

Real-Time GPS/GPRS Based Vehicle Tracking System

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Abstract: *Designing a vehicle tracking system which can work effective, accurate and reliable is emerging in many areas. Such system is commonly used GPS technology to determine location of the vehicle. It can be used to track a vehicle or fleet of vehicles and get information related to current location of the vehicles. High required operating cost of the vehicle tracking systems, including hardware and software requirements, usually, prevent these systems from being widespread applicable. In this paper a vehicle tracking system based on GPS and GPRS is proposed. The location of the vehicle is retrieved using embedded GPS sensor. A modified coding method is used to encode and compress location data before it is sent to offer cost effective usage of network traffic. The privacy of the transmitted data is guaranteed using a simple security mechanism. The encoded and encrypted location data then send to tracking server using GPRS technology. The authorized user can track a vehicle using a secure web interface.*

Keywords: Vehicle Tracking, GPRS, GPS, GSM, Data Coding.

1. Introduction

The high transportation cost and oil price make the researchers to try to find methods that cause in effective transportation and logistics [1]. One of the methods that cause in providing better transportation services is vehicle tracking system, which by determining and controlling current and previous locations of the vehicles manage group of vehicles such as fleet tracks efficiently [2]. Tracking systems were first developed for the shipping industry because they wanted to determine where each vehicle was at any given time. Passive systems were developed in the beginning to fulfill these requirements. For the applications which require real time location information of the vehicle, these systems can't be employed because they save the location information in the internal storage and location information can only be accessed when vehicle is available. To achieve Automatic Vehicle Location (AVL) system that can transmit the location information in real time. Active systems are developed. Real time vehicular tracking system incorporates a hardware device installed in the vehicle (In-Vehicle Unit) and a remote Tracking server [3]. In recent years and by developing technologies such as embedded GPS sensors on mobile devices the vehicle tracking researches is applicable with more features as the mobile devices mainly has a powerful computation hardware.

The vehicle tracking is established by installing an hardware positioning sensor inside the vehicles and a tracking server to receive and decode the incoming signals from the vehicles. Many vehicle systems that are in use now days are some form of AVL [4] that is a concept for determining the geographic location of a vehicle and transmitting this information to a remotely located server. The location is determined using GPS and transmission mechanism could be a satellite, terrestrial radio or cellular connection from the vehicle to a radio receiver, satellite or nearby cell tower.

One of the problems with vehicle tracking system is the high required cost which prevent them from being widespread applicable. The operating costs can be divided into tracking device cost, location determination cost and transmission cost. In this paper a low cost vehicle tracking system is proposed

that take into account the required operating costs in a way that does not affect the quality, reliability or accuracy of the system. The system used open source based mobile device such as devices running Android operating system. This devices are mostly presented with embedded GPS sensor which is a free satellite system that provide information related to current location of the device. GPRS technology is used to data transmission between in-vehicle unit and tracking server. The data is encoded using modified coding method to reduce the transmission cost by reducing the data traffic.

2. Related Works

Many researchers proposed vehicle tracking systems with different features. Chadil et al [1] have proposed a GPS tracking system called Goo-Tracking that is composed of commodity hardware, open source software and an easy-to-manage user interface via a web server with Google Map or via Google Earth software. The system includes a GPS/GPRS module to location acquisition and message transmission, MMC to temporary store location information, and an 8-bit AVR microcontroller. Murugananham and Mukesh [4] have developed a real time vehicular tracking system incorporates a hardware device installed in the vehicle (In-Vehicle Unit) and a remote tracking server. The information is transmitted to tracking server using SMS or using direct TCP/IP connection. Tracking server stores this information in database and makes them available to authorized users of the system via website over the internet. Denkar and Shaikh [3] have designed a vehicle tracking system which consists of in-vehicle unit and tracking server/monitoring station. The in-vehicle is responsible for current location of vehicle, proximity sensors for parking assistance, vibration sensors and ultrasonic sensors for measuring the distance. GSM modem can send and receive data to and from the tracking server using SMS text messages and GPRS data over GSM network. Harshadhbhai [5] has developed vehicle tracking system that consists of embedded GPS sensor and a GSM modem to send the position of the vehicle from a remote place to the mobile at the other end from where the position of the vehicle is demanded. An EEPROM

