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Implementation of Smart Cupping Therapy System

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Abstract

The use of IoT technology in home automation systems, industrial automation systems and health care is on the rise. In health care, it is included in devices for fitness and wellness; furthermore, devices for diagnosis, treatment and health care are expected to increase owing to increased demand and aging in the future. This paper shows the system design and implementation of a smart cupping therapy system that aims to provide easy, safe therapy. In our system, the pressure of a cupping boil and therapy time are adjusted like a prescription from a doctor. The system consists of a smart sensing unit that detects and controls the degree of pressure, a ZigBee transmitter and receiver unit that can communicate wirelessly between a cupping device and a ZigBee coordinator, and a GUI application.

***Keywords**: WSN, health care, IoT, ZigBee*

1. Introduction

The concept of IoT (Internet of Things) has recently been introduced and various approaches to apply the IoT model have been attempted in home networking, health care and smart grids. There have been many studies of remote health monitoring services in hospitals, health centers, and parks. IoT includes sensing, communication between heterogeneous networks handling information, and services. Security is also considered. A WSN (wireless sensor network) is one of the components of IoT [1].

A WSN consists of distributed sensors to monitor remote locations and send their data through the network to the server. A sensor node consists of a radio frequency transmitter and receiver module that send sensing data to and receive control data from a server and an analog to digital module that monitors locations or environmental conditions like temperature, humidity and illumination. These sensor nodes are able to self-organize an ad-hoc multi-hop network to communicate with each other or with other networks [2]. WSN technology has been growing constantly in the medical instrument field due to its easy placement, installation and extension. In the field of wearable health care, small sensors measure bio medical data such as patients' ECG, heart rate, body temperature, and blood pressure and report to a doctor [3].

Several metrics such as data transmission rate, coverage dimension, power consumption, scalability and so on should be considered for any applications [4-6]. Bluetooth is an IEEE 802.15.1 standard that is designed for short-range and cheap computer peripherals such as wireless mice, keyboards, headsets, and so on. Bluetooth has only limited applications because of the small number of nodes that can be configured on the network [7]. In contrast, ZigBee consumes less power than Bluetooth and is suitable for transmitting data up to 300 m [8]. ZigBee has been growing rapidly owing to its economic price, low power consumption and stable communication. Deployment and management are easy because the system structure is simple and the installation of a

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backbone or infrastructure is not necessary. It has been used for military, environmental, health, home and other commercial applications, home networks, logistics, and industrial automation [9].

Cupping therapy helps to remove blood stasis and to relax muscles. Cupping therapy helps when feeling tired or when muscles ache and also works well on hypertension, arteriosclerosis, rheumatoid arthritis, constipation, neuralgia, obesity, gout and others [10]. Appropriate suction pressure from a cupping boil makes people feel refreshed. If the pressure is too high or the therapy lasts too long, the affected skin turns red and may blister depending on the individual patient.

This paper is organized as follows: Section 2 reviews ZigBee technology, Section 3 describes our implemented smart cupping system, and Section 4 presents the conclusion of our paper.

2. ZigBee Technology

2.1. ZigBee Architecture

The ZigBee stack is based on an OSI 7 layer and consists of several layers as in Figure 1, below. Every layer has a data entity that supports a data transmission service and a management entity that supports other services. Each layer provides services to the upper layer.

