Research and Design of Self-service Car Washer Remote Monitoring System Based on NB-IoT

IOP Conf. Series: Materials Science and Engineering **569** (2019) 042026 doi:10.1088/1757-899X/569/4/042026

Research and Design of Self-service Car Washer Remote Monitoring System Based on NB-IoT

Bin Li, Gaofei Wang, Jun Yao*

School of Mechatronic Engineering and Automation, Shanghai University, Shanghai 200072, PR China

grandone0529@shu.edu.cn

Abstract. In order to solve the problem of increasing maintenance cost of self-washing machine operators, this paper designs a self-service car washing machine remote monitoring system based on NB-IoT. In this system, MSP430F5438A chip is used as the controller and NB-IoT is used as the communication module to realize the remote communication between the car washer and the server. Based on ASP.NET Core, React and SQL SERVER database, the monitoring centre saves the running state information of the car washing machine in the cloud for management. The test results displaying on the browser show that the system is stable and reliable, and has the advantages of low deployment cost and great real-time performance.

1. Introduction

Self-service car washing machines are widely used in Europe and the United States. The bus station, gas station and parking lot, which can be seen everywhere, provide the car owners with economical and fashionable self-service car washing service. According to the Auto Laundry News website, in the United States, from 2015 to 2017, the proportion of car owners choosing self-service car wash in the all car owners was 58%, 64%, and 62% respectively[1]. These data show that self-service car washing machines have already played a pivotal role in the European and American car wash market. However, as the operation scale of car washing machine increases, the operating costs of manual coin withdrawal, patrol maintenance, etc. will also increase. Therefore, it is of great practical significance to study and design a stable, low-cost remote monitoring system for car washing machine operator.

Combining the development of modern communication technology and embedded technology, this paper designs a remote monitoring system for self-service car washing machine based on NB-IoT. The system uses NB-IoT technology to send information such as the machine working state, geographic location, and alarm of the machine to the cloud server. The server is responsible for saving and displaying these data on browser for management by WEB technology. At the same time, the manager can also send commands to the device through NB-IoT. The system meets the design requirements of low-power consumption, wide coverage, and low cost.

2. Related works

With the development of IoT and communication technology, the research results of remote monitoring systems based on WIFI, ZigBee, GPRS, Bluetooth and other technologies are constantly emerging at home and abroad. For example, Kun Li of Shanghai University designed a self-service Car washing machine remote monitoring system based on GPRS[2]; Changhai Peng et al. proposed a greenhouse monitoring system based on ZigBee[3].

IOP Conf. Series: Materials Science and Engineering **569** (2019) 042026 doi:10.1088/1757-899X/569/4/042026

Short-distance communication methods such as ZigBee, Bluetooth, and WIFI are widely used, but due to the short signal transmission distance, multiple relay nodes need to be deployed for long distance transmission of signals. Therefore, the system network topology is complex and the cost is high. The GPRS is based on the traditional cellular technology, which can effectively solve the problem of short communication distance. However, its signal coverage is low, power consumption is large, and signal penetration is poor. These factors make GPRS unsuitable as the underlying IoT communication technology[4]. In order to solve the contradiction between signal transmission distance and energy consumption in the field of IoT communication technology, low-power wide area network (LPWAN)[5] communication technology emerges. LPWAN is mainly divided into two categories: working in licensed bands (such as NB-IoT) or unlicensed bands (such as Sigfox and LoRa). The performance comparison of three communication methods is shown in table 1[6].

Table 1. Overview of LPWAN technologies: Sigfox, LoRaWAN, and NB-IoT

	Sigfox	**LoRaWAN**	**NB-IoT**
Frequency	Unlicensed ISM bands	Unlicensed ISM bands	Licensed LTE bands
Bandwidth	100 Hz	250 kHz and 125 kHz	200 kHz
Maximum data rate	100 bps	50 kbps	200 kbps
Bidirectional	Limited / Half-duplex	Yes / Half-duplex	Yes / Half-duplex
Maximum payload length	12 bytes (UL) 8 bytes (DL)	243 bytes	1600 bytes
Standardization	None	LoRa-Alliance	3GPP

With the advantage of excellent quality of service (QoS), higher scalability, more maximum payload length and lower deployment cost[6], NB-IoT has gradually become a leader in LPWAN communication, and the mainstream of the China's IoT market[7].

3. System description

In general, the system is comprised of the device layer, communication layer, application layer. The architecture of the system is shown in figure 1 as follows.

