An Internet of Vehicles System for Remote Monitoring and Fault Diagnosis of Automobiles

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***Abstract*—Internet of Vehicles (IOV) and Intelligent Transportation System have drawn a lot of attention in both the academy and industry. The remote monitoring and fault diagnosis of vehicles are two of the most important aspects of the IOV system. This paper presents an IOV system which contains an intelligent vehicle terminal installed in the car, wireless network for information transmission, cloud server for providing the functional services, mobile terminal for supplying user interaction services. In the proposed IOV system, there implements a series of valuable functions including real-time emission inspection, vehicle fault alarm and disposal recommendation, automatic maintenance reservation, path to maintenance optimization, driving habits statistics. This system can greatly improve the efficiency, accuracy and instantaneous of the vehicle fault diagnostic and finally the customer satisfaction.**

***Index Terms*—Internet of vehicles, emission inspection, remote vehicle diagnosis, remote monitoring**

I. Introduction

The automobile has become an essential tool for human travel and provides a great convenience. With the dramatic increase in the number of vehicles, automobile safety issues have started to emerge. In all kinds of safety issues, car accidents caused by vehicle failures and hazards account for the major part [1]. Although the regulators specify more stringent safety indicators for vehicles, meanwhile the level of vehicle safety technology also constantly increases, there still frequently occur accidents caused by vehicle failures [2].

To carry out the vehicle diagnosis and maintenance, the OBD II (On-Board Diagnostics) system is applied to acquire detailed failure information [3]. The OBD II system monitors the operation status of the engine and the working status of the tail gas processing system, and it will send a warning signal immediately on condition that there exists any parameter exceeds recommended level. When a fault is detected, the MIL indicator on the dashboard will be lighted and the OBD system will store the fault message in memory, which can be read as the fault code form by standard diagnostic equipment and diagnostic interfaces. According to the fault code, the maintenance engineer can quickly and accurately locate the reason of the fault and solve it [4].

Although the OBD system can monitor the real-time behavior of the vehicle, the MIL will be lighted to warn the driver when the fault occurs, but the driver cannot accurately know the details of the vehicle fault. And when the vehicle conditions and road conditions were not good, the driver will not be able to deliver the vehicle to the maintenance point in time. In some cases, although the fault light indicates a fault, the driver cannot clearly recognize the severity of the fault. Some drivers ignore the fault alarm and continue to drive with potential safety problems, it may cause a security accident. The existing OBD fault system can only serve as a local reminder [5]. The specific execution also needs to rely on the consciousness of the driver and cannot effectively monitor and manage the faulty vehicle [6].

Therefore, the vehicle information remote monitoring and failure diagnosis system has become a key way to break the local limitations. The system reads the fault information of the vehicle in real time and transmits the information to the cloud server instantly through the wireless communication network. In the cloud server, classification and analysis of vehicle fault diagnosis algorithms are implemented to analyze the vehicle failure and generate the most efficient disposal method. And then, the analysis results are transmitted to the vehicle owners and maintenance engineers through the wireless communication network. The system can facilitate the vehicle owners to understand the details of the vehicle in time, and simultaneously facilitate the maintenance engineers to generate the accurate maintenance plan. At the same time, the system can also calculate the optimal path to the nearest maintenance location by analyzing the GPS information of the vehicle and the map information.

The remainder of the paper is organized as follows. Section II summarizes the existing IOV systems. Section III describes the proposed IOV system architecture. Section IV presents the procedure of the information interaction in the vehicle information remote monitoring and fault diagnosis system. Section IV illustrates the

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frame formats in the information interaction procedure. Section VI concludes this paper.

II. Related Works

The system of internet of vehicles can effectively improve the detection efficiency of vehicle failure and greatly reduce the vehicle safety hazards. There are several IOV systems which had been reported in the literature.

In [7], the authors proposed a remote vehicle diagnosis and maintenance system, which consisted of a front diagnostic client, network communication and a remote service center. Although the system implemented the conversion of different communication protocols between onboard network and diagnostic computer as well as the data transmission, initially realized the remote information monitoring and fault diagnosis of the vehicle, but it was difficult to achieve automatic detection and automatic warning.

