Tracking Solutions for Fleet Management Systems

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Design and development of commercial GPS receivers has gained tremendous momentum ever since GPS satellite systems were made available for general civilian use. With the increasing technology improvements and easy/cost effective availability of such devices, there has been great demand for tracking and navigation systems which deploy GPS receivers to estimate the current location and timing information. Such systems, when integrated with communication standards such as GSM/GPRS, additional sensors and a master controller, result in tracking systems which are nowadays used extensively in a number of application scenarios. In this article, we will discuss one such utility of these systems in fleet management systems wherein fleet owners may keep track of their vehicles’ location and status ensuring security and safety of the vehicles and increase the business productivity by better communication and tracking. Utility of these systems is further increased with the integration of MEMS accelerometers and gyroscopes, camera sensors and driver authentication systems which collectively implement a “black-box” type of functionality and provide anti-theft, vehicle crash detection, and warning to the administration, thereby triggering security and rescue operations.

The complete solution includes a vehicle tracking unit and fleet management software, wherein the location of the vehicles can be viewed in a map display format on a PC/Laptop/Phone with internet connectivity.

**OVERVIEW:**

In general, tracking solutions can be classified as ‘active real time tracking and passive tracking solutions.’ In passive tracking solutions, the location and status information of the vehicles is
continuously monitored and stored in the memory device at the vehicle end. Upon reaching the destination, this system is interfaced with the computer in order to download the information and display on a suitable software application. On the other hand, real time or active solutions acquire the vehicle’s location data and transmit the same in real time over a communication medium, generally GSM/GPRS. In real time tracking, systems can communicate with the web application in two ways.

1. Via SMS: In this case, a separate GSM receiver is required on the admin side, which extracts the information from SMS and transmits the same to the computer application.

2. Via GPRS: In this case, the system requires internet connectivity and a web server with Fleet tracking web application running on it. This real-time data can be viewed on internet enabled PC/Laptop by accessing the provided web link. In the present solution the Hyper Text Transfer Protocol (HTTP) GET and POST requests are used to communicate with web server.

Another classification of these systems can be done according to the application scenario - applications which require user interface such as those used by commercial car rental services or the systems where tracking system is embedded as a black box and is responsible for simply transmitting the vehicle location and status information and do not require user intervention.

**TRACKING SYSTEM DESCRIPTION:**

The tracking system consists of a vehicle unit and an optional remote unit for driver authentication, respectively showed in Figure 2 and Figure 3.

![Figure 2: Vehicle Unit](image1)

**Figure 2: Vehicle Unit**

The Vehicle unit collects the GPS/GLONASS information, shows it on an embedded OLED LCD and sends through GPRS to the web server application. Using on board MEMS, accelerometer and gyroscope, the
vehicle unit works as anti-theft mechanism too, monitoring senses car lift, and as black-box in case of crash event, sending real-time vehicle parameters by SMS and storing this information on onboard microSD.

The Tracking System Vehicle unit is based on ST’s ARM Cortex-M3 Microcontroller core, STM32F207. The application utilizes the high performance of STM32F2, providing 150DMIPS@120Mhz, really low power operation, an extensive peripheral set, embedded memory, up to 128KB of RAM and 1MB of Flash, eliminating any external processor or memory requirements.

The application firmware is based on FreeRTOS (open source Real Time Operating System) framework, utilizing benefits of multithreading real time operation for time bound tasks.

On board is available the one-chip GPS/GLONASS receiver, Teseo-II. ST’s new Teseo-II line of multi-constellation, System-on-Chip (SoC), single-die with integrated RF, GNSS receivers support additional accuracy and availability by tracking GPS, GLONASS, and Galileo satellites at the same time, with the net result of nearly doubling the number of available satellites in most signal environments.

The GSM/GPRS on-board SAGEM module is available for transmitting vehicle status and location information over GPRS to web server application.

The presence of MEMS sensors on board – Accelerometer and Gyroscope - detect unusual conditions such as vehicle-theft, skid/roll-over and communicate the status to the web application by GPRS or to mobile by SMS. These can also be used to extrapolate the location information for a limited period in case of GPS signal loss, dead-reckoning.

Real time information is displayed locally on the vehicle unit on board 2.5” OLED LCD. These vehicle units can be configured for various parameters such as over speed limit and valid driver list in real time. The report for previous journeys can be viewed from the web application. The solution can be powered
by 12V car battery or by re-chargeable 3.7V Li-ion battery, 1800 mAh. Otherwise there is a Super Cap, 0.22 Farads, that powers the STM32 BackUp Domain in case the main power is switched OFF.

**Driver Authentication:** A remote control can be used to authenticate the driver, in order to un-lock and start-up the tracking system vehicle unit. Upon entering the correct pin on remote control, the driver ID is transmitted over IrDA to the vehicle unit. If this ID matches with that found in the valid drivers’ list, the system unlocks. Repeated invalid access trials are monitored and the corresponding driver ID is blocked if the trials exceed the limit.

**Real Time Vehicle Location Tracking:** The location data such as latitude, longitude, time, date, ground speed, number of satellites fixed, is extracted from the NMEA output from the GPS/GLONASS module over UART interface. This information is communicated over GPRS to the web application. The rate at which tracking information is communicated to the web application can be a configurable parameter. In order to make the most of continuous real time tracking, system power consumption and best GPRS bandwidth utilization, this rate can be modulated as per the speed of the vehicle.

**System Alerts:** Vehicle location information is complemented with some alerts which allow the fleet owners to have more precise tracking and control over their vehicles’ movement. They include over speed event, vehicle lift - sensed by on board MEMS accelerometers sensors, vehicle overturn/skip event detection using on board gyroscopes, invalid access to the vehicle, tamper detection, PANIC button pressed event, etc.

