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Development of SMS-based G²I System to Generate Reference GIS Maps for Real Time Vehicle Tracking Applications

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ABSTRACT
In this paper details of development and applications of a navigation system known as GPS-GSM Integrator (G²I) are presented. G²I system consists of two modules namely In Vehicle Module (IVM) and Control Room Module (CRM). The IVM is micro controller based system equipped with Global Positioning System (GPS) receiver and Global System for Mobile communication (GSM) modem. The CRM consists of a Personal Computer (PC) and GSM mobile phone. Relevant software is developed for obtaining position information of vehicle. Drive tests are conducted with G²I system (in different modes) for cellular coverage area determination and for developing comprehensive digital reference Geographical Information System (GIS) maps in real time vehicle tracking. During these tests, the Received Signal Strength Indications (RSSI) of the cellular signal at various locations (latitude and longitude) in urban and rural regions are recorded and coverage area classification is done. The developed G²I system would be helpful for implementation of Location Based Services (LBS) of Third Generation (3G) communications.

INTRODUCTION

The ability to communicate on the move has evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide contact with ships sailing the English Channel in 1897 (Ibnkahla 2004). Since then, the world's communication market has been witnessing a tremendous growth in the field of mobile communication and became the focus for the economic and industrial development of the society. U.S. Federal Communications Commission (FCC) has made it mandatory that wireless emergency (E-911) callers must be located with an accuracy of 300m (CC Docket 1994). In India also, several companies are working towards providing location based services to their customers. Mobile Station (MS) positioning plays a vital role in LBS. To fulfill this requirement, cellular network operators can use either network based technique, handset based technique or hybrid technique. In network based technique the parameters used for computing location are measured at Base Station (BS) and transferred to a central facility for location determination (James et al., 1998). Handset based technique requires handset modifications such as installation of GPS chipset in the MS. Hybrid techniques are the combination of network based and handset based techniques. Currently, while the telecommunications industries are deploying 3G systems worldwide, emerging nations postulate enabling technologies like implementation of wireless position data transfer services. Wireless position data transfer involves two steps. The first step is to determine the location of the MS and the second step is to relay the location information to a central place. Many technologies currently exist for locating the MS such as GPS based one. GPS is the most popular radio navigational aid that provides three-dimensional position, time and velocity of users (Kaplan 1996). Similarly, the GSM technology is an extremely successful digital cellular evolution and offers a family of voice, data and LBS. Last few years have seen most of the applications in the consumer and commercial domain which integrates GPS with GSM and GIS. Location information of MS can be used for network planning where radio resources are dynamically redistributed to improve coverage and capacity of the cellular system (Yamamoto et al., 2001). GPS-GIS system allows the user to enter user defined attributes for each feature and used in utility management, fleet management and for public safety

(Chang 2003). This system helps the transit authorities to locate their fleet of buses on digital maps in real time. Estimation of position of MS has many important applications including both emergency and strategic applications. These issues are prompted for the development of G²I system at Research and Training Unit for Navigational Electronics (NERTU), Osmania University, Hyderabad, India. Details of G²I system such as architecture, software aspects, modes of operation and applications including development of reference GIS maps are described in this paper.

Significance of GIS maps in real time vehicle tracking

The three dimensional location parameters obtained by a GPS will provide very useful information, if they are presented in a graphical format. GIS is a tool to do such formatting. GIS is a computer based graphical tool capable of acquiring, storing, manipulating, analyzing and displaying geographically referenced data (Elfick 1994). It is also a visualization tool that presents data in the form of comprehensive and detailed digital maps, which are convenient and effective means of communicating complex information. By map projection, location of map (Cartesian) features is transformed into the location of spatial features which are based on geographic grid expressed in longitudes and latitudes. In recent years, many applications are explored with GPS-GIS integration such as developing reference digital maps, navigation application, in transportation planning and for emergency services like police, fire services, ambulance and for law enforcement etc. GPS incorporated digital road maps (developed in GIS) are suitable for providing route guidance electronically (Zhao 1997). To achieve these aims, GPS data has to be transmitted from one place to other place for position estimation of vehicle. Generally it is achieved through radio system based data transfer such as radio modems or existing cellular system (Salcic 1997). In addition to advanced digital cellular coverage and high data rates, 3G communication systems also allow voice and data to be mixed seamlessly. This makes the cellular system very attractive to a number of applications like wireless position data transfer for Automatic Fleet Management System (AFMS). AFMS optimizes the fleet operation through improved fleet utilization and effective monitoring on real time basis. Intelligent Transportation System (ITS) is developed based on integration of position technologies with communication technologies to modify traffic flow according to demand and other factors. The GPS determined vehicle location is superimposed on digital road map, containing information such as street names, directions, business listings, airports, attractions and other related information including traffic and weather conditions. GIS enabled LBS allow users to deliver and receive information that is related to a particular location through wireless telecommunication.