The first layer is the Device layer. Its main function is to collect, analyse and process the parameters of the self-service car washing machine such as water temperature, GPS information and alarm information, and send the data to the base station through the NB-IoT module; The communication layer is composed of the NB base station and the IoT core network; The application layer uses the database management system SQL Server, the Web server framework ASP.NET Core, etc. to build a browser-based self-service car washing machine monitoring software, which realizes functions such as querying historical record, real-time monitoring, and remote upgrade.

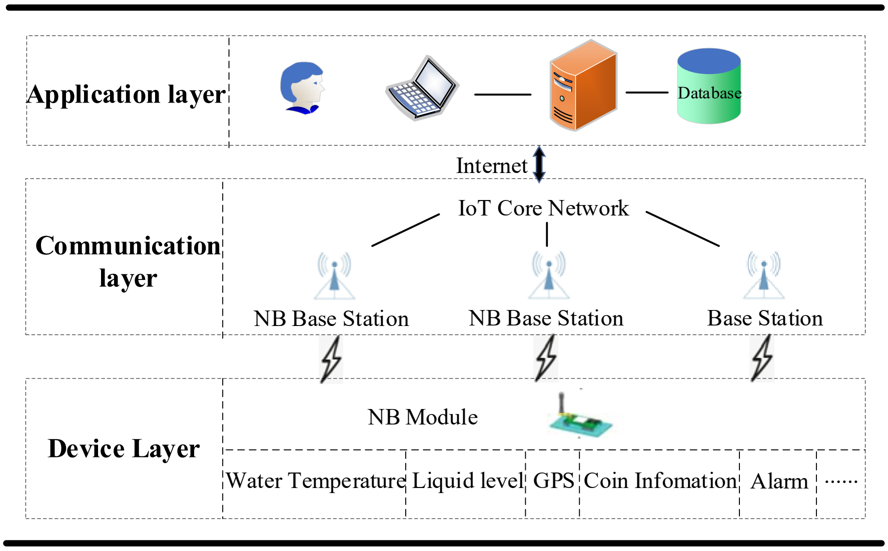


Figure 1. System overview

4. Hardware design of the system

4.1. Overall hardware design of the monitoring terminal

In this design, the main function of the monitoring terminal is to collect, analyse, store and upload information, and parse the instruction code from the remote monitoring centre. The overall hardware design of the monitoring terminal is shown in figure 2 as follows.

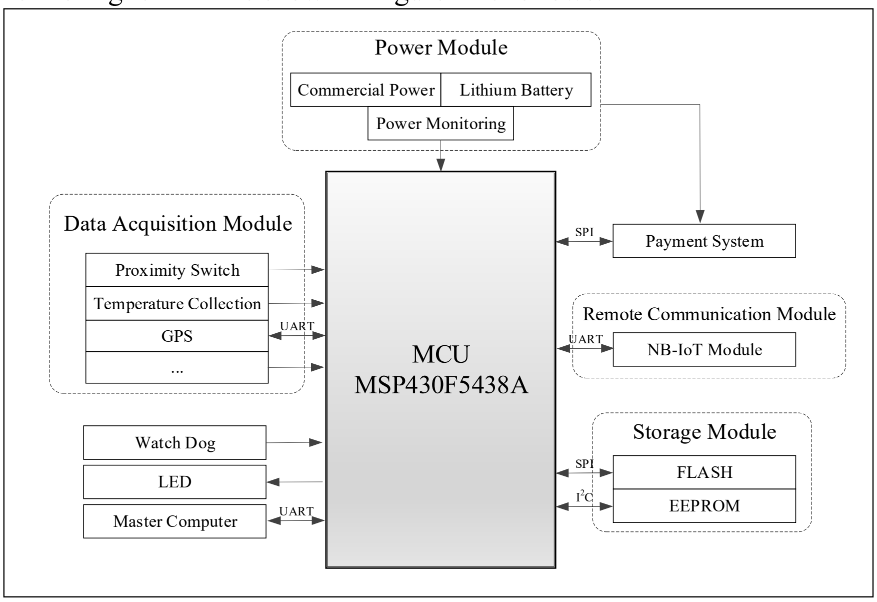


Figure 2. Overall hardware design of the monitoring terminal

The MCU in this system adopts the industrial MCU-MSP430F5438A of TI Company. The MCU has the advantages of low power consumption, rich functions, large capacity ROM, RAM and so on. The power module converts 100~240V AC power into 5V, 12V and 24V DC power, which respectively supplies power to different functional modules. Data acquisition module is used to collect field signals such as water temperature, GPS positioning, liquid level and alarm. The data storage module uses a storage scheme of EEPROM and FLASH. These two chips are used to store key business data such as operating parameters, state variables, coin counts, and remote transmission data packets. If the system fails, it can still ensure the security of the data and protect the interests of operators and owners. The remote communication module adopts NB-IoT module—NB86-G, which is a bridge between monitoring terminal and server layer. And it is responsible for uploading the data collected and processed by the monitoring terminal to the server and receiving the instructions of the server.

