Design and Implementation of Human Mobility Embedded System for Urban Planning of Smart City

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Abstract: The mobility model will help us to simulate the movements of people more realistic as in real case. This paper developed human mobility system using random way point and random walk methods to model the individual movement of person in different places within area of Baghdad, Iraq. There are a lot of types of mobility model but we use Random Way Point (RWP) because it is simple, most common use and needs less memory and time for computation. The geographical information and maps of the cities are used to tell the person about the constraints and correct the direction of motion in different areas to generate more accurate data. Tested areas are quite different in style, structure, social, history and culture. The most similar thing between them is that they are both in continuously changing which is the one of biggest difficulties in designing the city. Al-Sadar city is one of biggest population city in Baghdad, Iraq. It has three millions people population. We choose 5000 users moves from Al-Sadar city to two different places in Baghdad: Al-Khadmia and Al-Zawra. Al-Khadmiia is old and religion place and Al-Zawra is biggest public garden in Baghdad. In our work, we find the best ways that connect Al-Sadar city with both places. We decide the best ways depending on distances and traffic between them. It gives good method to build smart transportation and smart city using mobility and traffic models. .This paper will help urban decision maker to suggest the analytical model for urban space and have a clear picture about the city: how can it change, how do the people move in the city, what are the problems and how can solve them to generate smart city.

1 INTRODUCTION

The smart cities market size is estimated to grow from USD 312.03 Billion in 2015 to USD 757.74 Billion by 2020, at a Compound Annual Growth Rate (CAGR) of 19.4%. The base year considered for the study is 2014 and the market size is forecasted from 2015 to 2020.

Smart cities market has been segmented into four major focus areas across regions (Vicente Casares-Giner et al., 2011; Ignacio Martinez-Arrue et al., 2008). The focus areas include transportation, utilities, buildings, and smart citizen services. Technological advancements in Information and Communication Technology (ICT) and growing demographics & hyper-urbanization are the major driving factors for the market. Cities across the world are increasingly adopting smart solutions for their various sectors, such as buildings, transportation, utilities, and citizen services in order to achieve better living standards, increased efficiency, economic stability, optimization of energy, and higher environmental protection based on the technologies: IoT, cloud, mobile, and sensors.

Estimates forecast the smart energy technologies market (including smart grid) reaching $220 billion worldwide by 2020, whilst other sources estimate smart transport to be $156 billion, and smart water to be $22 billion globally by 2020 (Mir et al., 2006; Tamás Szálka et al., 2009). The example of Singapore next generation smart city. Singapore aims to have 80% of all its buildings meet its minimum ‘Green Mark Certified' energy efficiency standards by 2030. We identified eight key aspects that define a Smart City: smart governance, smart energy, smart building, smart mobility, smart infrastructure, smart technology, smart healthcare and smart citizen.

Geographic information systems, often known as GIS, are computer-based tools for the capture, analysis, storage, manipulation and visualization of geographic information. Companies, researchers and individuals use GIS to analyze spatial data and

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create maps of many different types. GIS-created maps can store and display large amounts of data within a single map (Yu-Liang Tang et al., 2010; Son et al., 2004; Tamás Szálka et al., 2009; Peppino Fazio et al., 2012).

According to the Environmental Protection Agency, a GIS, which refers to Geographic Information System, works by combining database functions with computer mapping to map and analyses geographic data. It uses a "layering" technique to combine various types of data. Special GIS software is used to analyse layered data and create new layers of data (Broch et al., 1998; Francesco Calabrese et al., 2010; Heiko Bauke et al., 2007).

GIS maps can be used to show an estimated number of people living in a given region. Because these maps are created after careful considerations of various data, the results are usually quite accurate. These maps can be quite specific and show the number of individuals in a region according to profession. Users can actually tell the number of doctors, lawyers or policemen in a region by simply going through a GIS map (Injong Rhee et al., 2011; Jae-Hyung Jeon et al., 2013).

