INTEGRATION OF GPS AND GSM FOR DETERMINATION OF CELLULAR COVERAGE AREA

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ABSTRACT

In this paper, details of design and applications of a navigation system known as GPS-GSM Integrator (G^2I) are presented. G^2I system consists of two modules namely In Vehicle Module (IVM) and Control Room Module (CRM). The IVM is microcontroller-based system equipped with GPS receiver and GSM modem. The CRM consists of a PC and GSM mobile phone. Drive tests are conducted with G^2I (in different modes) for cellular coverage area determination, for development of reference GIS maps and for 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 G^2I system would be helpful for implementation of Location Based Services (LBS)

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[1]. Since then, the world's communication market is witnessing a tremendous growth in the field of mobile communication and became the focus for the economic and industrial development of the society. Currently, while the telecommunications industries are deploying Third Generation (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 Mobile User (MU) and the second step is to relay the location information to a central place. Many technologies currently exist for locating the MU such as GPS based technologies. GPS has greater potential because of its accuracy and seamless navigation. Similarly, GSM technology is an extremely successful digital wireless cellular evolution and an exceptional story of global achievement [2]. GSM platform offer an expanded and feature-rich family of voice, data and location-enabled services. Intelligent cell concept for dynamic distribution of radio resources, assisted handoffs, real-time vehicle tracking, Automatic Fleet Management (AFM), cellular coverage area determination, location sensitive billing, providing emergency services, defense against emerging national threats are some applications of wireless position data transfer. A navigation device known as GPS-GSM Integrator (G^2I) was developed at R and T Unit for Navigational electronics (NERTU). The G^2I system is based on wireless position data transfer technique. The prime objective of G^2I system is to determine the real-time position of a vehicle with the help of GPS receiver and Received Signal Strength Indication (RSSI) value of the cellular signal with the help of a GSM modem and to relay that information to a control center. At control center the received data will be processed and presented in a graphical format for determination cellular coverage area, for development of reference GIS maps and for real time vehicle tracking. Details of architecture, various modules, modes of operation, hardware inter connections, software aspects and applications of G^2I system are described in this paper.

ARCHITECTURE OF G^2I SYSTEM

The architecture of G^2I system consists of two modules namely In Vehicle Module (IVM) and Control Room Module (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 microcontroller based system equipped with GPS receiver and GSM modem. The CRM consists of PC and GSM mobile phone. The architecture of G^2I system is shown in Fig.1.

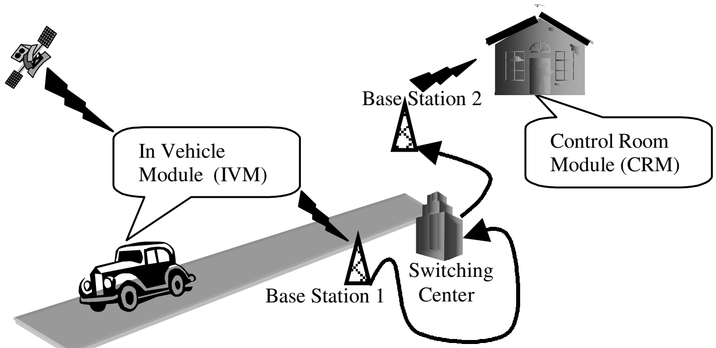

Fig. 1. Architecture of G^2I System

HARDWARE INTERCONNECTIONS OF G^2I 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 Micro Logic (ML)-250 GPS receiver estimates the Three Dimensional (3D) position of the vehicle. The Wavecom GSM modem computes RSSI value of the cellular signal and facilitates wireless position data transfer using Short Message Service (SMS) feature. The Philips-ARM make Least Pin Count (LPC)-2106 microcontroller 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 microcontroller 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.

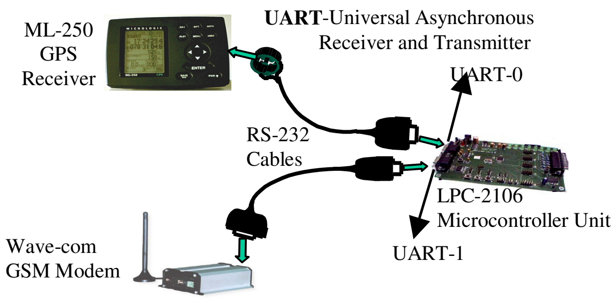

Fig. 2. IVM hardware interconnections

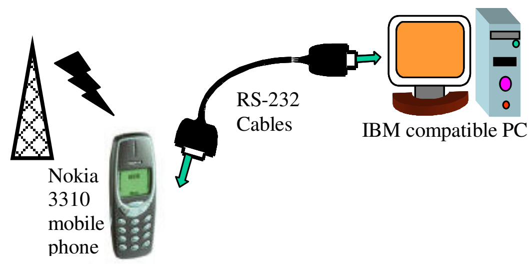

Fig. 3. CRM hardware interconnections

MODES OF OPERATION

The IVM can be operated in several modes. Typical modes are listed below.
Autonomous Mapping mode: In this mode, position and RSSI data are recorded on to flash memory of microcontroller unit at every 6 Seconds and are not transmitted to CRM. This is mainly used for determination of cellular coverage area and other mobile communication experiments.
Continuous mode: In this mode, GPS position data and RSSI data are transmitted from IVM to CRM periodically at 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.

