Available online at www.sciencedirect.com
ScienceDirect
Computer Communications 30 (2007) 3154–3160
computer communications
www.elsevier.com/locate/comcom

Location based services using geographical information systems

Balqies Sadoun *, Omar Al-Bayari

Surveying and Geomatics Engineering Department, Al-Balqa' Applied University, Al-Salt, Jordan

Available online 27 June 2007

Abstract

One of the most obvious technologies behind Location Based Services (LBS) is positioning, with the most widely recognized system being the Global Positioning System (GPS). There are, however, other means of positioning in addition to GPS. These other technologies are network based positioning and typically rely on various means of triangulation of the signal from cell sites serving a mobile phone. In addition, the serving cell site can be used as a fix for location of the user.

More and more organizations have started to apply location-based services over Wireless LANs to enable improvements to applications. Generally, a LBS keeps track of the position of users on the network as they roam through the facility. A central system collects and integrates this position information to drive additional functions that identify the position of users in relation to the facility and pertinent areas, such as information on hospitals and medical centers, booths, emergency centers, stores, police stations, gas stations, etc.

LBSs offer personalized services to the subscribers based on their current position using Global Navigation Satellite System (GNSS), Geographic Information System (GIS) and Wireless Communications and Networking technologies. LBSs offer modern world the tool for efficient management and continuous control. More and more people involve LBS in their industry and day-to-day life to better achieve their goals.

In this paper, we present a review of LBS using Geographical Information Systems and two applications that we developed. These are automatic vehicle location, which can provide better management and control for a moving fleet of vehicles and police traffic information system.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Location based service (LBS); Geographic information system (GIS); Global navigation satellite system (GNSS); Global positioning system (GPS) and Wireless networks (WNs); Wireless communications (WCs)

1. Introduction

The increasing demand for commercial LBS has driven scientists to focus on more accurate positioning solutions. LBS employs accurate, real-time positioning to connect users to points of interest and advises them of the current conditions, such as traffic and weather conditions, or provides routing and tracking information using wireless devices. It is important to integrate the mobile computing technology and the GIS technology in order to meet the needs of LBS, which is considered one of the most promising applications of GIS. The location of the caller could be determined by other position determination techniques. These include Cell-ID, Enhanced Observed Time Difference (E-OTD), Observed Timed Difference of Arrival (OTDOA), Wireless Assisted GNSS (A-GNSS) and hybrid technologies (combining A-GNSS with other standard technologies). Cell-ID is used for positioning purposes, but it is not accurate. In the following, we will present an introduction on the LBS, its combination with GIS and WC, and some of our recent related work [1–4].

LBS systems aim at improving user-friendly info-mobility services for position determination by combining wireless communications (WCs), GNSS and GIS based on mobile client/server architecture [1]. Location determination may be based on GNSS Technologies (mainly location intelligence is stored within terminal GPS), or on Network Technologies that exploit the cellular infrastructure to obtain geo-location information (Wireless Technology). Positioning techniques based on the use of a GNSS/GIS

* Corresponding author.
E-mail addresses: balqiessadoun@yahoo.com (B. Sadoun), obayari@bau.edu.jo (O. Al-Bayari).

0140-3664/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.comcom.2007.05.059

and cellular network infrastructure are progressing at an impressive pace.

GNSS receivers determine the position, precise time and velocity in the coordinate reference system. Then saves these data in the National Marine Electronics Association format (NMEA) to be transmitted to the control center via wireless communication means or downloaded directly via serial ports, such as RS-232, USB 2.0, etc.

GNSS is the technical interoperability and compatibility between various satellite navigation systems which are the modernized GPS, Galileo and GLONASS to be used globally by the public and the industry with no regard to the nationality of each system in order to promote the safety and convenience of life [2,3]. GNSS means the compatibility and interoperability of the three main satellite technologies: GPS, GLONASS and Galileo. At the time of writing this paper, the only complete Global Navigation Satellite System (GNSS) is basically the GPS system and most of the existing worldwide related applications are based on the GPS system/technology. The GNSS technology will become clearer after the operation of European Galileo and the reconstruction of Russian GLONASS by the end of 2008.

