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A WSN Smart Medication System

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Abstract

In this work, a smart medication system, which employs the wireless sensing network (WSN) technologies, is designed, implemented and demonstrated. The primary functions of the system include the medication reminder and tracking for the patients with chronic diseases. The system can be easily deployed in a nursing home which accommodates many elderly people. Each system consists of a master panel (MP) and seven portable smart pill-boxes (SPB). The MP serves as a network gateway/database for its own smart pillboxes. Each SPB independently provides the functions of medication reminder and monitoring for patients. The routing network among the MPs is constructed using the tree topology. The star topology is used for the communication between each MP and its own seven SPBs. Moreover, by using magnetic sensors, a mechanism is proposed for detecting the existence of pills in a SPB.

Keywords: wireless sensor network; magnetic sensor; medication system

1. Introduction

The recent rapid progress in wireless communications and integrated circuits has enabled the realization of low-cost wireless sensor networks [1][2]. The employment of WSN technologies have been demonstrated in various application areas. For example, the integration of WSN and existing consumer electronic infrastructures can be used for patient monitoring, in-home assistance, smart nursing homes, and so on [3][4]. Also, due to the advancement of healthcare and medical service, the average human life has been extended during the past decades. Therefore, aging society is one of the main issues for most of the countries in the world. Furthermore, the complexity of medication for senior citizens frequently results in errors of medicine taking, or wasting medicines due to ignorance. The former might cost a life at certain critical conditions, and the latter might cost significant healthcare resources. In this work, we develop a WSN smart medication system which can effectively provide various functions to help senior citizens taking medicines. The smart medication system includes a master panel (MP) and a few smart pill-boxes (SPBs). The primary functionalities of the MP include instructing users to dispense pills into pill-boxes as well as charging each SPB. The SPB, which have four pill cells for storing pills, can provide the functions of medicine-taking reminder as well as medicine-dispensing assistance. In addition, the MP serves as a network gateway for its own SPB. A database is implemented and installed in the MP for managing the prescription and medication records for users. Also, this database is essential for users to correctly refill pills in each cell of pill-boxes. The network of the tree topology and the star topology are used in the system. A magnetic sensing mechanism for detecting the existence of pills is proposed.

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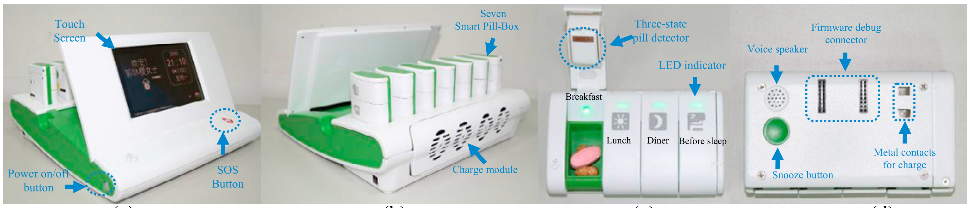
2. Design

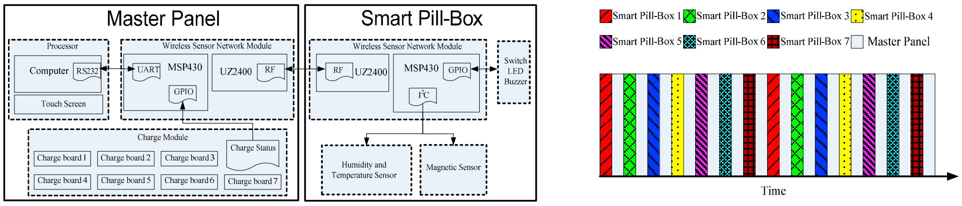
2.1. System architecture

Figure 1 shows the pictures of the smart medication system, including the MP (Figure 1(a) and (b)) and SPBs (Figure 1(c) and (d)). The MP serves as a network gateway/database for its own SPB. Also it is the charging dock for SPB. In principle, a SPB can offer sufficient pills for one patient for one day. As shown in Figure 1(c), in a SPB, there are four pill-cells, each of which is designed for storing pills which should be taken after a meal. The medication reminder is performed by voices (speaker) and light (LED indicators). The hardware architectures of the MP and the SPB are shown in Figure 2(a).
Both the MP and the SPB use the RF modules which are composed of a RF transceiver chip (UZ2400, UBEC®) and a 16-bit microcontroller chip (MSP430F1611, Texas Instruments®). The CSMA/CA [5] capability of the UZ2400 chip can effectively prevent the problem of packet collisions [6]. However, bandwidth contention problems will also result in packet loss. In order to reduce bandwidth contention, the time period for each communication cycle is divided into many time slots with specific tags of synchronization. We call this method as the *time division.* Depending on time slots, each SPB is allowed to send a packet in sequence, as shown in Fig. 2(b). This simple method can avoid that lots of packets are sent by different SPBs in a short time interval.



