

An Effective Cards Management Solution Using Smart Bracelet Based on NFC

Huafeng Shi ^a, Haiyun He ^b and Tianwei Wang ^c

Institute of Electronic and Information Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100191, China

^ahuafeng0328@buaa.edu.cn, ^bherian@buaa.edu.cn, ^cwtw216@outlook.com

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Abstract. Radio frequency identification devices (RFID) and business cards emerge as technology develops and it becomes hard to manage them or find a needed one from a piles. A smart bracelet aiming at providing an effective way to manage these cards is proposed in this paper, consisting of a near field communication (NFC) module for data exchanging, a microcontroller for controlling and configuring system, a Bluetooth Low Energy (BLE) module for communication with smartphones and indication module for give user quick feedback. An application on smart phones is built to interact with users and help configure the bracelet. There are three functions of this smart bracelet: 1. Reading cards content; 2. Simulating cards; 3. Exchanging virtual business cards. This smart bracelet is able to simulate MIFARE cards. And it can read content of card and display it on the smartphone. Besides, it also support exchanging personal information via shaking hands if both wear a smart bracelet.) Experiments are conducted to test functional integrity, performance and power consumption. The test result indicates this smart bracelet works and have a 5 days battery life, work distance of 2 cm and 1 second waiting time on operation.

1. Introduction

In the last decades, many efforts have been made to make pervasive computing reality [1]. And there is also tremendous demands for smart wearable devices [2]. Therefore, the rapid development of hardware and wireless communication leads to large-scale emergence of RFID cards.

However, the diversity of RFID cards may increase the interaction cognitive load [3]. Sometimes being unable to know the cards content is inconvenient. Moreover, numerous business cards and RFID cards confuse users and it's really a vexatious job finding a correct card from a piles when one is needed. Therefore, an effective management of cards is strongly desired by modern people

To manage numerous cards, Lee have purposed an authentication solution which disguises an Android smartphone as several cards [4]. Users only need to take a smartphone with them and do not waste time looking for the needed cards as the smartphone can emulate specific virtual cards. But since the solution is based on a smartphone with NFC function, it is not handiness enough to use a smartphone as a card, and the solution can't be used in smartphones without NFC.

Some other developers employ NFC technology to meliorate the current modality of socialization and reduce business cards. In [5], Haikio builds an application on a NFC smartphone to exchange personal information between unfamiliar people. In [6], Anokwa develop a model to simulate RFID tag on a smartphone. The user's smartphone impersonate the tag and others can interact with it. However, both of the two applications are useless for smartphones without NFC function, and encourage the use of smartphones which may contribute to the smartphone addiction according to habit theory [7].

In this paper, a NFC based smart bracelet aiming at providing an effective way to manage cards is proposed. The 20mm wide smart bracelet has circuits inside, including a NFC module for data collection and cards simulation, a microcontroller for system control, a Bluetooth module for communication with smartphones and indication module. The size of the circuits is 18mm*60mm. Linked to a personal smartphone with Bluetooth, the smart bracelet receives user's commands from

and transmits information to the smartphone. A MIFARE card—one common type RFID cards in numerous kinds of card—are simulated in the smart bracelet. And this bracelet can read content of card and display it on the smartphone. Besides, personal information such as name, telephone number and personal interest can be exchanged via shaking hands if both wear a smart bracelet, and then be stored in the smartphone. The smart bracelet can last for as long as 5 days with only Bluetooth connection to the smartphone, and can keep simulating cards for more than 4 hours continuously. With the smart bracelet, numbers of RFID cards and business cards will no longer needed.

The remainder of this paper describes this model in more detail. The second part introduces the major components of our system from aspects of circuits and software. Then some experiments of this device are presented. Lastly, evaluation of our device and estimation of possible challenges in future are presented.

2. System Design

The smart bracelet proposed in this paper consists of two parts: a small-scale circuit mounted in the bracelet and an application running on smartphone. Fig.1 describes the architecture of whole system.

