The research on intelligent monitoring system of key tire parameters for automotive driving safety based on vehicular networking

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Abstract. In this paper, the intelligent monitoring system of key tire parameters for automotive driving safety based on vehicular networking technology was researched. It is a whole life-cycle of tire tracking service system, which consists of tire pressure/temperature sensors, a vehicular transfer device, a smart phone and a cloud server. The technology of radio frequency identification, Bluetooth and cloud computing is applied to monitor tire pressure and temperature offline, analyze and feedback data online, providing a new valuable solution for automotive tire maintenance.

Introduction

According to statistics, the accident caused by sudden puncture while running at high speed is listed as the top highway accident, and more specifically, it takes up 49.81 percent of traffic fatalities, 63.94 percent of injuries, 43.38 percent of direct property loss [1].Tire pressure monitoring system (TPMS) is a car active safety system to ensure the safety of drivers' personal property, which shows the automobile tire pressure/temperature data collected by tire pressure/temperature sensors in the electronic display ,and alarms when the data is beyond the alarm threshold.

Internet of Things is regarded as the 3rd wave of industry after the computers and the Internet information industry. According to the study of CCID Consulting Company, the overall value of the internet of Things of China in 2015 will reach 750 billion yuan. Vehicular networking is an important application of the internet of things, it collects and shares information through cars to interconnect the car with the car, the car and roadside infrastructure, automotive and urban networks, and enables more intelligent and safe driving, but also provvides the owners with various entertainment services. Without doubt, the development of vehicular networking will play an important role in reducing traffic accidents [2].

The popularity of smart phones provides a terminal platform for the development and promotion of intelligent TPMS based on vehicle networking technology, and it also cuts off the production of

current TPMS electronic terminal display which will save the costs. The current TPMS electronic display has a poor show interface that can't meet people's growing aesthetic requirements, and is difficult to carry out a simple statistical analysis without the operation ability. But the intelligent TPMS based on vehicular networking technology not only has reliable and stable algorithm, but also has beautiful APP interface design, and can be easily shared on wechat which can entertain and interact with friends in traffic jams.

1 The principle and design of intelligent TPMS based on vehicle networking technology

1.1 The development of TPMS

TPMS is a car active safety system to ensure the safety of drivers' personal property, which shows the automobile tire pressure/temperature data collected by tire pressure/temperature sensors in the electronic display, and alarms when the data is beyond the alarm threshold. Around the 2000 year, our country began to introduce advanced foreign technology for the production and sale of TPMS, and there were about 300 firms and more than 30 professional TPMS manufacturers by 2004, which reached its peak .The current TPMS can be divided into two categories: direct TPMS and indirect TPMS.

Indirect TPMS is to monitor the tire pressure by the algorithm, which is comparing the speed difference between the wheels via the wheel speed sensors of the automobile ABS system, and. Only when a tire pressure is too high or low, the diameter of the tire will be larger or smaller, resulting in a corresponding change on wheel speed. The monitoring system will compare the wheel speed with the standard data which have been previously stored to get a conclusion whether the tire pressure is too high or low, then it alarms. What's more, low cost is its most prominent advantage, because we just need to upgrade the software of cars if they have been equipped with ABS.

Direct TPMS is to measure the pressure and temperature of the tire directly by using the tire pressure/temperature sensors installed inside the tire, then display the pressure/temperature data of each tire, and also alarm when the data is beyond the alarm threshold. Direct TPMS can be divided into TPMS –with-battery and TPMS-without-battery. Accurate data and real-time measurement are the obvious advantage of direct TPMS, but the larger volume of sensors and short life are its weakness.

Currently, the popular research direction on TPMS is passivity,which includes electromagnetic field coupling technique [3], SAW technology [4], piezoelectric ceramic technology [5] and so on. Now the selling of TPMS has crashed into a glass ceiling in the automotive aftermarket, because most middle-grade and high-grade cars have equipped with vehicle-mounted TPMS. But the TPMS based on vehicular networking technology is expected to inject fresh blood, and renew vitality for the TPMS market.

