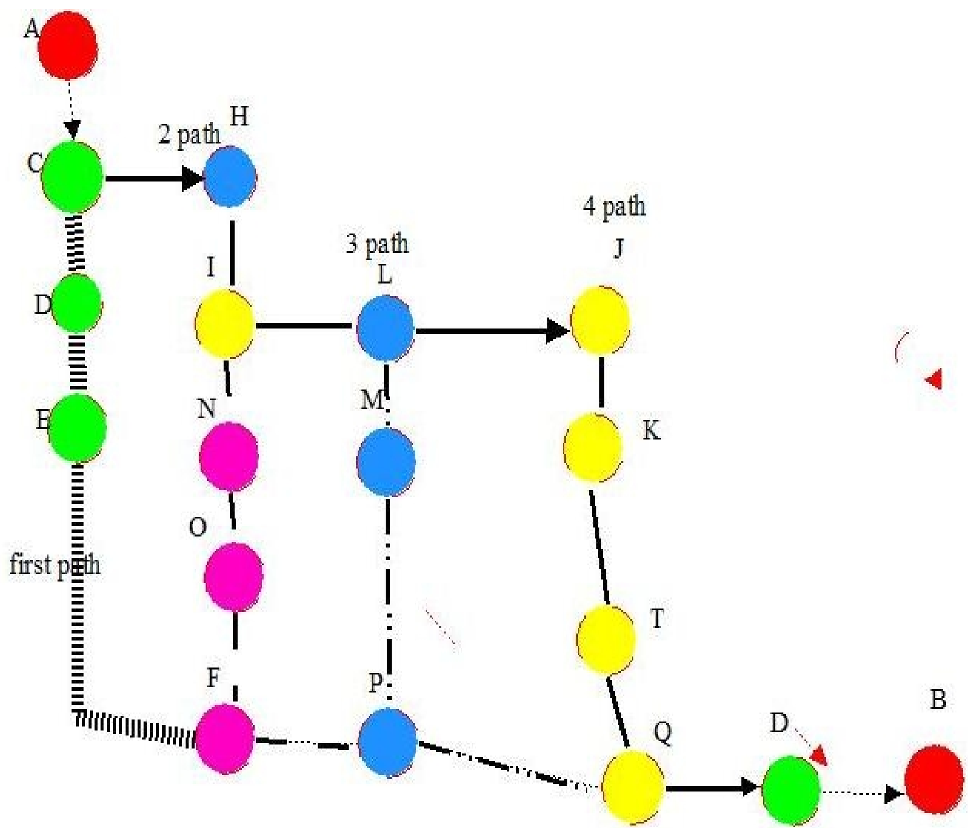

Fig. 6. Graph that represents the possible paths from Porta Lucca (pisa) to national

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] represent the states that match 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 is fixed.

4.2 Algorithm Description

1. The algorithm starts by reading 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 1.
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.