Present status

Recently, Cheung et al., (2003) estimated the position using RSS measurements. They transformed the nonlinear equations relating the RSS to the mobile position to a set of linear equations, which are solved by constrained weighted least squares. The accuracy achieved by using RSS measurements may not meet all emergency and strategic requirements but it is an attractive solution for less demanding LBS (Weiss, 2003). In another work for mobile location estimation, Yamamoto et al., (2001) considered the fluctuations of RSS due to shadowing and obtained the probability density function of the propagation distance. It is reported that the algorithm is more accurate than the conventional cell-based algorithm. Salcic (1997) presented an automatic GSM-based positioning and communication system for positioning of the mobile station in general way with out offering any technical details. Kyriazkos, Drakoulis &Theologou, (2001) have presented a position technique based on GPS and network-based technique but with very limited technical details. Several other recent papers also dealt about location based services with out offering many technical details (Krishna Murthy 2002 and Lee, Shin & Cho 2002). But the approach followed in this paper is different and with further improvement it is expected to offer more advantages over other systems.

Architecture of G²I system

The architecture of G²I system consists of IVM and CRM. The IVM is placed in a vehicle where as the CRM can be placed anywhere, where GSM cellular coverage is available. The IVM is an integrated unit of GPS receiver with GSM/GPRS modem through a micro controller (LPC 2106 MCU) to communicate wirelessly with CRM. The CRM consists of PC and GSM mobile phone. Switching center acts as an exchange between IVM and CRM. The architecture of G²I system is shown in Fig.1.

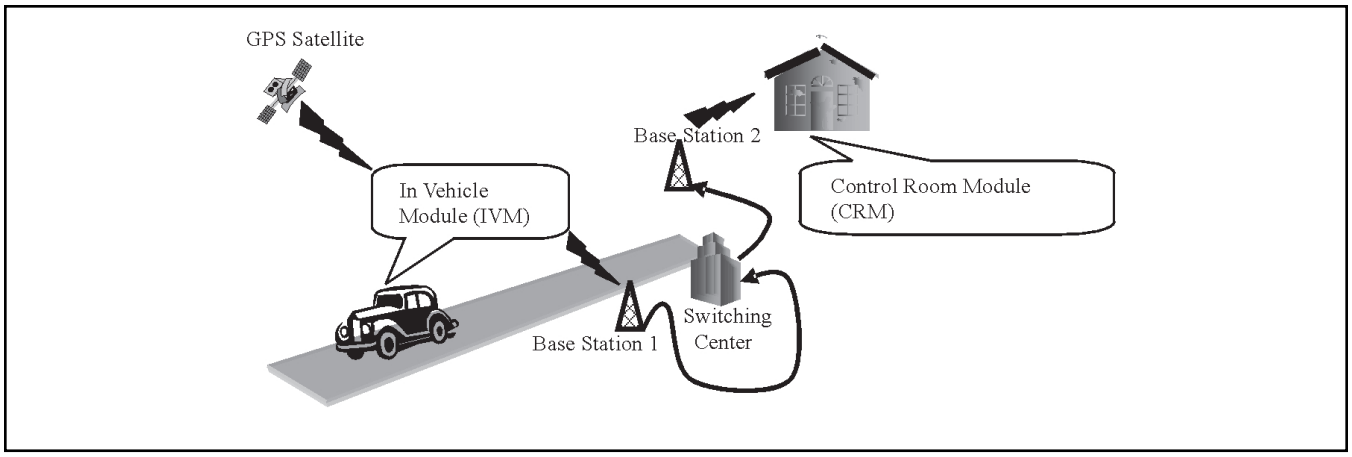

Figure 1. Architecture of G²I System.

Function of G²I system

The G²I system is based on wireless position data transfer technique. The basic function of G²I system is to determine the real-time position of a vehicle with the help of GPS receiver and RSSI value of the cellular signal from GSM modem and to relay this information wirelessly to CRM through GSM modem using Short Message Service (SMS) feature. At CRM the GSM mobile phone receives positional data and forwards to the PC. The received data will be processed and presented in a graphical format superimposed on reference GIS maps in real time. In addition to the real time display of vehicle position, these maps will also provide useful information about the cellular coverage area.