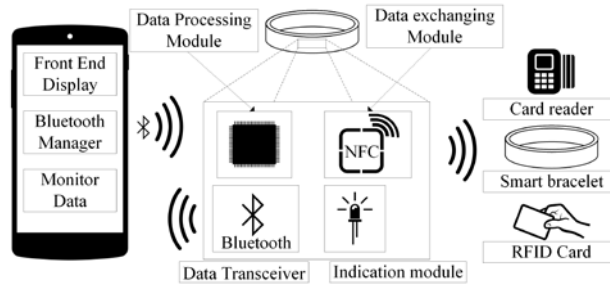


Fig.1 System architecture

2.1 The Circuit Mounted in the Bracelet

The circuit of this bracelet can be divided into four modules: NFC part serving as data exchanging module, controller serving as data processing module, Bluetooth serving as data transceiver and LED functions as indication module.

The NFC chip should support the three mode of NFC to accomplish the function of smart bracelet: reading cards, simulating cards and social communication. NXP PN532 that support these modes above is chosen as the solution for our device. There is a pin to shut down the power consumption in order to make this chip into sleep mode. By managing the power of NFC chip with this pin, this chip does not need energy when it is idle, which can save more energy and prolong working time of this smart bracelet. Besides, since our device is wear on the band, the area especially the width of this antenna is limited. But reading distance, which has a positive correlation with the antenna area, should be long in order to be recognized. So antenna in this smart bracelet are designed as a small appropriate rectangular to satisfy these requirements.

The antenna, whose characteristic impedance should be 80 ohm at 13.56MHZ, consists of three parts: EMC filter, matching circuits and antenna. Fig.2 describes these compositions and key parameters. This antenna is designed following the reliable design from NXP Company. First serial equivalent circuit of designed antenna is determined, which is used to calculate the damping resistor to make sure the quality factor equal to 35. With the parameters of parallel equivalent circuit and filter, the key parameters of matching circuit are designed with the formula (1) and (2).

$$C_1 = \frac{1}{\omega \cdot \left(\sqrt{\frac{R_{tr} \cdot R_{pa}}{4}} + \frac{X_{tr}}{2} \right)} \quad (1)$$

$$C_2 = \frac{1}{\omega^2 \cdot \frac{L_{pa}}{2}} - \frac{1}{\omega \cdot \left(\sqrt{\frac{R_{tr} \cdot R_{pa}}{4}} \right)} - 2 \cdot C_{pa} \quad (2)$$

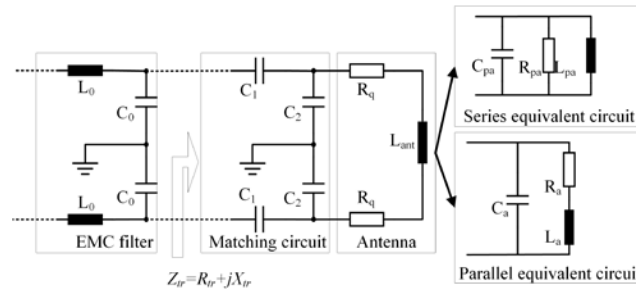


Fig.2 Composition of antenna

Except for that, the system also requires a controller to manage whole system. It can generate command to change the state of NFC. Besides, it can store the information received from NFC and send it to Bluetooth part. Since the length of data is less than 100byte, there is no demand for high calculation ability. And it should cost less energy for longer battery life. Besides, the area of chips should be limited to make the smart bracelet small.

Bluetooth is used for transmitting control commands from a smartphone to a smart bracelet. Because a longer working life is preferred and the highest data throughput of the system is less than 100 bytes, Bluetooth low energy (BLE) is more suitable for this task than traditional Bluetooth.

Based on these demands, the DA14580 of Dialog Company is chosen as the main chip to reach our goal. This chip provides BLE function and controller MCU instead of the pure baseband chip of BLE. In addition, this chip provides an effective event-driven operating system with many interface, which masks most directly manipulation to lower level hardware and simplifies the development of embedded software. And this chip has less power consumption: the emitting current of Bluetooth is as low as 3.4mA and operating system force device to sleep automatically.

The organization of embedded software comprise 3 task, one used for NFC operation, one aimed at monitoring devices and the left one designed for managing Bluetooth part. The first task is responsible for controlling NFC chip. It sending the packed information, which includes the cards content and command for mode changing, to NFC chip through UART interface. The second task interpret NFC or Bluetooth command and execute correspond operation. And some verify operations are designed to avoid repeat same data when device is in social communication modes. The left task is in charge of complex operation suitable for 100 bytes data transmission.

