Data Monitoring Sensor Network for BigNet Research Testbed

Aravinda S. Rao, Davood Izadi, Reuben F. Tellis, Samitha W. Ekanayake and Pubudu N. Pathirana
School of Engineering, Deakin University,
Geelong, Victoria - 3217, Australia.
Email: {asrid, diz, rft, samitha, pubudu}@deakin.edu.au

***Abstract*—Equipped with recent advances in electronics and communication, wireless sensor networks gained a rapid development to provide reliable information with higher Quality of Service (QoS) at lower costs. This paper presents a real-time tracking system developed as a part of the ISSNIP BigNet Testbed project. Here a GPS receiver was used to acquire position information of mobile nodes and GSM technology was used as the data communication media. Moreover, Google map based data visualization software was developed to locate the mobile nodes via internet. This system can be used to accommodate various sensors, such as temperature, pressure, pH etc., and monitor the status of the nodes.**

I. Introduction

Knowledge of the location of vehicles is of utmost importance for some organizations (taxi services, car rentals, postal/courier services, emergency services etc) that provide services based on locations or that needs to keep track of its vehicle fleet. There exist fleet management systems which provide GPS based tracking solutions to large scale vehicle fleets [1]. However, the astounding cost of the system and the lack of ability to incorporate other sensor devices to the same platform restrict the applicability of such system for wide range of applications. In this paper, we introduce a vehicle tracking platform which can be extended as a generic sensor networking platform having numerous applications ranging from medical to military and from aerospace to underwater.

Global Positioning System (GPS) is a well established localization and navigation infrastructure that has been extensively used almost for a decade. GPS receivers obtain geographical location on the earth using a set of four semi-geosynchronous circularly orbiting satellites. The Master Control station on the satellite controls the GPS receivers by periodical updates using time-dependent synchronisation signals [2]. The synchronisation provides the geographical coordinates every second. GPS receivers output National Marine Electronics Association (NMEA) standardised messages [3]. These messages can be interfaced with the development hardware to read the application specific GPS information to find location, velocity etc. Here we used the Recommended Minimum specific (RMC) Global Navigation Satellite Systems (GNSS) data to obtain the location of the moving node.

Global System for Mobile Communications (GSM) supports Short Message Service (SMS) that has revolutionised the interpersonal communications. The low latency of international SMS and its cost have made it popular among modern communication methods [4]. GSM modem modulates and demodulates the operator supported cellular network signals for SMS and other communication services. Our system uses GSM modem as the transceiver at the nodes and at the base station to transmit and receive the processed GPS RMC data and other control signals. General Packet Radio Service (GPRS) was used as data transmission medium in [5]. Since GPRS facilities may not be available from all GSM network towers, we are using SMS as a means of data carrier medium.

Fig. 1 represents the global outlook of the project, which consists of a set of mobile nodes, base station unit (including the database) and web based application which enable authorized users to access the information via a graphical interface. A MySQL database was used to store the information from mobile nodes which then be accessed via the web. MySQL is an open source relational database that uses Structured Query Language (SQL) to store and retrieve data. MySQL stores data and relationships among the data with minimal constraints on data extractions [6]. MySQL database used in our system records the GPS parameters – latitude, longitude, time and date – sorted by the Node number.

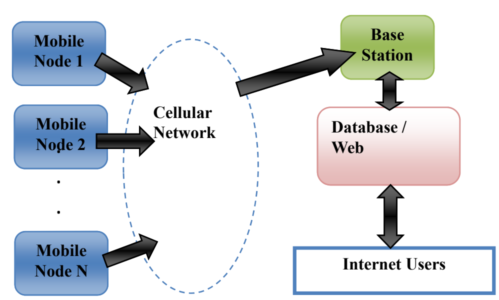

Fig. 1. Global outlook of the entire system

To display the location of the nodes', a "Google Map" [7] based web interface was developed, which is used to plot their present and past locations. Google map is a widely used utility to display location information on the earth. The application software provides option to embed the map on the webpage. Additionally, Google Application Programming Interfaces (APIs) supports additional features such as to plot a line from one coordinate to the other, centre the map to a particular location etc. Google map uses Java Script that can be embedded into our webpage code [8].

