Design and Realization of the Vehicle-mounted Unit for a Remote Electronic Monitoring and Calibration System

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Abstract - This paper introduced the GPS/GPRS-based remote electronic monitoring and calibration system, as well as its working principle and system framework. Then the hardware structure and software designing of vehicle mounted unit were introduced. Next, we emphasize testing the reliability and speed of communications while refreshing the data of ECU through GPRS. As a conclusion, it quickly implements the functions of vehicle remote supervision and ECU calibration.

Keywords - ECU, Vehicle Control and Supervision, Remote Calibration, Vehicle-mounted Unit (VMU), Communication Quality Control

I. INTRODUCTION

Since laws and regulations on vehicle emission are more and more strict, electronic control systems, used to improve combustibility and fuel economy as well as decrease emission of NOx and COx, become essential for automobiles. In the development and customization of electronic control systems, it is necessary to test vehicles, under different working conditions or on durability, etc. Because overall performance of engine is affected by many physical parameters and environmental factors in vehicle operation, to supervise and record engine's running status parameters will make great sense to evaluation and optimization of engine control strategies.

Several approaches about how to record data and errors in running vehicle have been developed in [1][2][3][4]. The record, which is downloaded to PC off-line, can help people make judgment in maintenances and tests. Some systems, which aim to realize remote control and supervision of vehicle running status, are also developed in [5][6][7][8]. But at present, single function, unchangeable protocol, narrow range of application and that record can only be off-line downloaded have become common problems with the vehicular monitor products on sale in market.

As the core of electronic control system, in its software, ECU stores a large amount of operation parameters and control parameters, such as engine speed, cooling water temperature, fuel injection pulse width, fuel injection advance angle and EGR valve opening, etc. Due to differences among parts and engine types, when vehicles leaving the factory, OEMs need to calibrate the parameter values of a large number of variables in vehicle control systems, to assure that engines and entire vehicles work in a fairly good and economical state. However, because structural components and engine's operating characteristics of vehicles will change as the result of time passing, the curves calibrated when leaving the factory, could hardly match the actual operation states. This discrepancy leads to rise of fuel consumption and affects comfort and power output negatively. As a result, it is necessary to re-calibrate vehicles. Furthermore, maintenances of electronic control vehicles also involve refreshing the data in ECU. At present, most maintenances, tests and update of ECU data are only available in 4S shops of manufacturers. However, owing to the limited coverage of 4S shops in a certain area, problems mentioned above cannot be solved conveniently. Meanwhile, for vehicle manufacturers, security and secrecy of vehicular calibration data can hardly be guaranteed.

An effective vehicle remote electronic monitoring and calibration system is developed in this paper. This system, which has involved multiple ports and ECU calibration function, is fairly convenient and meanwhile guarantees protocol adaptability, quality of communication and security of data. Except for conventional functions of data monitoring, remote fault diagnosis, GPS location tracking and data record, the system implements vehicle ECU remote calibration and more reliable program updating. System hardware interface is up to the KWP2000 agreement and has popular communication ports of electronic control vehicle, such as CAN and K. Moreover, it is convenient to make configuration of communication protocol, to adapt to different kinds of vehicles and expand its range of application.

II. BASIC PRINCIPLES OF SYSTEM

Figure 1 shows basic principles of vehicle remote monitoring and calibration system. The system is divided into vehicle-mounted hardware and server calibration software. Vehicle-mounted unit(VMU) is installed on vehicle. According to protocol configuration, this unit collects operating data and control parameters through vehicular communication ports (for example, CAN ports here). All the information is stored in high capacity FLASH memory. At the same time, GPS module collects real-time location information through satellites, and then sends it to the CPU of VMU. CPU packages GPS information and monitoring data into complete data packets, and sends them to wireless module. Based on TCP/IP protocol, wireless module makes data into TCP/IP packets and sends to SGSN (Serving GPRS Support Node) through wireless links. After carrying out protocol conversion, SGSN generates GTP packets according to GPRS Tunnel Protocol, and then sends these packets to corresponding GGSN (Gateway GPRS Support Node) through GPRS backbone network. GGSN also carries out corresponding protocol conversion and then complete new

packaging based on exterior INTERNET protocol, and according to destination IP add address, the route is selected and data reaches monitoring center finally[9]. When server has analyzed the data received, data monitoring and location tracking is implemented, by displaying real-time state and location of vehicle. Through network, the server can send different control commands to VMU, to alter working state of the unit and control the unit and ECU to carry out protocol configuration, return record data, update ECU data, etc.