GIS maps are capable of giving users a rough idea of each region on the map and what it is prone to. For example, a map can depict flood-prone regions against the landmarks situated close by. Researchers use these maps to analyze the characteristics of a given region over a period. This help in developing strategies to combat issues such as crime, flooding and any other form of disaster (Chellappa Doss et al., 2004; Berk Birand et al., 2011; Matteo Leccardi, 2005).

Disadvantages of using a geographic information system, or GIS, are that its technical nature might portray results as being more reliable than they actually are, and errors and assumptions can be hidden, leading to a lack of questioning into the results. Another disadvantage of analyzing the results from a GIS is that the results will only be as accurate as the data that they come from. Because of this, the data may not be able to serve different contexts, particularly if the data is not applicable (Francesco Calabrese et al., 2010; Matteo Leccardi, 2005).

For instance, if the input data on a GIS is entered at the county level, the results in the GIS will only be usable for the county level, not any other level, such as the district or ward levels. Data availability, in itself, is also a major issue. If the data is not available, than the GIS system is useless.

Furthermore, GIS systems are not like other programs. They do not come "off the shelf," which means that they must be assembled and constructed to a user design. This could be a long, complex and costly process. Because of this, many GIS systems don't come to fruition or fail outright in their implementation because their creation was rushed or inadequately planned (R. Chellappa Doss et al., 2004; Jae-Hyung Jeon et al., 2013).

GIS systems are often so complex, in fact, that it becomes difficult to describe the intangible benefits they may provide, making it difficult to find funding for their creation. Also, the technology behind GIS technology expands rapidly, causing GIS systems to have a high rate of obsolescence. It's also very difficult to make GIS programs that are both fast and user friendly. GIS systems typically require complex command language (Chellappa Doss et al., 2004; Broch et al., 1998). Data fields and their accessibility are also not very understood, and data can become incomplete, obsolete or erroneous, rendering the GIS misleading.

In this paper, we introduced the mobility model which help us to simulate the movement of users with more realistic as in the real case. There are a lot of types of mobility model depending on the characteristics of nodes such as historical model, correlated model and geographical depending. Each method has its advantages and disadvantages. In our work we use random way point method (RWP). It is simple; most common used in mobile networks and needs less memory and time for computation. It fits our requirements. Also we use random walk method. It is more realistic and near to human walk.

But the goal for our system is to find the location of users and decide the best way that can be used. Therefore we need also to predict the position of users. We use Polynomial method as a predicted method. It gives accurate and fast prediction of user position.

Beside the individual movement of user, we use the relative movements (within the area). We used geographical mobility depending using map from openstreet program and parsed the geographical constraints using Matlab (ways, nodes and tags) to present the required area.

Using the mobility model is very useful to decide the way taken by user and improve it. It helps the city planner to have correct decision depending on the data given from mobility model. It is one step to model smart city with enhanced transportation and improved the ways taken by users.

Using mobility model is much easier and accurate compared with GIS. It is more realistic and near to human walk. Also it takes into account the nature of the tested area by adding geographical mobility to the original mobility model.

In this paper, we show in section 2 the previous works for mobility and prediction. Sections 3 and 4 study the mobility algorithms. They give the mathematical models of RWP, random walk and Polynomial methods. They explain the principles and algorithms details of mobility and prediction methods. The simulation results and figures are shown in Section 5. We use Matlab and openstreet map for Al-Sadar city in Baghdad, Iraq to simulate mobility, prediction and urban planning management algorithms. The mobility tested areas include: Al-Khadmid and Al-Zawar. They are both in centre of Baghdad, Iraq. The best ways between these places and Al-Sadar city was founded using mobility and traffic models. Finally the conclusion and suggestion for future works is in section 6.

2 RELATED WORK

In (Ignacio Martinez-Arrue et al., 2008) a new model to predict the location of a person over time based on individual and collective behaviours. The model is based on the person's past trajectory and the geographical features of the area where the collectively data are organized in terms of land use, points of interests and distance of trips.