1.2 Overall Program Design

The real-time monitoring system based on vehicular networking technology for tire pressure and temperature is researched in this paper, and the safety monitoring system based on vehicular networking has been designed. The system consists of four parts: the monitoring device for tire pressure/temperature [8], the vehicle-mounted transition device, smart mobile terminals and cloud servers. The system collects pressure and temperature data through MPXY8300A sensors, and then transmit data to the vehicle-mounted transition device which based on MC33696 chip (the chip can be used for the radio frequency transmitter, but also for radio frequency receptor) through the 434M radio frequency, then send data to your phone via Bluetooth chip by the specific communication protocol and display, after processed by microcontroller with the method of PIC. Finally, the mobile terminal send data to the cloud server via General Packet Radio Service(GPRS) and Code Division

Multiple Access (CDMA) and other mobile Internet technologies [6,7] to store, analyze and dig out useful information, and then feedback to the user. The system not only enables real-time monitoring tire pressure and temperature offline, but also achieves the analyzing and feedback function, which ensures the safety of driving, so the drive can make a countermeasure prior to puncture, and the car owners can also receive feedback information that focuses on the vehicle's driving conditions and tire quality assessment from the cloud server each month. In this process, the system can judge whether the tire pressure and temperature is abnormal by the controller on the transition device. If the tire pressure is abnormal (exceeding a certain limit, or a flat tire) or the temperature is too high, the tire temperature / pressure monitoring device will transmit a specific fault code mobile phone, after the judgment by phone software, it will trigger an alarm to remind driver manner timely. Schematic of the system framework is shown in Fig. 1, and schematic of the system components is shown in Fig. 2.

