INTERNET BASED FLEET MANAGEMENT
USING GPS AND GSM/GPRS

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ABSTRACT

This paper presents the design and implementation of a large fleet management system, which is a true convergence solution of GPS, web-based GIS, GSM, GPRS and Internet technologies. The Short Message Service of the GSM is used to substitute the GPRS where GPRS is not available. A protocol stack including TCP/IP and PPP is implemented in vehicle unit to transmit data via Internet. A communication gateway is designed to distribute the location and control messages. The system tests confirm that the proposed scheme can perform a reliable management service for large fleets at low operating and maintaining costs.

KEYWORDS
Fleet Management, Internet, GSM, GPRS, Web-based GIS

INTRODUCTION

There is a large potential market for large fleet management, such as taxis, delivery vans, ambulances, buses, and lots of other applications. The objectives of managing a fleet of vehicles are to minimize response time, lower fuel bills, increase transport efficiency, eliminate theft, monitor speeding, reduce accidents, identify unauthorized vehicle use, etc. All these objectives can be met, if and only if, one has total knowledge and control over all his vehicles. Therefore, the realtime location and physical condition of any given vehicle must be known continuously and the control messages can duly reach the driver. That means an efficient and reliable data communication network is a key factor in the determination of the performance of a fleet management system (ref [1]).

The Internet has become indispensable to business for it allows organizations to conduct electronic
commerce, provide better customer service, reduce communications costs and access needed information rapidly. The development of the General Packet Radio Service (GPRS) and the web-based Geographic Information System (GIS) presents a feasible solution to integrate the fleet management systems with the Internet, for they permit the vehicle communication units and GIS servers become the nodes of the Internet.

As GPRS is newly implemented as a logical functional overlay on the Global System Mobile (GSM), its coverage area is smaller than that of the GSM. GSM is the most widespread wireless network today and covers almost all of the metropolitan area and even higher population areas, so the Short Message Service (SMS) of the Global System Mobile (GSM) could be used to substitute the GPRS where GPRS is not available. Although not advanced as GPRS, SMS also provides packet-based wireless data communication with high quality, reliability and low cost (ref [2,3]).

Based on these technologies, this paper presents the design and implementation of an Internet based fleet management system, which uses the Global Positioning System (GPS) to perform the positioning function. In order to manage large fleets, a communication gateway is designed and implemented to distribute the location messages and manage the alternation of GPRS and SMS. The system performance verification and tests are demonstrated to support the proposed scheme.

**SYSTEM INFRASTRUCTURE**

The purpose of this study is to take the advantage of the popularization of GSM/GPRS networks and Internet to design a fleet management system with the client/server architecture.

The proposed fleet management system includes three parts: vehicle unit, wireless segment and a monitoring unit as shown in Figure 1.

Vehicle unit is fitted in vehicle with appropriate GPS and wireless antenna. It is the communication client in the system and consists of a positioning device, several sensors to probe the physical condition of the vehicle, and a mobile communication interface to the GSM network.

Using public GSM/GPRS network as wireless communication media, fleet owners not only can save maintenance, but also can expand his fleet scale more easily because of the large capacity of the public network.

Fleet monitoring unit connects to the GSM/GPRS network with a communication server, which is
also the communication server of the system. The communication server distributes the communication data from all of the tracking vehicles to relevant motoring workstation. Then a web-based GIS server will process the data there. The control and response messages can also be sent back through the communication server and GSM/GPRS network to the vehicle units.

**WIRELESS SEGMENT**

1. **The GSM Network**

The main elements of GSM are divided into three parts: Mobile Station, Base Station System and Network System as shown in Figure 2.

The Mobile Station (MS) is the mobile terminal used by the final user to access the GSM network and to make use of its service. The Base Station System (BSS) is the network element converting the radio signals from the mobile terminals into signals for the fixed network. The Mobile Switching Center (MSC) is the primary element of the Network System. It routes and retransmits the data all through the network.

The flow of data in the network uses two different logic channels: traffic channel for the transport of the coded voice signals and for the user data; signaling channel for the transport of control and synchronization information between the base station and the mobile terminal.

The GSM system was designed to be compatible with ISDN services. This makes it compatible with the digital evolution of the fixed networks and telephonic system.

2. **The Short Message Service (SMS)**

The Short Message Service allows the transfer of binary data (with a maximum of 140 bytes) between two mobile systems. All the short messages are transmitted through the Short Message Service Center (SMSC). SMSC performs two functionalities: one is the provision of interworking capabilities between the mobile network and the local public fixed network; the other is offering a store and forward mechanism for each message when the destination mobile station is off-line.