The mobility aspects and some basic background on mobility are provided in (Son et al., 2004). They are being used in performance evaluation of relevant mobility management procedures. While in (Mir et al., 2006; Heiko Bauke, 2007) the same group proposed a new mobility model as an extension of the random walk model. It gathers mobility patterns with several degrees of randomness, so that both random walk and totally directional mobility patterns are modelled. This model is used as input to study and compare the location management cost of the distance-based and movement-based strategies as a function of the mobile terminal directional mobility patterns.

In (Tamás Szálka, 2009; Matteo Leccardi, 2005) authors proposed a mobility prediction algorithm based on dividing sensitive ranges. In the future distance prediction scheme proposed in (Peppino Fazio et al., 2012; R. Chellappa Doss et al., 2004), a node predicts its own future position from its current position, speed, and direction.

Tuduce and Gross in (Matteo Leccardi, 2005) present a mobility model based on real data from the campus wireless LAN at ETH in Zurich. They used a simulation area divided into squares and derive the probability of transitions between adjacent squares from the data of the access points.

MoVes (Berk Birand et al., 2001; Injong Rhee et al., 2011) is an embedded system generating vehicular mobility traces and also containing a basic network simulator. The major asset of this project is its ability to partition the geographical area into clusters and parallelize and distribute the processing of the tasks from them, which improves the simulation performance. Although the mobility model reaches a sufficient level of detail, the project's drawback is the poor network simulation.

MOVE (Injong Rhee et al., 2011) contains a single graphical user interface for the configuration the mobility modelling and network simulation. However, MOVE does not itself include a network simulator, but simply parses realistic mobility traces extracted from a micro-motion model.

In (Mir et al., 2006), authors also proposed an integrated vehicular and network simulator. As all solutions proposed by this approach, the authors developed their own traffic and network simulator.

In (Ignacio Martinez-Arrue et al., 2008; Francesco Calabrese et al., 2010) the City Form Lab has released a state-of-the-art toolbox for urban network analysis. As the first of its kind, the Centrality Tools this ArcGIS toolbox can be used to compute five types of graph analysis measures on spatial networks: Reach; Gravity; Betweenness; Closeness; and Straightness. Redundancy Tools additionally calculate the Redundancy Index, Redundant Paths, and the Wayfinding Index. The toolbox requires ArcGIS software with an ArcGIS Network Analyst Extension.

3 INTRODUCTION FOR MOBILITY MODEL

In this section we give the definition of mobility pattern, types, analysis and effect on the performance of the network. Studying mobility models will help us to choose the best model that can fit with our requirements. For example, the nodes move with random walks are different from the nodes with spatial dependency (move in group or follow leader of group).

In our work, we use the movement of individual users (location, velocity, direction) as well as the movement relative to given area.

The mobility models are divided into different classes. They are classified depending on their characteristics such as history dependence, spatial dependence and geographical dependence (Matteo Leccardi, 2005; Jae-Hyung Jeonet al., 2013).

Random walks are example of history dependence where the nodes change their speed, destination and direction randomly in each step. In temporal mobility model the velocities and directions of nodes at different slots are correlated such as Gauss-Markov Mobility Model. While the streets, freeways and geographical restrictions are important in designing the path mobility model

In our work, we use Random Way Point (RWP) and geographical restriction model. RWP is most common way used in different networks. It was first proposed by Johnson and Maltz (Francesco Calabrese et al., 2010). In simulation of RWP, the nodes start by choosing the starting point and velocity randomly.

The velocity is uniform distribution with ranges [0, Vmax] where Vmax is maximum velocity allowable by node. The velocities and targets points for given node are not correlated with other nodes. If Vmax is high then the node will move fast and mobility will be dynamic otherwise it will be stable. The average length of transition of all nodes is equal to the average length of single node at different times. Therefore RWP has mean-ergodic properties.