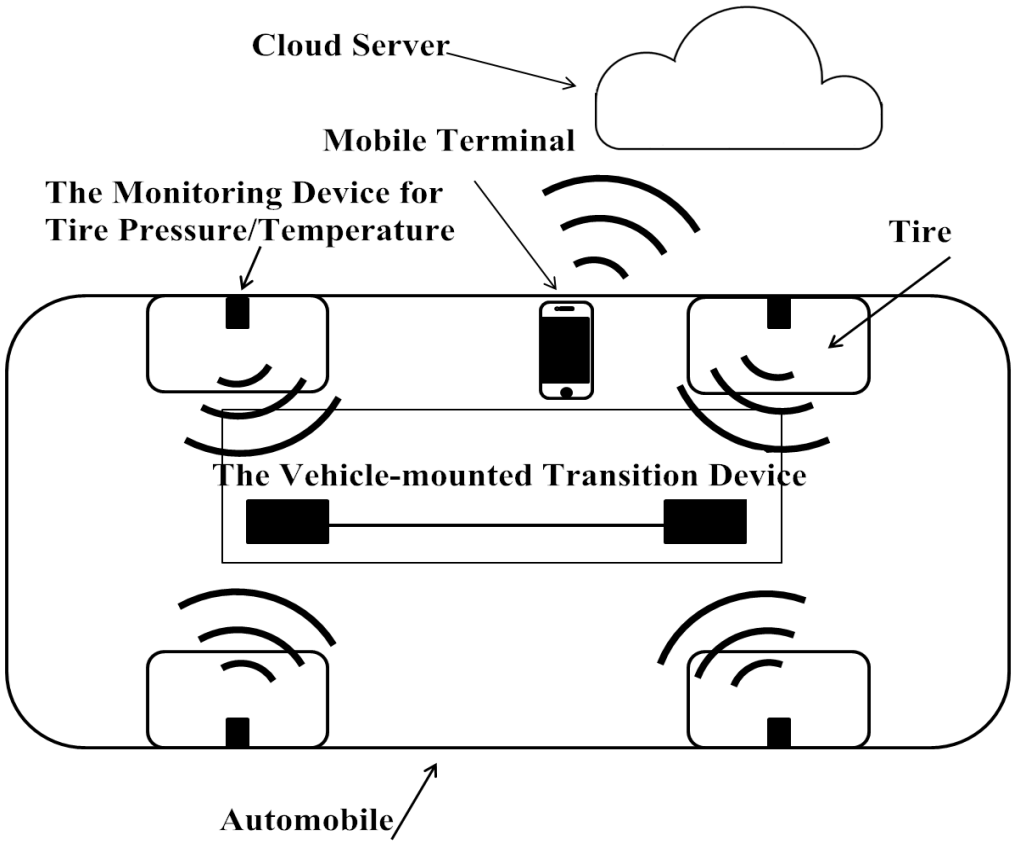

Fig. 1 Schematic of the system framework

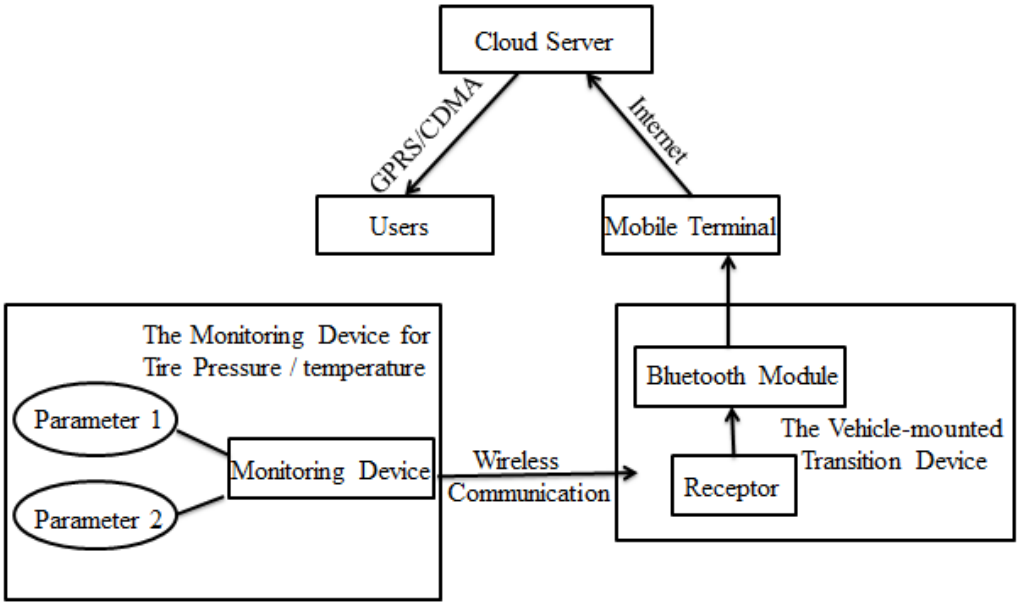

Fig. 2 Schematic of the system components

1.3 System hardware and software design

1.3.1 The design of tire pressure / temperature monitoring device

Tire pressure and temperature parameters are monitored by tire pressure/temperature monitoring device whose key component is Freescale MPXY8300A chip. The device consists of high precision sensor device SoC (System on Chip), 4-8-bit microcontrollers, RF transmitter chip, power supply, antenna and external packaging. The smart sensors have high monitoring accuracy; And the microcontroller has high processing speed; The transmission of RF transmitter chip and antenna can transfer stably; the power supply can give a long time power supply; external packaging material has high strength [9]. The circuit principle diagram for tire pressure/temperature monitoring system is shown in Fig. 3.