(a) (b) (c) (d)

Fig. 1. (a) master panel, (b) the rear view of the master panel, (c) smart pill-box, and (d) the bottom view of the smart pill-box



(a) (b)

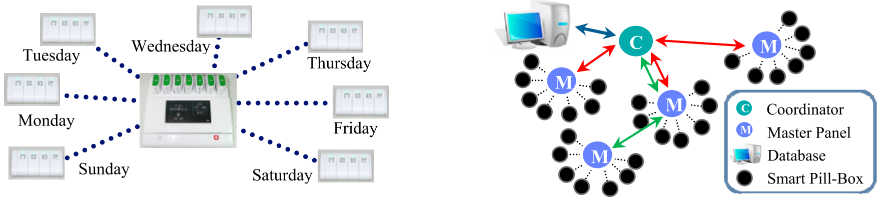
Fig. 2. (a)The hardware architectures (b) Time division

2.2. Network architecture

This system establishes the networking by combining two types of network topology. As shown in Fig. 3(a), the star topology is used for the communication between each MP and its own seven SPBs. The routing network among the MPs is constructed using the tree topology [7], as shown in Fig. 3(b). Also, the prescription, the records of medicine taking, as well as the sensed temperature/humidity data, can be wirelessly synchronized between the MP and the SPB. In order to decrease the power consumption, the SPB changes its operation mode between the sleep mode and the normal mode, while it still provides effective and efficient functions. Figure 4 shows the procedure of joining a tree topology of a wireless network. By this procedure, the smart medication system can be expended to serve many users. In this tree routing topology, a user's MP can send the information of its SPBs to a coordinator through other user's MP. The coordinator can receive information or commands from the database, and then send them back to the user's MP through the original path. Since the tree topology is based on the hierarchical structure, the transmission distance increases with the hop count, which further increases the packet transmission time. If the waiting time for receiving a packet is less than the transmission time of the packet, it probably causes packet loss. However, if the numbers of hop count is determined, the waiting time for receiving a packet can be estimated.

2.3. Three-state pill detector

A three-state pill detector is proposed for detecting the existence of pills in a cell of the SPB. Figure 5 shows the design and the operational principle of the module. As shown in Fig. 5(c) and 5(d), two magnets are fixed on the movable touch board, and a magnetic sensor chip is installed under the lower board. Once pills are placed into the cells, the position of the touch board is changed by the existence of pills. The magnetic sensor is employed to sense the magnet flux variation to determine the displacement of the touch board, and then distinguished the three states: “pills exist”, “no pills” and “box is open”.



(a) (b)

Fig. 3. The wireless sensing smart medication system use (a) Star topology and (b) Tree topology

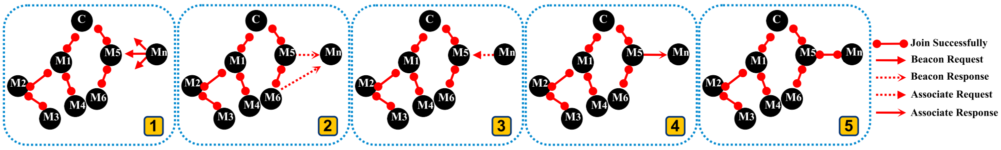
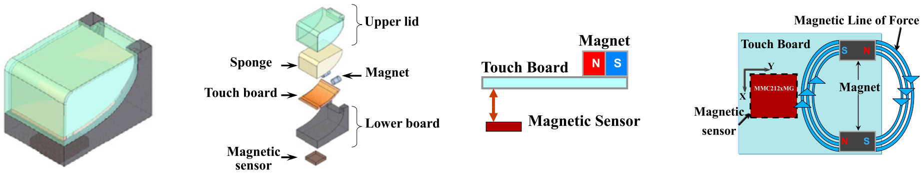


Fig. 4. The procedure of joining a tree topology. Step 1, Mn starts to send beacon to find a new network. Step 2, Mn has received the beacon response from M5 and M6. Step 3, Mn chooses M5 and request to become M5’s child. Step 4, M5 agrees the request and Mn will revive the response from M5. Step 5, Mn has become one of the M5’s children and finishes the procedure of joining a new network.



