

# ARCHITECTURE AND IMPLEMENTATION OF REAL TIME VEHICLE TRACKING SYSTEM USING WIRELESS, SENSOR DEVICES AND GOOGLE MAPS API

Syed Khizar Ahmed<sup>1</sup>, Kiran Kumar Sreenivasiah<sup>2</sup>, S. M. Ahmed<sup>3</sup>, Shiva Kumar A<sup>4</sup>

Tracking Solutions Department,  
Empowered Security Labs Private Limited,  
Bangalore, India.

khizarahmedsyed@gmail.com<sup>1</sup>, kirankumar8951@gmail.com<sup>2</sup>, smahmed\_blr@yahoo.com<sup>3</sup>, shivakumar1000@gmail.com<sup>4</sup>

**Abstract—** *The integration of different technologies potentially provides support to wide variety of applications and systems with vastly varying requirements and characteristics. Vehicle tracking system is one of such applications possible by embedding wireless sensor devices on the vehicles. The motor carrier industry has been investing in and implementing vehicle tracking, for a number of reasons, particularly the increase in efficiency achieved through better management of both personnel (drivers) and assets (trucks or, as they are known, tractors; cargo loads; and trailers). Recently, Vehicle Tracking Systems (VTS) are developed and deployed in numerous environments. These systems are capable of transmitting vehicle's location information and other custom parameters in real time. In these systems, the device installed in the vehicle can transmit the location information, speed of the vehicle at that particular instance, total kilometer run of the vehicle, ignition status, battery status and many other custom parameters in real time to a remote data centre using SDMP protocol. In this paper, we present the design and implementation of a real time VTS that incorporates a hardware device installed in the vehicle and a remote data center with tracking sever and a web application with Google Maps API to depict the trail of the vehicle.*

**Key Words—** *Vehicle Tracking, Wireless Sensor Devices, Positioning*

## 1. INTRODUCTION

With the rapid advancements in the micro-electrical-mechanical systems (MEMS) technology, coupled with processing, memory and radio technology has enabled small and cheap nodes capable of wireless communication [1]. The addition of sensing capability to such devices drives the development of innumerable applications such as monitoring environment, managing inventory, monitoring disaster areas etc. One of such important applications is vehicle tracking system.

Vehicle Tracking Systems aid in determining the geographic positioning information of vehicles and transmitting it to a remotely located server.

The vehicle's location is determined using GPS, while the transmission mechanism can be satellite, terrestrial radio or cellular connection from the vehicle to a radio receiver, satellite or nearby cell tower. Once the positioning data along with other custom data is collected, it is transmitted through a wireless communication system. The most economical viable service used for this purpose is GSM/GPRS. In this paper, we briefly describe the architecture and implementation of the real time Vehicle Tracking Systems (VTS) using GPS for positioning information and GSM/GPRS for transmission of the information. The design and implementation of the system includes acquisition and transmission of vehicle's location information along with ignition status, fuel status, battery status, input power, number of satellites locked, unit status, GPS antenna condition, total kilometers run of the vehicle and vehicle moving/stationary/idling information to the data center/tracking server.

Additionally, system also provides a web based application interfaced with Google Maps API to display all transmitted information to the end user along with location trail of the vehicle on the map. The web application has an internal global timer which refreshes the tracking website every forty seconds and fetches the latest location data and other customized vehicle parameters and updates the end user with the latest information of the vehicle. There are two basic components of the system: a hardware device called In-Vehicle-Device (IVD) and a Remote Tracking Server (RTS).

IVD has GPS receiver that receives signals from GPS satellites and calculates its position in the form of latitude and longitude. This information is transmitted to TS using GSM/GPRS on GSM network. The information is

transmitted using TCP/IP connection with TS through GPRS. The TS has a dedicated secured socket for this communication and stores the information in the database. This information is available to the authorized users of the system via website over the internet.

The rest of this paper is organized as follows: Section II describes the design and implementation details of the proposed system. It covers the hardware and software design of devices developed to determine and transmit the vehicle's information, such as its location, to the remote TS. It also discusses the design of hardware used on the TS side, and the design of web based interface for user interaction. Section III presents future work and concludes the paper. Figure 1 illustrates a generic architecture of the Vehicle Tracking System.