The user node (e.g. monitoring units) can connect to the SMSC by the TCP/IP protocol as shown in Figure 3. To communicate with a specific SMSC, the user should use a suitable interface protocol, such as SMPP, EMI, CIMD, and so on.
The fact that SMS are sent through the signaling channels provides an ideal link for the automatic vehicle location system. This is because it does not need any extra resources from the network provider side and also enables the user to make a circuit-switched connection at the same time (e.g., conversation). Therefore, periodic vehicle location and control information can be transmitted by a large number of users without having to increase the mobile network resources.

3. The General Packet Radio Service (GPRS)

GPRS is implemented as a logical functional overlay on GSM, and does not use any of GSM circuit-switched resources. It greatly improves and simplifies wireless access to packet data networks, e.g., to the Internet. It applies a packet radio principle to transfer user packets in an efficient way between GPRS mobile station and external packet data network (ref [4]).

GPRS Support Node (GSN) is the major functional extensions to the existing GSM network. A Serving GSN (SGSN) keeps track of the location of the mobile stations, performs security functions and user data packets to the mobile stations within its service area using the Gateway GSN (GGSN) if necessary. GGSN provides the necessary address, routing, and packet transfer functions to send user data packets to the specific SGSN for the destination mobile station. It also provides the appropriate interworking functions with external data networks. Figure 4 illustrates GPRS network architecture.

GPRS supports GSM style roaming and all the GSM security features. With GPRS the mobile user can profit from data rates up to 170 kb/s today. The capability of billing per volume is probably the biggest advantage of GPRS that will drive acceptance of the mobile Internet.

4. Comparison of SMS to GPRS

While the Short Message Service (SMS) of GSM does support packet mode data transfer over signaling channel and has advantages in transmitting the positioning data (ref [3]), substantial delay variance is unavoidable. The reasons are: the signaling channel is shared by signaling and user data, and SMS is designed as a storing and forwarding architecture. Therefore, the congestion can be problematic during peak periods. However, due to dedicated timeslots for GPRS services on GSM
networks and small message size “instantaneous” delivery is assured, a position report by GPRS takes only approximately 2 to 3 seconds to be received and handled. This is much faster than that of SMS, whose average delay from a mobile station to SMSC is around 3 seconds (ref [5]).

Another attractive feature of GPRS is that its service is billed based on the volume of transmitted data. At present, the cost of using GPRS is at least 3 times cheaper than that of using SMS in fleet management systems.

The only reason that we still keep using SMS is that its coverage area is much larger than that of GPRS currently. Using SMS where there is no GPRS service, we can make a real-time tracking system work in a much wider area and keep in a comparatively low cost.

**VEHICLE UNIT**

The vehicle unit can be divided into three parts: Positioning Subsystem, Control Subsystem and Communication Subsystem as shown in Figure 5.

1. **Positioning Subsystem**

Global Positioning System (GPS) receivers are elected for positioning function. The advances in the use of GPS and the dramatic price reduction experienced by GPS products over the last few years has turned GPS into a affordable and effective technology. It provides the most accurate and reliable method for the fleet management systems.

Position accuracy and position availability are two most important design parameters for GPS-based positioning systems (ref [1]). They can be enhanced substantially by Differential GPS (DGPS) and Dead Reckoning (DR) technologies.

2. **Control Subsystem**

The control subsystem is designed to integrate and control all elements of the vehicle unit, including control buttons, display screen, GPS receiver, GPRS modem, etc. We choose a single-chip microcontroller (SCM) as the main element to build the control system. Four RS-232 ports are designed to connect to GPRS modem, GPS receiver, physical condition sensors and other equipments. We use C language to write the control algorithms and communication protocols program code.
The control subsystem also controls the communication mode switching between SMS and GPRS according to the services availability. GPRS mode has service priority.

3. Communication Subsystem

Using GPRS and SMS as wireless media is their lower maintenance and wider coverage comparing with radio modem. GPRS modem is elected as the mobile communication device. In order to support the SMS service, the modem should provide SMS service function as well.

In the GPRS communication mode, we use the Point-to-Point Protocol (PPP), one of the dial-up remote access protocols, as the base communication protocol. PPP is a set of industrial standard protocols that provides a standard method for sending network data over a point-to-point link. Figure 6 is its simplified link state transition diagram. A complete communication protocol stack is composed with PPP and Transmission Control Protocol/Internet Protocol (TCP/IP). In the Intranet of GPRS Network, a private IP is distributed when mobile station dial-up to connect to the GPRS Network. By using the private IP, the data can be transmitted through TCP/IP in Internet.

Three interface protocols have been defined for the transfer of SMS short messages between a terminal equipment and mobile station via an asynchronous interface: block mode, text mode and PDU (protocol data unit) mode. According to the characteristics of positioning and control data, we use text mode as the short message submission protocol. It is a character-based protocol base on the AT command set modified for GSM. This mode is suitable for unintelligent terminals or terminal emulators, and for application software built on command structures.