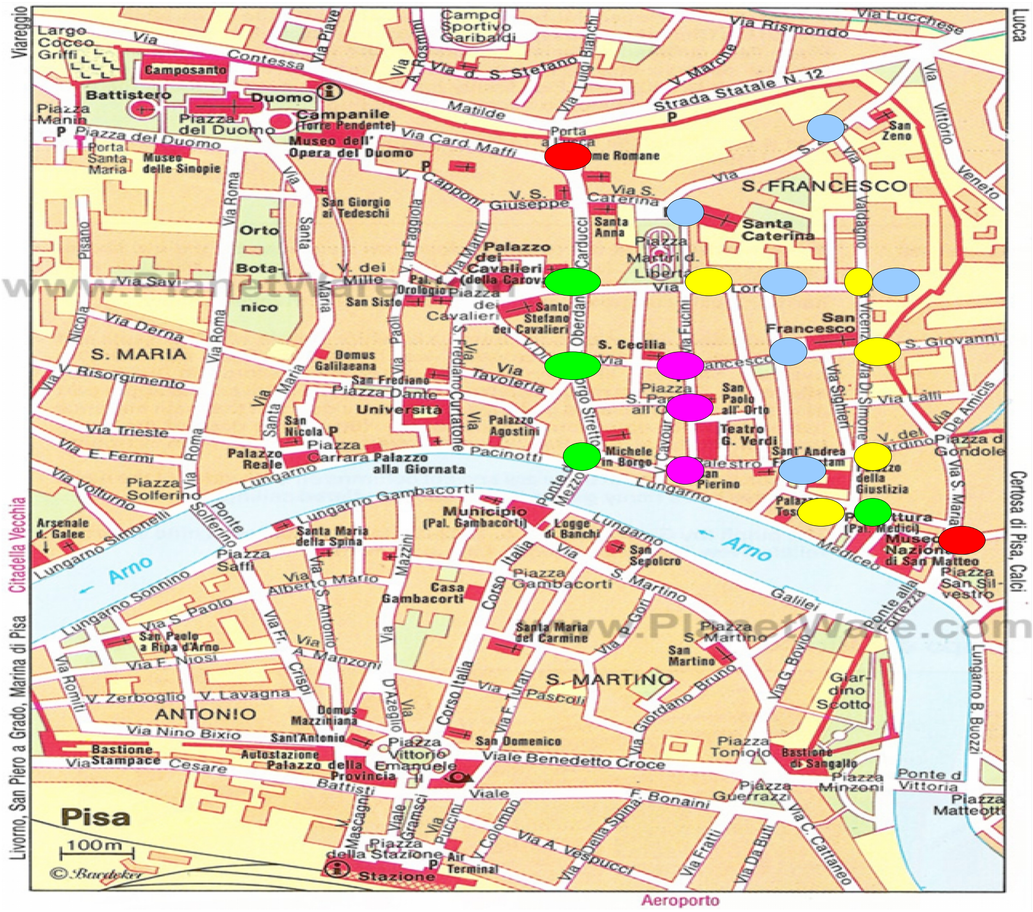

Fig. 7. Pisa (Italy) Map

4.3 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 Fig. 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 or N-F-O- path.

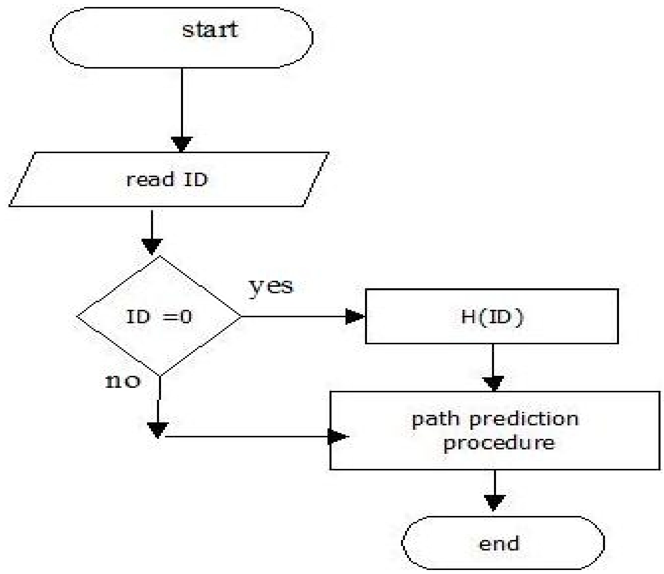

Fig. 8. Path prediction algorithm

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.

We have two tables: the first is the hash table that contains User ID and the predicted location.

H (ID) = 5key mod m (2)

H (ID) indicates the hash function used to determine the location in which is inserted the user ID

M is the size of the table; Key is the SIM card number. It is used hash table because searching and insertion require O (1).

When the prediction procedure end, the location predicted is inserted in the hash table to be used as reference in the next predictions.

The second table is the indications table that contains indications to be followed for each destination. It is n*m table where n is the number of rows. T_{n1} (the first column in each row) must contain the location (destination) and in the other columns is inserted the indications that identify such destination. The following example explains how data is organized in our table and how prediction procedure works.

