Journal of Physics: Conference Series

PAPER • OPEN ACCESS

An Intelligent Electronic Lock for Remote-Control System Based on the Internet of Things

To cite this article: Wei Li *et al* 2018 *J. Phys.: Conf. Ser.* **1069** 012134

IOP Conf. Series: Journal of Physics: Conf. Series **1069** (2018) 012134 doi:10.1088/1742-6596/1069/1/012134

An Intelligent Electronic Lock for Remote-Control System Based on the Internet of Things

Wei Li[1], Hongrui Li[1], Aini Gong[1], Yining Ou[1] and Menglu Li[2]

[1]College of Internet of Things Engineering, Hohai University, 213022, Changzhou, China
[2]Handan No.1 High School, 056006, Handan, China
Email: liwei@hhu.edu.cn, lihongrui1206@163.com, zwzdlkgan@163.com, ouyiningenid@163.com, 109361569@qq.com

Abstract. With the rapid development of smart home systems, intelligent electronic locks have attracted much attention. In this paper, a novel intelligent electronic lock is proposed for remote-control system, based on the Narrow Band Internet of Things (NB-IoT), which has the advantages of strong link, high coverage and low power consumption. The intelligent electronic lock is composed of radio frequency identification (RFID) module, NB-IoT module, electronic lock and microcontroller. In the system, the non-contact terminal sends the identity information to the control board through serial port. By NB-IoT transferring, real-time identity information from the control board can be uploaded to the Cloud service platform, and the confirmation information can be downloaded to the control board in return. The intelligent electronic lock is characterized by identification and state monitoring, which is suitable for both public and household application.

1. Introduction

In the past, people had to carry bunches of keys; these keys were exposed to the risks of not only being lost but also being easily duplicated. Though the level of urbanization and the frequency of criminal activities increased in the past few decades, this old-fashioned key-and-lock system are still widely used in today’s guard system and brings challenges to the security and efficiency.

In recent years, with the development of modern economic construction and management, several of hotels, office buildings, smart buildings, government agencies, enterprises and institutions are undergoing great changes to the requirements of the access control system. However, as worried by [1], the locks can be attacked in the real word. Thus, a new kind of lock generates: the intelligent electronic lock. The core needs of the locks are the intelligent management and the state-monitoring. With the evolution of inductive card and biological recognition technology, the electronic lock has developed significantly and stepped into the mature period. The intelligent locks using inductive card, fingerprinting, iris recognition and facial recognition are unique and highly complex in safety, convenience, manageability etc. Among them, as introduced in [2], electronic locks using RFID technologies have reached a breakthrough in achieving energy-efficient, low-cost tag data acquisition. RFID can be used in cargo management, theft prevention and pre-paid card applications. Therefore, RFID is used as access control in the intelligent electronic lock.

As demonstrated in [3], the advancement in Nano-semiconductor manufacturing opens up the era of the Internet of Things (IoT). It is unquestionable to say that the concept of IoT has infiltrated into every aspect of our daily life, such as medical care, transportation, food industry etc. Moreover, the security system protecting people’s life and properties undergoes the rapidly changes because of the development of IoT. However, the security system linked with IoT still needs further research and urgent improvement on stability and security.

2. Related Work

Nowadays, there are several advanced intelligent electronic locks. For example, an electronic lock for security system called 'E-Zip' is proposed in [4]. E-Zip takes advantages of Bluetooth. Bluetooth is a wide-used device pairing technology. Information is transmitted only when pairing is completed through Bluetooth. Bluetooth is convenient and devices using it can be easily connected with users' cell phones. However, the connection is established only if the devices are in very short distance, usually within one meter even shorter.

Another typical intelligent electronic lock is introduced in [5]. It uses Wi-Fi as the wireless communication technology. It allows people to connect and control locks within the local area network (LAN). However, Wi-Fi has disadvantages like low-security and poor networking capability. Wi-Fi only lets 16 devices access to the network at the same time within the LAN. Poor networking capability prevents Wi-Fi from developing because IoT net usually includes hundreds even thousands of nodes.

