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Real-Time Vehicle Tracking System Using GPS/GSM/GPRS Technology – Kosovo Government Vehicles Case

Kujtim GASHI[1], Arbnor HALILI[2]
[1]e-Government Department, Government of Kosovo, kujt_gashi@hotmail.com
[2]Faculty of Electrical and Computer Engineering, UP, arbnor.halili@gmail.com

Abstract
Vehicle tracking is one of the most problematic issues that governments or large enterprises have to deal with. Manipulation with kilometers, fuel and other issues are not rare. This paper treats real-time vehicle tracking system. Paper covers detail description of the problem, need for an electronic system and its implementation from gathering phase due to the maintenance phase. The main focus is on describing the intercommunication of different technologies in a real-time system including GPS technology for gathering position, GPRS for transferring positions data to the central server and presentation of these collected data. Certain protocols and approaches are also discussed that enables functioning of the system. Security aspect has not been skipped. Paper also has a focus on economic side of the system, mainly in possible economic benefits of the system. The approach of this paper is referenced on a special case of a similar Kosovo Government project.

Keywords: *vehicle tracking, GPS/GSM/GPRS, Kosovo, real-time system*

1. Introduction

Vehicle and fleet tracking systems presents a challenging system and have raised a great interest to many companies and developers. This interest is based on the need for such a system but it is also based on the complexity and the challenge for making such a useful and necessary system. The main problem is about cost. Having in mind that there are many technologies incorporated, than easily can be understood that the cost can often be very high.
An approach of developing a system that can give information about vehicle geo position was made by [1**].** The basic idea behind was to make a system that gives the coordinates of the vehicle from its location regarding GPS satellites whenever these data are requested. The request was designed to be made using Short Message Services (SMS). This kind of system has somewhat bigger cost and it is not a real time system.
Another approach that is very interesting is made by [2]. The basic idea behind this approach was to make a system that serves as a vehicle tracking system and is based on GPS and GPRS services. This system tends to be more cost effective than previous one discussed above. Interesting thing about this approach is that it uses mobile phones based on Android platform. As authors mentioned in their paper, the decision to use smart phones was made because smartphones have GPS receiver and a GPRS transmitter [2].
An extended approach of vehicle and fleet management system was made by [3]. This approach treats vehicle geo position but it is not limited to that. It also treats the distance between points in a certain geo area and it proposes two algorithms for solving this type of problem, Dijkstra Algorithm and Kruskals Algorithm.
One of the most advanced approaches toward this system is also [4]. This system is based on GPRS and does not include GSM (SMS). This paper was published in 2009 and is based on open source technologies like MySql and Php for presentation of the data gathered from GPS module. Another interesting thing is the usage of the Google Maps for presentation of position of the vehicle. A disadvantage that can be depicted here deals with seat sensors and fuel sensors that are not mentioned to be implemented.

2. Problem description

In order to make a clear problem description it is better to firstly depict the need for such a system. Imagine how operate large enterprises or institutions that have a huge number of

workers and also of vehicles. It is almost impossible to manage in the right way and to know every simple detail in these cases. Having this situation it can easily be understood than manipulation with fuel, kilometers and other issues are not rare. This abuse can cause considerable losses. In this situation it must be considered an electronic solution, a digital system. Basically from the management's general perspective, this system should be simple to use and should offer details about possible manipulation aspects.
Having a clear idea about the need we can now pass to the detail description of the problem, system. System should be modeled in three parts:

- GPS module
- GPRS/GSM communication
- Presentation of the data.

GPS module should be a device that can be mounted on the vehicle and that can communicate with GPS satellites. This module should be able to save few records in case of communication with server fails. GPS module should save also other sensors data. Here are included sensors of seat (how many persons are in the vehicle) and fuel sensor.
GPRS/GSM communication deals with communication "line" from GPS module to the server where data are stored. Data gathered from sensors and from GPS satellites need to be sent to the server and for that intent GPRS communication is used. This decision is made because GPRS Point-To-Point (PTP) services are used (beside others) also for burst transactive or interactive applications [5]. It is worth mentioning that system should have the possibility of communication through GSM. This communication should be based on SMS. Specific messages sent to the GPS module should give us related information. This would avoid the chance of data absence in case of absence of GPRS services.
Last part of the system deals with the presentation of data gathered form GPS module. We suppose that we have GPS geo position of the vehicle and now we want these data to be presented in an understanding way for the user. There are many ways to achieve this. It can be based on open source or non-open source platforms. The main issue here is on deciding on what type of map will be made presentation. The advent of the technologies (like AJAX) and standards have led to the emergence of numerous neogeography applications which utilise the Google, Yahoo and Microsoft (GYM) mapping APIs to create rich geographic websites [6]. This gives the advantage on the selection because whichever of these technologies is selected, features are almost all identic.