A Bluetooth based vehicle remote diagnosis system was presented in [8]. The system connected the can bus, the internet, and the mobile terminal through Bluetooth technology. The system broke through the traditional diagnosis and shortened the time of diagnosis. However, the Bluetooth technology used in this system restricts the range of information transmission.

In [9], the remote diagnosis systems choose a DTU (Data Transfer Unit) rather than the OBD device as the information acquisition module. And in [10], a lookup tables and fault models combined diagnostic method was applied on a hybrid electric vehicle by implementing a series of sensors. These systems need plenty of data collecting devices to collect different kinds of signals for each vehicle.

To solve the above problems, this paper designs a multi-purpose remote monitoring and fault diagnosis system for vehicles. The proposed IOV system can detect the running status of the vehicle in real time, diagnose the potential fault or intermittent fault in time. It can also obtain the vehicle speed, the amount of fuel remaining in the fuel tank, the current GPS location, door lock and etc. The system has advantages of instantaneity, accuracy, and practicability.

III. The Proposed IOV System Architecture

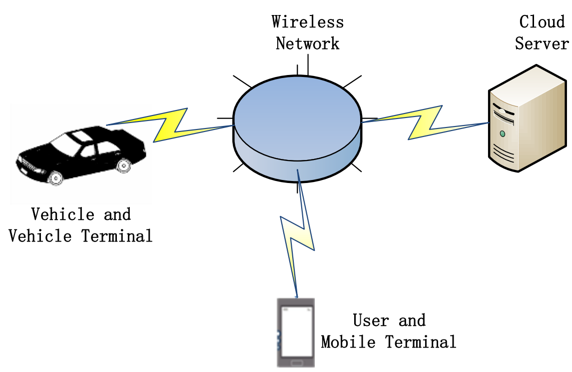

Figure 1. System structure and composition.

The proposed vehicle information remote monitoring and fault diagnosis system includes a vehicle terminal which installed in a vehicle, a cloud server platform, and user's mobile terminals. All of these are interconnected through the internet, and the connecting structure is shown in Fig. 1.

A. The Intelligent Vehicle Terminal

The intelligent vehicle terminal is used to obtain the real-time running information and the fault code information of the vehicle, and then the information is packed and sent to the cloud server. The intelligent vehicle terminal consists of the information acquisition module, the microcontroller unit (MCU), the wireless communication module and the information storage module. The composition of the intelligent vehicle terminal is shown in Fig. 2.

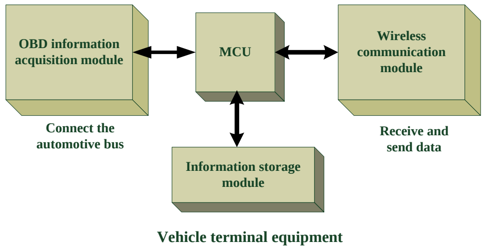

Figure 2. The composition of intelligent vehicle terminal

The acquisition module of the intelligent vehicle terminal obtains the real-time running information and fault code information through the CAN bus of the vehicle. The wireless communication module sends the information collected by the acquisition module to the cloud server, and it also receives the fault diagnosis packet from the cloud server platform. The information storage module stores the fault information of the vehicle as the historical vehicle fault information. The MCU is the central process unit, which communicates and controls the other modules. In addition, the intelligent vehicle terminal has the GPS positioning system, which provides the real-time geographic information.

The intelligent vehicle terminal supports all the OBD2 protocols including 12 kinds of conventional vehicle International Standard Organization (ISO) and Society of Automotive Engineers (SAE) protocols. It also be used to diagnose communication with the ECU and various control modules. Meanwhile, the intelligent vehicle terminal can operates in multiple working modes, such as quick diagnosis mode, data statistics mode, intelligent alarm mode, and sleep mode. And the mode switching is determined by user requirements.

B. The Cloud Server Platform

The cloud server platform of the vehicle information remote monitoring and fault diagnosis system can receive and manage the registration information of the vehicle, receive, store and classify the information of the vehicle state and the fault code from the vehicle intelligent terminal, and then analyze the received information. As shown in the Fig.3, the cloud server platform has the function of expert diagnosis [11], fault solution guidance, fault prediction [12], and driving behavior analysis.