The rest of the paper is organized as follows: Section II describes the hardware and embedded system development for the mobile nodes and the base station. Also, a subsection of Section II explains about the data handling method implemented in the system. Section III details about the web interface and Section IV about curve smoothing followed by the results in the Section V. Finally, in the concluding remarks, we state future work to develop a generic sensor network platform based on this work.

II. Hardware Development

The hardware platform consists of two embedded electronic units: mobile node and the base station. Mobile nodes consist of self-localization sensor (GPS receiver) and a communication platform that enables them to send the sensor information to the base station. The base station, on the other hand, is equipped with communication platform to receive the information from mobile nodes and to transfer them to the database server. The operation of these units are explained in the following subsections of the paper.

A. Mobile Node

The mobile node consists of five major components - processor, GPS receiver, GSM modem, memory and power supply unit - as illustrated in Fig. 2. The Freescale HCS08 [9] family microcontroller was used as the processor, which supports two external SCI (Serial Communication Interface) based devices and (Inter-Integrated Circuit) IIC based devices. The GPS receiver and the GSM modem communicates with the processor through the SCI module. The memory unit (external) is an Electrically Erasable Programmable Read Only Memory (EEPROM), which is interfaced with the processor using the IIC interface supported by the processor. The power supply unit supplies required power to different components i.e. 4.2V for the SIMCom's SIM300C GSM modem [10], 3V for the microcontroller, EEPROM and the GPS receiver. Fig. 3 illustrates the assembled components in the prototype of mobile node developed at the NSC lab. The processor in the mobile node fetches the RMC data from the GPS receiver at predetermined intervals and stores them in the EEPROM. Data is accumulated into the memory for a fixed time interval based on memory and time constraints. An EEPROM function that reads the stored data in the memory and transfers data to the GSM Modem, is called to send the processed GPS data to the Base Station. In this system, SMS was used as data transfer medium to transfer information from mobile nodes to the base station. This mode of acquiring, processing, accumulating and then sending the data to the base station forms a non realtime vehicle tracking system. However, a real-time vehicle tracking system can be implemented using the data call feature supported by the GSM modem where in the data from the mobile node will be transfered in real-time to the base station.

B. Base Station Unit

Similar to the mobile node, the base station is also controlled by a Freescale HCS08 family microcontroller. The block diagram representation of the base station is shown in Fig. 4. The processor receives sensory information from the mobile nodes via the GSM modem connected to the SCI module. The received information is then processed before sending to the computer (database/ web server) via the RS232 link. The prototype base station linker unit is illustrated in Fig. 5. As a part of the base station unit, a computer program resides in the server computer that receives the data packet from the linker module and updates the database with the location information.

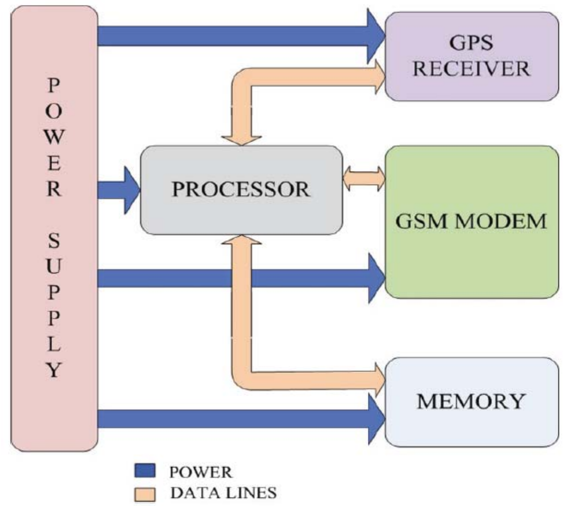

Fig. 2. Node mounted to the moving object that processes GPS coordinates and transmits data to the Base Station.