GNSS applications in all fields will play a key role, moving its use from the transportation domain to multimodal use, outdoors and indoors. It is expected that GNSS will increase significantly the precision in position domain [4]. The combined and competitive benefits of GPS and Galileo will result in major improvements in navigation, timing, accuracy and related applications and services [5]. To realize these benefits, Galileo receivers must be made available to enable the commercial exploitation and market penetration of the Galileo system and services. These should be based on flexible system design principles and equally flexible implementation.

Precise positioning using GNSS technology is limited by the availability of satellite signals in specific locations.

With Galileo system, more satellites have been added to the current GPS and GLONASS systems, users will have the possibility to track a large number of the total 75 available satellites.

2. GNSS positioning technique

The basic concept of point position depends on the trilateration between the receiver and satellite. Range measurements from four satellites are needed to determine the four unknown X, Y, Z and receiver clock offset ($\Delta\delta$). The analytical solution for receiver A and four satellites could be written as [6]:

$$R^1_{\mathrm{A}}(t) = \sqrt{(X^1(t) - X_{\mathrm{A}})^2 + (Y^1(t) - Y_{\mathrm{A}})^2 + (Z^1(t) - Z_{\mathrm{A}})^2} + c \cdot \Delta\delta$$

$$R^2_{\mathrm{A}}(t) = \sqrt{(X^2(t) - X_{\mathrm{A}})^2 + (Y^2(t) - Y_{\mathrm{A}})^2 + (Z^2(t) - Z_{\mathrm{A}})^2} + c \cdot \Delta\delta$$

$$R^2_{\mathrm{A}}(t) = \sqrt{(X^3(t) - X_{\mathrm{A}})^2 + (Y^3(t) - Y_{\mathrm{A}})^2 + (Z^3(t) - Z_{\mathrm{A}})^2} + c \cdot \Delta\delta$$

$$R^4_{\mathrm{A}}(t) = \sqrt{(X^4(t) - X_{\mathrm{A}})^4 + (Y^4(t) - Y_{\mathrm{A}})^2 + (Z^4(t) - Z_{\mathrm{A}})^2} + c \cdot \Delta\delta$$

The range R is measured by the receiver and the coordinates of satellite are extracted from the navigation message. The unknowns in the above equation are X, Y, Z and the clock error $\Delta\delta$. In case of observing more than four satellites, the least square adjustment is performed to estimate the unknowns.

Hence, coordinates of the receiver and time offset could be obtained directly in real time with one epoch measurement. Due to un-modeled errors in pseudo range, such as ionosphere, troposphere and orbital errors, the accuracy level of absolute positioning is within 10 m [7].

The basic concept of LBS network-based techniques is to calculate the time difference between the transmitted and received signal.

Then multiply the calculated time difference by the velocity of light to obtain the distance.

To calculate the caller location (x, y), we need two equations. If we have more than three Towers (Base Stations), the position will be more precise and least square computation is needed [8].

$$f_i(X) = c(\tau_i - \tau) - \sqrt{(x_i - x)^2 + (y_i - y)^2}$$

The most common non-GNSS solutions for mobile positioning are: (i) Cell-ID (taking into consideration cell size and timing advance), (ii) TOA (Time of Arrival), (iii) Angle of Arrival (AOA) and (iv) Enhanced Observed Time Difference (EOTD); all make use of the wireless telecommunications system itself [9].

Cell-ID is the most straightforward solution, and uses the cell identification information within the mobile telephony network to identify the approximate location of the caller. However, this technique is often not very useful because of the low positioning accuracy.

GNSS based location technology (currently Assisted-GPS) can also be combined with ETOA or TDOA. This approach requires spot deployment of ETOD and TDOA, allowing A-GPS to be used in the majority of the network in order to provide basis for most location information (Fig. 1). Hybrid approach generally improves performance of location technology [8,10].