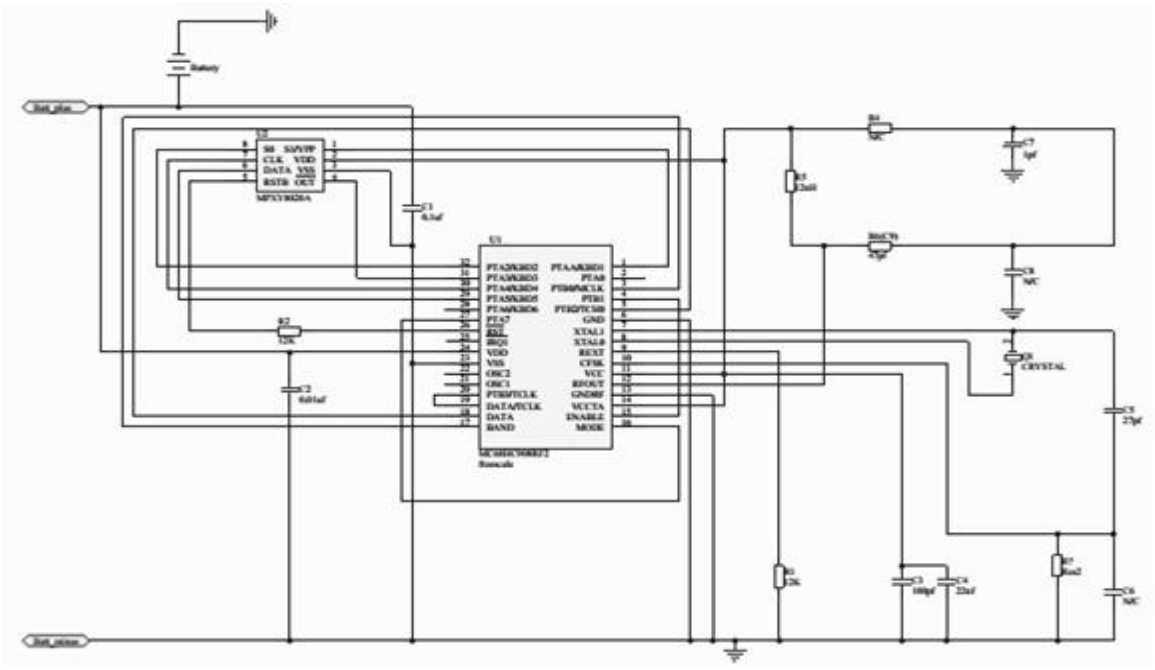

Fig. 3 The circuit principle diagram for tire pressure/temperature monitoring system

The rate of wireless radio frequency communication used in the system is 9600bps, and FSK (Frequency-shift keying) modulation was applied in the system. In order to reduce the bit error rate and improve the communication distance, the Manchester coding method for the data frame and the strong anti-interference performance of the CRC (Cyclic Redundancy Check) verification mode [9] were applied in the Single Chip Microcomputer of this tire pressure / temperature monitoring device. In order to ensure the tire dynamic balance, the tire pressure / temperature monitoring system is designed in small size and light weight.

1.3.2 The Design for vehicle-mounted Transition Device

The vehicle-mounted transition device selects the wireless receiving chip MC33596(this chip can not only be used for transmitting the RF, but also for receiving the RF) of the Freescale, and the micro controller selects Single Chip Microcomputer of the 8 bit PIC's Series. The PIC micro controller serial port is used to connect with the Bluetooth module, and the SPI interface is connected with the RF Wireless Receiver Module [9, 10].The circuit principle diagram of the transfer device in tire temperature /pressure detection device is shown in Fig. 4.