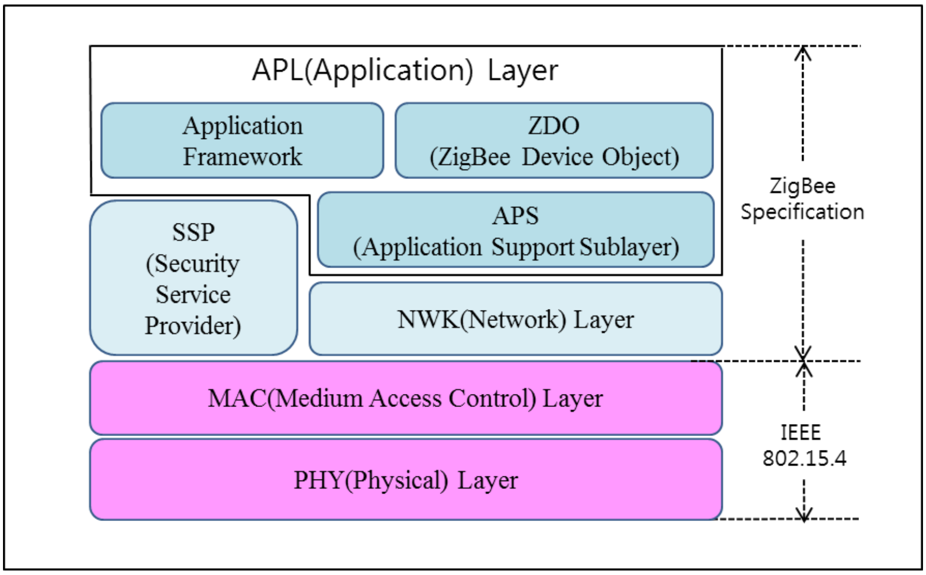

Figure 1. ZigBee Stack Architecture [11]

The IEEE 802.15.4 standard defines the PHY layer and MAC layer. ZigBee specifications define the NWK layer, APS, ZDO and application framework. The PHY layer supports basic wireless communication for physical data transmission and reception. This layer performs modulation and demodulation. The MAC layer transmits data between neighborhood devices and supports a security service that is defined in IEEE 801.15.4 [8]. This layer is responsible for reliable data transmission. The NWK layer supports the joining mechanism, address assignment and routing for transmitted frames. The application layer is composed of APS, ZDO and the application framework. APS supports the interface between the NWK layer and application layer. APSD (APS data entity) supports the data transmission service to transmit PDU among two or more devices in the same network. APSME (APS management entity) supports the service that manages the AIB (APS information base) database and binds and detects devices.

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Application objects receive data from the endpoint interface defined as APSDE-SAP in the application framework. ZDO controls and manages application objects via a public interface. ZDO supports device discovery, security management, network management, binding management and node management. The application framework provides key value pair and generic message services. SSP provides security mechanisms to APS and the NWK layer.

2.2. ZigBee Network

IEEE 802.15.4 is related to the network layer and supports star and peer-to-peer topology. Star topology consists of a PAN coordinator and numerous devices. In star topology, a master-slave network model is adopted. The master is denoted the PAN coordinator and slaves can be coordinators or end devices. Peer-to-peer topology also consists of a PAN coordinator and several end devices. However, an end device is able to send to and receive from other end devices including a PAN coordinator. Peer-to-peer topology supports more complex topologies like mesh topology.

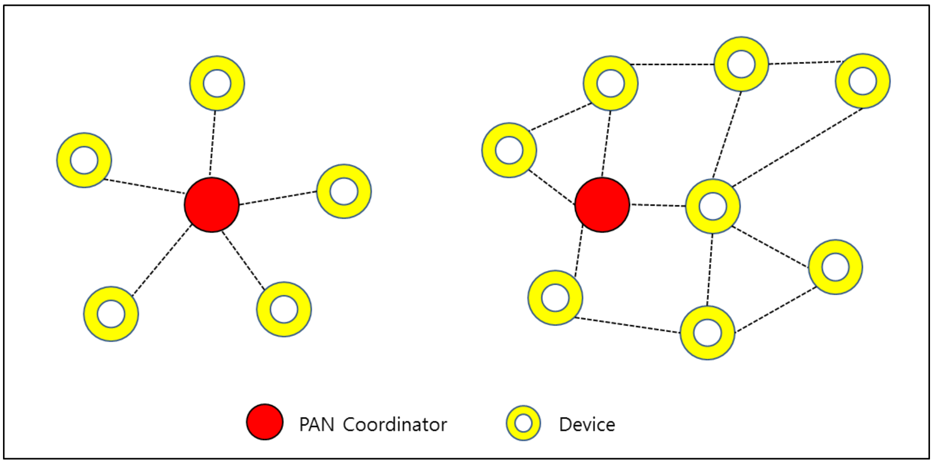

Figure 2. ZigBee Network Topology

The PAN coordinator collects data from and controls end devices in whole networks. The coordinator controls end devices in the assigned network and delivers data from end devices to the PAN coordinator. An end device transmits data from sensors to coordinators. A ZigBee network must consist of at least one coordinator.