Example: considering we have the indication table as follow:

Table 1. Indication table

Destination	Indications							
A	X_1	X_2	Y_1	Z_1	X_3	X_4	Z_2	Z_4
B	Z_4	Z_3	Y_2	X_1	X_2	Z_1	Z_2	Y_3
C	Y_1	Y_2	Y_3	Y_4	Z_1	X_1	X_2	Y_2
D	X_1	X_2	Y_2	Z_2	Z_3	Z_4	Y_4	Y_3

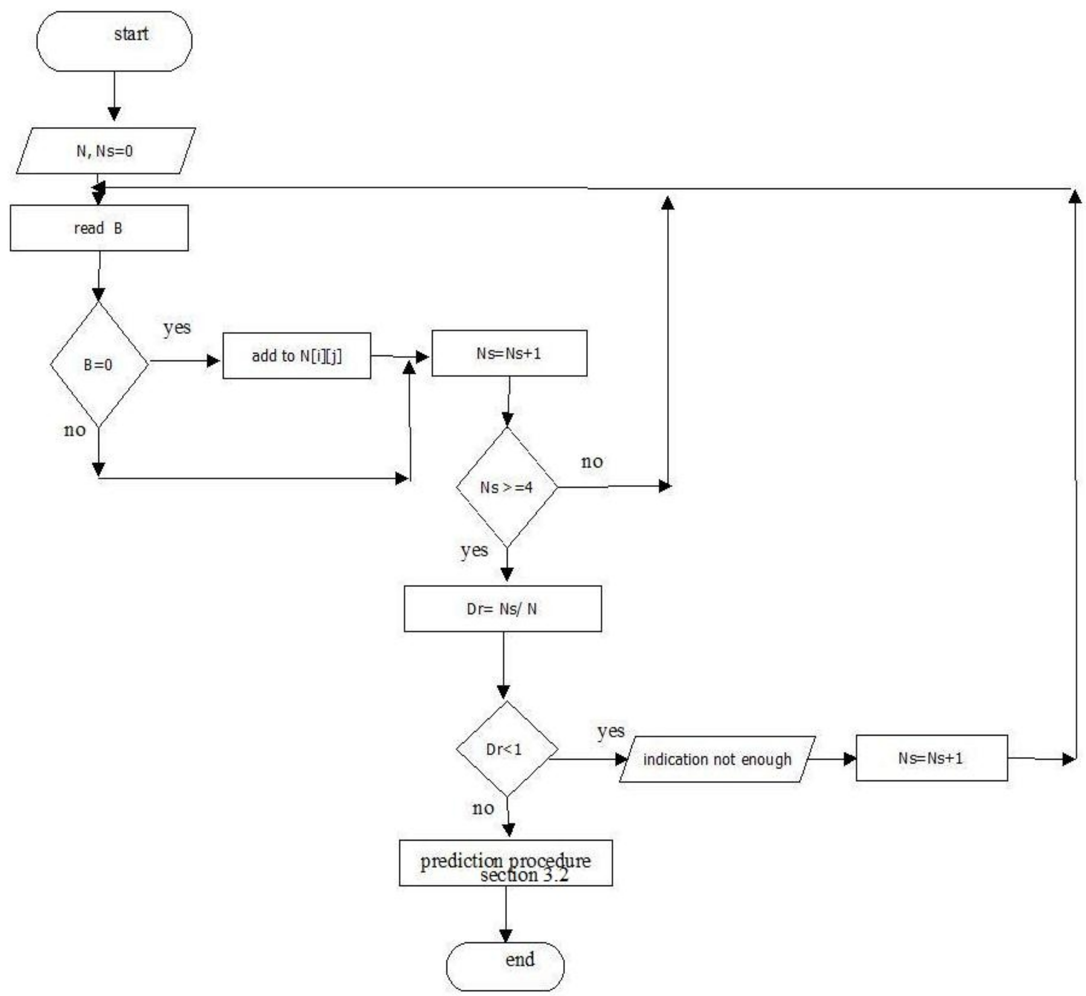

Fig. 9. Path prediction procedure

Considering that the first indication referred about the user where X_1 that means the user maybe will reach one of the following destination: A, D or B, C (the counter of X_1 is incremented and is predicted the second indication that is X_2) this indication also matches in both destination A, D (the counter of X_2) is increased . We expect the third indication if the next indication is Y_1 so we can expect with high probability that the user destination will be A after the fourth indication the destination can be predicted correctly based on the indications stored in the previous indication table (highlighted cells indicate the predicted cells). If the third indication comes Y_2 the prediction will shifted to C and D so we wait the fourth indication to decide with high accuracy which destination the user will follow. However, if the third destination is Z_1 so it is followed the row of B for the indications.