The positioning and control data are packed in our positioning packet format.

MONITORING UNIT

The monitoring unit, illustrated in Figure 7, is a computer network system central to collating and displaying information for the purpose of ultimately controlling the fleet. A communication server connects to GGSN of the GPRS, SMSC of the SMS and the distributed management centers, and it is configured as a host computer in the GSM network for using SMS and as a host computer in Internet for using GPRS. The management center may be either stand-alone or networked based on the fleet size it managed. Web-base Geographic Information System (GIS) is used to map positioning data onto visual friendly display via the Internet if necessary.
1. Communication Server

A communication server is designed to connect to the SMSC through a dedicated line and to the GGSN through Internet. To be a host node in Internet, the communication server should have a fixed IP address of the Internet. The communication server performs three main functions: protocols conversion, data packet switching, and DGPS correction data distribution.

Protocols conversion is to convert the received packet format to sending format according to their protocols. Data packets from SMSC and GGSN have different format from that of Gateway Interface Protocol (GIP) between the communication server and the GIS servers because different SMSC may have different external interface protocols.

Data packet switching here means one routing function in each direction. In the direction from vehicles to monitoring unit, the data packet should be routed to appropriate management center, for several management centers are needed in large-scale fleet management systems. In the opposite direction, the communication server forwards packets to GGSN or SMSC according to the communication mode of the destination vehicle unit. The vehicle unit’s communication mode is recorded every time when the communication server received its packet.

If necessary, the communication server collects the DGPS correction data every 3~8 seconds and distributes them to the connecting management centers by its packet switching module.

2. Communication Protocols

In GPRS mode, a vehicle unit is connected to the communication server through an IP based GGSN. TCP or UDP may be elected as the transport protocol. We defined an application layer protocol called GIP. The GIP is designed based on SMPP (ref [6]), which will be described next. Some improvements (e.g., packet format and response method) have been introduced in order to be more efficient and reliable.

In SMS mode, the communication server connects to SMSC by TCP/IP protocols. Over the TCP/IP network, there are many protocols have been designed to provide flexible data communications interfaces for transfer of short message data between the SMSC and the External Short Message
Entity (ESME), such as SMPP, CIMD, UCP, TAP, etc. Each SMSC provides one or several of these submission protocols. To be used in various SMS networks, the proposed communication gateway is equipped with the realization of SMPP, CIMD and UCP protocols.

3. Fleet Management Center

A large fleet management center consists of a network, including web-based GIS servers and monitoring workstations as illustrated in Figure 8. The GIS server provides GIS databases, GIS services, and vehicle positioning data for the workstations via the WWW.

Operators can monitor and control the fleet with the web browser on monitoring workstations. The browser should first download Java applets, which will be used to display the map and location information received from the GIS server according to the operators’ command. With this service, operators can even do their management works via the Internet. Clients with single or few vehicles can avoid investing on management center by leasing this system to monitor their vehicles. What they need is only a vehicle unit installed on their vehicles and a computer that can login to the web site of the GIS server via the Internet.

Fleet customers may send their business request to the management center via Internet, mobile phone or telephone. The operators process these requests and store them in the dispatch server. With the aid of the dispatch software, they scheme out dispatch and control messages, which will be sent out to the corresponding vehicles through the communication server.

The fleet management center might connect to the communication server by LAN, leased dedicated line, or the Internet. If DGPS correction is needed, the GIS server computes the positioning data with the correction data matching on the time before using or archiving it. Positioning data is archived at the GIS server for documentation and purposes as well as later play back. Virtually every transmission from all of the vehicles is stored. This archive of data allows operator to recall vehicles tracks for analysis of situation or for historical or liability reasons.

CONCLUSION

The proposed system may be used to manage large-scale fleets anywhere the GSM/GPRS networks covered. After the implementation, it has been tested for a long time and also been used in several projects. With the aid of the communication server, our simulation system can manage more than
3500 vehicles, and up to 64 management centers. The transmission delay is less than 3s in GPRS mode. It varied in SMS mode with the service load from less than 2s to more than 10s, but in most cases, less than 5s, which might match the requirement of most fleet management. We have received GPS accuracy of about 20 to 30 meters without DGPS, and this accuracy might be acceptable to the long distance systems. With a DGPS, the positioning accuracy can be improved to less than 10 meters, and this accuracy might be acceptable in short distance systems, for example, buses and taxies.

As public GSM networks provide both GPRS and SMS, therefore, the maintenance of the whole system is lowered to as a small or middle scale mobile LAN.

REFERENCES