According to the related research, it is urgent to find an intelligent electronic lock which is more solid and stable, to lower the power consumption, and importantly, to save the cost. Based on the description introduced in [6], a brand-new communication technology: NB-IoT is proposed. NB-IoT is a novel narrow-band cellular communication LPWAN technology. Intelligent electronic lock with NB-IoT can solve the problems with following characteristics: strong link, high coverage, low power consumption and low cost. In addition, NB-IoT no longer has the concept of QoS (Quality of Sever) because NB-IoT does not intend to transfer delay sensitive data packets, like real-time IMS.

3. System Description

A new type of intelligent electronic lock for remote-control system is developed to combine the traditional mechanical lock with the technology of NB-IoT. As shown in 0, the communication between the intelligent electronic lock and the intelligent devices is established through NB-IoT. When a packed message about the ID number of the passenger and the current time is sent to the Cloud server, the server checks whether the number is authorized in advance. Once confirmed, the server sends the confirmation message to the control board by NB-IoT. Meanwhile, users can access to the server to monitor the statement of the lock and check the entry time and ID of passenger through intelligent devices.

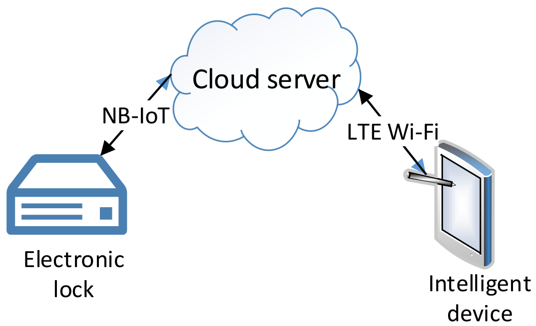

Figure 1. System design block diagram

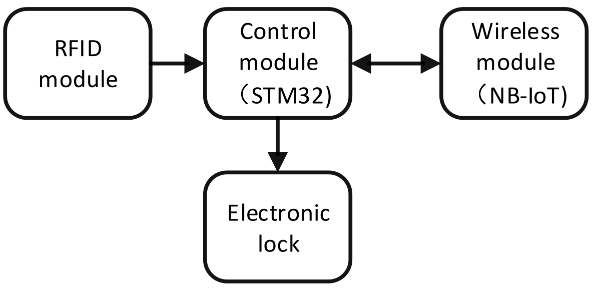

Figure 2. Structure diagram of intelligent lock

3.1. Intelligent Identification

The intelligent electronic lock is constituted by the control module, RFID module, electronic lock and NB-IoT module. It realizes the intelligent identification. When the reader of the RFID module senses the signal of ID card, it sends the identity of the ID card to the control module, which means there is request to unlock. Then the message will be transferred from the control module to the Cloud server through NB-IoT. The server compares the identity information with the current database, if the identity is authorized before; the server will send the 'prove to open' signal through the NB-IoT module back to the control module. If the identity is illegal, it will send 'not prove to open' instead. Once the control module receives the signal, it will respond to unlock or not immediately. The structure diagram of the intelligent electronic lock is shown in 0.

3.2. Remote Monitoring

Users can monitor the statement of the door by connecting to the Internet and accessing to the Cloud server through a little program developed by WeChat, which is shorted as ‘CX’. CX can help developers quickly develop small programs. We develop a CX to access to the server. It can be easily acquired and diffused in WeChat. CX is an application that does not require downloading and installation, and is a parallel system to the original three WeChat public numbers. It makes the system more convenient for users to monitor the statement of the lock. Users can view the message about the ID number and the time of unlocking through the CX. It enhances the security and practicability of the system.

4. The Hardware Design of the System

4.1. Main Control Module

A STM32F103 chip is the core of the main control board. It is a low-power and high-performance microprocessor. The capacity of the chip is 128K, which is suitable for programming. The control board has voltage-reduce module to transfer 12v to 3.3v to supply the power of the chip. The chip can receive the signal from the intelligent terminal through a serial port then transfer the signal to the wireless module. When the chip receives the open command, it will drive the electronic lock to unlock in respond. On the contrary, if the command is ‘not to open’, the chip will hold the electrical level of the pin. The inner hardware resource of the chip is shown in Figure 3.