Figure 1: Architecture of Real Time Vehicle Tracking System

## 2. SYSTEM DESIGN & IMPLEMENTATION

### A. System Architecture

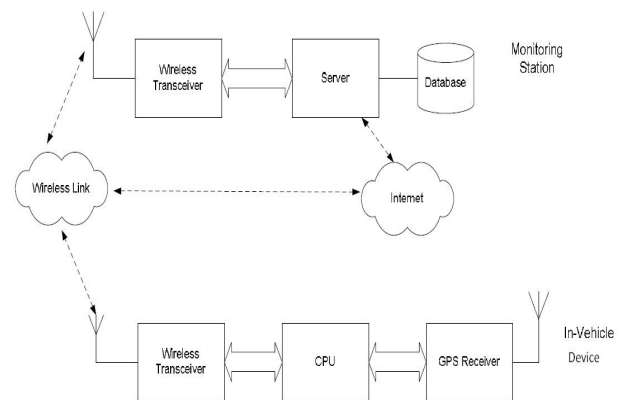


Figure 2: High-level architecture of the system

Figure 2 illustrates the high-level architecture of the system. Overall system is partitioned into two major design units: In Vehicle-Unit (IVU) and Tracking Server/Monitoring Station (TS). IVU is designed using Quectel L20 GPS module, Quectel M12 GSM module and ARM LPC2148 microcontroller. IVU is installed into the vehicle. It is responsible for capturing the current location of vehicle, speed of vehicle, ignition status, GPS antenna status, total kilometer run, fuel status, input power and vehicle main battery status. IVU is also responsible for transmitting this information to TS located anywhere in the world [2].

#### 1) GPS Receiver

IVU uses GPS receiver to capture the live parameters of the vehicle. This data provided by GPS is not in human understandable format. This raw data needs to be processed so that it can be converted into useful information, and then displayed on the map. CPU is required to perform the necessary calculations to achieve this goal. Quectel L20 GPS receiver [3] is used for this purpose. GPS receiver can also provide information of altitude, time of GPS fix, status of GPS fix, and number of satellite used to compute current location information along with other customized parameters. GPS fix means last reported location. For tracking purpose, only location is required; while the other data provided by GPS receiver can be used to determine the validity of location information.

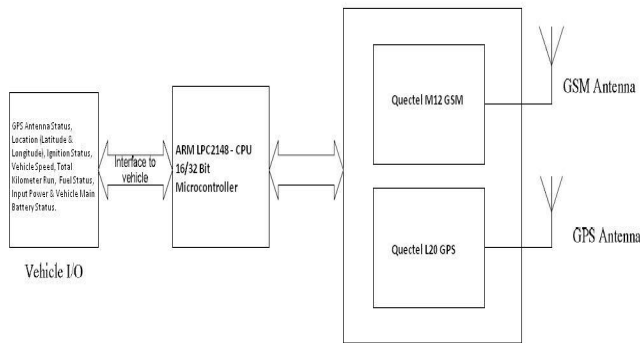


Figure 3: Architecture of In-Vehicle-Device (IVD)

## 2) Central Processing Unit (CPU)

The raw data provided by the GPS receiver is captured by the CPU and processed to extract the required. CPU is also responsible for monitoring the other customized parameters of the vehicle. CPU holds all the required information that is to be transmitted to remote TS. It also controls data transmission module to exchange information with remote TS. It actually acts as a bridge between GPS receiver, vehicle, and remote TS. The processing required in the IVD is not computationally intensive; therefore any low-end microcontroller can be used as a CPU. ACRON computer's ARM LPC2148 [8] is selected to serve as the CPU for IVD. This is a 32-bit microcontroller and runs at the speed of 60 MHz, which is enough speed for the system to operate smoothly.

## 3) Data Transceiver

When all required information is extracted and processed, it needs to be transmitted to remote TS. TS is responsible for providing this information to the end user or application. We have used wireless network to transmit vehicle's information to remote TS. Existing GSM network is selected to transmit vehicle's information to remote TS, since it has wide coverage. It is also less expensive approach as compared to deploying our own network for transmission of vehicle's information. GSM modem is required for data transmission over GSM network.