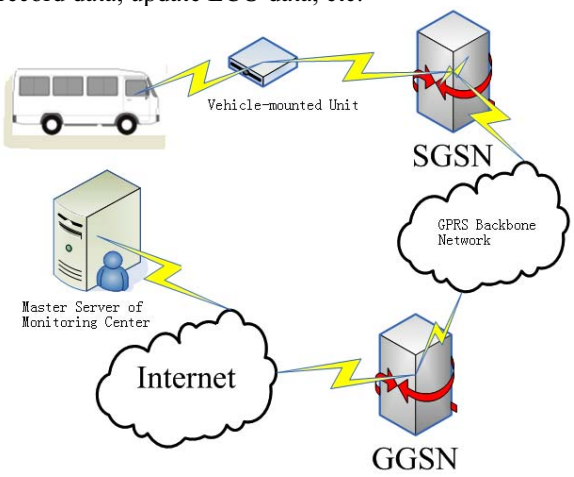

Fig.1: Basic principle of system

III. DESIGN AND IMPLEMENTATION OF VEHICLE-MOUNTED UNIT

Based on system structure, main functions of the VMU include:

- Network Management: log on GPRS network, connect to server, test network connection, maintain network state, re-connect when losing connection, log off, etc. Most of these actions are completely automatically.
- GPS (Global Positioning System): obtain GPS data through connection to satellites.
- Data Monitoring: collect running state information (such as real-time speed of vehicle, mileage and vehicle position, etc.) and control data of ECU.
- Real-time Recording: store information collected to high capacity nonvolatile memory, and the information can be downloaded to PC and return to monitoring center online through high-speed port.
- Protocol Configuration: develop and implement software driver module with configurable communication protocol. Provided with the protocol configuration ports, developers can adapt prototypes to different communication protocols, through remote configuration of parameters on VMU.
- Data Calibration: according to KWP2000 protocol (standard protocol of vehicular ECU communication), implement the remote data calibration of master controller.
- Data Encryption: all the wireless communication data is encrypted.

A.Hardware Architecture of Vehicle-mounted Unit

Design of the VMU is based on the mind of modularization, it can be divided into five modules: central control, wirless communication, GPS, memory, vehicular communcation access. Central control module is responsible for coordinating all modules. The hardware configuration for VMU is shown in Figure 2.

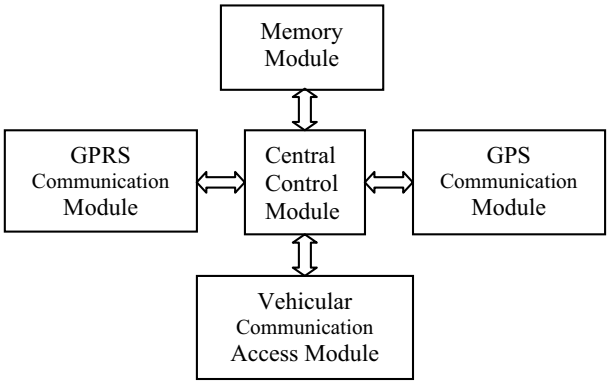

Fig. 2: Hardware configuration for the VMU

Central Control Module is the core of the entire VMU, according to the low power requirements of automotive equipments, the chip power consumption should be selected as small as possible, and can resist harsh automotive work environment. Wireless communication module provides the vehicle-mounted system with functions such as connection and maintainance to GPRS network, data transmission, etc. Since the system is installed on vehicle, wireless communication module should be able to resist vibration, noise, electromagnetic interference and extreme temprature, to ensure communication quality. Once power on, GPS module should be able to search satellites and complete positioning quickly. Memory module is used to store real-time record data of running vehicles. To meet the requirement of uninterrupted record, large-capacity memory chip is necessary. At the same time there are strict requirements on the chips, such as the rewritable number, reliability and the temperature range. Vehicular communication module provides the vehcular network accessibility of the system. Through the combination of vehicular communication module and configurable protocols, this system is able to operate on most electronic control vehicles, with wide range of application.

B. Design and implementation of system software

To meet the requirement on designed functions and hardware drivers, the information unit involves functions such as GPRS network management, data record and upload, ECU data update, data encryption, protocol configuration, etc.

- GPRS Network Management: log on GPRS network when power-on, guanratee the uninterrupted connection between VMU and GPRS network.
- Data Record and Upload: record realtime data of vehicle running state and upload vehicle data and GPS data to monitoring center.
- ECU Data Update: refresh data or update programs on vehicle ECU remotely, to guanratee data correctness strictly.
- Data Encryption: to prevent malicious intrusion to system and consequent data interception, communication between VMUs and servers must be encrypted. Security of data is of great importance to remote calibration of ECU for manufacturers.

• Protocol Configuration: through configuration of communication protocol, VMU can be equipped to different electronic control vehicles with wider range of application.

IV. PERFORMANCE TEST

Reliability and stability of data transmission is crucial for data supervision and remote calibration tasks. So TCP/IP connection is established, in order to provide reliable data interaction between VMU and calibration software of server. Thanks to TCP protocol, data interaction has fairly good reliability. Through the combination of proper communication protocols and intact TCP/IP protocol, communication module of VMU can provide reliable data interaction.

A. Tests of Communication data reliability

There is no error retransmission mechanism in the communication between VMUs and servers. With different TTI (Transmission Time Interval) and message length, communication reliability is tested, as showed in Figure 3. From Figure 3, when TTI is 2s and message length 500kB, the communication reliability remains on a fairly high level. Due to the variation of network congestion, there are modest decreases of communication quality between 14 and 18 o'clock during a single day. Reliable data transmission will be guaranteed by protocol configuration of communication between VMU and the server.