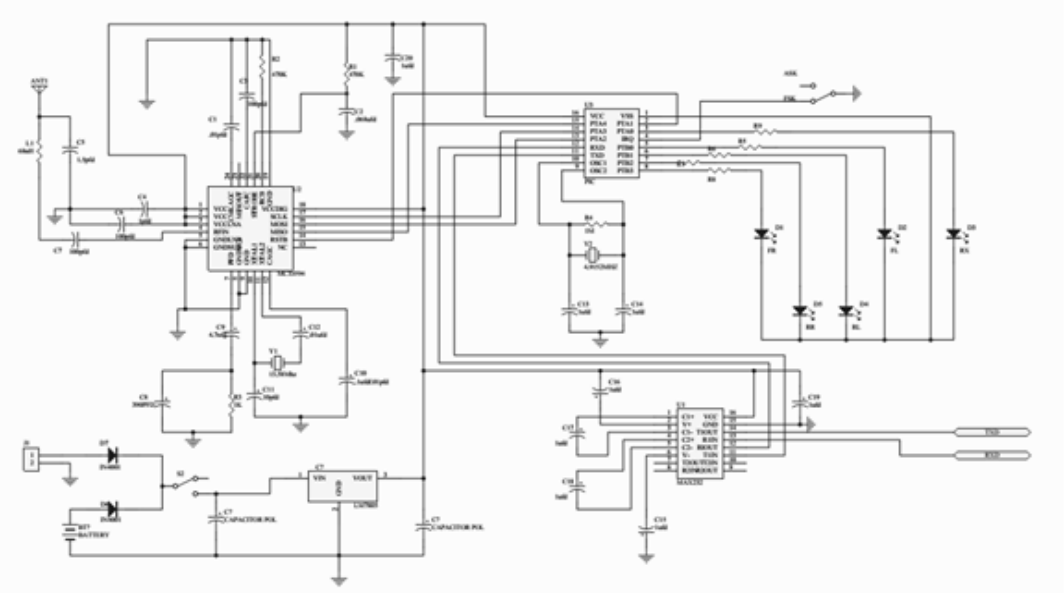

Fig. 4 A circuit principle diagram of the transfer device in tire temperature / pressure monitoring device

The Bluetooth module [6] selects the Bluetooth data transmission system ATK-HC05-V11 which is based on BC417 chip[7]. The ATK-HC05-V11 is a master-slave integral Bluetooth serial module which has a high performance, in support of very wide range of the Baud rate from 4800 to 1382400 and compatible with 5V or 3.3V single chip microcomputer system.

The operating voltage of the vehicle-mounted transition device located in the driver's cab is +5V, which is entirely powered by cigarette lighter interface or the port of USB. When using the cigarette lighter interface as power supply for the vehicle-mounted transfer device, it is very important to convert the voltage of +12V vehicle-mounted battery into a voltage of +5V.

High efficiency and stability and low power consumption are advantages of this vehicle–mounted transition device. And the processor controller unit which has high efficiency, low power consumption and easy instruction is chosen. The sensor has high precision and strong adaptability, and the Bluetooth module has advantages of stable transmission and large emission range.

1.3.3 System Software Design

The vehicle-mounted transition device will sent the effective data which reserved from the sensor in the tire to the mobile phone by the Bluetooth module with the specific communication protocols. So the vehicle-mounted transition device plays the role of forwarding. Fig. 5 is the

flow-process diagram of the tire pressure/temperature monitoring device, and Fig. 6 is the flow-process diagram of the vehicle-mounted transition device.

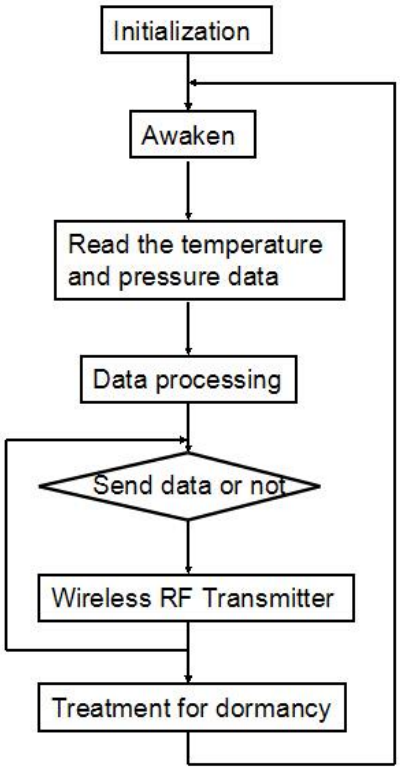

Fig. 5 Flow-process diagram of the tire pressure/temperature monitoring device.