<table>
<thead>
<tr>
<th>ST Products</th>
<th>Main features</th>
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<tbody>
<tr>
<td>STM32F207</td>
<td>ARM-Cortex M3 core, 150DMIPS@120Mhz, 128Kb RAM, 1MB Flash, DMA, Camera Ifs, USB OTG, other COM Ifs</td>
</tr>
<tr>
<td>TESEOII</td>
<td>FASTRAX IT600 Module based on TESEOII, ARM946 up to 208MHz, One-chip GPS/GLONASS, Anti-Jamming</td>
</tr>
<tr>
<td>LIS331DLH</td>
<td>MEMS three-axis Accelerometers, 12bit, ±2, ±4, ±8g</td>
</tr>
<tr>
<td>L3G4200D</td>
<td>MEMS three-axis Gyroscope, ±250/500/2000dps, 16 bit data output</td>
</tr>
<tr>
<td>STTS751</td>
<td>Temperature Sensor, -40°C to 125°C</td>
</tr>
<tr>
<td>M24M01</td>
<td>1 Mbit serial i2C bus EEPROM</td>
</tr>
<tr>
<td>L6924</td>
<td>Li-Ion battery Battery Charger</td>
</tr>
<tr>
<td>L4978, LD39150, LD39150</td>
<td>DC-DC converter, respectively: 12V to 5V, 5V to 3.3V,5V to 3.9V.</td>
</tr>
<tr>
<td>STLDC08, STS6NF20V</td>
<td>Voltage boost, N-Channel Power MOSFET</td>
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*Table: ST Key Products*
**Black Box Functionality:** On board MEMS sensors use an algorithm to determine events such as vehicle crash, overturn or skid, following which the vehicle location and status information is logged inside removable memory and the system transmits this information as an alert to the admin mobile number. On reception of such an alert, safety and rescue operations can be triggered.

**GPRS Network Signal Loss:** The communication between vehicle unit and web application follows a handshaking process, in the sense that if it does not receive an acknowledgement, the information is resent. In case of no network coverage, to ensure no data loss, the tracking information is stored inside the on board memory and sent as bulk data to the application when the GPRS communication is up and running.
Web Application Description

The fleet management software application is a web based interface used to track a fleet of vehicles by capturing the real-time data from the field and mapping it on the web interface. It is an integration of multitudinous technologies associated with a system that is executed over the internet.

![Web application](image)

Figure 5: Web application

Client-Server Model

The complete system is based on the Client – Server model of networking. The vehicle unit acts as the client in this model with the web application as the server. The web application makes use of ASP.NET Technology for the development of the application with JavaScript support for client-side scripting. The vehicle unit acts as client in this model and initiates the command in the form of request to the server using HTTP request format, which is passed over the World Wide Web (WWW) to the server as its destination. The web server acknowledges the request with a status code specified in the HTTP Protocol.

![Web Application Architecture](image)

Figure 6: Web Application Architecture
**Database Connectivity**

The server processes the data frame captured in the request from the vehicle unit and manipulates it to store the data in the form of tables in the database by executing SQL Query using ADO.NET connections with MS-SQL Server. The data is structured and stored in a database which is used by the web interface to map the data. The web application interacts with the database and runs on the Web Server.

**Embedding Maps in Application**

Maps are embedded into this web application using OpenStreetMaps which are based on the OpenLayers mapping library in JavaScript (Client-Side Scripting Language). There are varieties of mapping libraries available over the Internet like Bing Maps, Google Maps and OVI Maps etc. But the main advantage of OpenStreetMap over any of the above mentioned libraries is the open-source aspect of this library. This library provides many attributes and features with an additional property to customize it as per the requirements.

**User and application**

The user can interact with the web application by hitting a web link using any internet browser like Internet Explorer, Safari, Google Chrome, etc. The user is redirected to the main page of the application only with an authenticated login success. This application has a provision of adding/modifying the existing vehicles‘ and drivers‘ details. The vehicle location corresponding to an already registered vehicle can be viewed in real time over the map display.

**Application, Database and Web Server**

Th user interacts with the application to monitor the vehicles, which further interacts with the database server to update itself after a fixed interval of time that is also provided as a configurable parameter in the application. The database interacts with the web server to retrieve the latitude, longitude, speed, distance, time, and related parameters from the Vehicle Unit through GPRS.

**Journey Tracking**

Tracking is constructed and updated using the latitude and longitude co-ordinates stored in the form of an XML document, which is an input to the mapping library to generate the track from that file. The XML document is created dynamically in the application and is updated with the list of co-ordinates received from the device. The start of journey and current position of journey are indicated with the help of markers placed on the map. Markers also provide the latitude and longitude of the position marked.
Reports Generation for future Use

The utility of maintaining and organizing a database for the data received from the registered vehicles makes a provision to generate a report of any specific vehicle’s journey using a calendar selection mechanism.

![Image of vehicle tracking interface]

Figure 8: Generating Journey Reports

The use of such tracking solutions is not limited to fleet management systems, but is very well extended to asset tracking, and consumer applications such as handheld navigation devices. Integration with thermal printers is another value addition for tariff printing. Modern day tracking solutions also offer geofencing, where an imaginary boundary is implemented to mark certain area and an algorithm is implemented to determine if a vehicle enters or leaves the marked region. Existing camera sensors technologies can be integrated to boost the security and safety value of tracking solutions. Another useful feature for these systems is extrapolating the vehicle location and speed information in case of GPS signal outages. However, the accuracy and duration for which low cost MEMS can be effective in determining vehicle speed and location is still a topic of debate and research.

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