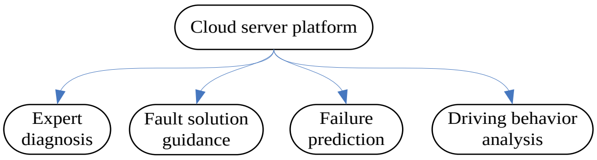

Figure 3. Functions of cloud server platform

1) *Expert diagnosis*

By comparing the acquired data from the intelligent vehicle terminal to the standard database, expert diagnosis function can intelligently analyze and generate fault solutions upon detection of faults, provide maintenance advice to users and maintenance personnel [13].

2) *Fault solution guidance*

The fault solution guidance function can help the driver leading to the most convenient automobile maintenance site. When the algorithm of the cloud server platform judges that the fault is difficult to be solved by the users themselves, the system will search for the address of the automobile maintenance sites nearby according to the vehicle's current GPS location [14]. User should follow the guidance and handle the safety problems.

3) *Fault prediction*

The fault prediction function can intelligently predict the time and type of vehicle failure. It analyzes the historical driving data of the vehicle, predicts the occurrence time and type of the vehicle fault, pushes the warning information to the user in advance, and reminds the user to repair and maintain the vehicle.

4) *Driving behavior analysis*

The driving behavior analysis function evaluates the driver's driving habits [15]. The statistics of driver's driving data such as the number of ignitions, rapid acceleration, and emergency brakes can indicate the driving features. This function can also remind users to correct bad driving habits.

C. *The Mobile Terminal*

The mobile phone is a part of the IOV system, and it's used for receiving information from the cloud server platform. The mobile terminal APP shows the vehicle information, such as the vehicle speed, engine coolant temperature, battery voltage, remaining oil and engine running time, and other real-time tracking vehicle running status. The user can observe the driving habits calculated by the number of ignition times, sudden braking times and acceleration times. Based on the statistical driving habit, the mobile terminal APP will push the warning and reminding the user to correct the improper driving habits.

IV. Information Interaction Procedures

The proposed vehicle information remote monitoring and fault diagnosis system is composed of the intelligent vehicle terminal, the cloud server and the intelligent mobile terminal, and these three modules are communicated through wireless network. There are some information interaction processes among the three modules, including vehicle terminal registration, vehicle fault diagnosis, vehicle real-time data statistics, driving habits statistics and so on. The information interaction procedure is shown in Fig 4.

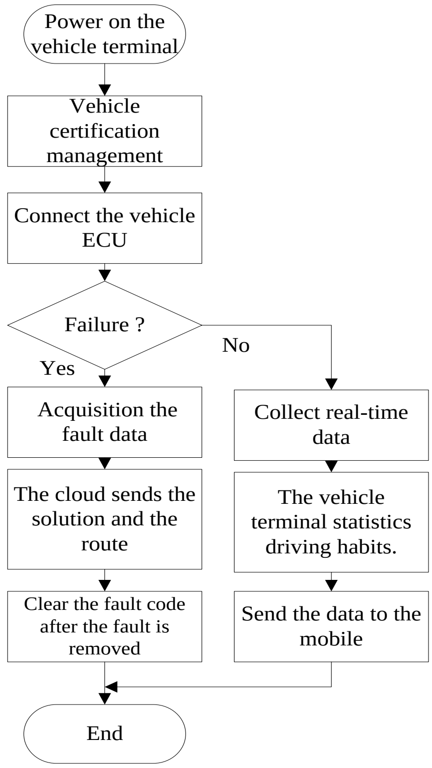

Figure 4. The information interaction procedure

A. *The Procedure of the Vehicle Terminal Registration*

As is shown in Fig. 4, when the intelligent vehicle terminal is powered on, it sends a registration request packet to the cloud server, and then the cloud management platform checks the registration status of the terminal. If the device is not registered, it checks the legality of the terminal identity code, and then registers and sends the registration successful response package. If the device is already registered, the registration success response packet will be sent directly. After the successful registration, the terminal sends a device login request packet to the cloud server. If the device is not registered, the login failure response packet will be sent. If the login is successful, a successful login response packet will be sent back, otherwise, a login failure response packet will be sent.