The PDF of transition length for rectangular field (as in our case) is Eq. (1). A rectangular area with length a and width b. Without losing the generality, we assume that b≤ a. The mean and variance of transition length L are given in Eqs. (2-3) respectively (Jae-Hyung Jeon et al., 2013).

$$f_L(l) = \frac{4l}{a^2 b^2} f_0(l)$$

$$f_0(l) = \begin{cases} \frac{\pi}{2}ab - al - bl + \frac{1}{2}l^2, \\ \quad \text{for } 0 \leqslant l \leqslant b, \\ ab \arcsin\frac{b}{l} + a\sqrt{l^2 - b^2} - \frac{1}{2}b^2 - al, \\ \quad \text{for } b < l < a, \\ ab \arcsin\frac{b}{l} + a\sqrt{l^2 - b^2} - \frac{1}{2}b^2 \\ \quad - ab \arccos\frac{a}{l} + b\sqrt{l^2 - a^2} - \frac{1}{2}a^2 - \frac{1}{2}l^2, \\ \quad \text{for } a \leqslant l \leqslant \sqrt{a^2 + b^2}, \\ 0, \quad \text{otherwise}. \end{cases} \tag{1}$$

$$E\{L\} = \frac{1}{15}\left[\frac{a^3}{b^2} + \frac{b^3}{a^2} + \sqrt{a^2+b^2}\left(3 - \frac{a^2}{b^2} - \frac{b^2}{a^2}\right)\right] + \frac{1}{6}\left[\frac{b^2}{a}\operatorname{arcosh}\frac{\sqrt{a^2+b^2}}{b} + \frac{a^2}{b}\operatorname{arcosh}\frac{\sqrt{a^2+b^2}}{a}\right] \tag{2}$$

$$E[L^2] = \frac{1}{6}(a^2 + b^2) \tag{3}$$

The expected time transition between two successive steps is:

E[T]=(E[L].(ln(Vmax/Vmin)))/(Vmax-Vmin)

RWP is memoryless process because each node does not correlate with other node. In our case we choose RWP because it is simple and fit the requirements for not correlated users move on map in random way with velocities of range [Vmin Vmax].

4 POLYNOMIAL PREDICTION ALGORITHM

If P(.) is a polynomial function with k + 1 unknown coefficients as follows:

$$P(t) = a_0 t^0 + a_1 t^1 + a_2 t^2 + \ldots + a_k t^k \tag{4}$$

The previous location data at H-times compose an original data sequence S(p) where (p = 1, 2, …, H).

If R_h is the location of the previous h-th process, the sum of the square of the difference between actual R_h and predictive P(t) of the previous n processes is defined as

$$D = \sum_{h=1}^{H}[R_h - (a_0 t_h^0 + a_1 t_h^1 + a_2 t_h^2 \ldots + a_k t_h^k)]^2 \tag{5}$$

Each a_i in each polynomial can be treated as a variable. The coefficient a_i can be determined by taking the partial differential of each a_i in equation (5), and setting each partial differential equation to zero. At the end, we can obtain the following equivalent polynomials:

$$\begin{cases} a_0(\sum_{h=1}^{H} t_h^0) + a_1(\sum_{h=1}^{H} t_h^1) + \ldots + a_k(\sum_{h=1}^{H} t_h^k) = \sum_{h=1}^{H} t_h^0 R_h \\ a_0(\sum_{h=1}^{H} t_h^1) + a_1(\sum_{h=1}^{H} t_h^2) + \ldots + a_k(\sum_{h=1}^{H} t_h^{k+1}) = \sum_{h=1}^{H} t_h^1 R_h \\ \quad \vdots \qquad\qquad \vdots \qquad\qquad\qquad \vdots \qquad\qquad \vdots \\ a_0(\sum_{h=1}^{H} t_h^k) + a_1(\sum_{h=1}^{H} t_h^{k+1}) + \ldots + a_k(\sum_{h=1}^{H} t_h^{2k}) = \sum_{h=1}^{H} t_h^k R_h \end{cases} \tag{6}$$

After determining all the summations of t in equation (6), this matrix of polynomials can simplify to an upper triangle matrix of polynomials. Each coefficient a_i can be determined by the native Gauss elimination method, Consequently, the polynomial function of $P(t_{n+1})$ can be obtained,

In our work, we will use the polynomial regression mobility prediction to predict the future user position. For the velocity we take the second derivative of Eq. (5) and equal the results for zero.