Hardware aspects of G²I system

The hardware interconnections of IVM and CRM are shown in Fig.2 and Fig.3 respectively. The interfaces between various subsystems of IVM as well as CRM are established using RS-232 protocol. At IVM, the GPS receiver estimates the three dimensional (3D) position of the vehicle. The Wavecom GSM modem computes RSSI value of the cellular signal and facilitates the position data transfer wirelessly using SMS feature. The Philips-ARM make Least Pin Count (LPC-2106) micro controller unit provides integration platform for GPS receiver and GSM modem and offers different modes of operation. The GPS receiver and GSM modem are connected to the two Universal Asynchronous Receiver and Transmitter (UART) ports on the micro controller unit. At CRM the Nokia 3310 mobile phone receives and forwards the data to the PC. The PC at CRM is responsible for all the data processing to determine cellular coverage area and for real-time vehicle tracking applications.

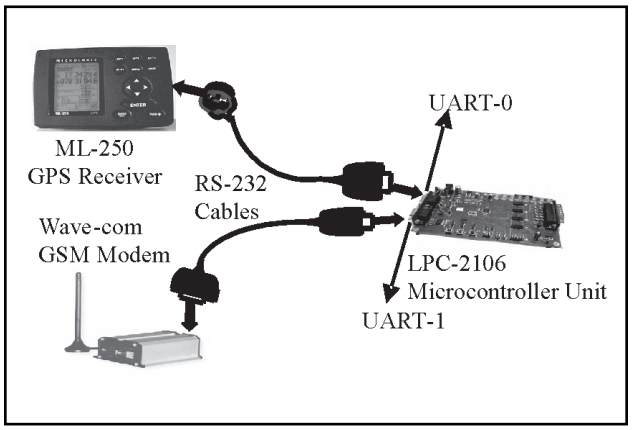

Figure 2. IVM hardware interconnections.

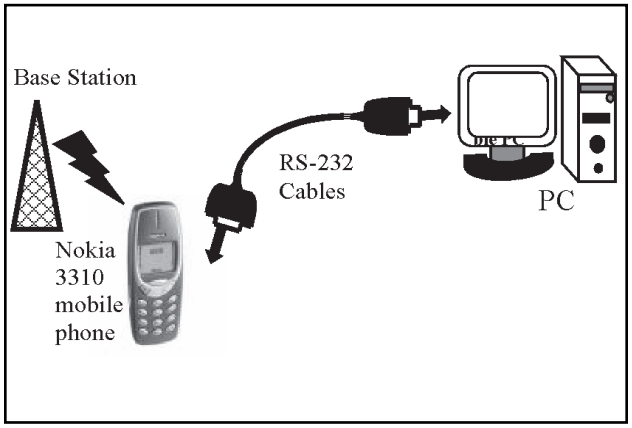

Figure 3. CRM hardware interconnections.

Software description of G²I system

Necessary software for the operation of the subsystems of IVM as well as CRM is developed. The software aspects ensure that all the subsystems of IVM and CRM work in tandem in an integrated environment. The software of IVM facilitates, reception of 12 strings of serial GPS position data in National Marine Electronics Association (NMEA) format, extraction of required parameters from received GPS data and its transmission to CRM through GSM modem using ATtention (AT) commands. The data is contained in a single line with data items like identity (GP for GPS) and position parameters separated by commas. GPS Position Geo Graphical Active (GPGGA) strings provide the information about latitude, longitude, altitude, Universal Coordinated Time (UTC), Dilution of Precision (DOP), number of satellites used for position fixing (Micrologic 1996). There are various groups of AT commands. For example, the AT Command Send Message (AT+CMGS) is used to send SMS in text mode, AT Command Signal Quality (AT+CSQ) is used to ascertain RSSI and AT Command Cell Environment Description (AT+CCED) is used for description of cell environment (Wave-com, 2001). The response to AT+CSQ command is a RSSI value ranging from 0 to 99. RSSI value of 0 means signal strength of the mobile signal is –113dBm or less (worst), 1 means signal strength of the mobile signal is –111dBm (Un-satisfactory), 30 means signal strength of the mobile signal lies between -109 to –53dBm (satisfactory), 31 means signal strength of the mobile signal is -51dBm or greater (good), 99 is a non detectable signal. The command AT+CCED can be used to retrieve the parameters like Cell Identity (CI), Base Station Identity Code (BSIC), Location Area Code (LAC) etc. Turbo C and Matlab are used to realize the software aspects of CRM. Micro controller used in IVM provides software interface between GPS module and GSM modem (Wavecom 2001). Additionally the micro controller assures that all the subsystems are working well in an integrated manner (Mazidi & Janice 2003). This was achieved by configuring the two UART ports (UART 0 and UART 1) simultaneously using Embedded C language. Software programs were also developed for the subsystems used in the CRM to work in an integrated environment.

EXPERIMENTAL DETAILS

The G²I system can be experimented in several modes. Three typical modes of operation are described in the following sections.