## B. Interface Board Design & IVD Software Design

First step in circuit design of IVU is to design interface circuit for Quectel L20 GPS so that it can be interfaced with microcontroller. Quectel

L20 GPS provides several features including GSM Antenna connector, board-to-board interface connector, SIM card reader and GPS antenna connector.

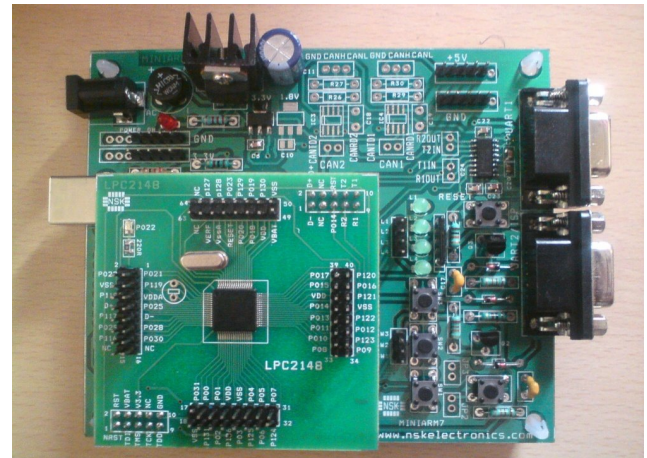


Figure 4: PCB board of LPC2148

The LPC2148 microcontroller is based on a 32 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory up to 512 kb. A 128-bit wide memory interface and a unique Accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty. The LPC2148 devices currently have two on-chip UARTS. They are both identical to use, except UART1 has additional modem support. Both peripherals conform to the "550industry standard" specification. Both have a built-in baud rate generator and 16 byte transmit and receive FIFOs [7].

The *UART Receiver Buffer Register* (U0RBR) is the top byte of the UART Rx FIFO. The top byte of the Rx FIFO contains the oldest character received and can be read via the bus interface. The LSB (bit 0) represents the "oldest" received data bit. If the character received is less than 8 bits, the unused MSBs are padded with zeroes. The Divisor Latch Access Bit (DLAB) in U0LCR must be zero in order to access the U0RBR. The U0RBR is always Read Only. Since PE, FE and BI bits correspond to the byte sitting on the top of the RBR FIFO (i.e. the one that will be read in the next read from the RBR), the right approach for fetching the valid pair of received byte and its status bits is first to read the content of the



U0LSRregister, and then to read a byte from the U0RBR.

The *UART Transmit Holding Register* (U0THR) is the top byte of the UART0 TX FIFO. The top byte is the newest character in the TX FIFO and can be written via the bus interface. The LSB represents the first bit to transmit. The Divisor Latch Access Bit (DLAB) in U0LCR must be zero in order to access the U0THR. The U0THR is always write only.

The *UART Divisor Latch Register* is part of the UART0 Fractional Baud Rate Generator and holds the value used to divide the clock supplied by the fractional pre-scalar in order to produce the baud rate clock, which must be 16x the desired baud rate. The U0DLL and U0DLM registers together form a 16 bit divisor where U0DLL contains the lower 8 bits of the divisor and U0DLM contains the higher 8 bits of the divisor. The Divisor Latch Access Bit (DLAB) in U0LCR must be one in order to access the UART0 Divisor Latches.



Figure 5: QUECTEL L20 GPS Module

Quectel L20 GPS is used to get exact location in terms of longitude and latitude so that the area in question can be exactly known. GPS receiver constantly receives the data from GPS satellites in the form of coded signals. These are decoded using a set of standards called NMEA. The received data is sent to ARM and stored in EPROM. NMEA has a variety of protocols we use the protocol “GPGGA” [4]. An example is as shown below

**\$GPGGA,134158.48,6016.3072,N,02458.3788,E,1,08,1.2,,,,,0000\*1E**

#### *Dissecting the GPS message string*

The NMEA standard dictates how each string is formed with a dollar sign (\$) leading each new GPS message. A brief description of the seven standard message strings is:

- \$GPGLL - Geographical position, latitude and longitude
- \$GPGSA - GPS dilution of precision and active satellites
- \$GPGSV - GPS satellite in view
- \$GPGGA - GPS fixed data
- \$GPRMC - Recommended minimum specific GPS/TRANSIT data
- \$GPVTG - Track made good and ground speed
- \$GPZDA - Time and date

The \$GPGGA string is popular examined because it contains navigational data most commonly sought after.