Also we can use geographical information after applying the predicted values on map and see the direction if there is forbidden area or error in prediction direction.

5 MOBILITY MODEL AND SIMULATION RESULTS

In our system, we have the requirement of design the smart city is with good quality of services as shown in Figure 1. It is specified in abstract layer where all arithmetic, optimized ways and solutions are used. The constraints and the measurements are used to choose the implantation ways in the abstract layer.

In first stages we chose the software platform and architecture and in last stages we proposed the services providing and advance performance monitoring of city urban planning.

The lower layer (architecture and space design) includes: fading, noise and shadowing models, mobility management (RWP and RW models), mobility prediction models (Polynomial model), network layout and traffic model. Architecture layer takes all these information, processes and sends the performance to the upper layer (Application layer) where evaluate, visualize and monitor the design according to the requirements and constraints.

The simulation program is divided into three phases: initial phase, processing phase and urban planning management phase. In the initial phase, we select the initial values such as number of users, number of steps, x, y and velocities for all users. The initial values of one user are not correlated with other users. It used dependent on the traffic model after entering the intra-segment components and inter-segment components. They are taken from tested field. The values of x and y are within the limit of our selected rectangular simulation area. The velocities are in uniform distribution and randomly selected within the range [Vmin, Vmax]. The time for the first phase is within t_int. The second phase is the processing phase where all computations and optimizations will run in this phase. It is divided into two parts: mobility models and prediction of user location, velocity and direction. The mobility models RWP and random walk. For prediction side, we use polynomial method. At the beginning, RWP chooses randomly the destination and velocity and repeats this in each step till it reaches to steps_end then it will go to next which is prediction. The same we do with Random Walk method.

The prediction methods will choose polynomial method. It is accurate, simple and need less memory storage for coding and processing. The mobility in our work deals with individual movement of users and relative movement within the selected simulated area.

For prediction method, we first predict the value of velocity using the last values of time, x and y of each user and move to direction and the location of users at selected time. The time required at the end of this step is t_int+t_processing. At the end of this step we have the predicted values of location, velocity and direction of user movement at selected time.

The last and important step in our system is the urban planning calculation, optimization and testing. The saving and advantage for design the city and how our work can help the city. The time required at the end of this step is t_int+t_processing+t_manag.

The Dijkstra algorithm is used to get the nearest and optimum way between the source and destination points.

To test the system with all phases, we use openstreet program. The simulated area is one place in Baghdad, Iraq called Al-Sadar City. It has high population in Baghdad. There is serious need to plan and manage the ways to enter and leave it. In our work, he users move from Al-Sadar City to two places; Al-Khadmia and Al-Zawra. Al-Khadmia is religion place and old city in centre of Baghdad. The map of Al-Khadmia is shown in Figure 2-a. Al-Zawra is biggest public garden in Baghdad. The map of Al-Zawra is shown in Figure 3-a.

We export files with type xml.osm files for Al-Khadmia city and Al-Zawra and parsed the data using Matlab such as:

Bounds: [2x2 double] → axis limitations of our areas

Node: [1x1 struct] → node_id, node_xy

Way: [1x1 struct] → combination of nodes, node_id, way_id, way_tag

For our area we have
id: [1x14626 double]
nd: {1x14626 cell}
tag: {1x14626 cell}

Figures 2-a and 3-a show the parsed files with ways for Al-Khadmia and Al-Zawar areas respectively. Figures 2-b and 3-b show the area with nodes and complete ways in Al-Khadmia and Al-Zawar areas respectively.

The connectivity of nodes and ways are parsed in connectivity matrix using Matlab as shown in the following:

Connectivity matrix =

(68,5)	1
(98,5)	1
(100,20)	1

The connectivity matrix is parsed matrix and “1” here means there is connection between the nodes. To decide the connection and route between ways we choose Dijkstra's algorithm to decide the shortest path between nodes and ways.