(a) (b) (c) (d)

Fig. 5. The components of three-state pill sensing technology, (a) the shape of pill detector (b) the exploded view of mechanical structure(c)the side view of the principle of magnetic sensor(d)the vertical view of the principle of magnetic sensor

3. Experiment results and discussions

3.1. Wireless link

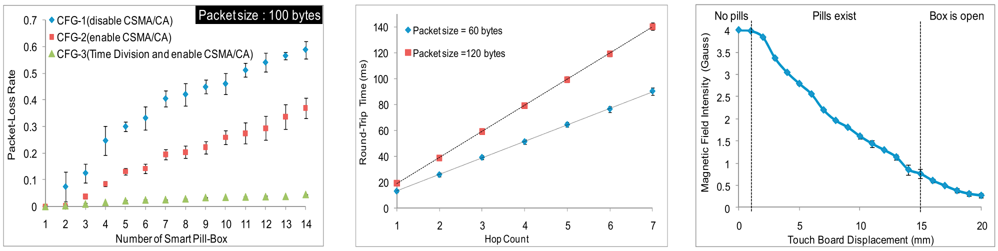
In this work, three communication configurations, CFG-1, CFG-2 and CFG-3, are tested. CFG-1 disables the CSMA/CA capability. CFG-2 enables the CSMA/CA. CFG-3 employs the *time division* and enables the CSMA/CA. The packet-loss rates of these three configurations are also compared. The experiments were performed in an area of 1 m × 1 m. Each SPB sent a packet of 100 bytes to the MP every 200 ms. When the MP receives a packet from the SPB, the MP will send a packet of 100 bytes back to the SPB immediately. After every SPB finishes sending 1000 packets, the packet-loss rate can be calculated. As shown in figure 6(a), it is obvious that the packet loss rate of CFG-2 is better than that of CFG-1. However, the packet-loss rates of both configurations increase with the number of SPBs. For example, as the number of SPBs is 14, the packet-loss rate of CFG-2 is as high as 38%. Fig. 6(a) also shows that the packet-loss rate of CFG-3 is about 5% when 14 SPBs are registered in the network. In other words, CFG-3 not only reduces the possibility of the packet collision but also reduces the bandwidth contention, and thus further provides higher transmission performance.

3.2. Wireless network

In order to calculate the transmission time of a packet under different hop count, the relationship between a *round-trip time* (RTT) and *hop count* are measured. RTT represents the required time for a packet to travel from a source to a destination and then back to the source again, and it can be used to describe the performance of a network. To measure RTT, the coordinator sends a packet to the specific MP, and the MP sends a packet back to the coordinator. Considering that the packet length may also change the transmission time, the experiment will find the relationship between RTT and hop count in the situations of 60 bytes or 120 bytes packet length. As shown in Fig. 6(b), the relationship between RTT and hop count is linear for both cases. As the number of hop count increases, the transmission distance increases, so that RTT also increases. At the same hop count, the transmission time of 120 bytes is always larger than that of 60 bytes. Also, the slope of the curve of 120 bytes is larger than 60 bytes, which indicates that the packets sizes also significantly affect RTT.

3.3. Magnetic sensor

Fig. 6(c) shows the measured relationship between magnetic field intensity and touch board displacement. As the distance of the touch board increases, the magnetic flux gradually changes from the high level to the low level. Also, because of the regular and stable variation of the magnetic flux, the result of the maximum magnetic flux can be seen as the "no pills" situation. When the displacement of the touch board is beyond 15mm, the result of the magnetic flux can be judged as the "box is open" situation. And when the displacement of the touch board is between 1 mm and 15 mm, the result of the magnetic flux is judged as the "pills exist" situation.



(a) (b) (c)

Fig. 6. (a)The relationship between packet-loss rate and number of smart pill-box.(b) The relationship between round-trip time and hop count.(c) The relationship between magnetic field intensity and touch board displacement.

4. Conclusion

In this work, we develop a smart medication system which employs the wireless sensor network (WSN) technology and a three-state pill sensing mechanism. A WSN communication configuration for reducing the probability of packet-loss rate is also proposed. In the condition of 14 SPBs, each SPB sending one 100-byte packet every 200 ms, more than 95% packets can be transmitted correctly with a simple time-division method and CSMA/CA. A tree topology network is applied to the smart medication system, which can expand this personal system into a multi-users system. The relationship between RTT and hop count is also measured. According to the measured results, the time of transmitting a packet in the tree topology network can be estimated. Furthermore, the measurement results show that the three-state pill detector has good repeatability.

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