Each time an indication is predicted correctly its counter is incremented by 1.

If the indication predicted in our example were B for example, this indication is added to the hash table in the row correspondent to the User ID.

5. RESULTS

Prediction accuracy in our work is calculated based on prediction correctness that is the number of user predicted correctly to the number of user detected.

$$\text{Prediction correctness} = \frac{\textit{the number of user predicted correctly}}{\textit{the number of user detected}} \quad (2)$$

$$\text{And so prediction accuracy} = \frac{\textit{prediction correctness}}{\frac{\textit{the number of user}}{\textit{in the network}}} * 100 \quad (3)$$

Our goal is to reduce the number of cars that reach some point in the crowded cities or in the case of accident. If we obtain a prediction correctness in the interval 40-50% (that means as described in our algorithm (Fig. 9) only four indications predicted correctly can identify the path. In consequence for each 10 cars, four of them are predicted correctly) the prediction accuracy obtained by equation 3 vary from 16% to 40%. And this result is a good results comparing it to that presented in [16] where the prediction accuracy is around 23%. Table .2, show our obtained results for prediction correctness up to 40-50%.

Table 2. Prediction accuracy results

# of user in the network	Prediction correctness40%		Prediction correctness 50%	
	# of user predicted correctly	Prediction accuracy	# of user predicted correctly	Prediction accuracy
1000	200	20%	250	25%
	240	24%	300	30%
	280	28%	350	35%
	320	32%	400	40%
3000	600	20%	750	25%
	680	22%	850	28%
	800	26%	1000	33.3%
	920	30.6%	1150	38%
5000	800	16%	1000	20%
	1200	24%	1500	30%
	1400	28%	1750	35%
	1600	32%	2000	40%

6. RELATED WORKS

The major part of prediction algorithms for wireless networks make use of history base that has a record of the previous user movement. These algorithms take in consideration different factors such as the direction of movement, velocity. For that, regular movement can be predicted with high accuracy. In our work, user movement pattern is restricted to the road layout. For that some of previous algorithms can be useful in our work. For example, MMP (Mobile Motion Prediction) algorithm [15] and regular path recognition method [16] attempt to exploit regularity in human behavior in terms of periodic or repetitive activities. The performance of these algorithms is accurate with regular movement. However, in wireless ad- hoc networks prediction cannot be based only on past history due to dynamic topology. In [17], path prediction is considered based on the presence of link between any two mobile nodes. The authors calculate the velocity and predict the direction of motion based on link expiration time between any two nodes. Wand et al in [18], use group mobility model to predict the user movement pattern considering that velocity is not time variant in mobile ad-hoc network.

In [19], the movement pattern of mobile useris viewed in respect to the cluster that belong to it. Areas are divided into clusters and every node in the network belong to a cluster and the prediction process should be restricted to areas of high cluster change probability. So, the location of the user id defined with respect to its position in the cluster. The cluster head has complete knowledge of each of its member nodes. Predicton acuuracy is calculated by the following formula:

prediction accuracy=

$$\frac{\sum \frac{\#\, of user execudes cluster change}{\#\, of predicted user cluster change}}{Total\ number\ of users\ in\ the\ network}$$

In [20], a survey of vehicular mobility models is presented, where user movement is classified in four classes based on the method used to generate such movement. A comparison between different simulation methods used to illustrate relationship between network simulator and traffic generation and transportation infrastructure studied in a realistic mobility models. Realistic mobility model must take in consideration the realistic topological maps, accelaration and deaccelaration, obstacles, simulation time, random distribution of vehicles, intelligent driving pattern.

7. CONCLUSION AND FUTURE WORKS

In this paper, we proposed Virtual Explorer system that is a new system that detects the motion of the mobile user to be able to predict his destination.

Our system is an information system that provides the user information about the traffic on the major or minor roads to make him satisfied when travelling on such roads. We expect that our system will reduce the traffic in the congested points about 40-50%. Our results show that the prediction accuracy will vary from 20-40% and that is a good results considering our goal. Our future work is to implement our prediction algorithm to confirm our analytical results in addition we expect to develop our system to simulate a real mobile distributed system where the base station that collects and disseminates information is any car on the road.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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