B. *The Procedure of the Vehicle Fault Diagnosis*

After the vehicle registered in the cloud server, the vehicle terminal obtains the vehicle's information and transmits to the cloud. When a vehicle failure occurs, the vehicle terminal automatically acquires the vehicle's fault code, packages this data in a specific frame, and then sends the frame to the cloud server. The cloud server receives the fault information frame, analyzes the failure of the vehicle, and automatically generates the fault solution. Then the cloud sends the fault diagnosis frame back to the vehicle terminal and the mobile terminal. Users can see the detailed fault solution and the address of nearby vehicle maintenance station on the vehicle terminal and the mobile terminal.

C. The Procedure of the Vehicle Real-time Data Statistics

The intelligent vehicle terminal sends the vehicle real-time running state data to the could server periodically. The vehicle real-time running state frame concludes vehicle speed, engine coolant temperature, battery voltage, remaining fuel, engine running time and so on. The cloud server receives the vehicle real-time running state frame, classifies and stores in the data base. The vehicle real-time data statistics can be published on both the Web side and the mobile terminal side.

D. The Procedure of the Driving Habits Statistics

A driving habits collection algorithm is executing in the intelligent vehicle terminal for acquiring data such as maximum speed, break times, acceleration, and so on. The intelligent vehicle terminal sends the driving habits frame to the could server periodically. The cloud server receives the driving habits frame, and then classifies and stores the information in the data base. An algorithm of driving habits statistics is implemented in the cloud server, and analyzes the driver's driving habits by the statistics of driving data. The driving habits statistics can also be published on both the Web and the mobile terminal sides.

V. Information Frame Formats

There are huge and complex information interaction processes among the intelligent vehicle terminal, the cloud server, and the intelligent mobile terminal. In order to avoid the information interaction disorder, this work defines the detailed network transmission frame structures.

A. The Frame Format of the Vehicle Terminal Registration

The structure of the vehicle terminal registration frame is shown in Table I. The frame header and the frame end consist of special key characters, and can be applied to distinguish the data packet. The serial number accounts for two bytes, it’s used for counting the packets’ number, which increases from zero to the maximum value 0xFFFF and then return to zero. The terminal identification (ID) is applied to identify the terminal identity from the cloud platform. Registration status is “1” for registered or “0” for non-registered. The request time of registration is composed of ASCII codes, for example, the time of ASCII code 32303138303232323137313030 (in hex) is 2018-02-22 17:10:00.

TABLE I. The Vehicle Terminal Registration Frame

Communication byte	Field	Length(Byte)
Byte 0～1	Frame header	2
Byte 2～3	Serial number	2
Byte 4	Status information	1
Byte 5～18	Terminal ID	14
Byte 19～20	Registration status	2
Byte 21～34	Request time	14
Byte 35～36	Frame end	2

B. The Frame Format of the Vehicle Daily Fault Diagnosis

When a fault occurs, the vehicle terminal sends a fault diagnosis packet to the cloud. As shown in Table II, the fault diagnostic data frame consists of a frame header, serial number, status information, terminal ID, the number of the fault code, fault code, GPS information, fault time, transmission status, and frame end. The number of fault code and fault code are used to indicate the number of faults and their corresponding fault codes. The GPS information is used to represent the vehicle’s current geographic location in the form of longitude and latitude. The transmission status indicates whether the diagnosis data be sent successfully or not. The fault time is composed of ASCII codes.

TABLE II. The Fault Diagnostic Data Frame

Communication byte	Field	Length (Byte)
Byte 0～1	Frame header	2
Byte 2～3	Serial number	2
Byte 4	Status information	1
Byte 5～18	Terminal ID	14
Byte 19～20	The number of fault code	2
Byte 21～44	Fault codes	24
Byte 45～60	GPS information	16
Byte 61	Retention	1
Byte 62	Transmission status	1
Byte 63～76	Failure time	14
Byte 77～78	Frame end	2

TABLE III. Fault Responses Frame

Communication byte	Field	Length (Byte)
Byte 0～1	Frame header	2
Byte 2～3	Serial number	2
Byte 4	Status information	1
Byte 5～18	Terminal ID	14
Byte 18～47	Fault name	30
Byte 48～87	Solution	40
Byte 88～103	GPS of nearby maintenance station	16
Byte 104～105	Transmission status	2
Byte 106～107	Frame end	2

When having received the fault diagnosis packet, the cloud server diagnoses the fault codes, matches the solutions, and then sends a fault response packet to the mobile terminal. As shown in Table III, the response frame consists of a frame header, serial number, status message code, terminal ID, fault name, fault solution, GPS data of nearby maintenance station, transmission status, and the packet end. The fault name accounts for 30 characters, which are obtained from the cloud server by matching the fault database according to the fault codes. The cloud server employes the expert diagnostic database to generate the corresponding solution.