Autonomous mapping mode

In this mode, position (latitude and longitude) data and RSSI data are recorded on to flash memory of micro controller unit for every 6 Seconds and are not transmitted to CRM. This is mainly used for determination of cellular coverage area and for developing of GIS maps.

Continuous mode

In this mode, GPS position data and RSSI data are transmitted from IVM to CRM periodically for every 6 Seconds (or more). This mode is mainly used for real time vehicle tracking purposes.

Discrete mode

In this mode, IVM transfers the current position and RSSI data, only when it receives a request from CRM. This is a compromise between autonomous mapping and continuous modes. This mode can be used to provide emergency services. IVM can be initiated to send SMS on to a help line.

RESULTS AND DISCUSSION

Among the error sources in GPS, ionospheric error is predominant and least predictable (Xu 2003). As the signal propagates through the ionosphere, the carrier experiences a phase advance and the codes experience a group delay (Hofmann-Wellenhof, Lichtenegger & Collins 1992). The extent to which the measurements are delayed depends on the Total Electron Content (TEC) along the signal path, which is a measure of the electron density of ionosphere. It is dependent on several factors such as geomagnetic latitude, time of the day, elevation of the satellite, Kp index and Sun Spot Number (SSN). Significantly larger delays occur for signals emitted from low elevation satellites. Delay during the daytime is more. The ionospheric zenith delay typically varies at mid latitudes from about 1-3 m at night to 5-15 m in the mid-afternoon. The zenith delay has been observed to be as high as 36 m near the equator at the peak of the solar cycle (Langley 2000). Drive tests are conducted using with G²I system to collect the position data for developing reference GIS maps on two typical days. However, these two days happened to be magnetically quite days. Typical 1σ error in GPS from all sources lies between 5.3 – 31m (Parkinson & Spilker 1996).

Drive tests are conducted in three modes (autonomous, continuous and discrete) to demonstrate the applications of the G²I system. The

G²I applications require development of reference GIS maps that will run in the back ground over which the real time position of the vehicle will be displayed. Experiments were conducted with hand held ML-250 GPS receiver, to collect the location data and present the information in the form of reference GIS maps. The GIS maps were developed for two different routes in the premises of Osmania University namely Route 1 (NERTU-Parsigutta -VST-NERTU) and Route 2 (NERTU-Habsiguda –Tarnaka –NERTU).

In autonomous mapping mode, the RSSI of the cellular signal at various locations (latitude and longitude) in rural region (Case-1) and in urban region (Case-2) are recorded periodically at every 6 seconds. Normally, rural base stations operate at high transmitted power to derive maximum coverage area from a single base station, whereas, in urban areas a number of base stations with low transmitted power are used to provide intensive coverage. These scenarios are as shown in figs 4 and 5 for rural and urban base stations respectively. Three directional antennas can be seen in Fig. 4 for rural base station, whereas in urban area various base stations are shown in Fig.5. The recorded position and RSSI data are processed and coverage area classification is made as good and satisfactory coverage areas. The results (coverage area classification) of the drive tests are shown in figs 6 and 7 for rural and urban areas respectively. Further, coverage area histograms are presented for both the cases in figs.8 and 9. These histograms provide information about the number of locations with good coverage and satisfactory coverage. A rural base station with Cell Identity (CI): 9163 (belongs to third sector of the 16th base station in 9th Base Station Subsystem) is chosen. The + symbol indicates the location of the base station. In rural area, measurements are taken at 354 locations out of which 63 locations have good coverage and rest of the points have satisfactory coverage. Similar test is conducted in urban region along the route in which many base stations are

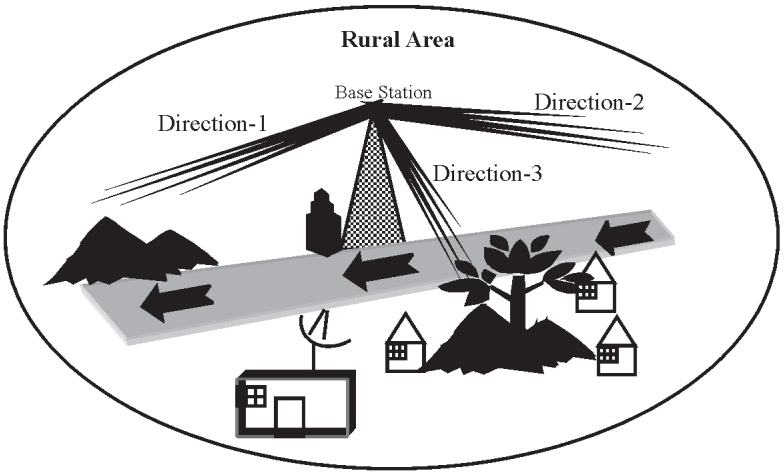

Figure 4. Arial view of a rural base station.