4.2. Hardware design of the remote communication module

The remote communication module is composed of NB86-G module, antenna circuit, plug-in SIM socket and so on. Hardware design of the remote communication module is shown in figure 3.

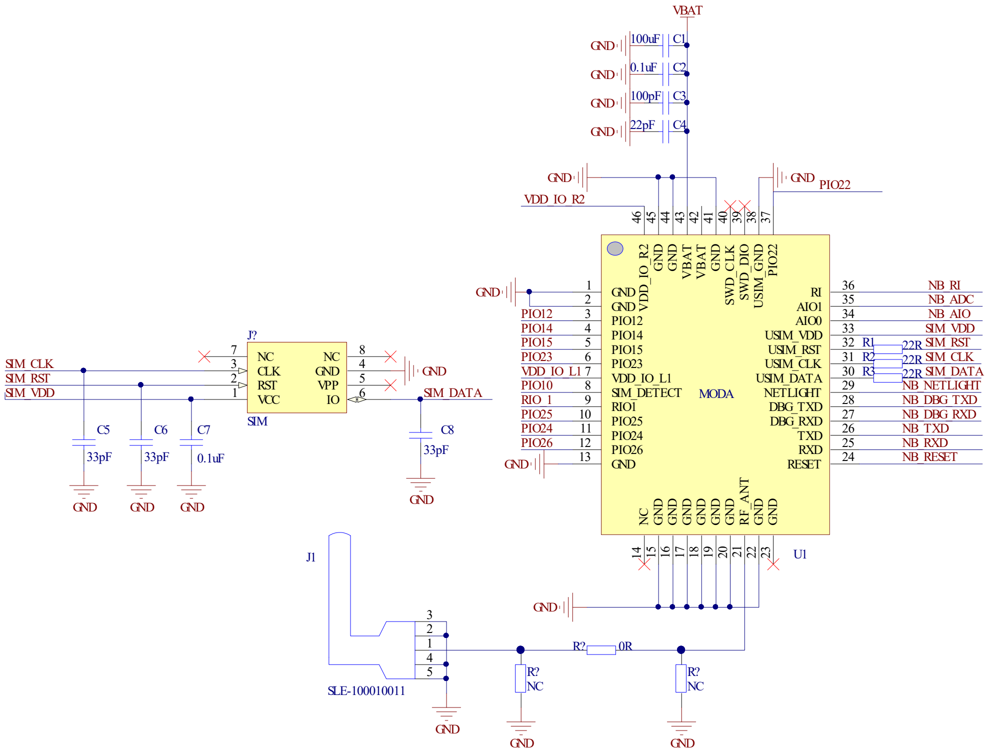


Figure 3. Hardware design of the remote communication module

This system selects NB86-G series NB-IoT module of Lierda Company, which consumes power no more than 5μA in PSM (Power Saving Mode), transmits at 23dBm±2dB, and embeds network protocol stacks such as UDP, IP, and COAP. The MCU sends the AT command to the NB module through the UART, and the NB module parses the AT command, and sends the data contained in the command to the server. At the same time, the module can also send data from server to the MCU through the UART. When designing RF antenna, it is necessary to do 50 Ω impedance matching, use smooth bent, and reserve π type circuit, which can adjust RF performance conveniently.

5. Software design of the system

5.1. Software design of the monitoring terminal

The monitoring terminal software mainly has two functions: the collection of sensor information; the realization of remote communication between the NB module and the server.

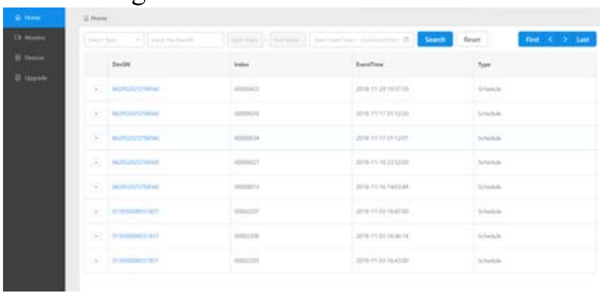
The system adopts the communication mechanism that the terminal actively initiates the connection request, and designs three different communication functions, namely terminal sign-in, timed upload and terminal wake-up. After the washing machine monitoring terminal is powered on again, the terminal firstly checks in to notify the server that the device has been operating in good situation. And the device state information is uploaded to server at regular time, this way can avoid the burden on server when a large number of monitoring terminals are connected to the server at the same time.