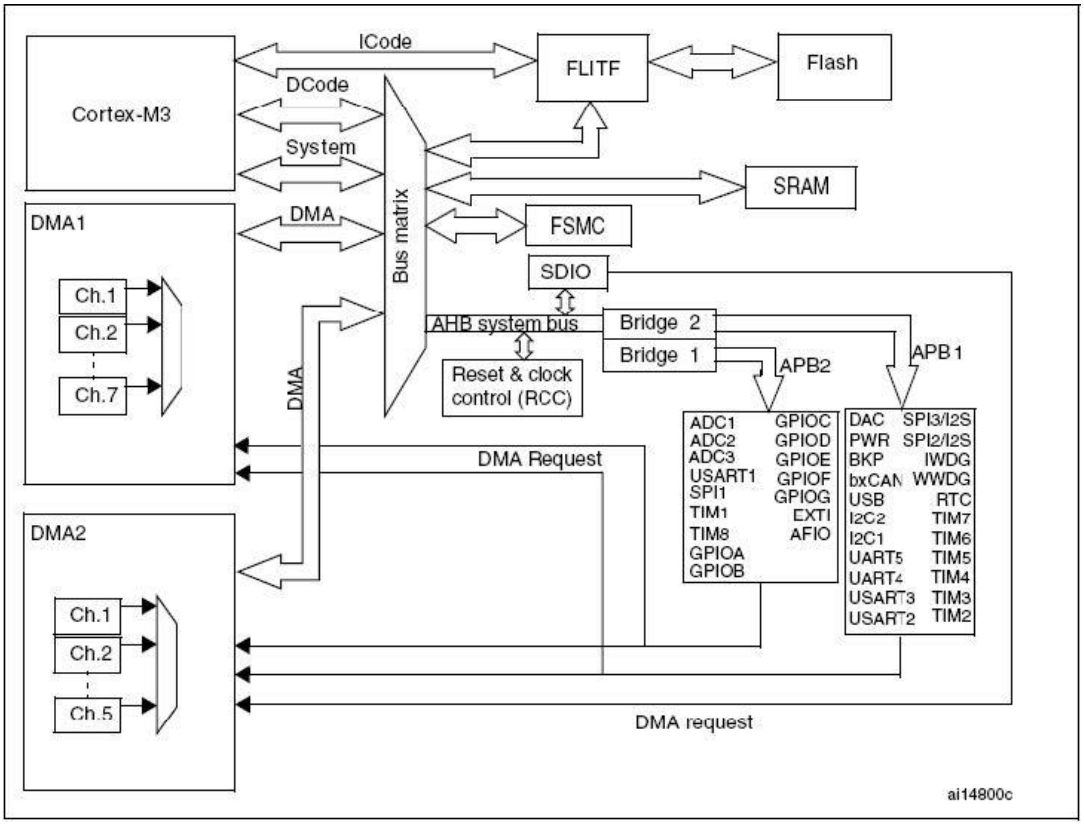

Figure 3. Hardware resource of STM32F103

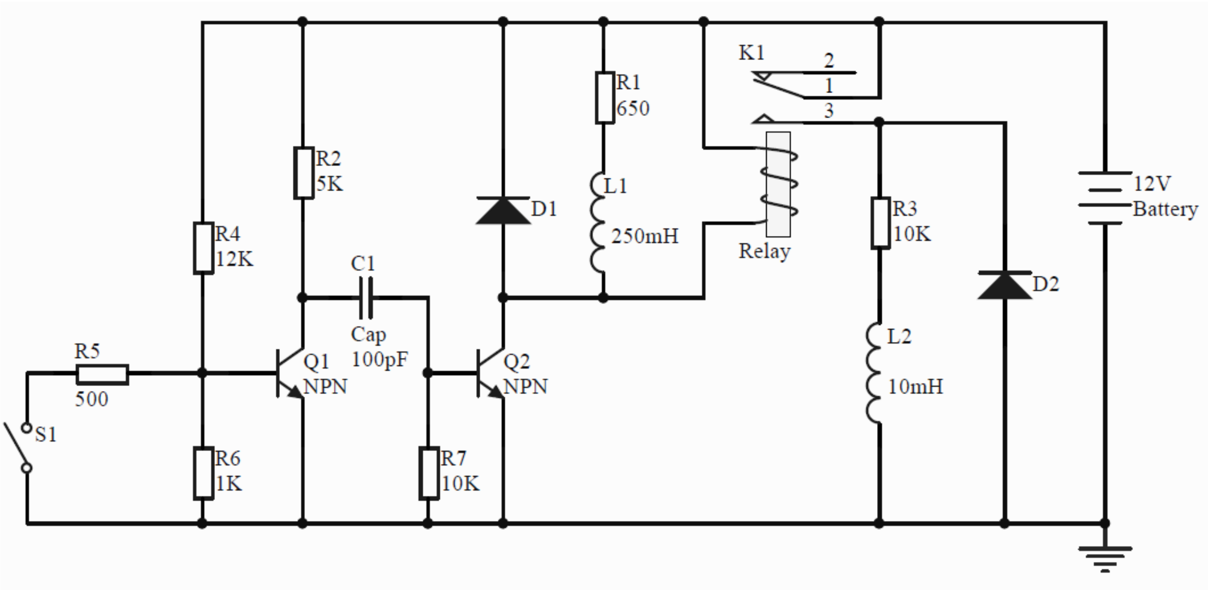

Figure 4. The control circuit of the electronic lock

4.2. Electronic Lock Module
The control circuit of the electronic lock is shown in 0. S represents for equivalent control resistance. R5 represents for equivalent lead internal resistance. Q1 and Q2 are switching transistors. R1 and L1 compose the equivalent circuit to control relay. R2 and L2 compose the equivalent circuit of work coil L. When S is switched off, the circuit is under steady state, Q1 is saturated, Q2 is cut-off and the voltage across the control-relay is approximately 0V. The touch spot is cut-off, the voltage across R2 and L2 is 0V, the electronic lock is locked. When S is switched on, Q1 turns from saturated to cut-off and Q2 turns from cut-off to saturate. The voltage across the control-relay is approximately the supply voltage. The touch spot is on, the voltage across R2 and L2 is supply voltage, the armature in the lock is picked up, the electronic lock is unlocked.

4.3. RFID Module
Intelligent electronic lock uses RFID module. It communicates with ID card through the internal card reader. Once sensing the approaching of ID card, card reader will transmit ID card data to the control module. RFID delivers card from local. Users can add or delete cards rapidly by the master card. In addition, users can add cards with their own numbers. The external card reader is installed outside the door and the electronic lock is installed on the door. User swipes his non-contact ID card to go through the door. Different from the traditional RFID, in which the control module