The LBS system consists of three main components; see Fig. 2. The first component is the mobile positioning system,

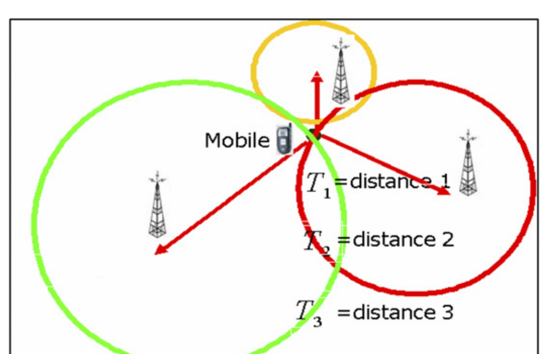

Fig. 1. Time Difference of Arrival (TDOA) approach.

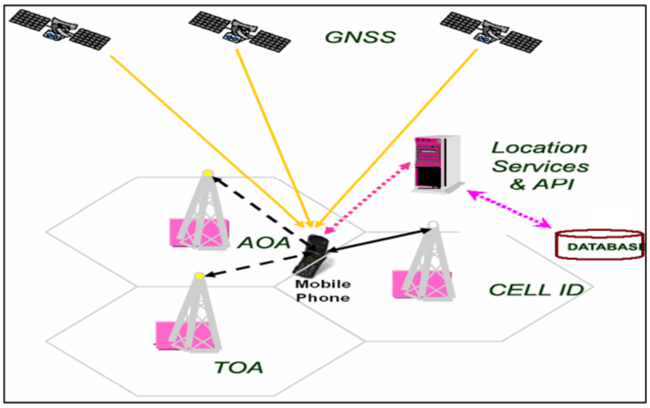

Fig. 2. The location technology and LBS system.

which can be the GNSS, Hybrid GNSS/A-GPS based, or network-based (AOA, TOA, TDOA). The second component is the mobile telephony network to deliver the service to users. The third is the location-based service application, which consists of a server and a spatial database.

The three components communicate with each other through application programming interfaces (API). The API are designed to help wireless Internet developers to integrate location-based services into mobile telephony networks and allow the application server to communicate with the spatial database and the billing server. The control center for a LBS platform is the server that handles user interface functions and communicates with the spatial database or data warehouse.

3. LBS applications

The LBS applications are divided into four main areas:

1. *Information and navigation services:* These services provide data directly to end-users, in particular for destination location and criteria for trip optimization. Moving map displays guided by navigation GNSS (currently GPS) receivers are provided by the Automobile manufacturers as a new option in their modern vehicles. Many rental car companies have GPS-equipped vehicles that give directions to drivers on display screens and through synthesized voice instructions. Moreover, the displays can be removed and taken into a home to plan a trip. A new international industry is born (such as Navtique and Tele Atlas), which is specialized in preparing the maps and voice guidance for navigation system to be used in old and new modern vehicles.
2. *Emergency assistance:* This type of service provides the location of mobile users in case of distress and need for assistance, such as E-911 in US and E-112 in Europe. GIS capabilities are essential in such services.
3. *Tracking services:* In general, an AVL system consists of a GNSS receiver integrated with GSM/GPRS module mounted on the vehicle, communication link between the vehicle and the dispatcher, and PC-based tracking software for dispatching [11].
4. *Network related services:* Location can be achieved by integrating a GNSS receiver in the mobile phone (handheld solution) or by using the communication network itself, where knowledge of user's position improves communication services.

The combination of GNSS receivers and GIS software for data collection and updating is usually sent via wireless communication links to the server and then, posted so as it will be globally accessible and available on the Internet. Most web GIS software packages have the capability to deal with the data via Internet and distribute these data to users in real time.

Developing software under web GIS systems gives a high possibility to integrate the Web GIS Server with wireless communication to be used for mobile GIS with any application, such as AVL [11]. One important factor in integrating of GIS and GNSS application is the working in the same coordinate system or datum. Working in different coordinate systems creates data miss-matching in GIS/GNSS applications.

LBS techniques based on GSM, GPRS and WCDMA (Wideband Code Division Multiple Access) networks alone do not offer high accuracy. Moreover, GNSS alone is insufficient to maintain continuous positioning due to the inevitable difficulties caused by obstacles. When GNSS signals are blocked or lost, the precision of positioning will be minimized to unacceptable level. It is expected that the GNSS will increase significantly the precision in the position domain [4,10].

Wide-area augmentation systems should be implemented as they allow a significant improvement of accuracy and integrity performance. WAAS, EGNOS and MSAS provide a useful augmentation to GPS, GLONASS and Galileo services over US, Europe and Japan, respectively [11].