has been used to store the mobile number. Lee et al [2] have designed a tracking system which consist of in-vehicle device that is embedded inside a vehicle and a microcontroller to control the GPS and GSM/GPRS modules. The vehicle tracking system uses the GPS module to get geographic coordinates at regular time intervals and GSM/GPRS module to transmit and update the vehicle location to a database. A Smartphone application has also developed for continuously monitoring the vehicle location.

3. Background

In this section a brief explanation of technologies used in the proposed system are presented.

3.1 General Packet Radio Service

Wireless communication is one of the important field of the communication industry. Many of systems changing previous wire communication between their entities with wireless communication which give them more features such as easily movement of members of the system. The 2.5G [6] is an evolution from the 2G technology such as GSM, and includes SMS and GPRS. These are 'always connected' network standards. GPRS is a technology of transmit packet data based on the existing GSM network and theoretically offers higher data transfer speed than 2G data services. As in the GSM specification, each radio channel carries TDMA frames of duration 4.615 ms, each containing eight time slots. GPRS provides data rates up to 171.2 kb/s, this upper limit achieved by assigning all eight time slots at 21.4 kb/s each, with no error-correction coding [7].

GPRS introduces a new functional element to the GSM infrastructure, GPRS Support Node (GSN) which can be either a Serving-GSN (SGSN) or a Gateway-GSN (GGSN). This addition is necessary for the GSM network in order to support packet data services. The network is generally divided into several service areas controlled by separate SGSNs. Only one SGSN serves a Mobile Station (MS) at a given time provided it is located in its service area. The SGSN is primarily responsible for keeping track of the MSs it serves, and for access control to data services. The GGSN on the other hand provides the interface to external Packet Data Networks (PDN)s [8]. The packet-switched principle is used throughout the GPRS network. The GPRS backbone connecting the dedicated GPRS nodes based on the Internet Protocol (IP). On the air interface the resources are assigned to MS only temporarily on a per-packet basis. In contrast to circuit-switched GSM bearers, where time slots are assigned to one user for the entire duration of a call, in GPRS the radio resources are only assigned for the duration of one or a few IP packets [9].

3.2 Global Positioning System

GPS technology was brought into the practice at the first time back in 1973 by U.S. Defense Department [10], and was declared fully operative in 1994 [11]. GPS consists of a constellation of 24 satellites, equally spaced in six orbital planes 20,200 kilometers above the Earth, that transmit two specially coded carrier signals: L1 frequency for civilian use, and L2 for military and government use [12]. Each satellite

follows a defined path, ensuring that at least four satellites are visible from any point on earth at any given time. The received GPS signals are decoded by receivers, so the smart phone in order to be able to use GPS must has built-in GPS receiver, but this receiver is useless without the rest of the system [13].

The GPS system consists of three segments: the space segment (satellites), the control segment and the user segment (receivers). The space segment sends navigation messages continuously at a rate of 50 bits per second; the main information in the message is the time when the message was sent, exact orbital information ("ephemeris") and the general system status and rough orbits of all satellites (the "almanac"). The control segment is composed of a number of stations and antennas, they are used to control and monitor the health of the satellites, and do the necessary orbit data corrections when needed, for instance adjust the satellites' clocks [11].