The 802.15.4 network is composed of FFD (full function devices) and RFD (reduced function devices). FFD can be operated in three modes: PAN coordinator, coordinator and device. FFD can communicate with both RFD and FFD. RFD can communicate with only FFD. RFD is suitable to deliver small and lightweight data to FFD and can be operated only as an end device [6] [12]. FFD has the ability to send beacons and offer synchronization, communication and network join services. RFD can only act as end devices and are equipped with sensors or actuators; they are light switches, lamps and so on [13].

In the sensor network, a routing protocol should be designed to avoid the power exhaustion of a specific sensor node and to increase the life of the entire network [14]. It should be able to quickly respond to the dynamic positioning of the sensor nodes to guarantee the mobility of a sensor node. Several factors including communication cost, packet overhead, flash size, RAM size and computation cost should also be considered.

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3. Smart Cupping System

3.1. System Description

The proposed system is designed to protect against the side effects of cupping therapy. This system is divided into cupping devices, a coordinator and a CTMS (cupping therapy management system). The cupping device consists of a MCU-embedded RF, a pump, a solenoid value, a pressure sensor, and two touch sensors. MCU is the central controller of the cupping device during cupping therapy. Embedded RF is implemented for protocol transfer and wireless communication between a cupping device and the coordinator. The coordinator transfers the data from devices to the CTMS or transfers the control command from the CTMS to devices. The CTMS stores the data from devices on a therapy database and transfers the control command to devices. The basic design of the system was as shown in Figure 3.

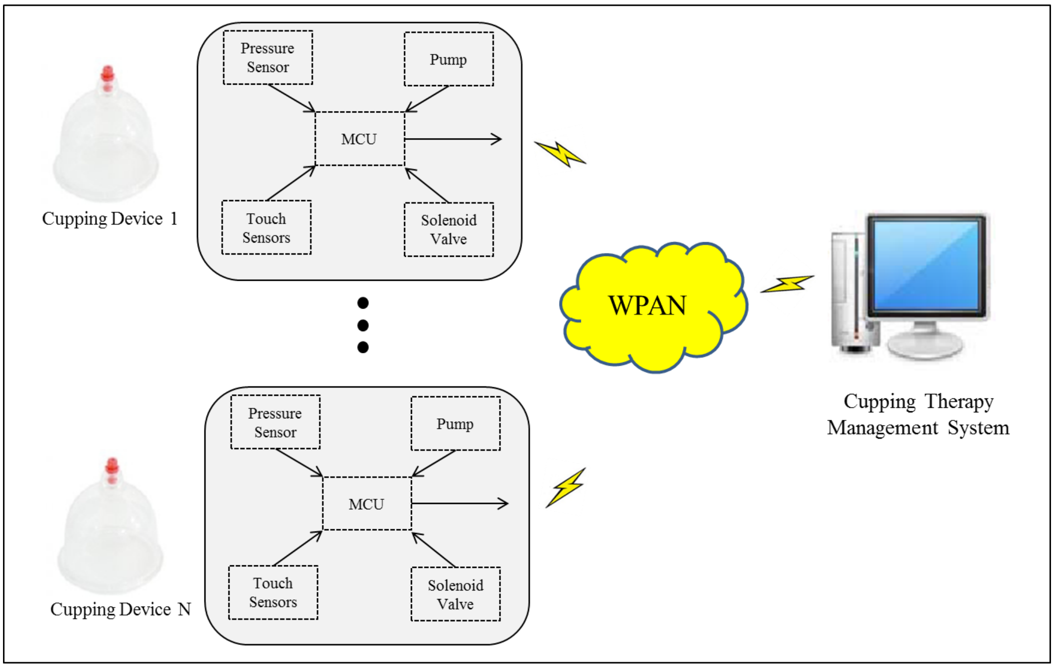

Figure 3. Basic Design of Smart Cupping System [15]