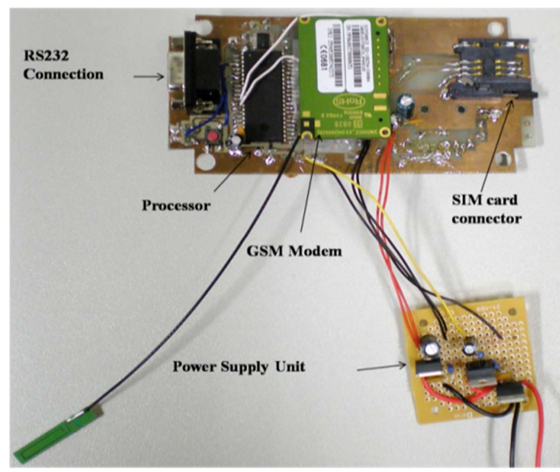

Fig. 3. Prototype of the mobile Node developed at Networked Sensing and Control (NSC) lab.

C. Data Handling

The data processing involves separating the Node number and the received GPS data respectively. An SMS might contain more than one GPS sampled data. Our system used single GPS sampled data in an SMS to the Base Station. The GPS data sampling time may be varied by programming the

microcontroller. The raw RMC data from the GPS receiver is in the following form:
$GPRMC,020713.000,A,3811.8177,S,14417.8550,E,0.51, 169.42,191208,,,A*76

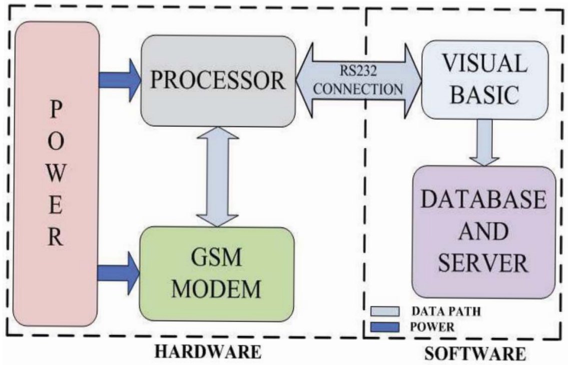

Fig. 4. Base Station acting as a controller and receiver, and connected to database through computer.

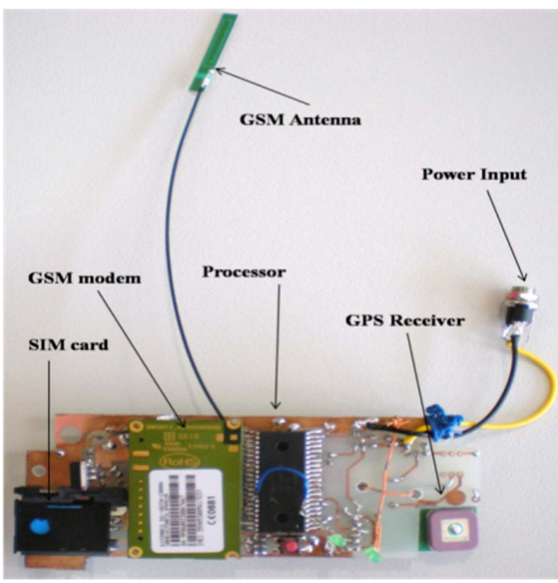

Fig. 5. Prototype of Base Station developed at NSC lab

Table I briefs about the information of sampled raw GPS RMC data. Tables II, III and IV represent sampled GPS data stored after processing at the base station using Visual Basic (VB). The Greenwich Meridian Time (GMT+0) is a standard time that most GPS receivers provide as their output NMEA messages. GPS receiver provides the latitudes and longitudes in ddmm.mmmm format, which is then converted to decimal degrees (dd.dddddd) format at the Base Station before storing into the database and the corresponding date is in ddmmyy format.

III. Web Interface Development

This section describes the web technologies used for displaying the tracking information based on user requirements.

TABLE I
EXPLANATION OF GPS RMC MESSAGE.