SOFTWARE DESCRIPTION OF G^2I 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 are working well together in an integrated environment. The software aspects of IVM are, reception of serial GPS position data in a standard National Marine Electronics Association (NMEA) format, extraction of required parameters from the above data and its transmission to CRM through GSM modem using ATtention (AT) control commands. All the GPS receivers can communicate and understand the NMEA data strings. Every NMEA string begins with a ' $' symbol and ends with a Carriage Return (CR)/Line Feed (LF) sequence and can be no longer than 80 ASCII characters. The data is contained in a single line with data items like talker identity (GP for GPS) and position parameters separated by commas. ML-250 GPS receiver periodically outputs a series of twelve NMEA strings at the rate of two strings per second. Out of these twelve, $GPGGA data strings are of our interest. GPGGA strings provide the information about latitude, longitude, altitude, UTC time, Dilution of Precision (DoP), number of satellites used for position fixing. Further, the operations of GSM modem are controlled by a set of control commands called AT commands. There are various groups of AT commands. For example the command AT+CMGS is used to send SMS in text mode and AT+CSQ used to ascertain RSSI and AT+CCED for cell environment description [3]. 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 –113 dBm or less (worst), 1 means signal strength of the mobile signal is –111 dBm (Un-satisfactory), 30 means signal strength of the mobile signal lies between -109 to –53 dBm (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 by the application to retrieve the parameters like Cell Identity (CI), Base Station Identity Code (BSIC), Location Area Code (LAC) etc of the main cell and of up to six neighboring cells. Software for IVM was developed using 'Embedded C' language. The software aspects of CRM are, storage and graphical representation of received GPS data from IVM. The mobile phone available at CRM receives wireless position data from IVM. It forwards the received data on to a PC with the help of an automatic SMS tool [4]. At the PC the data will be stored (for future use), processed and presented graphically for cellular coverage area determination, for development of comprehensive and detailed reference GIS maps and for real time vehicle tracking. The software tools Turbo C and Matlab are used to realize the software aspects of CRM

RESULTS AND DISCUSSION

Drive tests are conducted in different modes to demonstrate various applications of the G^2I system. In autonomous mapping mode, the RSSI of the cellular signal at various locations (latitude and longitude) in a rural region (Case-1) and an urban region (Case-2) are recorded periodically at every 6 seconds. Normally, rural base stations operate at high transmitter powers to derive maximum coverage area from a single base station. Where as, in urban areas a number of base stations with low transmitter powers are used to provide coverage. These scenarios are shown in Fig .4 and Fig.5 respectively. The recorded position and RSSI data is processed and coverage area classification is made into areas with Good coverage and satisfactory coverage. Further, coverage histograms are drawn for both the cases. These histograms provide information about the number of locations with good coverage and satisfactory coverage. A rural base station with CI: 9163 is chosen (i.e. it belongs to third sector of the 16^{th} base station in 9^{th} Base Station Subsystem, BSS). The result of the drive test is shown in Fig.6. The + symbol indicates the location of the base station. Its coverage histogram is shown in Fig.7. Similar test is conducted in an urban region along a route in which many base stations are involved to provide cellular coverage. The various CIs encountered along the route are 10332, 10333, 10171, 10172, 10173, 10261, 10141 and 10051 respectively. Their coverage area classification and coverage histogram can be seen in Fig.8 and Fig.9 respectively. The * symbols in Fig.8 indicates the occurrence of Hand-off between the cells (i.e. transition in CIs). There are a total of 7 hand offs occurred during the test. Because of the small dimensions of Fig.8 five of the Hand-offs are overlapping with each other. Additionally, by experimenting in autonomous mapping mode of G^2I system, digital reference GIS maps are developed. These maps are very useful for real time vehicle tracking applications. They will run in the background, over which the real time position of the vehicle will be superimposed. Fig.10 shows one such reference GIS map developed in the premises of Osmania University (OU). In continuous mode, real time position of a vehicle (equipped with IVM) is transferred at every 30 seconds (instead of 6 seconds) wirelessly to a control room (equipped with CRM) for real time vehicle tracking purposes. Fig.11 shows the real time position of the vehicle superimposed on reference GIS map at various time instants. In discrete mode the IVM and CRM interacts with each other for wireless position data transfer.

CONCLUSIONS

The main objective of the paper is to integrate two global standards namely GPS and GSM. A navigation system known as G^2I is designed and developed for this purpose. Salient features of various subsystems involved in the system design are described. Drive tests are conducted with G^2I system and various applications of GPS -GSM integration such as cellular coverage area determination, development of comprehensive digital reference maps and real-time vehicle tracking are illustrated. Preliminary survey indicated that in rural areas, high transmitter powers are employed to cater the coverage needs with a single base station. So, the signal strength of the cellular signal is found decreasing gradually with increase in distance from base station. In urban base stations, low transmitter powers are used in order to reduce the interference between cells and to enable the efficient reuse of the frequencies. Majority of the points in both rural and urban areas are having signal strength falling between –53 to –109 dBm. An efficient Radio Frequency (RF) planning technique will considerably improve the efficiency of the cellular system. Further, the drive tests in different geometries signified the effects of environment and atmosphere on GPS signals. The real time vehicle tracking experiments demonstrated the importance wireless position data transfer in deploying Location Based Services (LBS) of 3G communications.