3.2. Cupping Device

The cupping device consists of a MCU-embedded RF, an air pressure pump, a solenoid value, a pressure sensor, and two touch sensors. The central controller is a RadioPulse RP-M100 module. The M100 module is based on an MG2455 ZigBee single chip and embedded with a chip antenna and 16 MHz X-Tal. The MG2455 is composed of a 2.4 GHz RF transceiver, baseband modem, hardware MAC, embedded flash memory, and 8051 MCU. This chip supports the timer, PWM, UART, ADC, and general purpose I/O pins. This module provides hardware AES encryption. The pump is KPM10A, which is suitable for blood pressure M/C, health care, medical equipment, and so on. The maximum pressure of this pump is 350 mmHg. The solenoid value is KSV04A, which controls the pressure degree of a cupping boil. The pressure sensor is ADP1131, which is suitable for medical equipment, home appliances, gas equipment, and industrial equipment. This sensor covers a wide range of pressure from a minute pressure of 4.9 kPa to a maximum pressure of 980.7 kPa and has linear detection characteristics. The touch sensor is ADA03, which is 1 channel and designed for detecting capacitance variation.

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This sensor detects 0.1 pF capacitance variances from average capacitance. The schematic of a cupping device is shown in Figure 4.

The analog signal from the pressure sensor is input into an ADC port on the MCU. The MCU processes the analog signal and controls a pump and a value to maintain the pressure value received from CTMS.

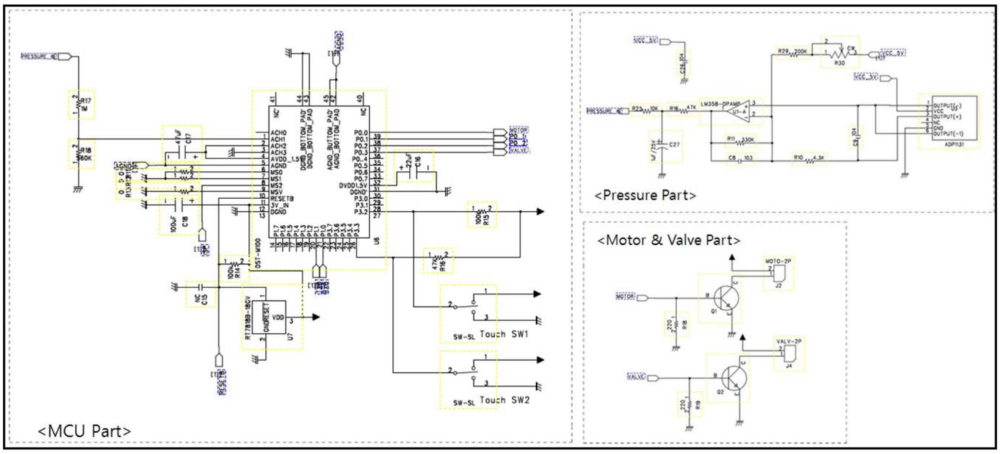

Figure 4. Schematic of Cupping Device

The developed cupping device is as in Figure 5. LEDs are used to display the relevant status. There is an interval between the cupping device and cupping boil. A coil on top of the cupping device is needed to increase the sensitivity of the touch sensor.

Figure 5. Cupping Device

3.3. ZigBee Coordinator

The coordinator is connected through a USB cable mapped on a virtual COM port of the host computer. The schematic of the coordinator is shown in Figure 6. The CP2102 is a USB-to-UART bridge controller. This is able to interface with CTMS via UART. Other external USB components are not required. The central controller is a RadioPulse RP-MR220 module embedded power amp. RP-MR220 provides hardware AES encryption. This module needs to use an external antenna. The communication distance depends on the dimensions of the antenna.