The applications of GNSS/GIS/LBS are growing rapidly, but they have some limitations such as:

- GIS data and maps should be periodically updated.
- There should be standards to control the quality of the GIS data.
- Transformation between GNSS reference system such as WGS 84 and the local coordinate systems should be well known for those working in the GIS data collection.
- Limitation of wireless communication (high cost), limitation of GPRS (number of lines for each base station) and rooming problems.
- Customization of GNSS solution (high cost).
- Integration between GNSS technology and other positioning technologies such as odometer, gyros and map matching is still not used.
- Standards for developing GNSS/LBS/GIS solution are not discussed yet.
- Combination between wireless location technology such as Cell-ID, TOA, AOA and ETOA is not implemented in our country.

4. Applications and case studies

GNSS/LBS/GIS applications that we have developed for local use are: (i) AVL system applied to the public transportation company in the capital city, Amman, and (ii) Police traffic information system to report and update about accidents' locations, the level of danger and the frequency of accidents at the location, etc.

4.1. Application 1

4.1.1. AVL system for local public transportation company

We have applied AVL system to the public transportation company that operates in Amman city. Vehicle tracking is one of the fastest-growing GNSS applications today. GPS-equipped fleet buses (public transportation systems) use GNSS receivers to monitor their locations at all times. The principal benefit of AVL system in fleet management is the opportunity for increasing and improving the efficient use of human and environmental resources in effective manners. Transportation infrastructure represents one of the largest and most critical investments by any country. Movements of people are vital to every aspect of the country's economy.

GIS and AVL based asset management for road transportation system can greatly improve the efficiency of operations (optimize services, cost and fleet usage), while at the same time, can make significant contributions to safety, including responses to natural and man-made disasters. A software package has been developed under web GIS software to integrate the Web GIS Server with wireless communication to be used for Mobile GIS with the LBS application as AVL (Fig. 3) for the transportation company control and management. The system has operated properly. It will change the local culture of public transportation to be dependable, efficient and time saving, which was never before. This has helped to give more confidence to the local transportation company. Local residents start to rely more on the local transportation system as such new mechanism has improved the working schedule and confidence of people in the accuracy of the entire operation.

Moreover, it will offer the management a tool for monitoring the fleet activities and resolving problems before they occur. We hope that better management