In the data indication module, indicators like a switch, a vibration motor and LED lights are used. This switch informs chip to change NFC mode. The controller receive the interrupt and send corresponding command to NFC chip. This design refrain users from using their smartphone to control their bands and decrease the time on smartphone as much as possible. In addition there are some LED lights to display this bracelet state. There is also a vibration motor on the board. This equipment vibrates when information is received, which give users directly feedback of exchange personal information via shaking hands.

2.2 The Application on the Smartphone

An application built on Android platform is developed to cooperate this bracelet. The first basic function of this application are to change the modes of this bracelet. The second function is to display corresponding information of cards on smartphone's screen in reading card mode. The last function is to send personal information into bracelet and read others virtual business card from bracelet.

Three processes are designed in this application: one is for front end displaying, another one is for Bluetooth link and the left one is used for monitoring data and controlling device. Fig.3 describes their relationship.

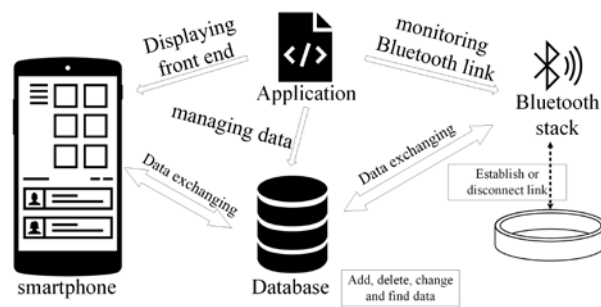


Fig.3 The relation of three processes

The display process interact with users and send correspond command to other processes. This process is forced to sleep when it is idle to save more energy while other processes stay in background of Android to ensure the link of BLE.

The data managing process is in charge of password, card information and businesses card information. The password diminishes the risk of leaking personal information and card information. Besides that, this process can import others virtual business cards into other application, which provides convenience for social communication.

The process monitoring Bluetooth link uses the interface provided by Android to set BLE link with bracelet. Besides, it is in charge of sending and receiving commands and data of this bracelet. Since the storage of this bracelet is limited, the number of virtual business cards stored in bracelet is up to 5. Once the storage is full, other information is discarded. So this process checks bracelet and extract information repeatedly. The interval is set to one minutes since frequent check cost more energy of both devices.

3. Experiment and Discussion

The circuit of this smart bracelet is displayed in Fig.4. To ensure the smart bracelet functioning well in practical application scenes, experiments are conducted to evaluate the functional integrity and the practicability of the smart bracelet. Experiments towards functional integrity includes reading cards, simulating cards and exchanging virtual cards, while the ones towards practicability includes battery life, time for different operations and maximum distance of working.

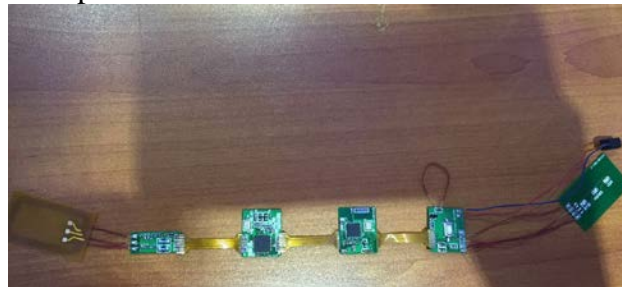


Fig.4 Full view of the circuit

3.1 Experiments towards functional aspects

The first experiment is set to read Beijing transportation pass. A transportation pass is attached to this device. Then smartphone switches to reading cards mode and waits for result. In the end, the balance is successfully showed on the screen which verify that reading cards function works well.

In the second experiment, this bracelet simulate a MIFARE card. It can be identified by the verifying machine after being registered in registering machine. It cannot be recognized when it is switched to other modes. This indicates that this bracelet is capable to emulate a MIFARE card.

In the last experiment, an experiment to test exchanging virtual business cards function is performed. After saving user's virtual cards into this bracelet and setting this bracelet into exchanging virtual business cards modes, two smart bracelets are put near each other. Then other's virtual business card is showed on screen of smartphone. Since the information sent is the same as that received, this indicates that changing virtual business cards function works well.

3.2 Experiments towards practical aspects

Table 1 displays the test result of working time of this bracelet. The experiment evaluates four different modes: idle mode of NFC chip, emulating mode, reading mode and exchanging information mode. And with a battery capacity of 190 mA·h, this bracelet can last for near 5 hours on each modes. With the estimation that this bracelet stays idle for 23.5 hours and enters work modes for half an hour, the battery life of this device can last for 5 days.