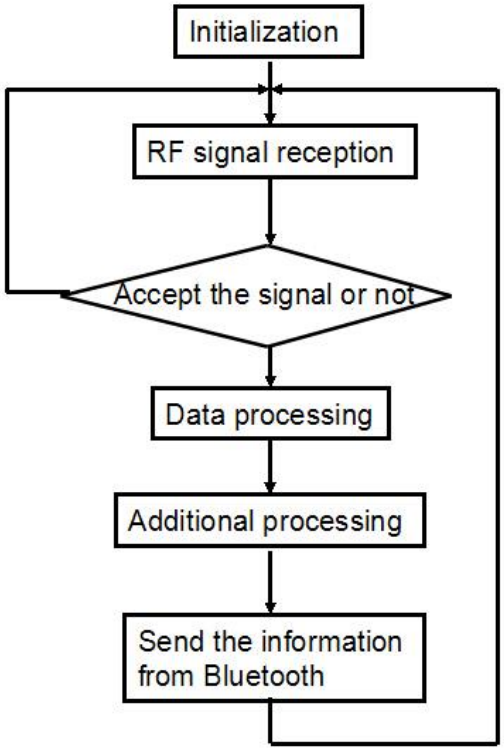

Fig. 6 The flow-process diagram of the vehicle-mounted transfer device.

1.4 Mobile Application-program Development

A smartphone APP based on android system is developed in this system, and it achieved many functions, such as displaying tire pressure and temperature data on the mobile terminal, storage and analyze data, early warning and so on.

Smartphone must be within 10 meters [7] of the vehicle-mounted transition device to ensure the Bluetooth communication smooth. After establishing the connection with smartphone and the vehicle-mounted transition device, the smartphone APP can receive the specific forms of data communication protocols from the vehicle-mounted transition device, then display the useful data or perform other functions through the manipulation data and calculations. At the same time, the mobile terminal sends the specific forms of data communication protocols to the cloud servers by the mobile internet such as the GPRS or CDMA. Fig. 7 shows the APP interface on the smartphone including four pages, which are the main page of the tire temperature/pressure display, the page of user information, the page of tire temperature/pressure changing trend and the page of one-touch sharing on wechat.