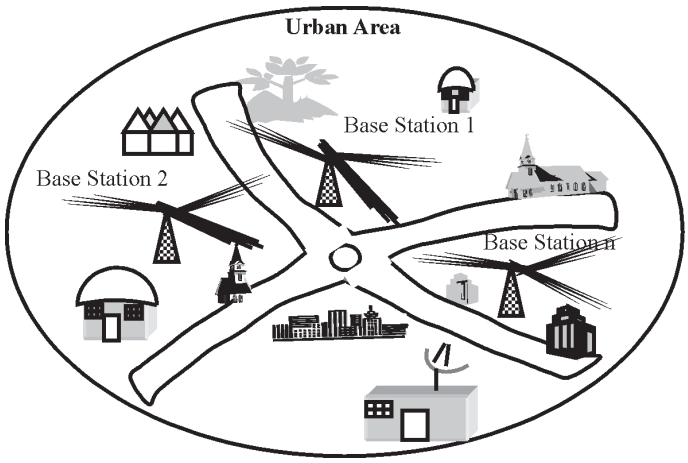

Figure 5. Arial view of an urban base station.

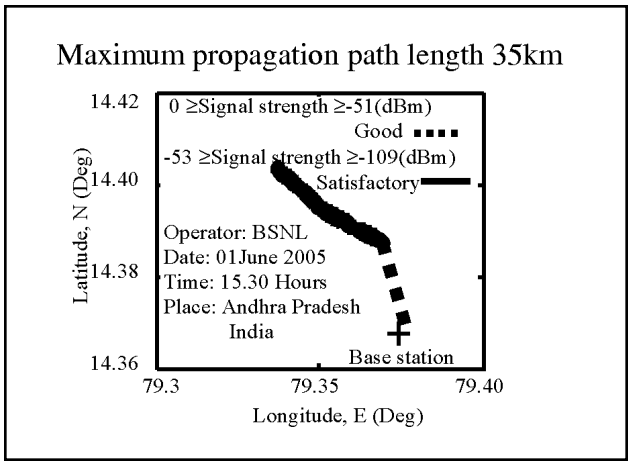

Figure 6. Coverage area classification (rural area).

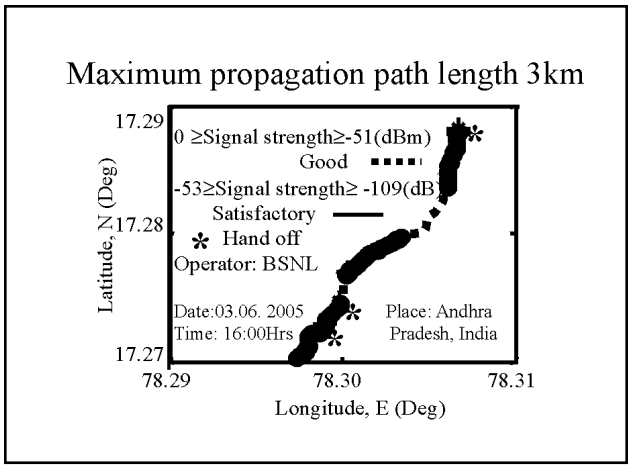

Figure 7. Coverage area classification (urban area).

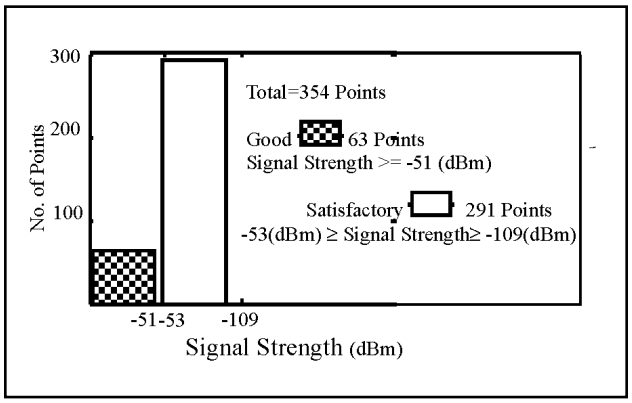

Figure 8. Coverage area histograms (rural area).