3. Implementation of the system

Implementation of this project is separated into two parts:

- Hardware implementation and
- Software implementation

Hardware implementation has to do with hardware issues, including here GPS module and other sensors for seats and fuel. GPS module should be equipment that can be mounted on the vehicle and normally can communicate with GPS satellites. This module should also have a place for sim card which will be used to communicate through GPRS with central server. It must be mentioned that also seat sensors and fuel sensors must communicate with GPS module in order to send their data to that module.
Software implementation deals with database and application implementation. Sometimes software implementation leads only to application or presentation layer but in this paper this concept means somewhat deeper.
Implementation will be described in its phases including:

- Requirement gathering phase
- System design phase
- System development

- System testing
- System maintenance

3.1 Requirement gathering phase

As it is mentioned in first section, this paper is based and uses as a case study a Kosovo government project for vehicle tracking. This project will be the base for describing requirement gathering phase. Requirements were divided in two main parts:

- Hardware requirements and
- Software requirements.

Basic functional requirements were given by the client in the tender dossier [7] for this project. Some of crucial hardware requirements that define overall system are:

- GPS equipment must have a rechargeable battery
- GPS equipment must have the possibility to save up 64000 records offline
- GPS equipment must support GPRS class 10 and GSM
- GPS equipment must have 4 digital and analog I/O
- GPS equipment must have RS232 connection port

Software requirements were defined also as well. These requirements were defined in more details but some of them are:

- System should be web based with unlimited number of users
- System should track and monitor vehicles in real time all the time
- System should have Kosovo Map with all roads depicted
- System should support reporting
- System should have the possibility to view in playback in a period of time 12 months
- System should have a daily backup
- Communication of the GPS equipment and central system should be encrypted in order to disable possibility for someone to use (abuse with) these data
- Encryption should be done with SSL 256 bits.

3.2 System design phase

Based on requirements gathered in first phase, in second one, the system design is realized. System design is divided in two parts:

- Conceptual architectural design
- Hardware definition

Analyzing requirements gathered based on tender dossier is the process that comes next to the first phase. Based on this process system architects can make the system design. Design elements describe the desired software features in detail, and generally include functional hierarchy diagrams, screen layout diagrams, tables of business rules, business process diagrams, pseudocode, and a complete entity-relationship diagram with a full data dictionary [8].
The process of getting data and presenting them to the user is as follows:
GPS equipment gets the GPS signal from satellites >> Connect to the GPRS >> Send data to the server through GPRS >> Store data on DB Server >> Present data from web application
This process is depicted in the figure below. It must be mentioned that similar architecture has also the communication with SMS but in that case there is no need to connect to the GPRS, it uses GSM.