The user segment is mainly composed of a very stable internal clock, the software for calculating the user's location and speed, and usually a display for providing the information to the user [11]. To calculate device's location, GPS receiver must be able to determine its distance from multiple satellites. It does this using the ephemeris data; it includes the data that is transmitted from the satellite. Along with the position data, is the time at which the transmission started. Using the data from transmission start time, the GPS receiver calculates the time it took for the transmission to be received; by its internal clock the receiver knows when the transmission ended. This calculation is made with the assumption that the GPS radio waves travel at the speed of light in a vacuum. Using the start time, end time, and the values of light speed; GPS receiver can calculate the distance of the satellite from the receiver [13]. To operate properly, however, conventional GPS receivers need a clear view of the skies and signals from at least four satellites, requirements that exclude operation in buildings or other RF-shadowed environments [12].

4. Proposed Vehicle Tracking System

The proposed vehicle tracking system consists of a tracking server to monitor and control the system, web interface to check vehicles' location and number of in-vehicle units with embedded GPS receivers that have been installed inside each vehicle as illustrated in figure 1. The in-vehicle unit is responsible for capturing the location data continuously and store these information in an internal database. These data is then sent to the tracking server periodically. The time interval of data transmission depends on the preferred operation cost and the in-vehicle unit reliability.

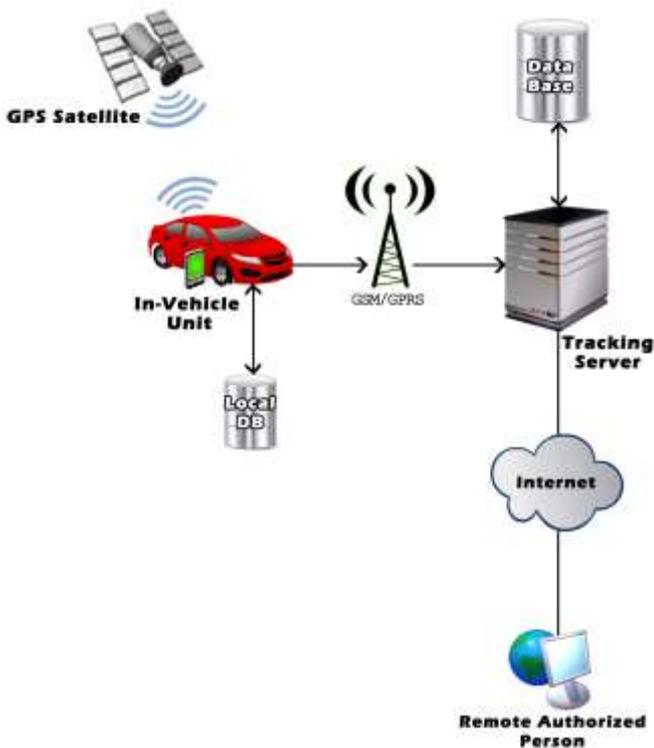


Figure 1: Block Diagram of Proposed Vehicle Tracking System

The in-vehicle unit consists of five main modules: Location Data Logger (LDL), Location Data Synchronizer (LDS), Location Data Encoder (LDE), Session Management Module (SMM) and Security Key Exchanger Module (KEM). The tracking server on the other hand, consists of four main modules: Web Request Handler (WRH), Location Data Synchronizer (LDS), incoming Request Listener (IRL) and Security Key Distributor (SKD) as shown in figure 2.

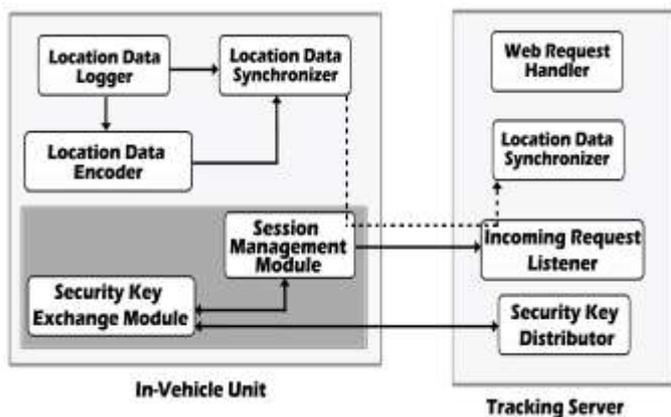


Figure 2: Modules of System Components

LDL get the location information from the GPS receiver and store these data in an internal database. These data can be used by LDE to encode the data that will be sent to the tracking server. LDL stores the location data along with the corresponding time on the local database.