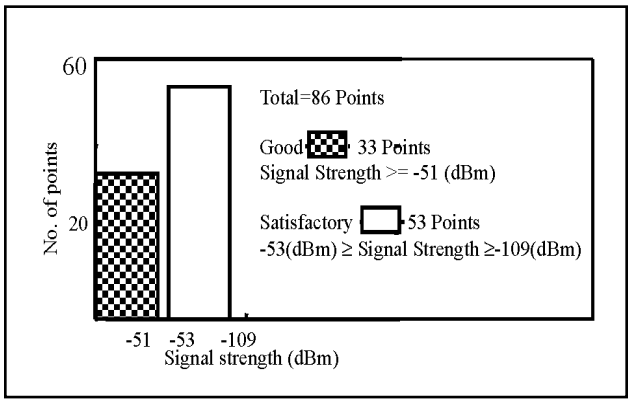

Figure 9. Coverage area histograms (urban area).

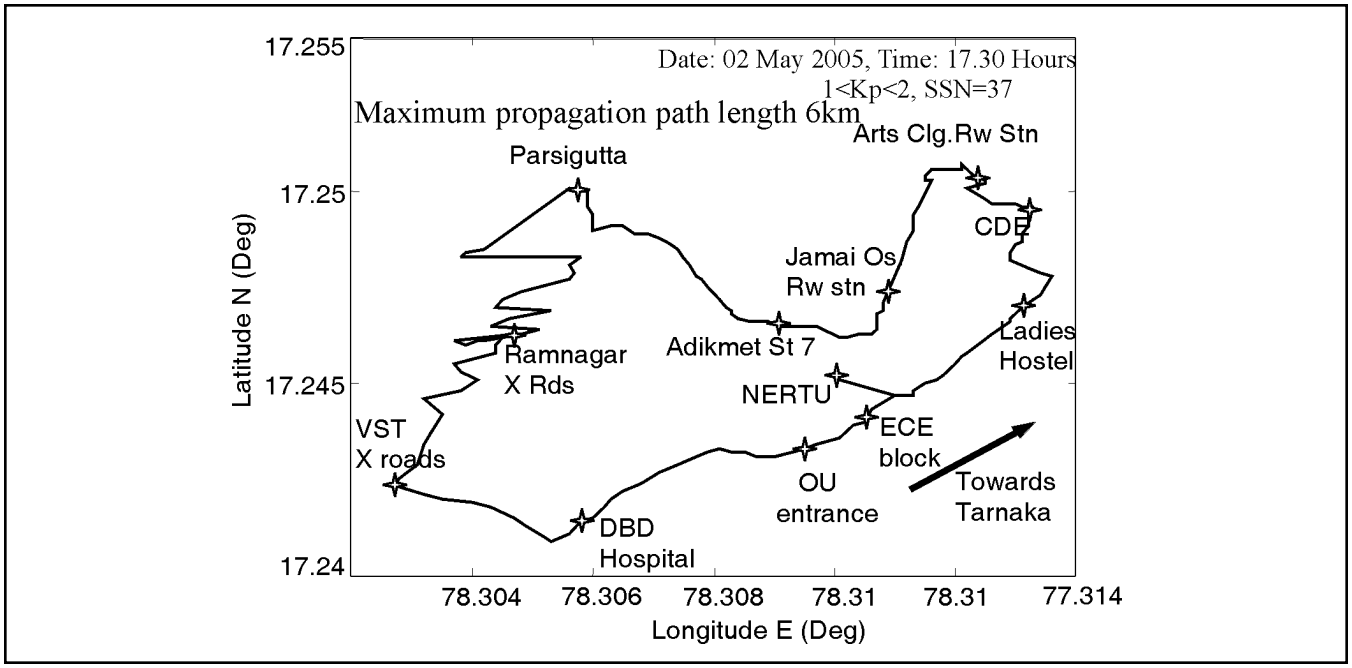

Figure 10. Reference GIS map for route 1 (NERTU-Parsigutta –VST-NERTU).

