

Vehicle Security and Management System on GPS Assisted Vehicle using Geofence and Google Map

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Abstract. Global Positioning System (GPS) receiver installed in motor vehicles have been used to track vehicles. The position of vehicle is transmitted via a wireless network using cellular telephone network known as GSM (Global System for Mobile communication). A vehicle that has GPS receiver installed onboard connected with GPRS modem and connected to a computer system in the Internet can be monitored and then provide alert when it travels outside the predefined area. This area is very important for many situations such as city car rental, trucking company to send goods from one city to another and logistic company with many fleets. The system designed here is a module with a GPS and a GPRS already integrated in one module. The output of the GPS receiver is connected to a microcontroller. The microcontroller dictates which data is collected via the GPS receiver and then sends the information to a computer system via GPRS modem. The microcontroller also receives command from the computer system via the GPRS connection and then can act accordingly, such as change the frequency of geo-coordinate or turn the vehicle engine off if necessary. This device will help the user to track its vehicle via GoogleMap with the GPS coordinate data sent to the database server every 10. This device will enable the operator to turn off the vehicle engine and one other device onboard the vehicle if necessary. With the feature of Geofence on the Web server using HTML5, a virtual fence has been built around the GoogleMap and when the vehicle moving outside the fence the user can be alerted either via email or color change on the web page. The device has been tested and shown to be working with all the conditioned mentioned above. The computer system that displays the web page together with the geofence has been developed and shown to be working properly as indicated.

Keywords: vehicle geofence, Google map, fleet management, GPS assisted vehicle tracking

1. Introduction

Vehicle tracking system using Global Positioning System (GPS) is a system that uses the GPS to locate the geographic coordinate of vehicle was developed previously [1]. The device itself is basically a radio receiver tuned into the frequency of the transmitting frequency of the GPS satellites in which it enables the receiver to compute its geographic coordinate. There are several data sets that can be obtained from the GPS satellites such as the accurate position of the receiver within certain radius, number of satellites received by the unit, speed of the GPS receiver moving, and accurate date/time based on the Universal Time Coordinated). Distance between the transmitting satellites and the GPS receiver is determined by using accurate time lapse between the satellites – which uses very accurate atomic clock – and the receiver using less accurate quartz crystal. Although the crystal clock is less accurate, but the result of the distance is still very accurate up to one meter resolution or less. The signal sent by the satellites includes the timestamp of the signal send and the receiver will determine the distance by measuring the time to travel to the receiver.

Using a triangulation method based on the distance from the GPS satellites, the position of the GPS receiver will be known precisely within a few meters as describe in [1-5]. This can be achieved because the precise position of the GPS satellites is excellent and reliable. Uncertainties of the distance can arise because of several physical phenomena such as temperature gradient on the atmosphere, signal bounce due to objects, and strength of satellites signals received by the GPS receiver. Other data is also obtained from the GPS receiver such as speed of the vehicle moving, heading of the movement of the GPS receiver, accuracy of position, number of satellite signal received, and strength of the signal received.

Data send from the GPS receiver is generally already in digital format and send to a computer or microcontroller using serial connection with signal amplitude of 0 – 5 Volts. Format of the data is already standardized using format of NMEA-0183 with the latest standard being version 4.10. Based on the NMEA-

0183 standard, the serial data rate of the GPS receiver is 4800 bits per second with 8 bits of data and one stop bit (4800 bps 8N1). Other than sending data via this serial connection, setting of the GPS receiver can be performed via this serial connection. Setting includes the data format, unit of measurement, and time information.

The GPS data obtained from a moving vehicle is transmitted using wireless data network from part of the GSM (Global System for Mobile Communication) also known as cellular telephone. The data component part of the GSM is called General Packet Radio Service (GPRS) can connect to the host computer with speed up to 128 kbit/s which is fast enough for this application. In order to use the GPRS part of the GSM network, a GPRS modem is needed to connect the data portion of the wireless network. The GPRS modem connects to the microcontroller via a serial connection similar to the connection to the GPS mentioned previously.