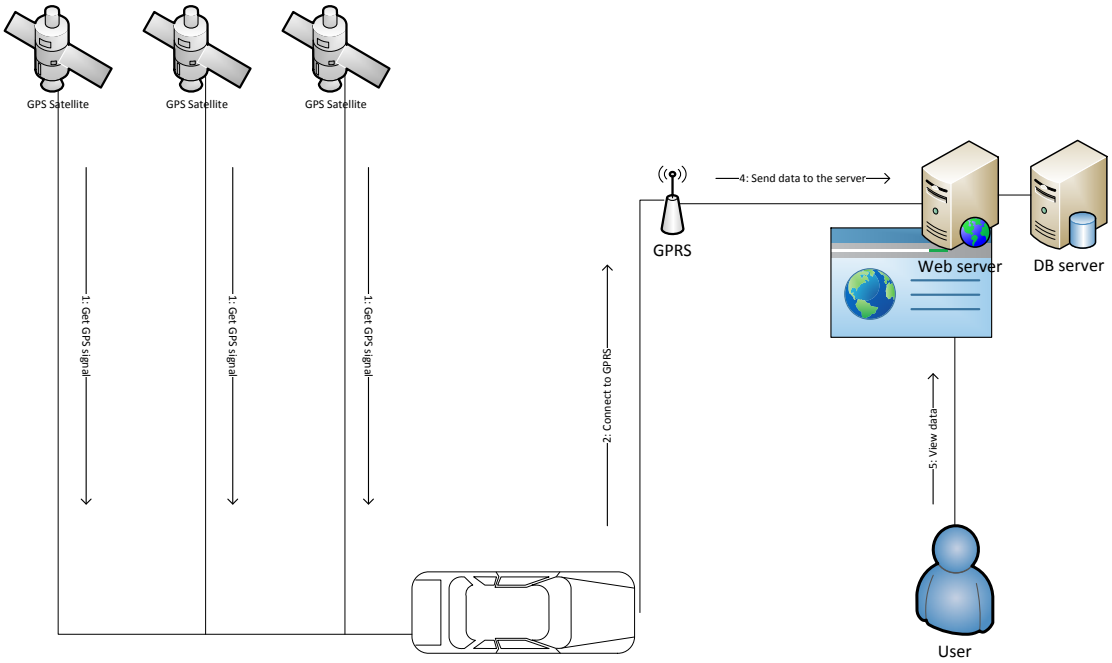

Figure. 1. Systems architecture

Knowing the architecture of the system, next step was defining of the GPS equipment. In Kosovo Government system, GPS equipment installed on vehicles and that fulfills the requirements is from a well-known vendor Teltonika. Below are depicted some of main features of this module gathered from official site [9]:

- The device supports the following GSM bearers:
  - GPRS class 10 (up to 85,6 kbps)
  - SMS (text/data)
- Dual-band GSM - 900 MHz / 1800 MHz
- LOW energy consumption in deep sleep mode (less then 6 mA@12V)
- Option of internal (or external) rechargeable battery with charge controller
- FM4200 has:
  - 4 digital inputs
  - 4 digital outputs
  - 4 analogue inputs (2 ranges 10V and 30 V, 10 bit resolution)

This could be used for performing tasks on remote objects, such as monitoring fuel tank level, engine status, or controlling truck door etc.

- FM4200 has 1-Wire® I/O protocol integrated for temperature measuring or key ID identification.
- FM4200 has CAN interface for FMS interface of trucks, which enables data acquisition from trucks on-board computer.
- FM4200 has RS232 port which could be used for external peripheral data acquire
- Voice function
- 2 LED indicators: “Status” and “Navigate”
- The package includes antenna, Coloured I/O cables and data cables

Teltonika’s firmware for the device enables such functions as:

- GPS and I/O, 1-Wire, CAN data acquisition
- External sensors connection capability
- Real Time tracking
- Smart algorithm of data acquisition (time and distance based
- Sending acquired data via GPRS (TCP/IP and UDP/IP protocols)

- Smart algorithm of GPRS connections (GPRS traffic saving)
- Flexible configuration of data sending in roaming networks (depending on GSM providers list)
- Events on I/O detection and sending via GPRS or SMS
- Scheduled 24 coordinates SMS sending
- Multi geofence zones (rectangular or circle)
- Sleep mode and deep sleep mode (saving vehicle's accumulators)
- Acceleration detection (harsh breaking and accelerate measuring)
- OTA (firmware updating via GPRS)
- Real time internal processes monitoring
- Authorized numbers list for commanding

One of the requirements requested was also fuel tank level measurement. It is very important to have the exact information about fuel. Special fuel sensor has been used for this project. Details about sensor can be found on official site [10].

3.3 System development

After having defined user needs and requirements, development is what comes next. Development of this system has been oriented in free open source solutions, MySQL and php. In this section we will not explain in detail user interface and other graphical parts, but instead we will concentrate in overall system communication.

Firstly, it must be known where the location of the vehicle is. In order to get this information GPS is needed. This kind of technology has been found a great usage in aeronautic. It dates long time ago. The basic principle is that it uses satellite location in order to get current precise location. There are 24 satellites that provide this kind of service.

Location is defined from 4 satellites. If we measure distance to one satellite, we know that we are located on a sphere of that radius, centered on the satellite. With two satellite range measurements, our location is limited to a circle and with three satellites to one of two points. A fourth satellite can be used to find the correct point and to take care of the time coordination [11].

Our GPS module is able to find these four satellites and writes on its memory current longitude and latitude. Now these data (including also fuel sensor data) must be sent to the central server. This can be done through GPRS. An excellent explanation of how GPRS connection works is given in [12]:

"When a user turns on a GPRS device, typically it will automatically scan for a local GPRS channel. If an appropriate channel is detected, the device will attempt to attach to the network. The Serving GPRS Support Node receives the attach request, fetches subscriber profile information from the subscriber's Home Location Register node, and authenticates the user. Ciphering may be established at this point. The SGSN uses the profile information (including the access-point name, which identifies the network and operator) to determine which Gateway GPRS Support Node to route to. The selected gateway may perform a Remote Authentication Dial-In User Service (RADIUS) authentication and allocate a dynamic Internet Protocol (IP) address to the user before setting up connections to outside networks."