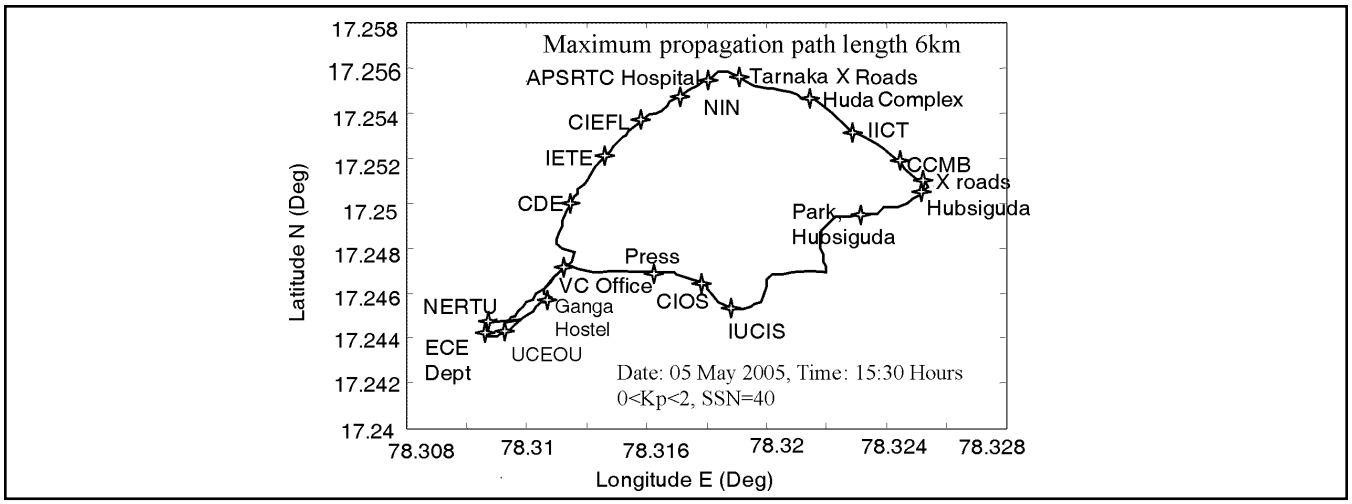

Figure 11. Reference GIS map for route 2 (NERTU-Habsiguda- Tarnaka- NERTU).

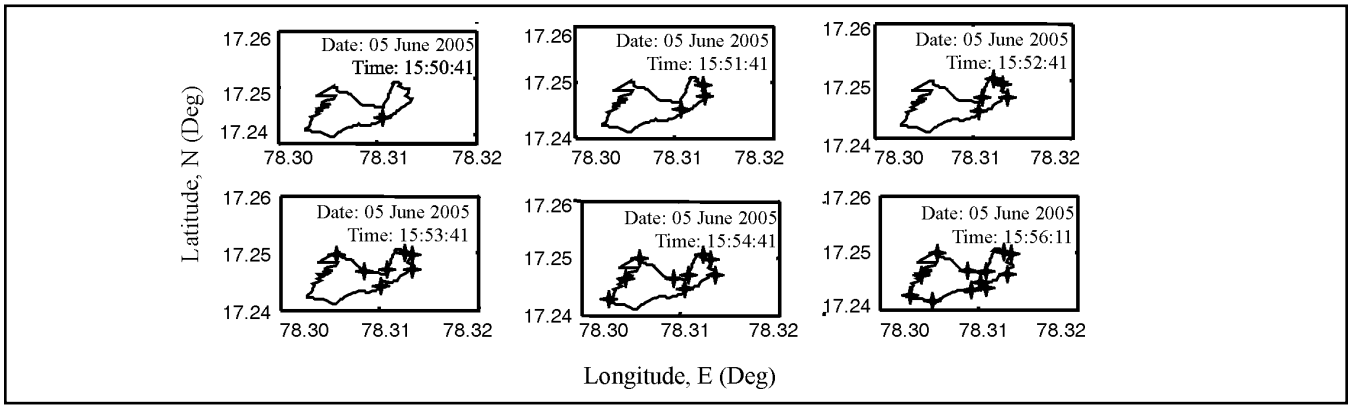

Figure 12. Real time vehicle positions superimposed on reference GIS map.