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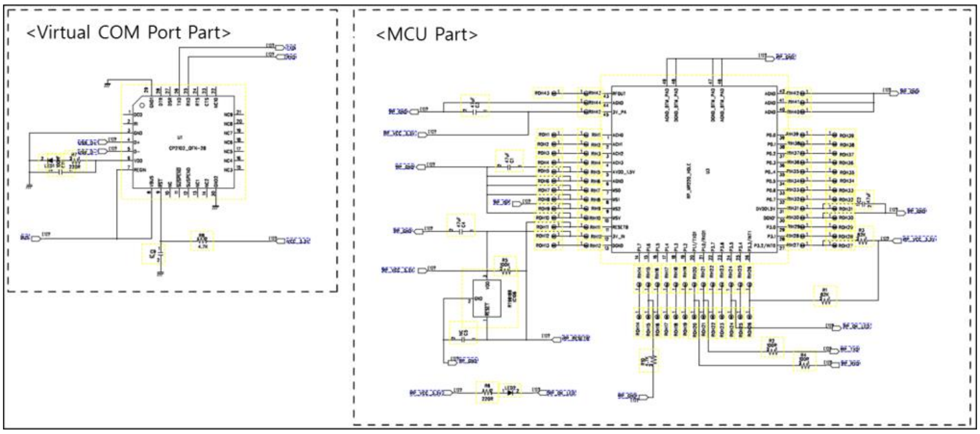

Figure 6. Schematic of Coordinator

The ZigBee coordinator used is depicted in Figure 7. The coordinator collects the data from cupping devices and delivers the data to the CTMS. It broadcasts the control command from the CTMS to cupping devices. A LED is used to display the status of RF communication. The coordinator checks the heartbeat data of the cupping device. If the heartbeat is not received three times, the coordinator reports the abnormal condition of the corresponding cupping device to the CTMS.

Figure 7. ZigBee Coordinator

3.4. CTMS (Cupping Therapy Management System)

CTMS is used for real-time analysis and corresponding management of the cupping therapy. An MFC-based GUI application for PC is developed that enables a therapist to control the cupping therapy remotely. MS carries out operations such as starting or stopping therapy and indicating the therapy status. It also receives data from cupping devices and stores the data on the therapy database. The therapy database has SQLite implemented. SQLite is a software library and its code is open source and free for any purpose, commercial or private. This is a file-based processing database management system. The rocking occurs as table units rather than database units. TMS keeps patients' therapy data and stores it in the database after completion of therapy. The CTMS GUI is as in Figure 8.

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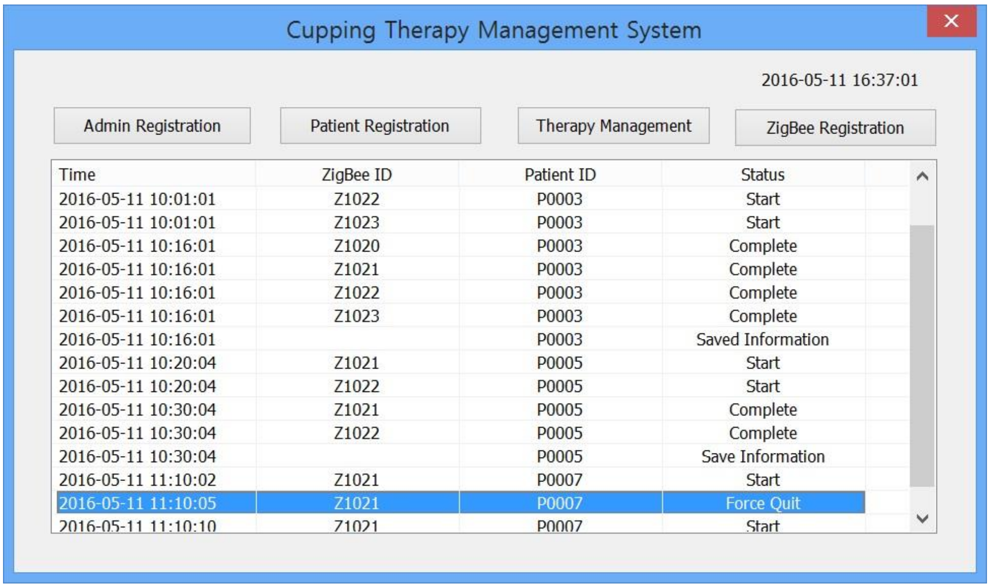

Figure 8. Cupping Therapy Management System

CTMS consists of admin registration, patient registration, therapy management, ZigBee registration, and status display. Admin registration supports registration of a doctor's or therapist's information including doctor or therapist ID, password, name, mobile phone number, and e-mail. Only registered therapists or doctors are able to access patient registration, therapy management and ZigBee registration. Patient registration supports registration of patient information such as patient ID, name, age, mobile phone number, and e-mail. ZigBee registration supports registration of ZigBee information such as ZigBee end device ID and MAC address. Therapy management supports registration of disease codes and symptom codes, matches patients to cupping devices, sets pressure value and therapy time, and supports search by patient, by disease or by symptom. Status display shows the status of the cupping therapy process.