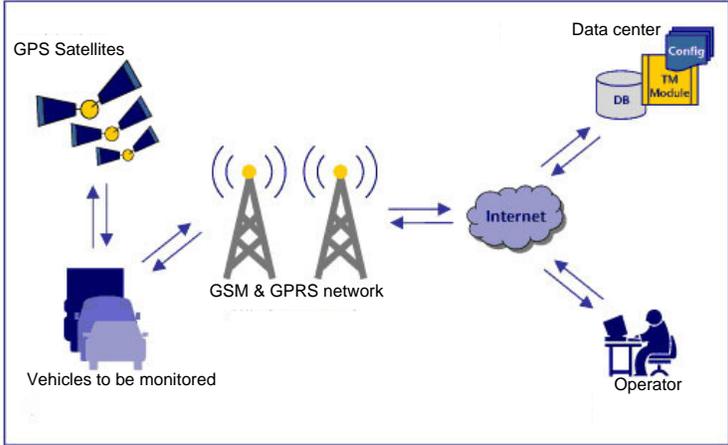


Figure 1. Vehicle monitoring/ management system using GPS via GPRS network.

Figure 1 illustrates the system used for Vehicle security and management system on GPS assisted vehicle using geofence and Google map system. There are GPS satellites to assist the GPS receiver mounted on vehicles to be monitored to find their geographical coordinates. The coordinates of the vehicles are send via GPRS modem using GSM network to the Internet to a computer system – usually in a data center – with database server and web server already installed on the system. An operator – also connected to the Internet – access the server via web browser to access the corrdinate data of the vehicles to be monitored. The web server of the computer system with HTML5 capability can provide the geolocation of the vehicle to be monitored on the web page overlaid with the map of the location using Google Map.

The operator has several monitoring privileges and control of the vehicle. Operator can track the vehicle and place a geo-fence around the vehicle and some other features discussed later. With this feature, a vehicle that is going beyond the geo-fence or virtual fence can be displayed on the screen and operator can be visually alerted and then can take action accordingly.

2. System design and constructions

The system design of the vehicle security and management system in block diagram is shown in Figure 2. There is a GPS module and a GPRS module integrated in one larger module in SIMCOM 908. This system also has a power management module to control the charging of a backup lithium battery which will be used to power the system in case there is a power failure of the main power system. Each of the modules (GPS and GPRS) has serial input/ output UART (Universal Asynchronous Receiver Transmitter) in which the devices will send or recive the data. The serial input/ output is connected to a microcontroller ATMEGA 164PA which has two serial input/ output. All of the modules are powered using the same power supply which is 3.3V which can be obtained from the external power or from the internal lithium battery.

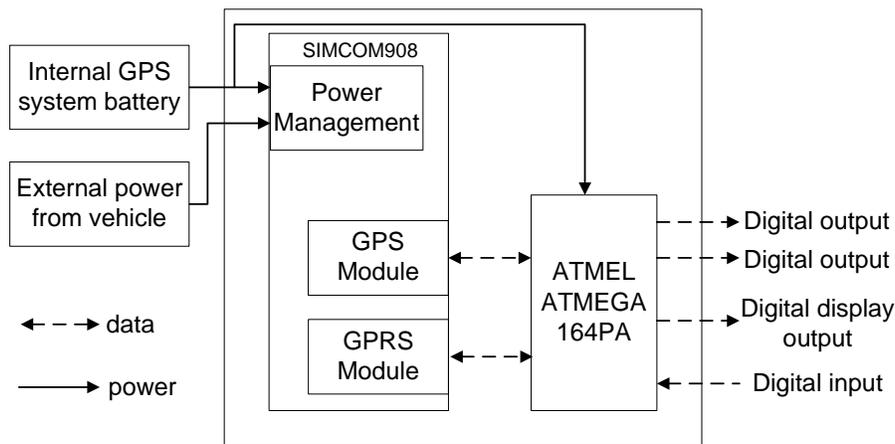


Figure 3. Block diagram of vehicle monitoring/ management system using GPS via GPRS network.