Dijkstra's algorithm is invented by scientist Edsger Dijkstra in 1956 and published in 1959 (Matteo Leccardi, 2005; Jae-Hyung Jeon et al., 2014). It is used to find the shortest path between two points in graph.

We use Dijkstra's algorithm to find the shortest path in each step and the best route to reach the destination point for RWP model in our limited area (Baghdad). In each step there are number of hops (nodes) to pass during the complete route. The parsed data provides us with node_id and node_xy of each hope.

The number of users in our work is 5000 users move from Al-Sadar city to both Al-Khadmia and Al-Zawara. For RWP point we use 400 steps for ech user. After running the program with random 5000 user with 400 steps for each user in both places (Al-Khadmia and Al-Zawara), we get the best ways from Al-Sadar city to Al-Khadmia and Al-Zawar. The program decides the best ways depending on Dijkstra's algorithm for l and traffic in both tested areas.

In this case, we solve the one of biggest problem in Baghdad. Al-Sadar city has a population for more than 3 million people. It needs to plan and manage in smart way. It is one example how to solve the problems and build smart city.

6 CONCLUSIONS

Transportation and choosing the best way are very important factors in designing the smart city. Needing for designing the smart transportation is increased with increasing number of people and the cars.In our work, we study the mobility of users and predict their locations in the tested area. It will help the designer to choose the best way in advance to cover the users and have the chance to manage congestion and traffic for different ways within the tested area.

We use RWP and Random Walk models to represent the individual mobility of a user and use geographical dependent to represent the relative mobility (corresponding to the tested area). The mixing models provide more realistic representation for the movement of users.

For prediction side we used polynomial method to calculate the user's velocity, direction and location at given time slot. Also we deal with traffic and number of users when decide the ways within the tested areas and optimized the best way taken by users.

Al-Sadar City in Baghdad, Iraq is chosen as tested area. It has high population near 3 millions people. The users move from Al-Sadar city to different places: Al-Khadmia and Al-Zawra. They are different areas. Al-Khadmia is religion and old city. It has also big market. The second one, Al-Zawra, is biggest public garden in Baghdad. It has big green places, games and restaurants. In Baghdad there is serious need to manage and plan the best ways to to enter and leave Al-Sadar city.

In our work, we find the best ways to connect Al-Sada city with both Al-Khadmia and Al-Zawra using mobility model and traffic model in both places. It will help the designer to take the correct decision when design and manage the ways and transportation of the cities. It will help us to build smart cites with good planning and smart transportation ways.