is responsible for the identification of ID card holder, Cloud server is in charge of the identification. The authorized information is stored in the Cloud server, thus can lower the capacity of the control module and lower the consumption. If the ID card has the authorization to go through the door, the Cloud server sends the message to the open the electronic lock, allows the user to enter the room.

XXTEA algorithm is used as the system’s encryption algorithm to protect the dynamic data exchange between RFID reader and RFID card. The XXTEA algorithm mainly concludes operations like add, shift and xor, with which the structure is simple. The system only needs to carry out operations like add, xor and the register. The XXTEA algorithm is short and can be easily transformed into different occasions of embedded application.

4.4. NB-IoT Module
NB-IoT module transmits reliable, connective and real-time data. In the system, a novel low-cost NB-IoT switch module, BC95, is used as the wireless module. BC95 turns the LCC package to pin header. The module can realize the basic circuit and properly function with external power 5v or battery charge 3.3v. The module can work only with four main serial ports: VCC, GND, TXD and RXD. Thus, the

module can not only be applied to design quickly, but also easily access to the developing board for testing and debugging. The size of the module is 48mm * 32mm, this kind of miniaturization design makes it more convenient to integrate the module to application. The module adopts super-low-power design and provides power enable pins, so as to facilitate the management of power supply. The appearance of the module is shown in 0.