3.5. Communication Protocol

3.5.1. Matching Protocol

Before starting therapy, the patient ID (P_{ID}) of a patient to be treated must be registered on cupping devices. CTMS notifies cupping devices of the patient ID. If CTMS doesn't receive an ACK from a cupping device, CTMS attempts to send the notification three times. CTMS receives the ACK and then requests the matching information. A cupping device sends the patient ID and the ZigBee ID to CTMS. The matching protocol sequence diagram is shown as Figure 9.

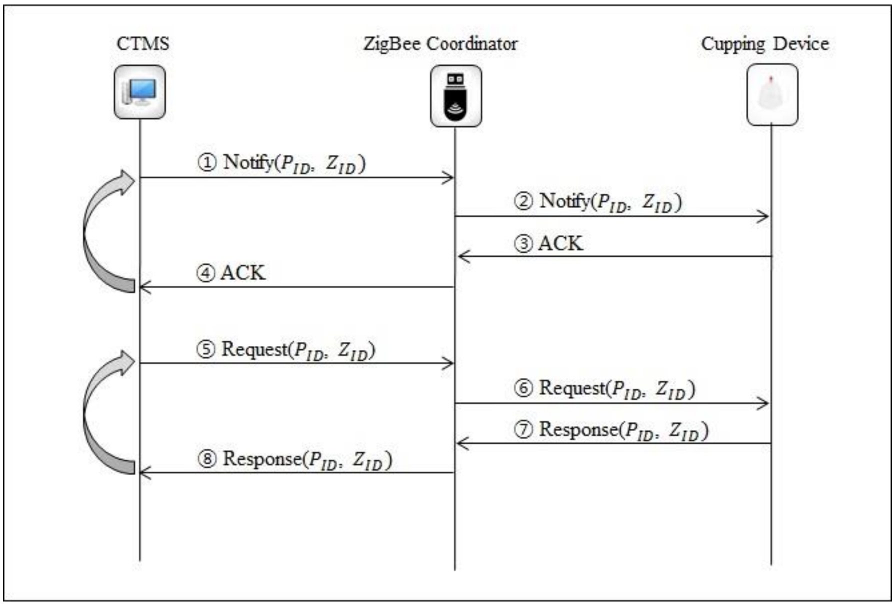

Figure 9. Matching Protocol

3.5.2. Therapy Protocol

After matching the process, CTMS is able to start the cupping therapy. CTMS sends a start therapy command that contains a patient ID, degree of pressure and therapy time. If CTMS doesn't receive the ACK from a cupping device, CTMS attempts to send the Start Therapy command three times. After completion of therapy, a cupping device informs CTMS. If a cupping device doesn't receive the ACK from CTMS, the cupping device attempts to send the Complete Therapy Notification message three times. The therapy protocol sequence diagram is shown in Figure 10.