Message	Information
$GPRMC	RMC header
020713.000	UTC time (hhmmss.sss)
A	Message Validity (A=Valid / V=Invalid)
3811.8177	Latitude (ddmm.mmmm)
S	Direction (N=North / S=South)
14417.8550	Longitude (dddmm.mmmm)
E	Direction (E=East / W=west)
0.51	Speed over ground (in knots)
169.42	Course over ground (in degrees)
191208	Date (ddmmyy)
	Magnetic variation (in degrees)
	Variation sense (E=East / W=west)
A	Mode (A=autonomous /D=DGPS/ E=DR)
*76	Checksum
{CR} {LF}	End of message

TABLE II
DATABASE CONTAING GPS DATA SAMPLED AT 11S.

Date	Latitude	Longitude	(GMT+0)
100709	-38.196810	+144.296915	225006
100709	-38.196831	+144.296861	225017
100709	-38.197108	+144.296658	225028
100709	-38.196991	+144.296121	225039
100709	-38.197396	+144.295916	225050
100709	-38.197968	+144.295811	225101
100709	-38.198771	+144.295538	225112
100709	-38.199718	+144.294800	225122

TABLE III
DATABASE CONTAING GPS DATA SAMPLED AT 8S.

Date	Latitude	Longitude	(GMT+0)
100709	-38.196550	+144.304103	000844
100709	-38.196495	+144.304115	000852
100709	-38.196278	+144.304155	000900
100709	-38.195826	+144.304168	000909
100709	-38.195395	+144.303790	000917
100709	-38.195211	+144.303146	000925
100709	-38.195181	+144.302151	000933
100709	-38.195411	+144.300968	000941

TABLE IV
DATABASE CONTAING GPS DATA SAMPLED AT 5S.

Date	Latitude	Longitude	(GMT+0)
100709	-38.196471	+144.303958	023826
100709	-38.196431	+144.304036	023831
100709	-38.196250	+144.304088	023836
100709	-38.195925	+144.304143	023842
100709	-38.195665	+144.304023	023847
100709	-38.195385	+144.303748	023852
100709	-38.195233	+144.303305	023857
100709	-38.195180	+144.302760	023902

This interface is also the only point for the user to interact with the system. The database in the web server will be constantly updated by the base station with sensor location information received from the mobile nodes. This updated data is then used by the PHP program to plot the most recent coordinate and moves the balloon to indicate the most recent position of the vehicle being tracked to that point. Multiple vehicles can also be tracked at the same time. In such scenarios the system needs to be flexible to handle multiple data simultaneously such that the system retains its normal processing speed even with high data influx. For this reason, the database is designed to store information from mobile nodes (vehicles) under separate tables.

The vehicle is identified by the Subscriber Identity Module (SIM) number. If an entry in the database already exists for a particular vehicle, then the coordinates of the vehicle are directly transferred into the data table, else a new table will be created at runtime and the incoming data is stored into it. The database is created to store the newly arrived data up to 48 hours and clear the stored data automatically from the database after the time interval. Extracts of data stored in the database are shown in Tables II, III and IV. Vehicle and user details are also stored in the database. The system permits authorized users to track required vehicles based on their username and password.

Google map is the most popular tool available for plotting the geographical coordinates. It supports Asynchronous JavaScript and XML (AJAX) APIs for mapping applications [11]. It also provides option for the web programmer to embed the Java Scripted map API into the developer's web program. We have used PHP programming to embed Google map into our web page. The PHP program is linked to the MySQL database to fetch the data. On successful connection establishment, the PHP program fetches the stored information from the database and plots at regular intervals. Our system uses GLatLng, an object provided by Google API to plot latitude and longitude and Gpolyline to connect the latitudes and longitudes linearly.