The NB-IoT module is integrated with the intelligent electronic lock. It communicates with the control board through serial port and transfers information to Cloud server through antenna. Due to the characteristics of low power consumption, NB-IoT remains dormant intermittently. It needs to send packets to Cloud server every 20 seconds to keep NB-IoT from sleeping. As introduced in [7], The NB-IoT module takes protocol produced by 3GPP to communicate with the server. Motivated by a vision of a digital society with billions of devices communicating over cellular radio access technologies, 3GPP - in Release 13 developed no less than three new technologies for the support of internet of things: Extended Coverage GSM Internet of Things (EC-GSM-IoT), LTE for Machine-Type Communications (LTE-M) and Narrowband Internet of Things (NB-IoT). Each has been standardized to ensure that increasingly diverse devices are supported by 3GPP networks.

Figure 5. Appearance of NB-IoT module

5. The Software Design of the System

Software design uses KEIL compiler and program is developed with C language. Modular software design is conductive to modify and debug. Program is divided into three parts: the main program, card-swiping subprogram and unlock subprogram. Main program initializes all data registers and peripheral circuits. Then, the card-swiping subprogram sends the package to the Cloud server through NB-IoT. After processing the package in the Cloud, the main program enters the unlock subprogram. The flow diagram is shown in 0.

Card-swiping subprogram flow diagram is shown in 0. The subsystem remains to monitor the card reader. Once there is an ID card approaching the card reader, the ID number with the current time will be packed by control board. Then the package is sent by NB-IoT.

Unlock program flow diagram is shown in 0. When the subprogram begins, it will start to judge whether there is a command to unlock. Once the command from the NB-IoT module is received, the control board lows the electrical level of the pin related to the electronic lock. If the control board successfully unlocks the electronic lock, the control board will report successful message to the server. On the contrary, an error will be reported. After a short time of delay, the electronic lock will back to the statement of locked.