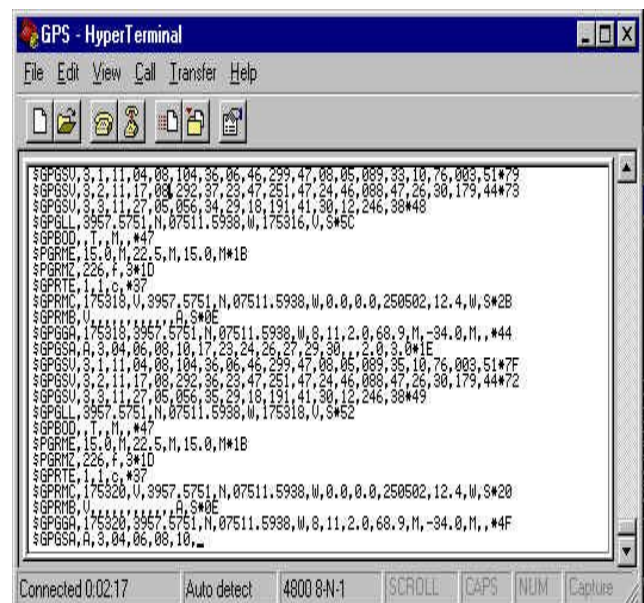


Figure 6: Hyper Terminal Output

#### *Format of \$GPGGA message string*

The format for the \$GPGGA message string is:  
\$GPGGA, hhmmss.dd, xxmm.dddd, <N | S>, yyymm.dddd, <E | W>, v, ss, d.d, h.h, M, g.g, M, a.a, xxxx\*hh<CR><LF>

Table 1 shows the format of *GPGLA* message string

hhmmss.dd	UTC time hh = hours mm = minutes ss = seconds dd = decimal part of seconds
xxmm.dddd	Latitude xx = degrees mm = minutes dddd = decimal part of minutes
<N   S>	Either character N or character S, (N = North, S = South)
yyymm.dddd	Longitude yyy = degrees mm = minutes dddd = decimal part of minutes
<E   W>	Either character E or character W, (E = East, W = West)
V	Fix valid indicator 0 = Fix not valid 1 = Fix valid
Ss	Number of satellites used in position fix, 00-12. Fixed length.
d.d	HDOP – Horizontal Dilution Of Precision
h.h	Altitude (mean-sea-level, geoid)
M	Letter m
g.g	Difference between the WGS-84 reference ellipsoid surface and the mean-sea-level altitude
M	Letter M
a.a	NULL (missing)
Xxxx	NULL (missing).

Quectel M12 GSM module is a digital wireless network standard used in the project to send the data from the IVD to the TS [9].

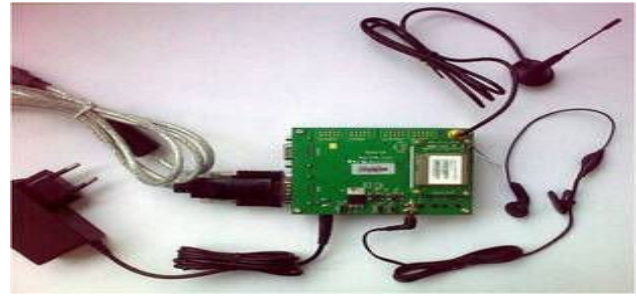


Figure 7: Quectel M12 GSM module

The GSM network is divided into three major systems,

1. Switching System (SS).
2. Base station System (BSS)
3. Network Switching System(NSS)
4. Operation and Support System (OSS).