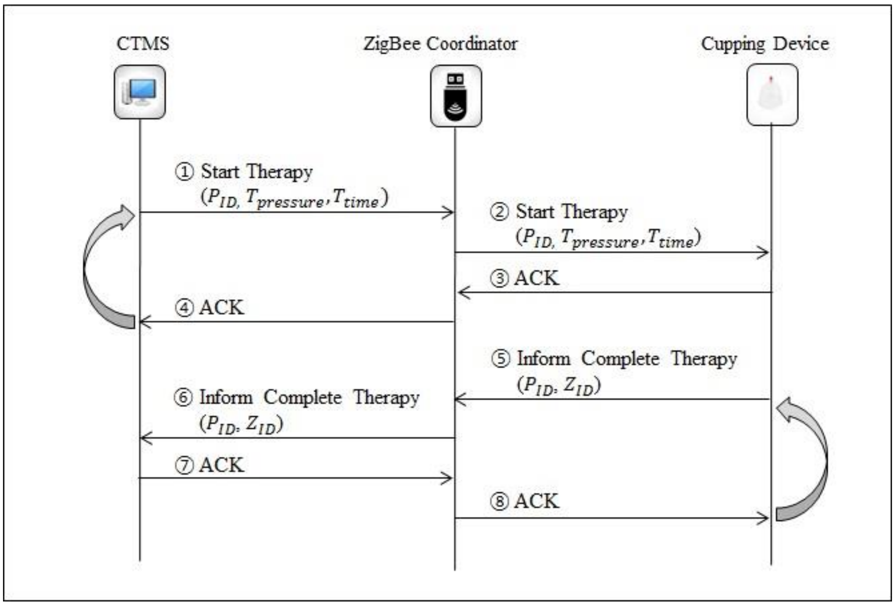

Figure 10. Therapy Protocol

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3.5.3. Fault Detection Protocol

The ZigBee coordinator periodically checks the heartbeat message from the cupping device. If the coordinator doesn't receive the message three times, the coordinator sends an alarm message to CTMS. If a cupping device detects an abnormal condition such as excess time or excess pressure, the device stops the therapy and sends an alarm message to CTMS. CTMS transmits the alarm to the registered doctor and therapist. The fault detection protocol sequence diagram is as in Figure 11.

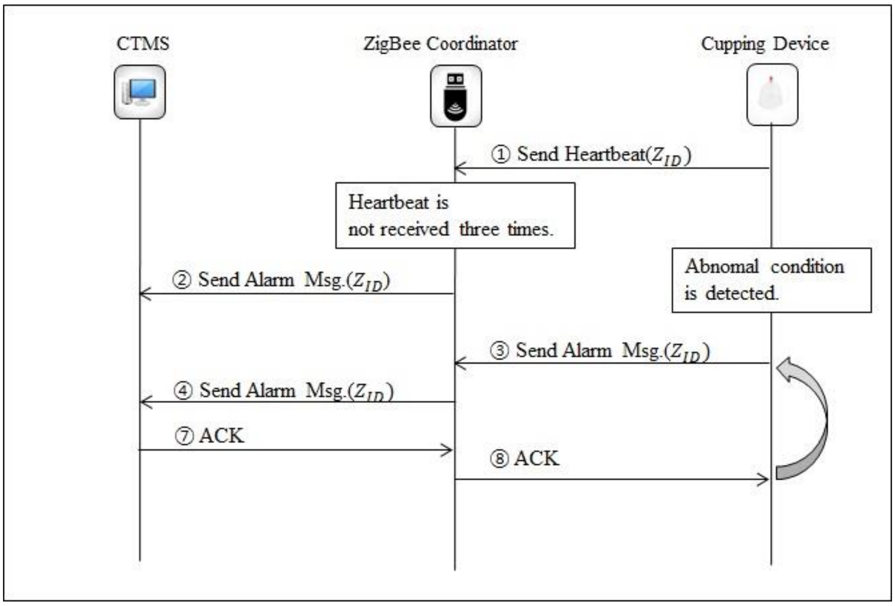

Figure 11. Fault Detection Protocol

4. Conclusion

Wireless technology has been designed for various applications. ZigBee is an efficient short range wireless technology suitable for remote controlling and monitoring of applications. This paper describes a smart cupping therapy system using the ZigBee technology. A GUI application developed on MFC provides an easy way of controlling and monitoring the cupping therapy and displays the therapy's progress. The stored therapy information will help the user to determine a more precise prescription to avoid side effects. This system can monitor multiple cupping devices at the same time. A therapist puts cupping boils on the affected area of a patient and starts the cupping therapy by clicking a button on the GUI application. When detecting any abnormal condition, the cupping device itself stops ongoing therapy and sends an alarm message to the GUI application. A therapist can respond quickly and a patient can get treatment safely.

At present, the battery is very small because of the limitations of the cupping boil space. Furthermore, it is difficult to charge the battery because it uses a USB cable for charging. A wireless charging method is required to improve upon these problems.

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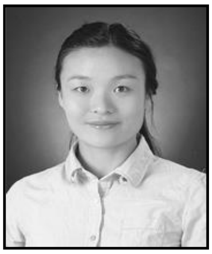

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