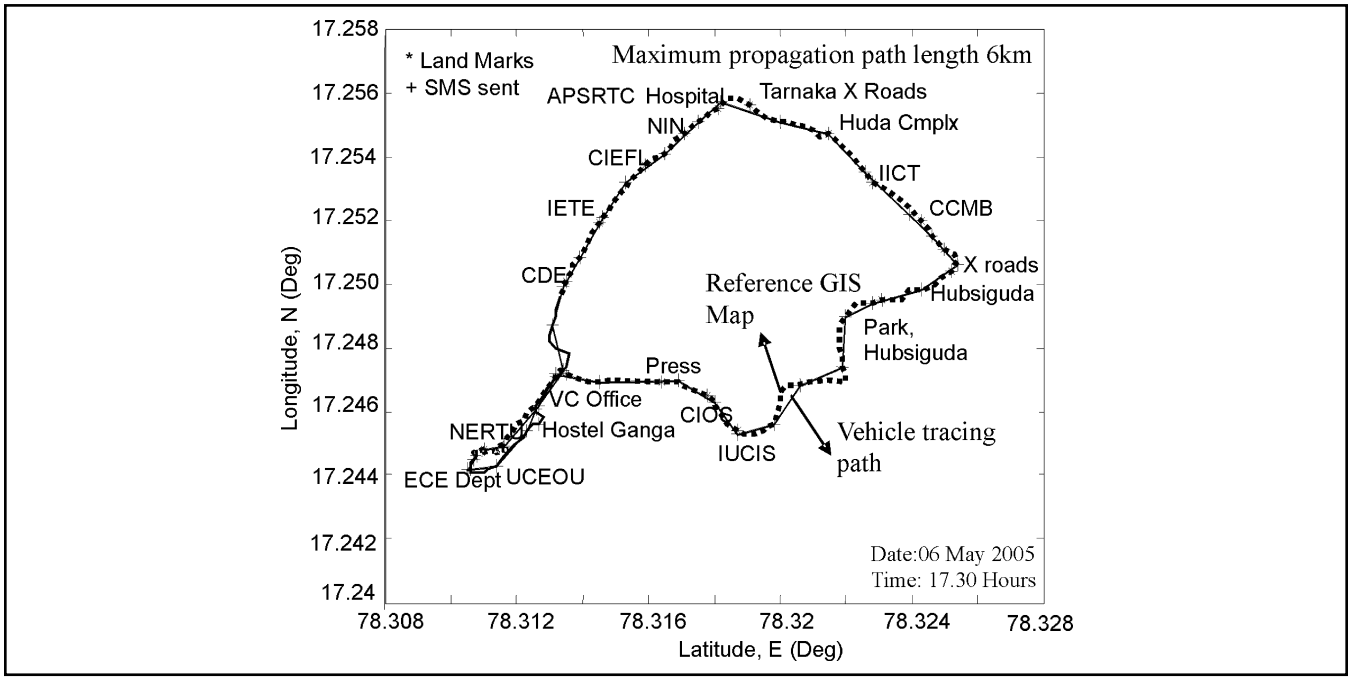

Figure 13. Map of SMS points obtained at CRM on route 2.

involved to provide cellular coverage. In urban area, 86 points are considered, out of which 33 points have good coverage and rest have satisfactory coverage. The various CIs encountered along the route are 10332, 10333, 10171, 10172, 10173, 10261, 10141 and 10051 respectively. The * symbol in Fig.7 indicates the occurrence of Hand-off between the cells (i.e. transition in CIs). 7 hand offs were occurred during the test. Because of the small dimensions of Fig.7 five of the Hand-offs are overlapping with each other. The developed digital reference GIS maps for both the route 1 and route 2 are shown in figs 10 and 11 respectively. Along the route 1 various land marks namely Ladies Hostel, Arts College Railway Station, Parsigutta, Ramnagar X roads, DBD Hospital etc are noted. Similar procedure is followed for route 2 also. These maps are useful for real time vehicle tracking applications.

In continuous mode, real time position of a vehicle (equipped with IVM) is transmitted at every 30 seconds (instead of 6 seconds) wirelessly to a control room (equipped with CRM) for real time vehicle tracking purposes. For every minute two more locations are added in the map. Fig.12 shows the real time position of the vehicle by superimposing on reference GIS map at regular intervals of time.12 different vehicle positions are noted in six minutes of test duration are shown in different plots (Fig.12).

In discrete mode the IVM and CRM interacts with each other for wireless position data transfer. SMS is transmitted on request from IVM and the data was presented in a graphical format at CRM. The position of the vehicle equipped with IVM will be updated accordingly on the reference GIS maps that run in the background. Fig.13 shows the map of SMS points obtained at CRM on route 2 at various landmarks. The + symbol shows the real time position of the vehicle at that time instant. Thus the real time position of the vehicle is identified with the nearest landmark.

For position fixing of MS, no single technique is superior, different techniques are used in different environments and for different services. The acquired vehicle position at IVM of G²I system is transmitted wirelessly to central place for LBS applications such as route guidance. Experimentally acquired positional data (latitude and longitude) along with RSS values due to G²I system can be used for predicting coverage area contours which are necessary for cell site planners. G²I system is a primary tool to develop digital GIS maps for vehicle tracking applications. G²I system operated in discrete mode offers emergency services, which are part of LBS.

CONCLUSIONS

An attempt is made to integrate the two most widely used technologies namely GPS and GSM for developing navigator called G²I system. Salient features of various subsystems involved in the system development are described. Drive tests are conducted with G²I system in three modes namely autonomous, continuous and discrete modes for applications such as cellular coverage area determination, developing comprehensive digital reference GIS maps and for real-time vehicle tracking. Majority of the points in both rural and urban areas are having signal strength falling between –53 to –109dBm. It is found that, it is possible to integrate GPS with GSM modem for reliable vehicle position information and to ascertain the coverage area. The real time vehicle tracking experiments demonstrated the importance of wireless position data transfer in deploying LBS in 3G communications. G²I system plays an important role in the emerging applications like Intelligent Transposition System (ITS) to achieve a safe and efficient surface transportation. The drive tests are to be conducted during magnetically disturbed days to further confirm the reliability of the system.

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