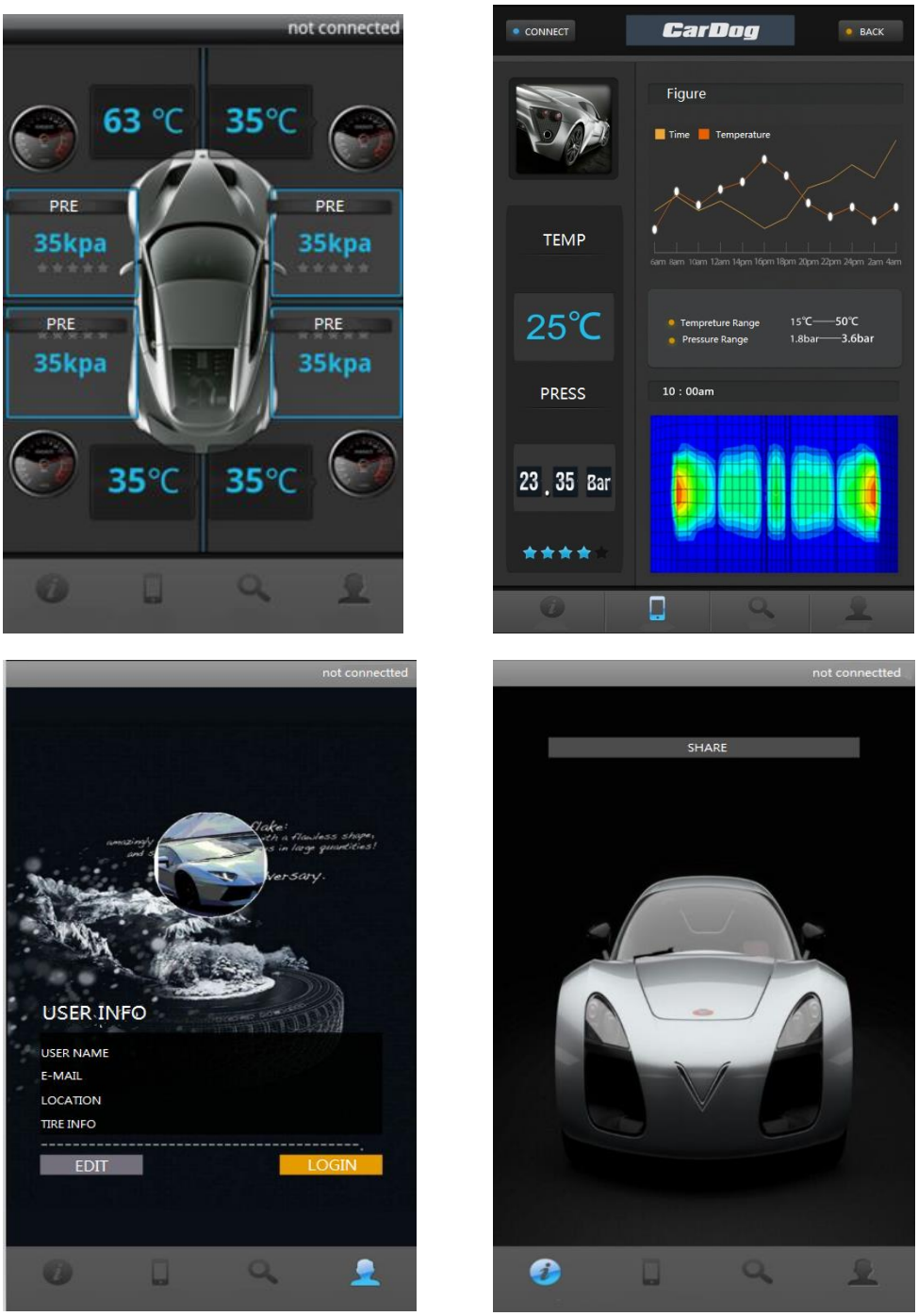

Fig. 7 The APP interface on the smartphone

1.5 Design for Cloud Server and the Service Function

Cloud server is provided by a cloud server provider [11], the data which collected from the mobile client can be sent to the cloud server with the specific forms of communication protocols by the mobile internet, and then are stored and dug. Users can know the vehicle driving conditions and assess the quality of the tires via the information coming from the cloud server.

2 Research on the key technology of the system

2.1 Research on the tire positioning technology

2.1.1 The problem of Tire Pressure/Temperature Monitoring System

The manufacturer offers each tire pressure/temperature sensor a unique ID [9], so when one of the tire pressure/temperature sensor is replaced while it is damaged, the sensor's ID is different from previous one which leading to receiving the signal of TPMS unsuccessfully.

2.1.2 The positioning technology of Tire Pressure/Temperature Monitoring System

In order to solve the repositioning of tire pressure/temperature monitoring system, the engineers usuallyadopte the following technology, such as Coding, User Interfacing, LF Wakeup and Antenna Technology[10]. However, the above technologies have obvious weakness during practical uses. According to the real condition and the characteristic of sensor, the system's design a unique positioning method to solve the problem. When the mobile applications designed, applications added the function of Initialization.This function will receive new ID of the tire sensor and save it to solve the problem of repositioning.

2.2 Research on the technology of vehicular networking and cloud computing

In order to enrich the function of TPMS, the technology of vehicular networking and cloud computing is applied to achieve interconnection and interactive features. This system that provides a complete service from online to offline combines real-time monitoring system, internet of thing and cloud computing technologies. Logically, the logical structure of the system can be divided into four parts as shown in Fig. 8, such as Application Service Layer, Management Layer, Virtualization Layer and Resource Layer.