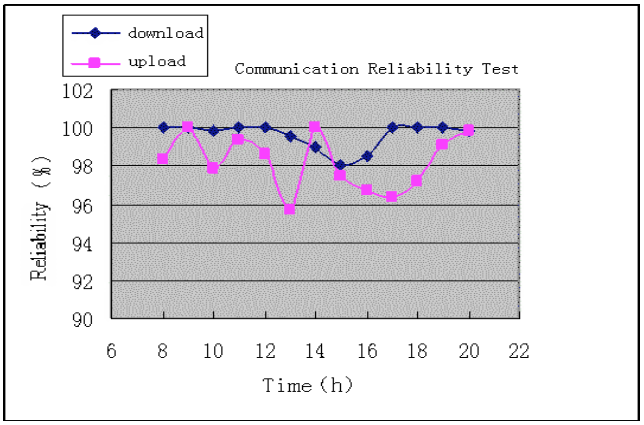

Fig. 3: Tests of communication data reliability

B. Tests of communication speed

Communication speed should meet certain requirements, especially when system is remote downloading ECU data or updating programs. Overlong time of downloading involves more risks to the task failure. Generally speaking, all data areas of ECU, which are used to test communication speed, are in size of 300KB. They will be split into 300 packages with the sending interval of 0.5s by the server. VMU receives the data and temporarily stores them into FLASH memories. After checking the correctness, data refresh will be carried out. The communication between VMUs and servers involves error retransmission mechanism. Figure 4 shows the different time costs of downloading 300KB data at different time in a single day. From Figure 4, the average time cost is 200s. Due to high network congestion in afternoon, retransmission times and delays of packets increase, but it is tolerated

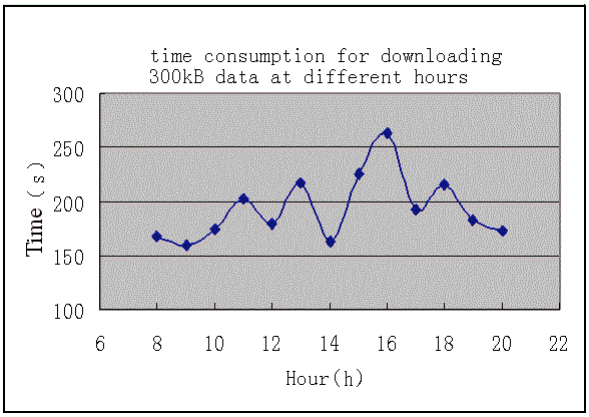

Fig. 4: Time consumption for downloading 300kB data at different hours

V. CONCLUSION

A vehicle-mounted device, which aims to remote maintenance of vehicular electronic control, is developed in this paper. This system integrates GPRS and GPS module, with multiple interfaces accessed to vehicular electronic control unit. The VMU mentioned here is able to be connected to internet through GPRS, measure and record data online in high capacity. With configurable communication protocol, this system can be applied a wide range of electric control vehicles.

This paper mainly focused on ECU's functions of remote calibration, data refresh and program update. With this system, fixed servers are able to monitor, measure, calibrate and position running vehicles remotely, and it has been an ideal tool of high altitude, high temperature and extremely cold testing on electronic control vehicles. This system has been applied successfully in several projects.

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REFERENCES

[1]. TIAN Wei, ZHANG Zhi-jun, LIU Jlao-yu: 'Overloading moniter and recoder with embedded', Transducer and Microsystem Technology, 26, (12), 2007, pp.75-76,79

[2]. Cui Ming Yan Ting-qin Zhou Chang-xiong Yu Xing-ming: 'The Application of GSM Engine TC35 in Driving Information Recorder', Shanxi Electronic Technology, (5), 2007, pp.35-36,39

[3]. ZOU Yi-hui, GENG Xiang-ming: 'Application of the GPS/GPRS Vehicle Traveling Data Recorder', Automation and Instrumentation, 22,(6), 2007, pp.17-19,53

[4]. Liu Tao: 'The Design and Development of Vehicle Traveling Data Recorder', Mechatronics, 13, (5), 2007, pp.56-58,61

[5]. ZHANG Chunrong,FAN Hanbai: Research of Data Terminal in Remote Monitoring System Based on GPRS, Modern Electronic Technique, 29, (15), 2006, pp.110-112
[6]. Hua Lei, 'GPRS-based remote vehicle monitoring system', Telecommunications Information: network and communication, (2), 2007, pp. 16-18,44
[7]. WANG Song-hong， LI De-hua: 'Design of Mobile Terminal of Vehicle for Monitoring System Based on GPRS', Application Research of Computers, 22, (6), 2005, pp.184-186
[8]. ZHU Jian-liang, Wang Xing-quan: 'Design of long-range management and diagnoses system terminal for engineering vehicles', Journal of Chinese Inertial Technology, 15, (3), 2007, pp.312-315
[9]. Zhang Xun-yong: 'Development and research on remote communication unit based on GPRS for electric vehicles and communication protocol' , Dissertation of Tianjin University, 2005.