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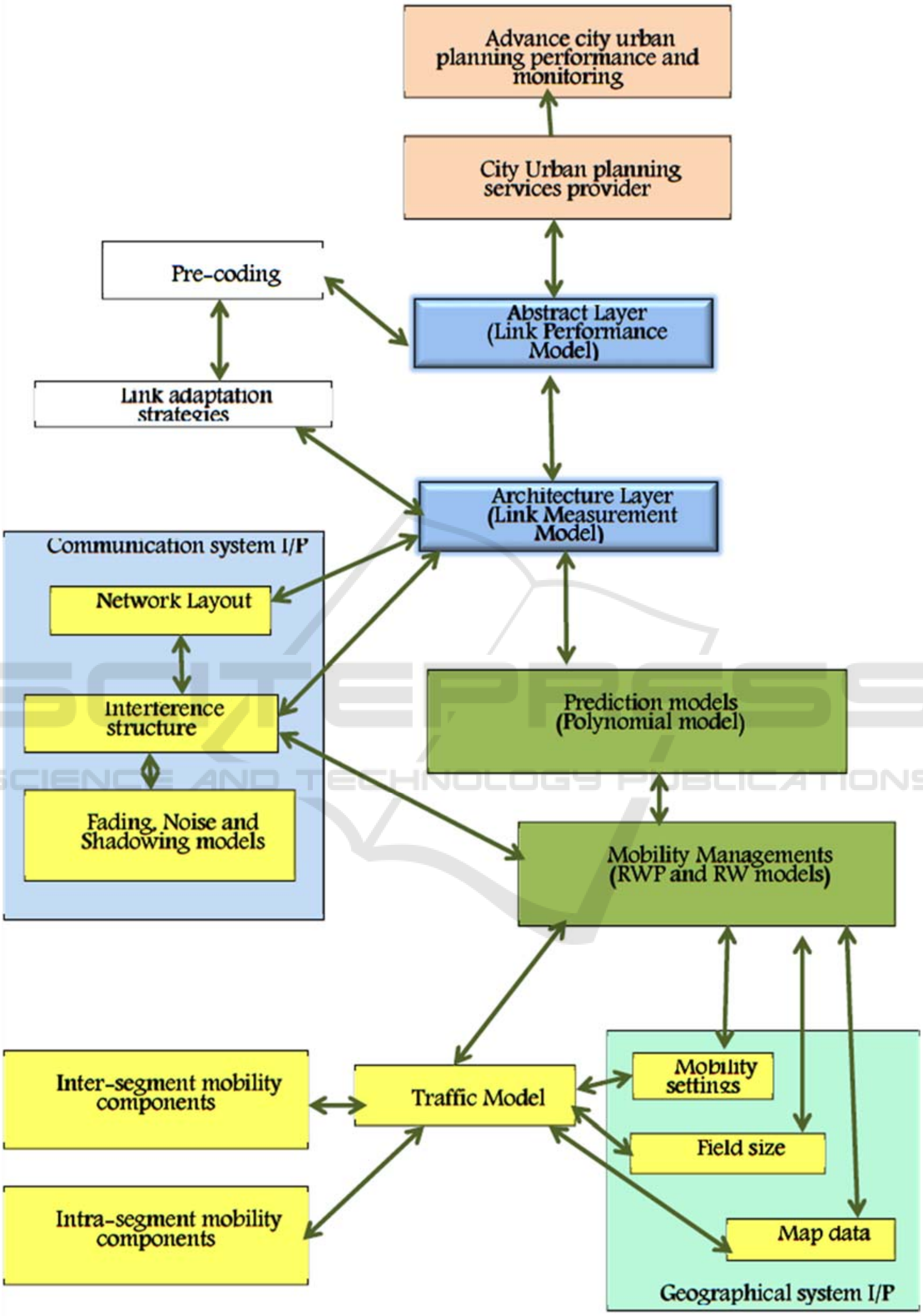
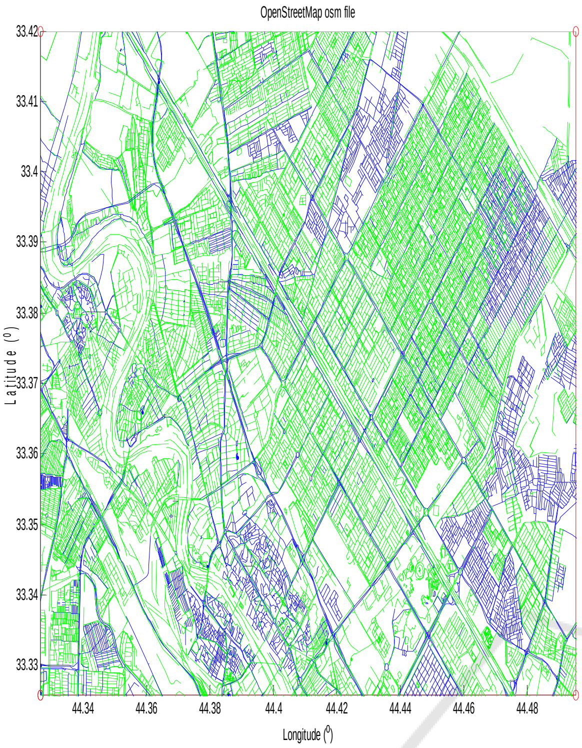
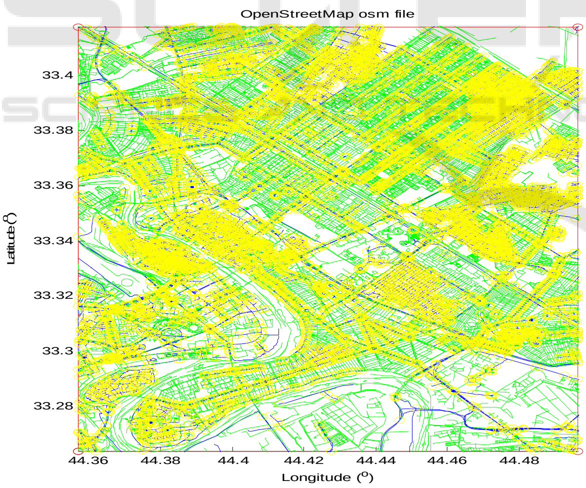