This system has one line for the digital input is utilized as the emergency button. In this case if the driver of the vehicle encounters any emergency condition such as carjacking (taking over the vehicle by force) or taking the payload of a truck by force, the driver can just press the emergency button for more than three seconds. After the three second period, the GPRS modem will send emergency signal to the operator in the Internet for an alert so the operator can take an appropriate action. There are two digital output channels can be utilized to control the vehicle by using relay switch. One output of the device will be normally open and the other switch will be normally closed. This usage can be used to save the vehicle such as to disable the vehicle by cutting the fuel supply (diesel engine) or by cutting the electrical power supply to the engine (gasoline engine). The other digital output can be used as secondary control to the vehicle such as air conditioner or any other convenience inside the vehicle and also by turning on an external alarm. Digital display output port is used in conjunction with an LCD display used for the new features added to the system later.

2.1 Global Positioning System (GPS)

Global Positioning System (GPS) is a satellite based positioning, in which there is a need for at least three visible satellites to determine the position – including altitude – of a GPS receiver. The basic method of position determination is trilateration which has been described elsewhere [6-8]. In reality with more than three visible satellites, the accuracy of the position will increase and accuracy can be within 2 meters in many situations where there is not much obstruction to the satellite signals. In many situations the signal strength received from the satellites will also improve the accuracy the calculation of the position. On the average without any special antenna a GPS receiver can detect 7 – 11 satellites at the same time with signal strength between 11 – 25 dB with accuracy of less than 5 meters.

Most GPS systems have serial output similar to RS-232 or UART (Universal Asynchronous Receiver Transmitter) and the output format usually comply with the NMEA-0183 output. Serial output of NMEA-0183 compliance device will have character '\$' as the first character followed by two characters talker identification such as 'GP' for GPS device. The next identifier after the \$GP are three letter-identifier related to the GPS data such as GGA (constant GPS data), GLL (Geographic Position Latitude/ Longitude), GSA (GNSS/ Global Navigation Satellite Systems Dilution of Accuracy), ZDA (GPS time and date Information), VTG (Course Over Ground and Ground Speed), RMB (Recommended Minimum Navigation Information), and RMC (Recommended Minimum Specific GNSS Data). The data followed after the three-letter-identifier is data related to the identifier. For example, after ZDA identifier, the time and date data will follow, each data are separated by comma and then the last data is character '*' followed by the checksum data of two characters ended by <CR><LF> [9, 10].

2.2 General Packet Radio Service (GPRS)

General packet radio service (GPRS) is a packet oriented mobile data service available to users of the 2nd generation cellular communication systems global system for mobile communications (GSM). This system developed here uses the 2nd generation instead of the 3G system. In 2G systems, GPRS provides data rates of 56-114 kbit/s [1, 2, 11, 12]. The purpose of this system is to communicate data from the GPS to the computer

which is attached to the Internet. Detail connection of a GPRS modem to the Internet is described in details in [1].

Connection establishment from the device to the GPRS network is conducted via a GPRS modem with connection which has a serial connection to computer/ microprocessor. Command to connect to the GPRS network is via Hayes command which is also known as AT+ command (Attention Command) [13-15].

2.3 SIMCOM908 (GPS and GPRS modules in one unit)

One of the most important modules used in this device is SIMCOM908. It is a module which comprise of a GPS module which is described above combined with a GPRS and GSM modules integrated into one larger module with its function blocks shown in Figure 2a.

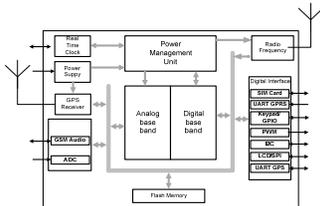


Figure 2a. SIMCOM908n function block with power management



Figure 2b. Top view of SIMCOM908 module with I-Pex antenna connector.