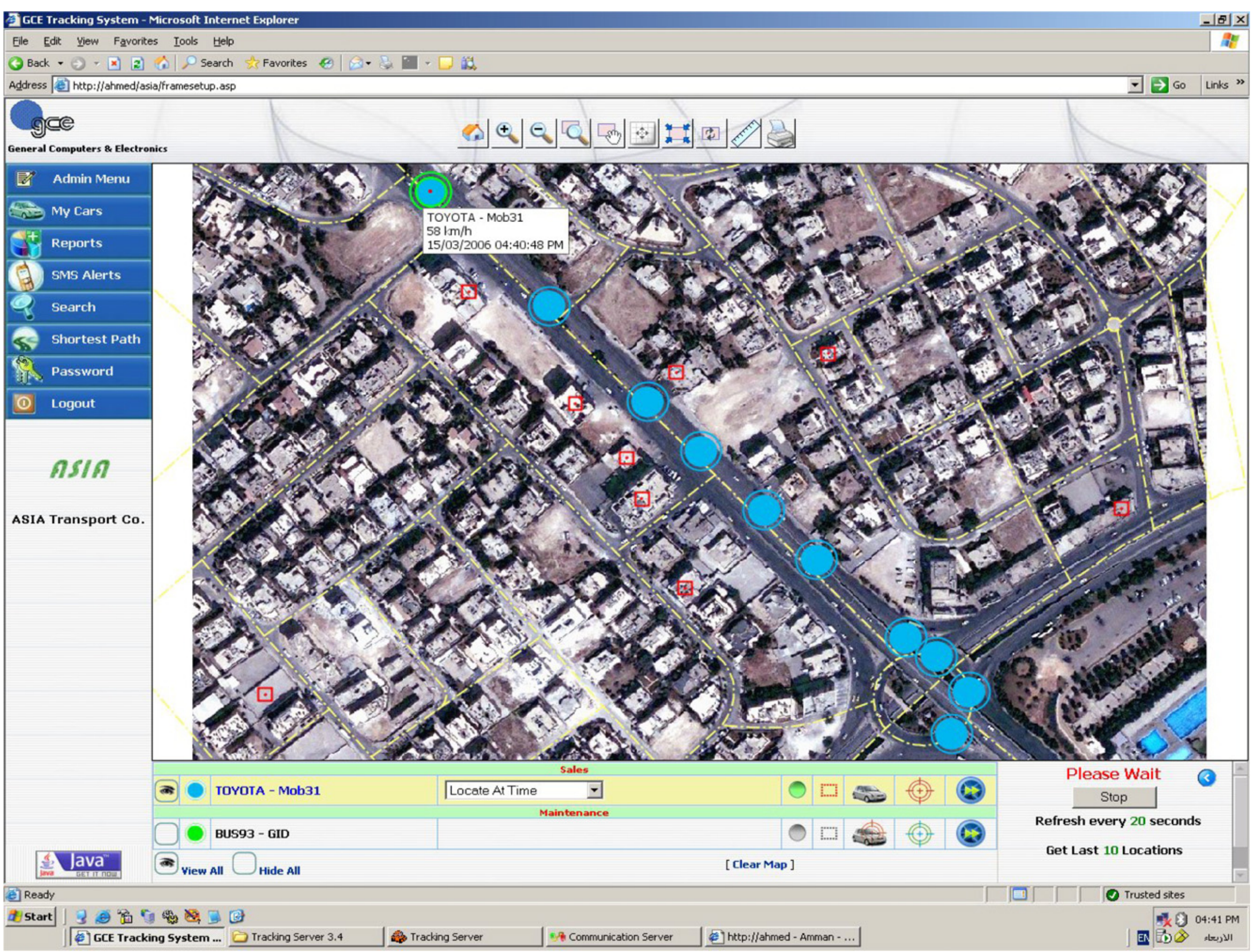

Fig. 3. Web Tracking Software applied for fleet management of the transportation company in Amman city.

and control on the operating vehicles will provide integrity and prosperity to the operating transportation company.

It is expected that such a mechanism will improve the confidence in the local transportation company in Amman and improve its image among the citizens of the city as in the past the company has an unfavorable reputation. Also this will help to save time, money, pollution and energy for the citizen and the country. The developed Web tracking software provides the control center with all needed information about the operation process. Continuous contact with drivers and follow up is also provided by the control center to avoid accidents, traffic and time schedule problems. We had to build a GIS system for the roads and the surrounding environment of Amman. Moreover, we included buffer zones to keep vehicles on track and to warn the control in case of mishaps.

4.2. Application 2

4.2.1. The police traffic information system

Information system – all accidents' information have to be localized using GNSS technology (mainly GPS) then, the information and location have to be sent to the server via wireless communication means, downloaded directly via serial port or transmitted to the server via Internet. The location Information server will be connected with all police stations in all cities for data updating via web GIS; see Fig. 4.

The database part is very critical in this application. There are two different types of database, the spatial database (street, district, etc.) and the entity database (driver, car, etc.). The arrangement of the data within the database and their interrelation will affect the efficiency of the software and lead to better management of the generation of reports and consequently the decision-making process; see Fig. 5. Interrelation within the database could be designed to allow certain tasks to improve a certain decision-making process, such as the total number of accidents at a certain location within a specific period of time. The report warning would require new traffic planning.

The asset management process in GIS/LBS application is developed on top of GIS software capabilities to facilitate the analysis, management and decision-making, especially when it is directly related to life saving.

In case of accident, the captured area will be determined as a buffer circle with a 100-m radius, then the location of the accident will be highlighted on the screen if the number of accidents (at the location) exceeded a specific number; without the need to read the report.

Asset management will help the decision makers to localize accident locations and to take the action needed to reduce or eliminate the accident causes automatically. The software classifies the accident danger level according to certain factors predefined by the police committee on road accidents. The success in such projects depends heavily on the GIS data quality in the initiation process and on its maintenance afterward.