LDE uses modified model that has been produced by Kamel and George [14] for coding geographic location coordinates. The modified method consists of three stages: (i) Set Accuracy

(ii) delta coding and (iii) run-length coding as shown in figure 3. For the first stage there are three input values: latitude, longitude and distance resolution (desired accuracy). Equal desired accuracy value can be set for whole vehicles in the system, or there is an ability to set different value for each vehicle depending on the needed accuracy information of that vehicle. For each coordinate and depending on the desired accuracy and computed values, at the first stage the relative horizontal distance counts (Xcount) and vertical distance counts (Ycount) will be computed as has been explained in [14], which will be the input to the second stage. The location data (Xcount, Ycount) is send periodically, so with each transmitted frame, a set of Xcounts and Ycounts are exist. In the second stage a simple prediction coding model is applied on the location data to compress the location data before transmission. In perspective of the system and according to the desired accuracy, this compression will be lossless. The delta coding model is selected as a predictive model due to its simplicity and low computation load requirements. In the third stage of coding, run-length coding is applied on the resulted data which may have redundant values.

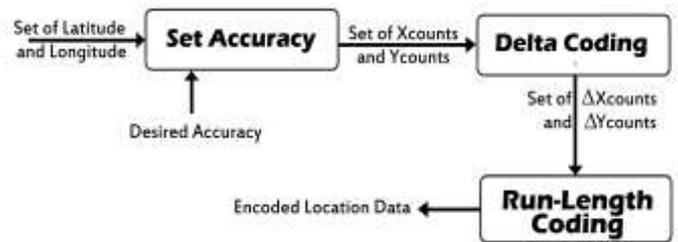


Figure 3: Modified Location Data Coding

LDS of in-vehicle unit and tracking server are responsible for ensuring that the tracking server has the latest and historical location data of the vehicle. These data can be sent directly from the LDL through SMM as soon as a new location data is received from the GPS receiver. In this case the LDE will be disabled. Another scenario is to send the location data periodically. The time interval of data transmission has to be compute correctly. Very small time interval consumes more traffic to transmit the data over GSM and will cause in high network load and as a result high operating cost. Very large time interval will cause in mismatch between current vehicle location and related information of the vehicle in the tracking server.

KEM securely exchange the key with SKD on the tracking server using Diffie-Hellman key exchange algorithm. This key will be used by SMM for subsequent symmetric encryption of transmitted location data. The Diffie-Hellman algorithm depends for its effectiveness on the difficulty of computing discrete logarithms. The security of the Diffie-Hellman key exchange lies in the fact that, while it is relatively easy to calculate exponentials modulo a prime, it is very difficult to calculate discrete logarithms. For large primes, the latter task is considered infeasible [15]. The key exchange steps are illustrates in figure 4. The final shared key will be computed as following equation:

$$K = Y_a^{X_b} \bmod q = Y_b^{X_a} \bmod q \quad (1)$$

In which X_a , X_b and q values are private and Y_a and Y_b are sent between in-vehicle unit and tracking server through public communication channel. To protect against man-in-the-middle attack the 'a' and 'q' numbers of the key exchange protocol in the proposed system will keep private. Therefore, for each in-vehicle unit there are a set of unique private parameters which are used by security key exchange module. SMM is responsible for starting a secure communication channel with IRL to securely send the location data to the tracking server. SMM uses the previously available key which has been received from KEM.