When device is not connected to the monitoring centre for a long time, the monitoring centre can wake up the device by short message, and request the device to check in or upload the running state data.

5.2. Software design of the monitoring server

The monitoring system server software mainly includes two aspects: data transmission software and data browsing software. The data transmission software uses the socket technology to receive the data transmitted by the terminal, and parses and stores the data into the SQL SERVER database.

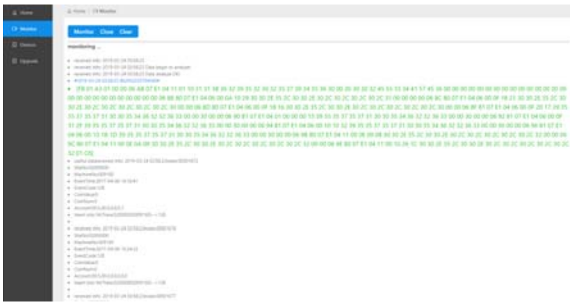
The data browsing software adopts the MVC (Model-View-Controller) design pattern. The back-end part uses the Microsoft ASP.NET Core framework to design a set of API interfaces for front-end page calls. The API interface design is shown in table 2. The front-end design adopts the React framework, and the Ajax technology calls the API interface provided by the back-end to obtain the database data, and the acquired data is displayed through the front-end page. The design result is shown in figure 4.



(a). Data uploaded by all terminals

(b). Latest state of the specified device

(c). Alter device parameters



(d). Real-time monitoring interface

Figure 4. Design result of the monitoring server

Table 2. API Interface Design

URI	HTTP Method	Description
api/home/All	GET	Get all types of data uploaded by all terminals
api/home/Status	GET	Get all device status data uploaded by all terminals
api/home/AlarmOrLogin	GET	Get all alarm or login data uploaded by all terminals
api/props/getList	GET	Get devices list
api/home/McTrans	GET	Get all transaction data uploaded by all terminals
api/tableData/getData/{DevSN}	GET	Get all uploaded data of specified device according to device DevSN number
api/props/alterProps/{DevSN}	POST	Setting specified device parameters according to device DevSN number

6. Conclusion

This paper designs a remote monitoring system for self-service car washing machine based on NB-IoT. The system sends the data such as the working state and GPS information, etc. of the car washing machine to the cloud server through the NB-IoT module. And managers can view data and issue instructions on browser. This system meets the design requirements of low-power consumption, wide coverage, and reduces the operating cost of the operator.

References

[1] Auto Laundry News, (2018) SELF-SERVICE SURVEY 2018. http://www.carwashmag.com/fi-leadmin/pdfs/aln_2018_SELFSERVE_Survey.pdf.
[2] Li, K., Yao J., Shi, J. (2013) Design of the remote monitoring system for self-service car washer. Process Automation Instrumentation, 34(9): 78-81.
[3] Zhang, Q., Yang, X.L., Zhou, Y.M., Wang, L.R., Guo, X.S. (2007) A wireless solution for greenhouse monitoring and control system based on ZigBee technology. Journal of Zhejiang University (Science A: An International Applied Physics & Engineering Journal), 10:1584-1587.
[4] Landström, S., Bergström, J., Westerberg, E., Hammarwall, D. (2016) NB-IoT: A sustainable technology for connecting billions of devices. Ericsson Technology Review, 4:2-11.
[5] Boulogeorgos, A. A. A., Diamantoulakis, P. D., & Karagiannidis, G. K. (2016) Low power wide area networks (lpwans) for internet of things (iot) applications: Research challenges and future trends. arXiv preprint arXiv:1611.07449.
[6] Mekki, K., Bajic, E., Chaxel, F., Meyer, F. (2018) Overview of Cellular LPWAN Technologies for IoT Deployment: Sigfox, LoRaWAN, and NB-IoT. In: 2018 IEEE International Conference on Pervasive Computing and Communications Workshops. Athens. pp. 197-202.
[7] Wang, Y. P. E., Lin, X., Adhikary, A., Grövlen, A., Sui, Y., Blankenship, Y., ... & Razaghi, H. S. (2016) A primer on 3GPP narrowband Internet of Things (NB-IoT). arXiv preprint arXiv:1606.04171.