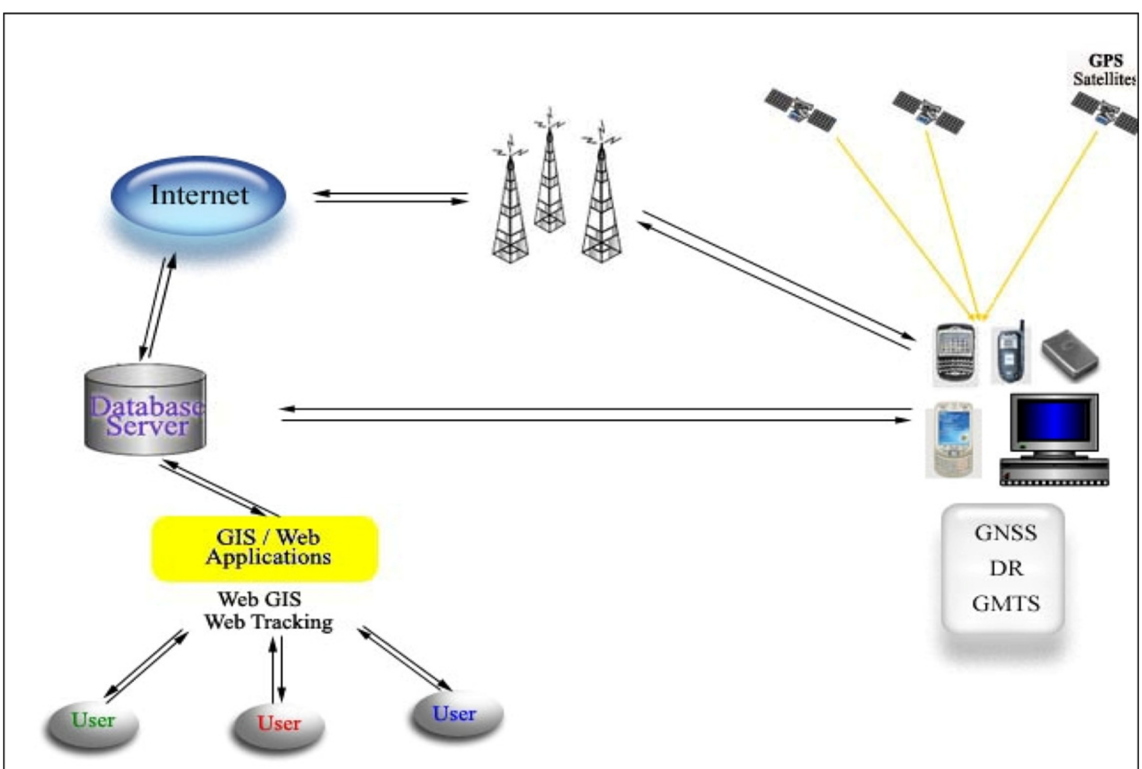

Fig. 4. GNSS/LBS/GIS combination.