IV. Curve Smoothing

The curves that are plotted are not smooth. One method to smoothen the curve is to sample the GPS data regularly maintaining high sampling rate. Data can be sampled every second, processed and stored into a memory. However, sampling the GPS data at every second requires more power to store the data. Apart from power, system needs huge memory to store the processed data. On top of that, if the nodes need to be tracked in real-time, SMSs should be sent frequently that burdens the entire network. To overcome this problem, one possible solution is to sample the GPS data at less frequent times and send an SMS to the Base Station. At the Base Station, the data be extrapolated using mathematical tools to smoothen the curve.

V. Results

Fig. 6 depicts the path traversed by the test vehicle on the outskirts of the Deakin University. The blue colored line is the path traversed by the test vehicle. For the purpose of testing, the mobile Node was plugged into the cigarette lighter charger to supply power to the circuit. Upon receiving the GPS signal, the processor on the Mobile Node processed the GPS data and SMSs containing GPS information were sent to the Base Station. Transmission of SMS can be marked as the

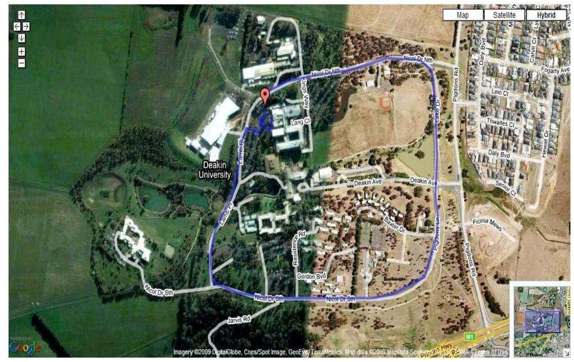

Fig. 6. Path traversed (dark blue line) by the mobile Node (i.e. the test vehicle) around Deakin University - compiled using Google Maps.

commencement of the test. The test vehicle driven around the campus is shown in Fig. 6. LEDs (Light Emitting Diodes) were successfully under normal conditions and could approximate the actual path traveled by the vehicle being tracked. The plot in Fig. 6, however, shows that the path drawn is not smooth. This is related to the fact that the coordinates are sampled at predefined intervals (11s) and sent via SMSs. Sampling time and processing speed of the node can be the two main factors affecting the plot. With the same sampling rate, if the vehicle moves at higher speed, then the error associated with the plotting increases significantly and vice versa. Fig. 8 and Fig. 9 show the path traversed by the test vehicle for 8s and 5s sampling time respectively. The driving speed was maintained at 30-40Km/h while testing. Clearly, for the 5s sampling rate, the accuracy of the path traversed has increased significantly.

Fig. 7. Path traversed for data sampled at 11s - compiled using Google Maps.

VI. Concluding Remarks

Sensor networks can be deployed to places that are uninhabitable to humans and monitor real-time via SMS. Since the cellular network is widely established, it is feasible to use SMS as data carrier. However, there may be some delay in SMS arrival depending on the network properties. Also, places where the network strength is low may pose a serious problem in transmitting the sensor data via SMS. Therefore, in places where there is a good cellular network, SMS supported by GSM can be used to monitor the sensor data. Apart from communication limitations, the system needs to consider other limitations [12] such as available energy to power up the system, memory to hold sensor data and the processing capacity.

Fig. 8. Path traversed for data sampled at 8s - compiled using Google Maps.

Fig. 9. Path traversed for data sampled at 5s - compiled using Google Maps.

According to [13], the work carried on SMS delay for the 160 character message highlights that the delay for an SMS was about 12s. The maximum delay for the bulk message scenarios was less than 45s. In our system, to reduce the bulkiness of the SMS, work is being carried on data compression algorithm that reduces the SMS size as well as to incorporate more GPS sampled data in a single message without losing data. This enables our system to be reliable with reasonable delay in updates and less network congestion.

This work lays the foundation to the GSM based data collection network. Apart from GPS sensors, there are other sensors such as temperature, pressure, pH, vibration (acceleration) etc., that have numerous applications in industrial, environmental and military aspects. As future developments, the system will be equipped with Internet based programming capabilities that allows users to test their algorithms in a real-world wireless sensor network with the use of radio communications at much lesser costs and improved accuracy [14].

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