Figure 2c. Bottom view of SIMCOM908 module with the pin connection to PCB

As shown in Figure 2a, this module also has a power management module which is utilized to manage internal rechargeable battery. This battery is a backup power in case the external power from the car battery is unplugged and the backup is embedded inside the unit. Charge management unit include the full power recharge if the backup battery is low in power, trickle charge the backup battery for a period of time when it is full, and then stop the charging when the backup battery is completely full. Figure 2a also shows that the module has complete GPS receiver, complete GPRS packet data connection along with GSM telephone with external SIM card connection for the GSM with 'Mini SIM (2FF)' form factor. The GPS, GSM and GPRS unit are controlled by two different UART port, one UART for the GPS and the other UART for the GSM/GPRS unit. The GSM module is Quad-band with power to the SIM card (1.8 – 3 Volts) compatible with providers in Indonesia. Serial port connection support data rate from 4800 – 115200 bit/second (bps). Figure 2b is the photograph of the top side of the module and Figure 2c is the bottom part. Antennas for the GSM and GPS module are connected via two different I-Pex connectors on the component side as shown in Figure 2b. The same module is used in previous work [1].

2.4 Microcontroller ATMEL ATMEGA164PA

The SIMCOM908 module used for this device has two serial UART connections to control the GPS and GPRS modules. Controlling the sub-system requires two different UART connections that can be active at the same time, therefore a microprocessor with two serial ports will be used. The choice of this system is the ATMEGA164PA. This microcontroller has two independent serial ports that can be programmed for different types of data requirements.

2.5 Data connection to the server in Internet

Before sending the data, GPRS modem must establish data connection via APN (Access Point Name) which is the gateway to the public Internet. A user needs to know the APN the provider in order to connect, and the information is usually available in the Internet. Connection to the APN will involve sending the user name and the password. Usually the provider will inform the username and password, but it must be programmed first in the microcontroller.

After the establishment of data connection, the system onboard the vehicle will start sending information of its location, speed, heading and other information to the computer system in the Internet which already has MySQL database application software installed. MySQL is a Relational Database Management System (REBMS) capable of handling large amount of data arranged as tables with rows and columns.

Google Maps is a web mapping service application and technology provided by Google free of charge – for non commercial use – that provides information about geographical region such as road and places. Google Maps uses JavaScript very extensively together with the API key to display the map. Google user account is

needed via 'https://developers.google.com/maps/licensing' to obtain the key. After the connection to the Internet, this system has to connect to the proper website to display the location of the vehicle using Google Map. The website is coded into the system is 'www.gpsfence.web.id'.

3. Implementation of the GPS/GPRS system and geo-fence web interface

The vehicle tracking system using GPS and GPRS for data connection has been designed and constructed using all the subsystem mentioned above. The system uses double sided board to conserve space with the SIM908 on one side together with several external parts such as output driver and regulator. The top part of the system with the SIM908 module is shown in Figure 5a. Shown also in this figure the pigtail for the antennas, the top part is the GPS antenna connector while the bottom connection is for the GPRS antenna. Figure 5b is the reverse side of the circuit board. On this side there is the microprocessor in the form of SMT quad pack together with the crystal and the SIM card holder, and two regulators and on the left-hand side of the board there is an 8-pin header for the programming of the microprocessor via the ISP port of the microcontroller.



Figure 5a. Top side of the GPS vehicle tracking with the SIM908 module shown on top of it

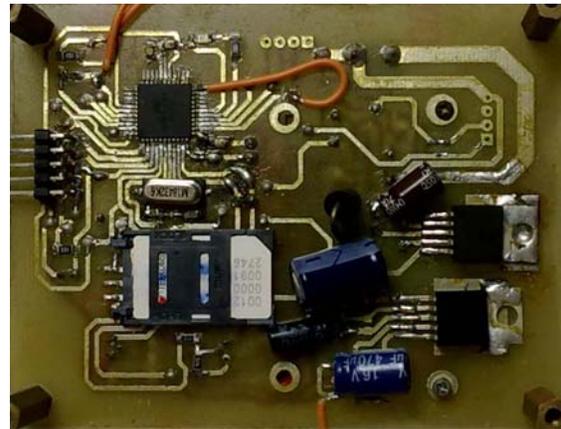


Figure 5b. Bottom side of the GPS vehicle tracking with microprocessor and SIM card shown

The vehicle location information obtained from the GPS is stored in a database file (MySQL) with the data shown in Table 2. Other than geographic data, the time, battery condition and vehicle status are also stored in the database and can be recalled from the web by clicking on the marker of the vehicle. The database and also the web interface can be accessed via <http://www.gpsfence.web.id>.