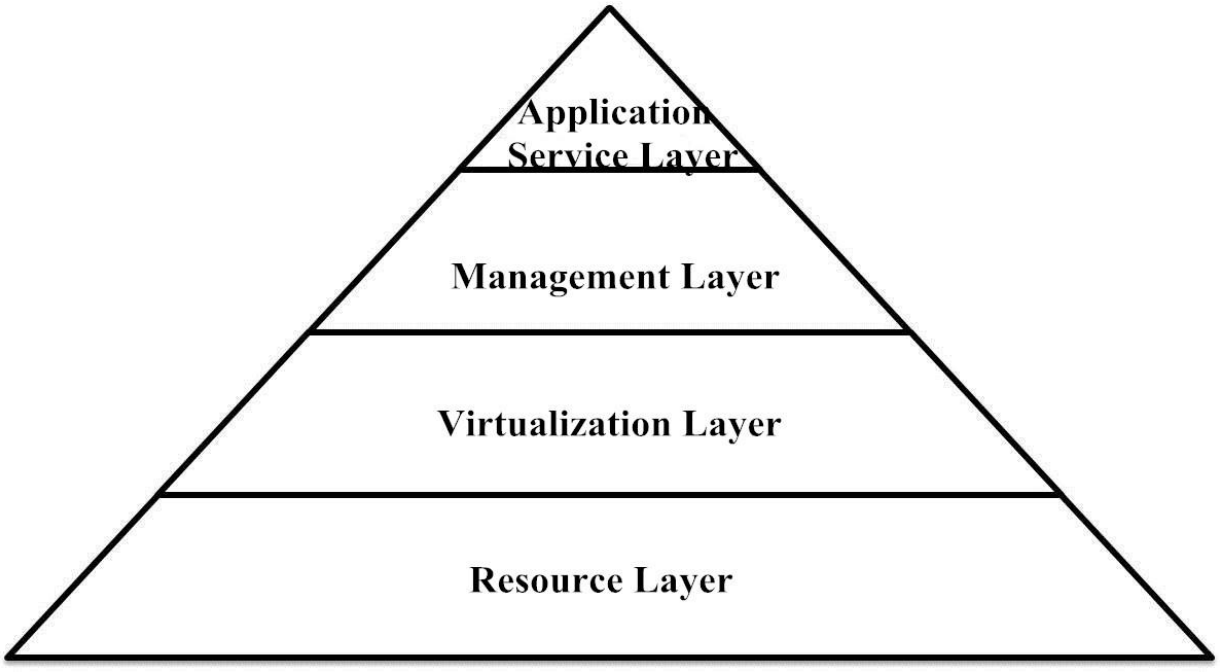

Fig. 8 logical structure

(1) Application Service Layer

According to the needs of users, this layer provides applications and information services throug h a web browser and smartphone APP. According to their needs,

the applications and information services including vehicle speed information and tire safety inf ormation can be customized.

(2) Management Layer

This layer mainly provides management. It manages user, identifies the authentication, rationally allocates the resource of the cloud services, then monitors and treats fault.

(3) Virtualization Layer

This layer will virtualize the main hardware resources and specific data. The data will be transfo rmed into text in order to save in the cloud computer.

(4) Resource Layer

This layer includes the servers, storage, networking, and other hardware resources.

3 Test and Experiment

According to national standards GBT 26149-2010 requirements of TPMS, testing of the tire pressure/temperature monitoring system used the digital pressure gauge and precision timers, test results are as follows:

(1) The range of tire pressure: 50kpa-600kpa; The maximum error is: ±5kpa;
(2) Car's tire pressure is generally ranging from 210kpa to 290kpa.
(3) Sensor matching time is almost 40 seconds.
(4) When the tire pressure is low or high, smartphone applications make mobile vibration and alarm.

4 Conclusion

The intelligent TPMS based on vehicular networking technology was developed in the paper, which is a full tire life-cycle tracking service system and provides a new solution for the tire maintenance. The system transmits the monitoring data to the cloud server via the mobile Internet, and digs out the tire pressure and temperature varying pattern, then feedbacks to the users. The current TPMS system problems were analyzed, and a brief study on the positioning technology and vehicular networking technology and cloud computing technology of the tire pressure/temperature monitoring device was done in the paper. Because research on the system in this paper is still in experimental stage, many technologies need further exploration. Without any doubt, research of the system will be more in-depth and move towards industrialization with the development of vehicular networking technology.

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