C. The Frame Format of the Vehicle Real-time Data Statistics

The vehicle real-time running status packet, as listed in Table IV, consists of frame header, serial number, status code, terminal ID, GPS information, battery voltage, engine speed, vehicle speed, engine load, coolant temperature, remaining fuel tank, instantaneous fuel consumption and etc.

TABLE IV. THE REAL-TIME RUNNING STATUS DATA FRAME

Communication byte	Field	Length (Byte)
Byte 0～1	Frame header	2
Byte 2～3	Serial number	2
Byte 4	Status information	1
Byte 5～18	Terminal ID	14
Byte 19～35	GPS information	16
Byte 36～38	Battery voltage(VBAT)	2
Byte 39～40	Engine speed(RPM)	2
Byte 41～42	Vehicle speed(SPD)	2
Byte 43～44	Throttle opening(TP)	2
Byte 45～46	Engine load(LOD)	2
Byte 47～48	Coolant temperature	2
Byte 49～50	Fuel tank remaining oil(FLI)	2
Byte 51～52	Instantaneous fuel consumption(MPH)	2
Byte 31	Retention 1	1
Byte 32	Retention 2	1
Byte 33～34	Frame end	2

D. The Frame Format of the Driving Habits Statistics

The driving behavior data is accumulated during every 15 minutes and formalized as a driving habits statistics format. As shown in Table V.

TABLE V. DRIVING HABITS DATA STATISTICS PACKET

Communication byte	Field	Length (Byte)
Byte 0～1	Frame header	2
Byte 2～3	Serial number	2
Byte 4	Status information	1
Byte 5～18	Terminal ID	14
Byte 19～32	Data generation time	14
Byte 33～34	Maximum engine speed	2
Byte 35～36	Minimum engine speed	2
Byte 37～38	Maximum speed	2
Byte 39～40	Average speed	2
Byte 41～42	Mileage	2
Byte 43～44	Cumulative total mileage	2
Byte 45～46	Fuel consumption	2
Byte 47～48	Brake times	2
Byte 49～50	Ignition frequency	2
Byte 51～52	Seat belts condition	2
Byte 53	Retention 1	1
Byte 54	Retention 2	1
Byte 55-56	Frame end	2

The driving habits data statistics packet concludes the information of engine speed, break times, ignition times, seat belts condition, the average speed, maximum speed, accumulated mileage, and so on. The cloud server applies these data to evaluate and score the driver's driving behavior. The statistics and evaluation information will be announced by the website and the APP.

VI. CONCLUSIONS

The internet of vehicle remote monitoring and fault diagnosis system eliminates the limitation of the existing vehicle OBD system and can extend the usage of OBD information by communicating the vehicles, the cloud server (or management platform) and the mobile terminal. The proposed IOV system serves not only for the vehicle owners, but also for the vehicle related organizations such as the vehicle administration departments, the maintenance stations, the insurance companies, and the automobile factories.

For the vehicle owners, the proposed IOV system can inform the vehicle's real-time running information in detail. This system evaluates the operation status of vehicles on time. When occurring a vehicle malfunction, the IOV system can help the owner to understand what the problem is, how to solve it, and where to repair the vehicle. And the system can model the driving behaviors and correct the bad habits, evaluate the operation status of vehicles, and improve the driving safety greatly.

For the vehicle related organizations, the IOV system statistics the main vehicle failures. Based on the information, the maintenance stations should prepare some corresponding auto parts in advance to shorten the repair time. The automobile factories could improve the manufacturing quality by analyzing the failure causes. The insurance companies can identify the responsibilities of the vehicle accidents by applying the proposed IOV system.

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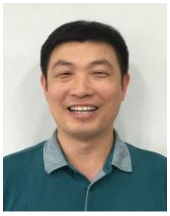

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