Data transmission from the GPS to the database is done via GPRS wireless connection which has been discussed previously. Data connection has been tested with all the prepaid GSM network in Indonesia and it has been shown to work properly. For this work, the data connection uses Telkomsel GSM provider with the Access Point Name (APN) coded internally to the microcontroller. The code for the work has been discussed elsewhere [1].

The web page stated on the address above is HTML5 capable and therefore can accommodate geofence and the first page shown is similar to Figure 6. When the location of the vehicle is within the geofence (maked with gray color of a quad-angle) the marker is shown red and when the location is outside the fence, then the marker is shown as blue color. Clicking on the marker will show that the location is inside or outside the geofence. In this figure the vehicle is monitored using the GPS and shown to be inside the geo fence (four locations) and two locations are outside the fence. The page will also show that the vehicle is outside the fence when the mouse is clicked. When the vehicle inside the fence is clicked, then a window will show that the vehicle is inside the fence as shown in Figure 7.

Table 2. Parameters saved on the database for the information of the vehicle

Field	Parameter saved
UTC	Time data are taken based on the Universal Time Coordinated time zone
Longitude	Longitude coordinate of the vehicle in signed degree format (DDD.dddd) from -180 East to +180 West
Latitude	Latitude coordinate of the vehicle in signed degree (DD.dddd) from -90 North to +90 South

GPSU	Number of satellites visible to the GPS receiver and used to calculate the position
Speed	Speed of the vehicle in kilometer per hour
Internal battery	Internal battery capacity in percent
External power	Indicator of external battery connection
Relay 1	ON/ OFF condition (usually for engine, normally open)
Relay 2	On/ OFF condition usually for external alarm or others (normally closed)
Emergency	On/ OFF condition of emergency button, normally off/ open

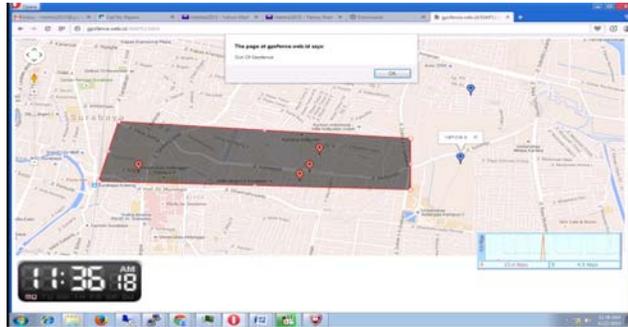


Figure 6. First page of the vehicle tracked inside and outside the geo-fence.

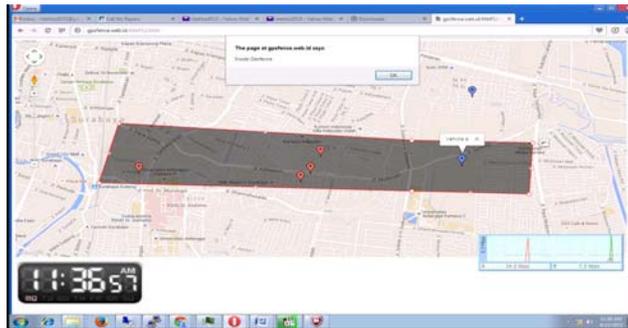


Figure 7. First page of the vehicle tracked inside and inside the geo-fence.