Having IP address now the packet of data with encrypted location/fuel sensor data are sent to the central server. In case that there is no GPRS connection (lost or services are down), these records are saved locally on GPS module. When the connection is back then data are synchronized. This kind of synchronization is called offline synchronization.

Security issues have been treated while developing the system. There have been depicted two main issues. First one was mentioned above and it has to do with data transferring from GPS module to the central server. Second one deals with security of web application.

Application is secured via SSL. The SSL record layer provides confidentiality, authenticity, and replay protection over a connection-oriented reliable transport protocol such as TCP. Layered above the record layer is the SSL handshake protocol, a key-exchange protocol which initializes and synchronizes cryptographic state at the two endpoints. After the key-exchange protocol completes, sensitive application data can be sent via the SSL record layer [13].
Before proceeding to the next phase it is worth mentioning that presentation of maps is made through Google Maps and it has been shown that was a very good decision.

3.4 System testing
Testing phase was a pretty long phase. Testing was made on testing environment of the client. After final testing a detailed report was produced that is property of client.

3.5 System maintenance
Final phase that is ongoing is maintenance phase. During this phase maintenance of eventual malfunctioning GPS modules will be made and also will be provided support for eventual software problems.

4. Economic impact
Information technology investments in developing digital systems are one the main objectives of modern world. The cost of these investments is not low but there are many benefits that comes behind these investments and that has been shown to be higher. This argument convince us every day more and more to make investments even more higher where the possibility exists.
It has been proved that usage of GPS technology for monitoring vehicles unavoidable brings with itself different positive benefits. GPS technology application in Kosovo has been shown to have many benefits including:

- Direct budget saving
- Driver education and care for public property
- Rationalization of time and activity management
- Increase of public safety
- Contribution on saving natural environment

Direct budget saving – this is fulfilled through rational utilization of vehicles which results in direct reduction of fuel expenses. It is considered that every vehicle that is monitored by GPS technology reduces expenses between 15 and 30 per cent.
Driver education and care for public property – the ability of system to monitor on real time and on playback disables possible abuse with vehicles. This directly increases care about vehicles utilization and decreases its amortization level.
Rationalization of time and activity management – controlling and monitoring process's impact like in any other process also in vehicle monitoring is obvious and has its effects in time and manner of utilization. This affects directly on rationalization of time and on increasing of performance and efficacy on work.
Increase of public safety – every vehicle that use GPS technology creates conditions and circumstances that its utilization regarding traffic rules be examined and analyzed in detail. All these possibilities offered by the system affect driver attention and indirectly public safety.
Contribution on saving natural environment – every vehicle that is monitored through GPS technology is directly connected with conditions and consequences described above. Optimal utilization of vehicle and reduction of fuel expenses affects directly and contributes on saving natural environment.

5. Conclusions

Vehicle tracking system includes in itself many technical issues from GPS signal to the presentation on map. In this paper a Government of Kosovo project has been taken as a study case. Through this paper all implementation phases has been discussed. The main focus was in system design and development phases. The economic impact has been also treated as a part of this paper.

As a conclusion, it can be said that vehicle tracking system is a good challenge in engineering aspect. Its implementation is not easy and it has many aspects where it can be improved. Even it is an expensive project, its benefits in economic aspects for large enterprises and governments are considerable and justify investment.

There can be a lot of work in the future on this system. One of the main improvements deals with system scalability. The scalability must be considered in number of vehicles that system monitors at the same time and system performance regarding this capacity. Improvements can be also made on fuel sensor precision. On software aspect system can be improved on data presentation on map and on system personalization (for each user).

Personally, we recommend all enthusiasts that love complex systems to work on possible improvements in near future.

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Kujtim GASHI /PhD Candidate - has graduated the Faculty of Economics in University of Prishtina and gained title ecc. dipl. He has finished master studies in field of management, with emphasis on e-Government, and has gained scientific title MSc at International University of Prishtina. Since academic year 2010-2011, he is a Phd candidate at Faculty of Economics, Department of Mathematics, Statistics and Applied Informatics, University of Tirana.

Arbnor HALILI /BSc. - has graduated the Faculty of Electrical and Computer Engineering in 2010. He is an MSc candidate and holds a BSc diploma in Computer Engineering. He is the author of several mobile applications and his research interest is closely connected with mobile services and software quality management. His work focuses on the analysis of quality of software applications.