The frequency range specified for GSM is 1,850 to 1,990 MHz (mobile station to base station). The duplex distance is 80 MHz. Duplex distance is the distance between the uplink and downlink frequencies. A channel has two frequencies, 80 MHz apart. The separation between adjacent carrier frequencies. In GSM, this is 200 kHz. Modulation: Modulation is the process of sending a signal by changing the characteristics of a carrier frequency. This is done in GSM via Gaussian minimum shift keying (GMSK). GSM is a digital system with an over-the-air bit rate of 270 kbps. GSM utilizes the time division multiple access (TDMA) concept. TDMA is a technique in which several different calls may share the same carrier. Each call is assigned a particular time slot. GSM uses linear predictive coding (LPC). The purpose of LPC is to reduce the bit rate. The LPC provides parameters for a filter that mimics the vocal tract. The signal passes through this filter, leaving behind a residual signal. Speech is encoded at 13 kbps [5].

### C. Design of Tracking Server (TS)

Figure 8 illustrates the architecture of TS. TS maintains the information received from all of the IVUs installed in different vehicles in a database. This database is accessible from internet to authorized users through a web interface. Authorized users can track their vehicle and view all of the legitimate information stored in the database.

### 1) MAP App Server

The MAP App Server is a Microsoft window form application with the implementation of secured socket programming in it. The server has a static IP Address and a dedicated socket for the communication. The MAP App application runs continuously in the server and is constantly listening on a dedicated port number. Once the data string is read, this application parses the string and stores the data in their corresponding columns in the table of the database. This is a continuous process [6].

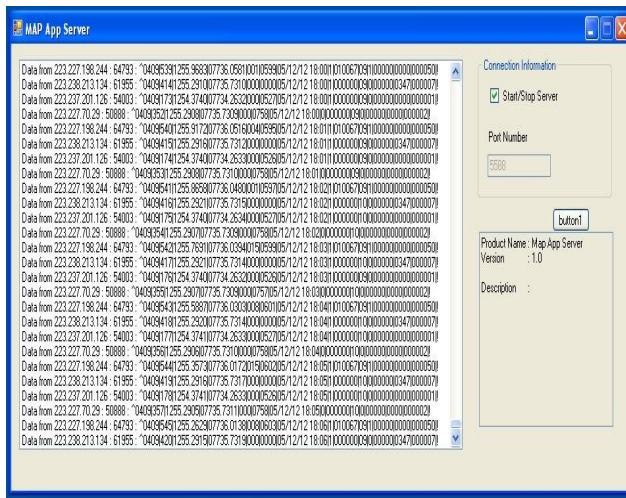


Figure 8: MAP App Server

### 2) E.S Labs Tracking Website

The Tracking website is a Microsoft web for application which is interfaced with Google Maps API [8] and Value First SMS API along with a timer which enables the web application to fetch the latest data from the database and display it on the Google Map in an interval of every 40 seconds. This web application queries the database for the latest records of the vehicles. The web application is a very dynamic fusion of a Real Time Vehicle Tracking System integrated with a Fleet Management System. This gives the end user the flexibility and power of vehicle tracking along with the fleet management to ensure optimum results.

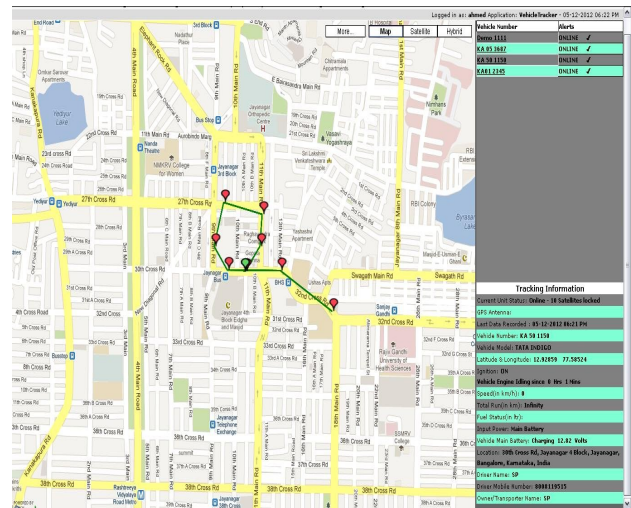


Figure 9: E.S Labs Tracking Website

The data obtained from the IVD is a raw string and needs to be converted into human understandable form. Hence many characters from the raw string are converted into equivalent results that can be understood by the end user. For Example: consider the speed of the vehicle as a raw value of 15 that is obtained from the IVD that is stored in the database. The web application reads this raw value which is then multiplied by 1.85 to obtain the actual speed of the vehicle which is 27.77 km/h.