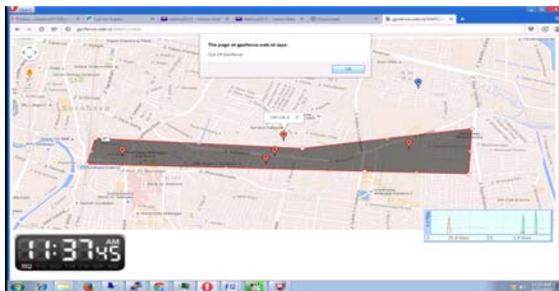


Figure 8a. Vehicle is outside the fence after reshaping the geo-fence

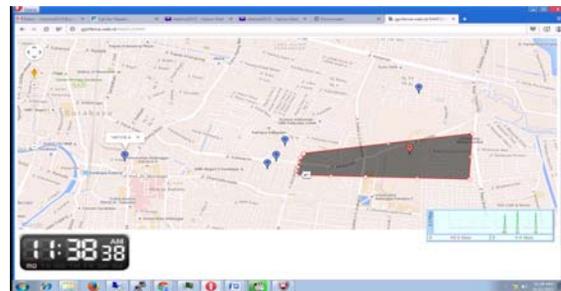


Figure 8b. Vehicle is inside the fence after reshaping the geo-fence

A vehicle equipped with GPS receiver can obtain its geographical coordinates easily and accurately and the data can be sent to a server in the Internet via GPRS wireless network. The data can then be displayed/overlaid using a map to indicate the location of the vehicle and then can be enhanced further by displaying a virtual fence called a geo-fence. With this geo-fence, the vehicle can be enclosed to be in a certain area of operation and when it moves outside the specified enclosed position, an operator can be alerted. With this alert system, the vehicle can be more secured against any wrongdoing or any other bad intention and thus the security of the vehicle is enhanced even further.

4. Conclusion

This work has shown the work of tracking the vehicle using GPS and GPRS is successful. From the end result of data, they show that the vehicle can be tracked properly using GPS and GPRS. When the emergency button is pressed for more than three second the status will be displayed on the web page. Control of vehicle can be carried out by the operator in charge of the vehicle to turn on and turn of the vehicle or part of the vehicle when necessary.

Acknowledgements

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References

- [1] Pranjoto, H., Agustine, L, Susilo, Y.S., Tehuayo, R., "GPS Based Vehicle Tracking over GPRS for Fleet Management and Passenger/ Payload/ Vehicle Security", ARPN Journal of Engineering and Applied Sciences, Vol. 9, No. 11.
- [2] Grewal, M.S., Weill, L.R., Andrews, A.P., Global Positioning System, Inertial Navigation and Integration, Wiley, New York, 2001.
- [3] Halonen, T., Romero, J., Melero, J. (eds), GSM, GPRS, and edge performance: evolution towards 3G/UMTS 2nd Ed., Wiley, New York, 2003.
- [4] Kaplan, E., Hegarty, C., Understanding GPS: Principles and Applications 2nd Ed., Artech House, Norwood, Massachussettes, 2006.
- [5] Kingsley-Hughes, K., Hacking GPS, Wiley, New York, 2005.
- [6] Maral, G., Bousquet, M., Satellite Communications Systems, Systems, Techniques and Technology 5th Ed., Wiley, West Sussex, 2009.
- [7] Meyer, E., Ahmed, I., Benefit-Cost Assessment of Automatic Vehicle Location (AVL) in Highway Maintenance, Proceedings of the 2003 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2003.
- [8] Peng, Z. R., Beimborn, E.A., Octania, S., Zygowics, R.J., Evaluation of the Benefits of Automated Vehicle Location Systems in Small and Medium Sized Transit Agencies, Center For Urban Transportation Studies, Milwaukee, Wisconsin, 1999.
- [9] Portillo, D., Automated Vehicle Location using Global Positioning Systems for First Responders, Institute for Information Technology Applications Technical Report Series, Colorado, 2008.
- [10] National Marine Electronic Association, NMEA 0183 Version 4.10 Electronic, National Marine Electronic Association, Severna Park, Maryland, 2012.
- [11] Sirf Technology, NMEA Reference Manual, SIRF Techology, San Jose, 2007.
- [12] Seurre, E., Savelli, P. Pietri, J-P., GPRS for Mobile Internet, Artech House, Norwood, Massachussettes, 2003.
- [13] Eberspächer , J., Vögel, HJ., Bettstetter, C., Hartmann, C., GSM – Architecture, Protocols and Services 3rd Ed., Wiley, Stuttgart, 2009.
- [14] European Telecommunications Standard Institute, Technical Specification AT command set for User Equipment 3GPP TS27.007 version 11.5.0 Release 11 (2013-01), Januari 2013.
- [15] Sim Tech, SIM 908 Hardware Design V. 2.00, 2012.