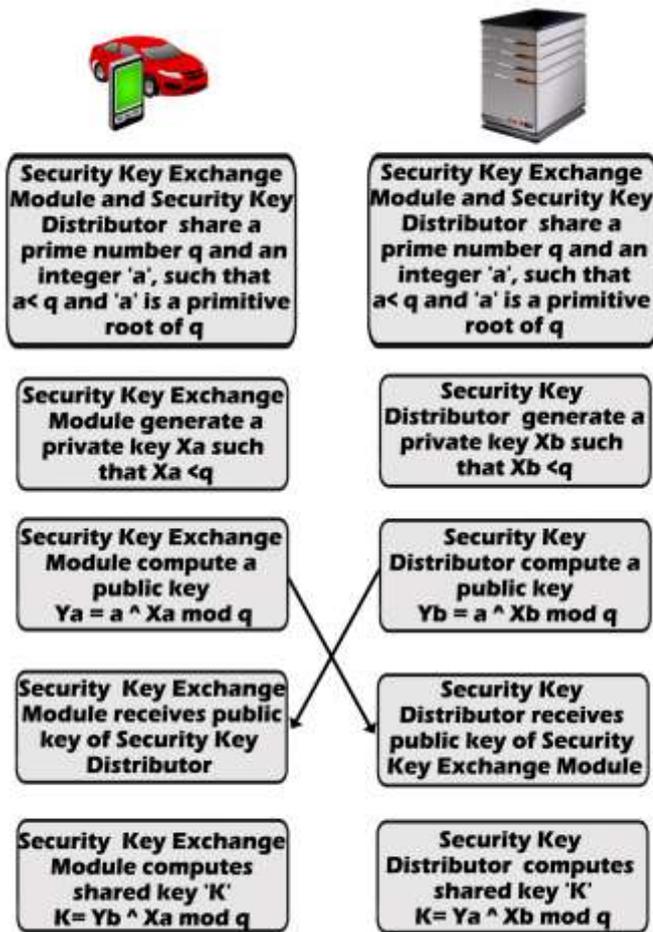


Figure 4: Key Exchange Protocol

Authorized persons can track a vehicle through web interface by sending a request to the WRH. The connection is secured by SSL/TLS to guarantee privacy of transmitted sensitive data. After authentication, the user is able to check the current and historical information about the location of a vehicle. Querying the tracking server can be one of two types: querying by vehicle by providing vehicle ID which result in its current location as shown in figure 5. The user can also query the historical locations of his/her vehicle. The second type is querying by location which will result in all vehicles in that particular location. This type is only accessible by administrator of the system.

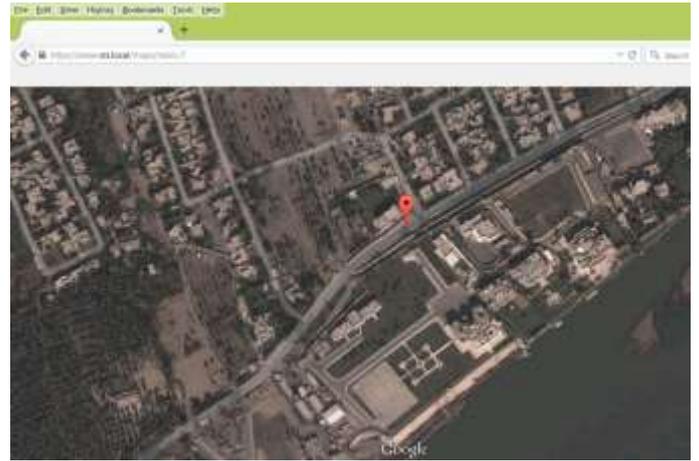


Figure 5: System Web Interface

5. Conclusion

The proposed vehicle tracking system is established using a tracking server and number of in-vehicle units. The system has a number of features to guarantee security, reliability and efficiency of the system. The key exchange method along with the secure session management method allow secure communication and transmission of sensitive location data without affecting processing time. The encoding method provides efficient use of the network traffic to transmit location data resulting high transmission time in real-time. The system has been designed to be cost effective with reasonable operating cost by using required low cost devices, encoding techniques for efficient use of network traffic which leads to low operating cost of GPRS connection.

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Author Profile

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