Figure 1: Schematic block diagram of mobility and city urban planning system.

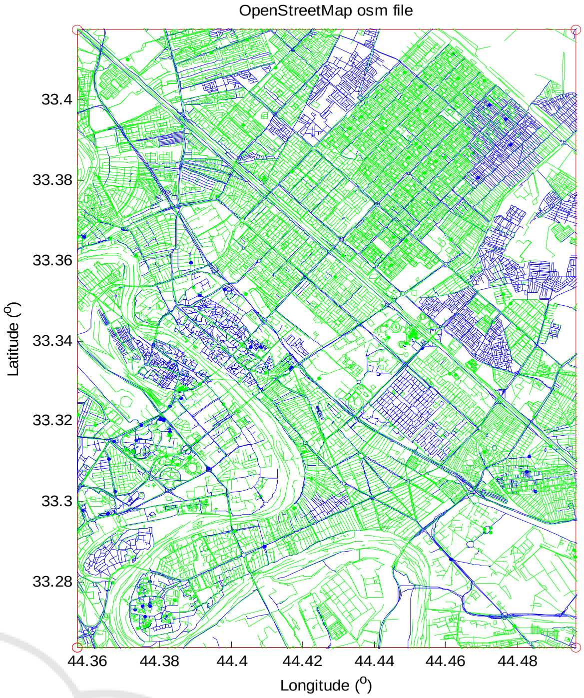


a) Parsed the map using Matlab program for Al-Sadar City and Al-Khadmia places in Baghdad, Iraq

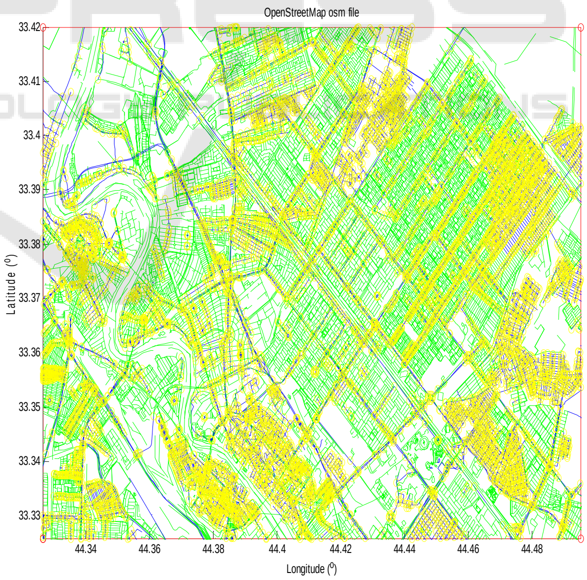


b) Parsed nodes from the map using Matlab program for Al-Sadar City and Al-Khadmia places in Baghdad, Iraq

Figure 2: Openstreet Map for for Al-Sadar City and Al-Khadmia places in Baghdad, Iraq with parsed information using Matlab.



a) Parsed the map using Matlab program for Al-Sadar City and Al-Zawra places in Baghdad, Iraq



b) Parsed nodes from the map using Matlab program for Al-Sadar City and Al-Zawraia places in Baghdad, Iraq

Figure 3 Openstreet Map for for Al-Sadar City and Al-Zawra places in Baghdad, Iraq with parsed information using Matlab.