Tracking Information	
Current Unit Status:	Online - 11 Satellites locked
GPS Antenna:	Connected
Last Data Recorded :	05-12-2012 06:48 PM
Vehicle Number:	KA01 2345
Vehicle Model:	Ford
Latitude & Longitude:	12.90629 77.57102
Ignition:	OFF
Vehicle Stationary since	1 Hrs 18 Mins
Speed(in km/h):	0
Total Run(in km):	13759.22
Pulse Counter	Disconnected
Fuel Status(in Itr):	
Input Power:	Main Battery
Vehicle Main Battery:	Discharging 12.16 Volts
Location:	Outer Ring Rd, Ilyas Nagar, Kumaraswamy Layout, Bangalore, Karnataka, India
Driver Name:	N...
Driver Mobile Number:	8...
Owner/Transporter Name:	N...

Figure 10: Tracking Information Data

The tracking web application also offers a very unique option of the route replay for the end user where the user can select the vehicles along with the start date time and end date time and query the database to obtain the entire route travelled by the selected vehicle between the start and end date time as shown in the Figure 11 below:



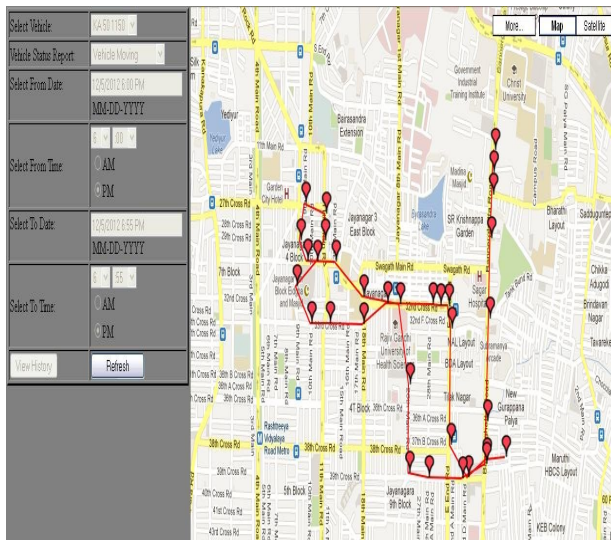


Figure 11: Route Replay

The web application also has various reporting features where the end user can obtain daily reports, fuel entry reports, correction reports etc for the desired vehicle. The user can register the vehicles and map them to different drivers. End user can also keep a record of the fuel consumption of the vehicle on a monthly basis and also download the information in the report form.

The integration of SMS API enables the user to obtain critical information regarding the vehicle when the user is not connected to the internet these alerts could be vehicle theft alerts and accident alerts etc this is done via sending sms to the user's registered cell phone number. There are few standard conditions during which sms is triggered to the user's cell phone. These alerts help the end user keep a track of the vehicles even when they are not connected to the internet through the E.S Labs Tracking Website. The below Figure 12 shows SMS alert triggered during critical conditions.



Figure 12: SMS Alerts

### 3. CONCLUSTION & FEATURE WORK

Real time vehicle tracking system is successfully implemented using GSM network where GPRS is used as communication medium to achieve the desired properties of Vehicle Tracking System (VTS). The earlier versions had two boards interfaced; however the current implementation has a single board which reduces the number of components and the cost reduction as well. Further, advanced user interaction will be employed into IVD to allow the vehicle driver to exchange information with the remote TS while driving the vehicle. Future works also include recording of audio & video of up to 40 hours to view, once the vehicle comes back from an assigned trip. Data can be downloaded to a USB pen drive. Built in microphone to listen to what is happening in the vehicle in case of theft, hijacking or for spying. Camera can be installed to monitor unwanted stops and to know the actual cause in case of an accident. Ignition Immobilizer functions from server in case of theft. CAN BUS integration and Keypads, graphical display, touch screen etc can also be implemented to provide advanced security features.

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