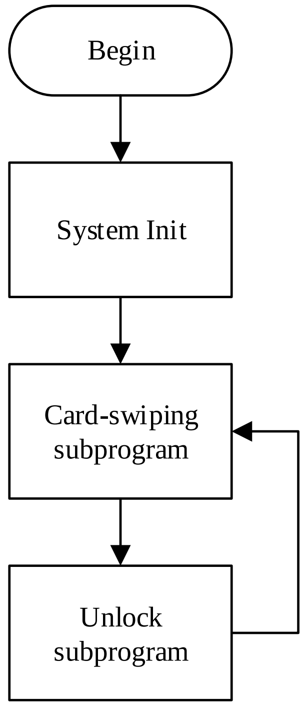

Figure 6. Main program flow diagram

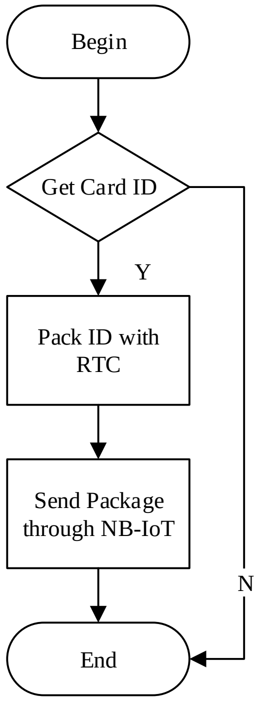

Figure 7. Card-swiping subprogram flow diagram

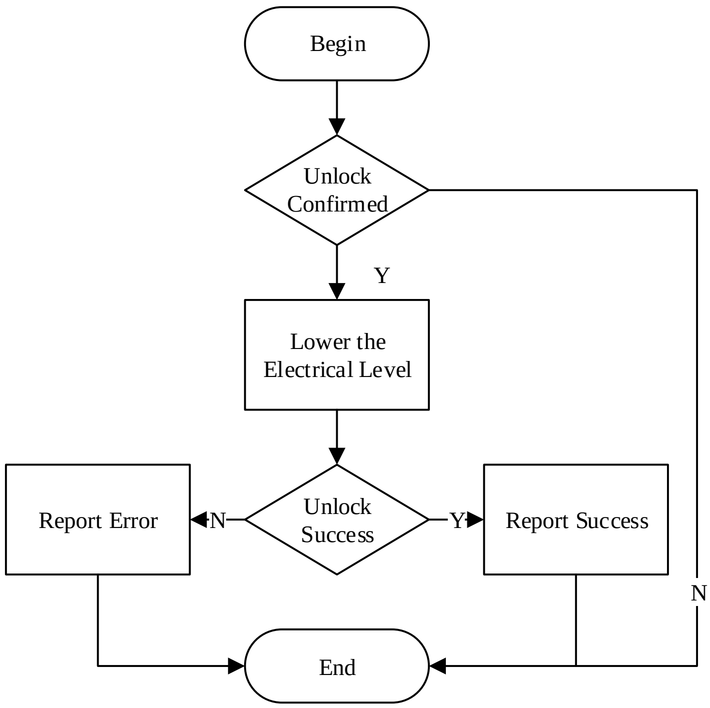

Figure 8. Unlock subprogram flow diagram

6. Conclusion and Expectation

The Internet of Things draws great attention to the electrons industry; it has been increasingly developed since recent years. This study aims to develop a novel intelligent electronic lock using a new kind of IoT technology, NB-IoT. The system can realize remote control, and can be used in homes, offices and other occasions, which have a certain practicality. Furthermore, the system has user-friendly interface, which is suitable for users of all age group. However, the system still has its shortcoming. For example, when the lock is destroyed by physical attack, the system cannot well function as normal and cannot set alarm to these emergencies, which needs further researches.

7. Acknowledgments

This work was supported by the National Natural Science Foundation of China under Grant 61401147.

8. References

[1] C. T. Lee, T. C. Shen, W. D. Lee and K. W. Weng, "A novel electronic lock using optical Morse code based on the Internet of Things," in *Proceedings of the 2016 International Conference on Advanced Materials for Science and Engineering*, Tainan, Taiwan, Nov. 2016, pp. 585-588.

[2] M. K. Shafin, K. L. Kabir, N. Hasan, I. J. Mouri, S. T. Islam, L. Ansari and M. A. Hossain, "Development of an RFID based access control system in the context of Bangladesh," in *Proceedings of the 2015 International Conference on Innovations in Information, Embedded and Communication Systems,* Coimbatore, India, March 2016, pp 1-5.

[3] M. Ye, N, Jiang, H. Yang and Q. Yan, "Security Analysis of Internet-of-Things: A Case Study of August Smart Lock," in *Proceedings of the 2017 IEEE Conference on Computer Communications Workshops*, Atlanta, GA, USA, May 2017, pp 499 -504.

[4] A. Chun, A. Bhat, R. Mohite and P. P. Churi, "E –zip: An electronic lock for secured system," in *Proceedings of the 2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology,* Pune, India, Dec. 2016, pp 45 - 49.

[5] A. Kassem, S. El Murr, G. Jamous, E. Saad and M. Geagea, "A smart lock system using Wi-Fi security," in *Proceedings of the 2016 3rd International Conference on Advances in Computational Tools for Engineering Applications,* Beirut, Lebanon, July 2016, pp 222 - 225.

[6] Y. D. Beyene, R. Jantti, K. Ruttik, and S. Iraji, "On the Performance of Narrow-Band Internet of Things (NB-IoT)," in *Proceedings of the 2017 IEEE Wireless Communications and Networking Conference,* San Francisco, CA, USA, March 2017, pp 1-6.

[7] A. D Zayas and P. Merino, "The 3GPP NB-IoT system architecture for the Internet of Things," in *Proceedings of the 2017 IEEE International Conference on Communications Workshops*, Paris, France, May 2017, pp 277-282.