Table 1 Current and max working time

Smart bracelet mode	Current (mA)	Max working time (hours)
Idle mode	0.59	322.02
Reading mode	38.12	4.98
Emulating mode	40.17	4.73
Exchanging mode	38.35	4.95

Table 2 lists the maximum distance that this bracelet can be recognized in different modes is tested. This smart bracelet is tested in the same work conditions as functional experiments except for the distance of two antennas. Since the antenna does not work in idle mode, the max work distance is 0 cm. In the other three mode, the work distances are about 2 cm, which indicates that this bracelet is convenient to use.

Table 2 Working distance

Smart bracelet mode	Max working distance (cm)
Idle mode	—
Reading mode	2.1
Emulating mode	2.2
Exchanging mode	1.7

Besides, the time for different operations is measured. When this smart bracelet reads a card, it will take some time to translate this card and transfer results to cellphone. The time length are measured for 10 times and the results are drawn in Fig.5 (a), which is 0.71 second on average. The exchanging information mode also take some time to deliver one virtual cards to device. The time of transmitting different cards is measured and is listed in Fig.5 (b). The average time of exchanging is 1.08 second.

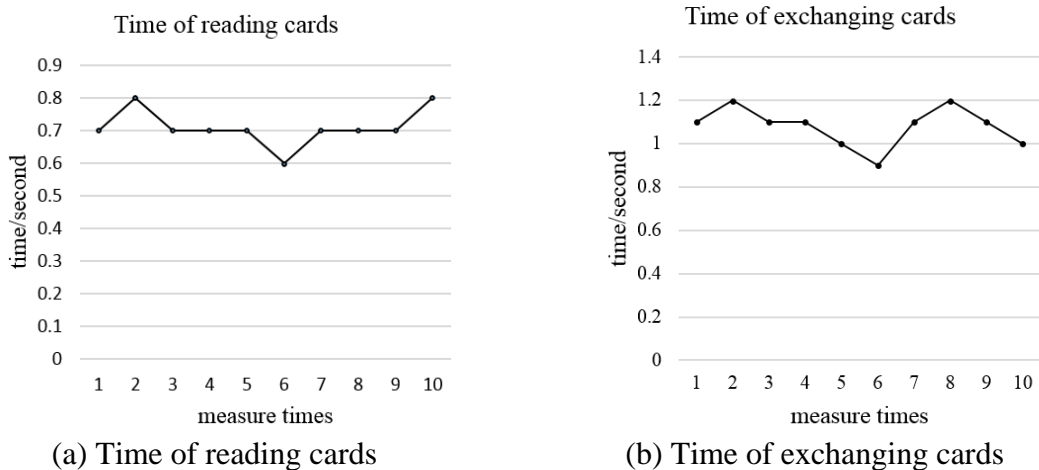


Fig.5 Operation time

3.3 Discussion

This bracelet can successfully execute every function. As for the battery life, it can continuously working for 5 days with assumption that 2 hours with NFC part work in these days. The distance of working is not strict and limited. In other word, user does not need to rectify their bracelets in order to put every device precisely. In addition, the time for each operation is short. Thus, users do not wait for a long time and become impatient since this application can provide information of this bracelet quickly.

4. Summary

In this paper, a NFC based smart bracelet aiming at providing an effective way to manage RFID cards and business cards is proposed. RFID cards like MIFARE cards can be simulated and replaced by the smart bracelet, which frees human from carrying numerous cards. Moreover, business cards are replaced by virtual ones which are exchanged during hand-shaking and stored in smartphones. Time is then saved as it is no longer needed to type information to the smartphone while first meeting or to look up someone's information from a piles of business cards.

The smart bracelet is only 20mm wide, which is portable enough. The 5-hour working life of the smart bracelet can meet the demand of the public. It's much safer to wear the smart bracelet than to carry a piles of cards as cards are easier to be lost. Besides, it provides better sense of safety using hand-shaking as the input action, because touching is the perfect action when perform a close and private action and can convey people the sense of security [9].

Since the detailed configuration information for advanced operation is not open source, this bracelet can only emulate basic card and is unable to execute complex operations like paying. And for security reason, not every card is able to be written or read without password or authority. Thus, this bracelet can only read authority provided cards.

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