ACKNOWLEDGEMENTS

Acknowledgements are due to staff of NERTU for their assistance during the drive tests.

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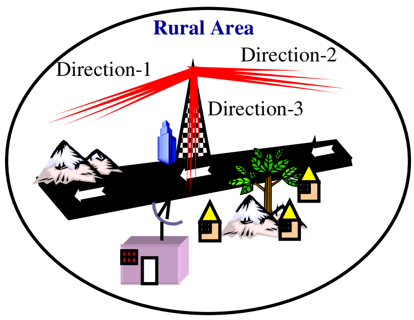

Fig. 4. Areal view of a rural base station

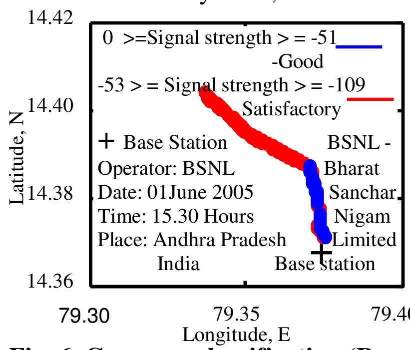

Fig. 6. Coverage classification (Rural area)

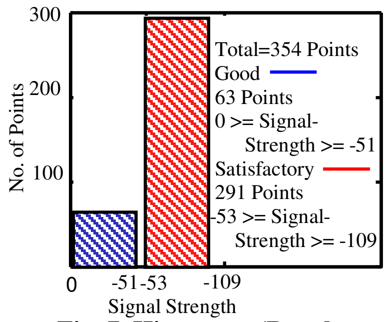

Fig. 7. Histogram (Rural area)

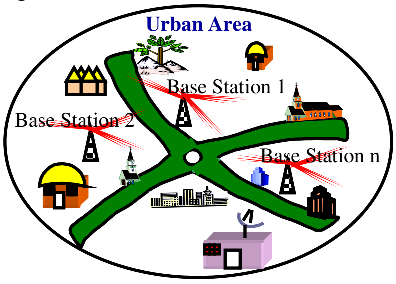

Fig. 5.Areal view of a urban base station

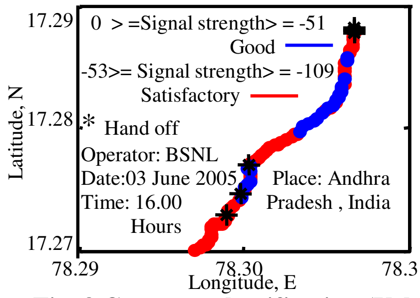

Fig. 8.Coverage classification (Urban area)

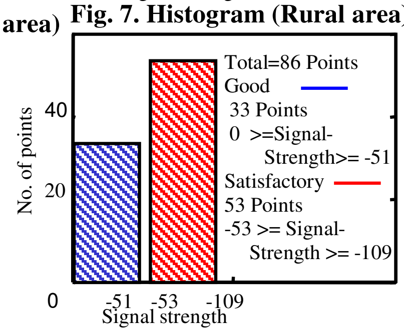

Fig. 9. Histogram (Urban area)

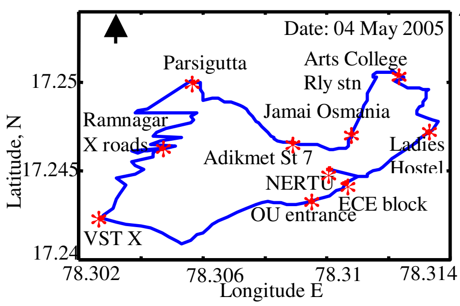

Fig.10. Reference GIS map

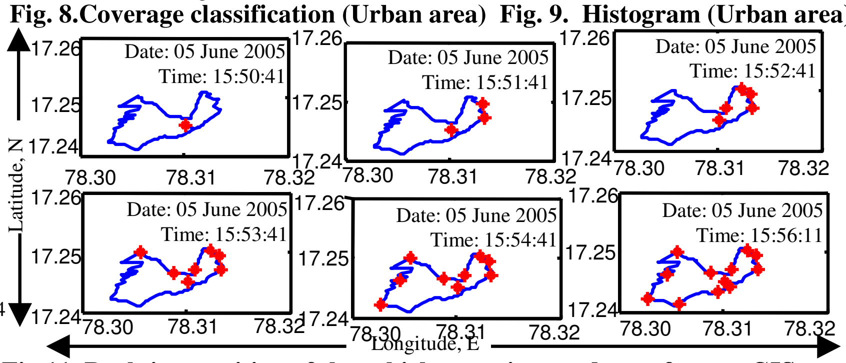

Fig.11. Real time position of the vehicle superimposed on reference GIS map