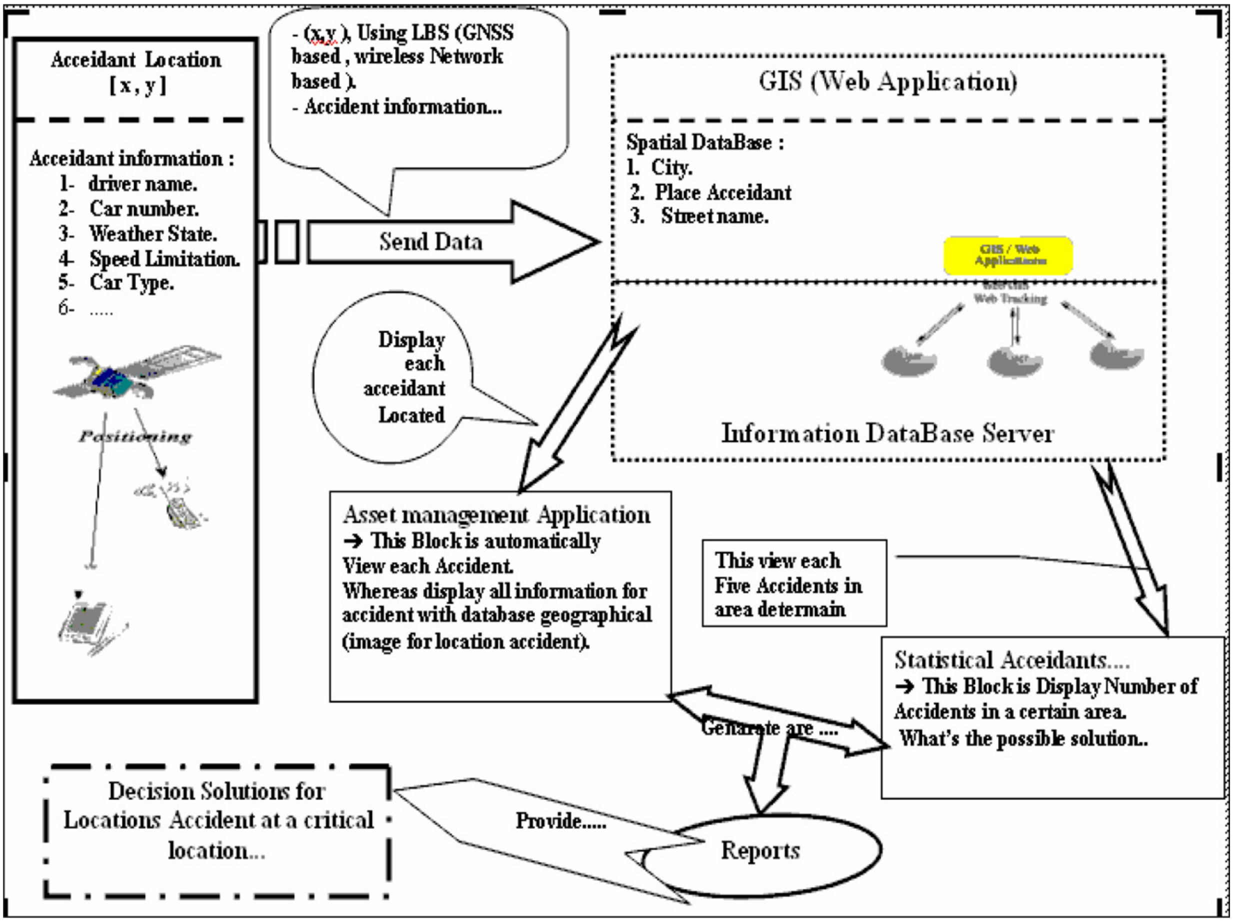

Fig. 5. The police traffic information system flowchart.

5. Conclusions

To conclude, increasing demand for commercial LBS is pushing at improving user mobility services for position determination by combining WC/GNSS/GIS technologies. Location may be based on GNSS Technologies or on Network Technologies (Wireless Technology), but the GNSS technology provides more accurate positions.

GNSS/LBS/GIS applications are at high demand for the time being, but they still have some limitations. LBS industry includes: Information and navigation services, emergency assistance, tracking services and network related services. It is an essential tool for better management of moving vehicles and is urgent for life saving in emergencies.

In this paper, we introduced two GNSS/LBS/GIS applications that we have developed for local use. These are: AVL system applied to a local public transportation company and police traffic information system to report and update about accidents' locations, the level of danger and the frequency of accidents at the location.

Automatic vehicle location application can provide better management and control for a moving fleet of vehicles, which may keep time schedules, increase operating efficiency and avoid/minimize accidents and traffic problems. Other LBS application is to create a police traffic information system to help in emergency management, better planning and prevention. Applications are increasing at an impressive rate. This area is becoming an attractive industry.

Acknowledgements

The authors gratefully acknowledge the support of GCE Company and Mr. S. Aqel.

References

[1] E. Lohnert, E. Wittmann, J. Pielmeier, F. Sayda, Pramount Public Safety & Commercial Info-mobility Applications and Services in the Mountains, ION GPS 2001, Salt Lake City, UT, 2001, pp. 319–325.

[2] GALILEO, Mission Requirement Document (MRD), European Commission, Issue 5 – Rev. 1.1, 27. March 2003. Available from: http://www.galileoju.com.

[3] Y. Feng, Combined galileo and GPS: a technical perspective, Journal of Global Positioning Systems (1) (2003) 67–72.

[4] G. Lachapelle, M.E. Cannon, K. O'Keefe, P. Alves, How will galileo improve positioning performance, GPS World 13 (9) (2002) 38–48.

[5] P. Mulassano, F. Dovis, F. Cllomb, European projects for innovative GNSS-related applications, GPS Solutions 7 (2004) 268–270.

[6] B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins, Global Positioning System: Theory and Practice, fifth ed., Springer Verlag, New York, 2001.
[7] A. Leick, GPS Satellite Surveying, third ed., John Wiley and Sons, New York, 2003.
[8] J.J. Caffery, G.L. Stüber, Overview of radiolocation in CDMA, IEEE Communications Magazine (1998) 38–45.
[9] R. Jain, A. Puri, R. Sengupta, Geographical routing using partial information for wireless ad hoc networks, IEEE Journal of Personal Communications 8 (1) (2001) 48–57.
[10] G. Heinrichs, G. Germany, J. Winkel, C. Drewes, L. Maurer, A. Springer, R. Stuhlberger, C. Wicpalek, A Hybrid Galileo/UMTS Receiver Architecture for Mass-Market Applications, GNSS 2005, Available from: http://www.gawain-receivers.com/publications/IfEN_Paper_GAWAIN_GNSS2005.pdf.
[11] O. Al-Bayari, B. Sadoun, New centralized automatic vehicle location communications software system under GIS environment, International Journal of Communication System 18 (9) (2005) 833–846.

Dr. Balqies Sadoun received her M.S. in Civil Engineering from the Ecole Nationale Des Travaux Publique de L'Etat, Lyon, France. She received another M.S. and Ph.D. degrees in City and Regional Planning Engineering, College of Engineering of The Ohio State University, Columbus, Ohio, USA. Currently, she is the Chairperson and an Associate Professor in the Department of Surveying Engineering and Geomatics, Faculty of Engineering, at the Al-Balqa' Applied University, Jordan. Previous positions include Chair of the Department of Architectural Engineering at Applied Science University, Amman, Jordan. Other previous academic experiences include working as a faculty member at the Faculty of Engineering of Yarmouk University and Jordan University of Science and Technology. Dr. Sadoun has worked also as a faculty member at the City University of New York, USA. Dr. Sadoun has authored or co-authored about sixty (60) refereed journals, and conference articles and book chapters. She served on the program and organization committees of several international conferences. In 1999, she served as the Program Co-chair of the 1999 Summer Computer Simulation Conference, SCSC'99, and co-edited the Proceedings of the 1999 Summer Computer Simulation Conference. Her article ''An efficient simulation methodology for the design of traffic lights at intersections in urban areas,'' by published in the Simulation Journal: Transactions of the Society for Modeling and Simulation International, Sage 79 (2003) 243–251,'' has been ranked on the top of the 50 most-frequently-read articles in the Simulation Journal (October 2003–February 2007); see: <http://sim.sagepub.com/reports/mfr1.dtl>. Dr. Sadoun's research interests include: modeling and simulation, Geographical Information Systems (GIS) and Global Navigation Satellite Systems (GNSS) applications, applications of information and communication technology to city planning/engineering, surveying and Geomatics engineering, transportation engineering and planning, environmental planning and engineering, applied neural networks, passive solar design, quantitative analysis and methods, system recognition and identification. Dr. Sadoun is a member of the Society for Modeling and Simulation and ASCE.

Dr. **Omar Al-Bayari** is an Assistant Professor in the Department of Surveying and Geomatics Engineering at Al-Balqa' Applied University, Jordan. He worked between 1999 and 2001 as Post Doctor at DISTART Engineering Department, University of Bologna, Italy. He obtained his B.S. in Civil Engineering from the University of Jordan, and his Ph.D. in Geodetic Sciences and Topography from the University of Bologna, Italy, in 1998. Dr. Al-Bayari has authored or co-authored more than fifteen articles in refereed international journals and conferences. His area of research include Geodetic Surveying and GPS Applications, Integration between GPS, GIS and GSM communicationsystems for Automatic Vehicle Location system, Global Geodesy and Geoid determination, and Airborne laser scanning system.