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Health parameter monitoring *via* a novel wireless system

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ABSTRACT

This study develops a novel remote healthcare system based on Wireless Sensors Network System (WSNs) and Radio Frequency Identification (RFID) technologies. Cloud equipment is used as sensing cloud architecture to create the system database, and Improved Particle Swarm Optimization (IPSO) is applied to build a personal physiological signal sensing system. The collected personal physiological signals are analyzed, and RFID technology is used to create an administrator identity and database. The integrated physiological instrument measures/monitors blood pressure, heart rate, blood oxygen content, body weight, BMI and cardiogram. This system can be applied to, say, employees, nursing-home residents and the elderly. Physiological changes are identified at any time *via* a self-health examination, promoting early diagnosis and treatment. The current ZigBee technology, which has many advantages, is used in medical institutions, industry, and agriculture, and for automated control and building monitoring. This study uses WSNs technology to transfer physiological data to the cloud for analysis, processing, and storage. The client-side and appropriate medical personnel are notified by e-mail and short messages *via* the Internet, such that they can provide timely diagnosis and deploy treatment. The IPSO scheme is used to increase the efficiency and accuracy when searching for at-risk groups, searching data, and defining and summing the weights of physiological data. If the first 10% of users with high weight values are a risky population that must be treated immediately, this system informs medical personnel immediately, potentially improving medical service quality and application of medical resources.

1. Introduction

The World Health Organization indicated that worldwide mortality caused by chronic disease increased continuously during 2000–2011. Chronic disease is a disease that cannot be fully cured. Once a chronic disease is diagnosed, there will be a long period of treatment. If a condition is serious, treatment cost may be considerable. When a chronic disease is diagnosed early, a patient's condition may be controlled due to its early discovery. Physiological medical equipment is employed in this study for periodic examination of a population prone to developing chronic disease such that chronic disease can be diagnosed as early as possible.

To reduce care costs and increase care efficiency, healthcare services are often transferred from a hospital to a patient's home; this is called "home care." At present, home care in Taiwan is characterized by patients leaving a hospital and staying at home with their families; however, they remain in contact with healthcare units and continue receiving care. Home care has four major advantages: (1) care one would experience at the hospital is received at home continuously, and complications caused by long-term hospitalization are eliminated; (2) family relationships are free from the reciprocation between hospital and home, reducing economic burden on a family; (3) expenditures related to hospital resources are reduced, and the range of services can be expanded; and (4) a patient's medical status is known, such that a hospital can diagnose diseases, and patients can track their illness state. Currently, with the development of technology, medical technologies for home care have developed toward microminiaturization, portability, wireless, customization, and humanization [1].

This study designs a physiological system that acquires physiological data by measuring oxygen concentration, blood pressure, body weight, BMI, and heart rate. The physiological data are transmitted by the ZigBee IP-Link 2250 wireless transmission module developed by Helicomm, and the ZigBee IP-Link 5501 wireless receiver module then displays the received data on a Visual Basic graphic user interface at the PC-side. The received data are integrated efficiently, and the user's rights are protected by RFID. The data are input into a personal case database for collective management. Under normal conditions, measurements are sent

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in messages *via* GSM to the user's mobile phone. However, under abnormal conditions, the user's emergency contact is informed by text messages. Finally, the IPSO is used to identify the most serious condition in physiological data of multiple patients, such that medical teams can implement treatment immediately and accurately.

2. Literature review

With advances in medical technology, average life expectancy has increased, society has aged, and disease patterns gradually change from acute to chronic. Demand for medical care is transformed from treatment alone to both treatment and care. Remote medical care is the future. Studies have proposed setting an additional mediation server between a remote monitoring device and home care equipment. Additionally, preventing a remote network device from unauthorized access enhances the safety of a home system, and the mediation server implements roaming authentication and information feedback to the system regarding a roaming patient, such that a user can use healthcare functions by means of other network nodes under a roaming status [2]. Many studies proposed an improved safety management mechanism based on the concept of bilinear pairing on an elliptic curve, applied to remote access of medical information, guaranteeing privacy and management of access control authority, and limiting the access control mechanism of a user in real time to enhance the security of remote medical information, and providing effective and safe remote access [3]. The literature proposed using an RFID bracelet for identification [4].

Remote medical care is not only suited to the elderly and chronically ill. A recent study recommends that artificial joint replacements should be tracked for at least 10 years to determine whether they were successful, and proposed a case management database for tracking management before and after an operation to provide patients with complete and continuous care [5]. Farshchi et al. used an analog signal measurement module, wireless transmission module, and microprocessor module to complete a remote medical system [6]. The analog measurement module measures ECG signals, the transmitter module modulates and transfers the signal, and the receiver module demodulates the original ECG signal. The microprocessor module then digitizes and transfers the signal to a local computer site, and it is then transferred to a remote computer *via* the TCP/IP communication protocol, such that medical care personnel can be aware of a patient's condition. Patients are therefore free from space constraints, and the inconvenience of examining patients electrocardiographically is reduced. In [7], the WSN was based on ZigBee communication protocol as the wireless transmission platform for a remote medical care system. The signal is sent *via* individual Reduced Function Device (RFD) nodes of the ZigBee protocol to the Full Function Device (FFD) modem; the RS-232 is connected to the C-composed Serial Forward and the Personal Home Page (PHP)-composed Socket Server programs on a PC, such that doctors can view these data on the Internet, and use video meeting technology to implement the remote medical care system.

In comparison to passive remote medical care, active health control is better at disease prevention. A recent study proposed an electronic healthcare system that extends mobile medical care services for personal health control [8]. The RFID ring-type device that measures physiological signals can be worn on a finger, and is therefore highly mobile (applicable to runners). It measures both pulse and temperature. The RF transfers the signal to a portable RFID Reader, and the RS232/Bluetooth converter transfers the information to a smart phone *via* Bluetooth. The Global Positioning System (GPS) built into a smart phone measures GPS coordinates of that mobile phone. The physiological information and position coordinates are then transmitted *via* wireless mobile communication (*e.g.*, GSM/GPRS/3G/Wi-Fi) to the backend health center computer host for integration with Google Map. Thus, the system can measure pulse and temperature, and track a person being measured to provide medical services. Additionally, this system provides GSM and SMS short message function on a smart phone, such that users can send their GPS coordinates to relatives and friends. A user or family can then view the measurement data on a website. The personal pulse record is provided rapidly by the management system. Reminders and encouragement are given to help users maintain a healthy body.

According to multiple studies, the key points in remote medical care are patient privacy, data security, and the use of multi-communication network integration technology. Although with remote medical care users are not subject to space constraints, excessive convenience reduces the security and privacy of data. A good remote medical system should have sufficient security. A massive system does not always use only one type of communication. According to studies, most remote healthcare systems use a wireless sensor network, the Internet and a mobile communication network. Different communication networks have different functions for, say, data acquisition, data transmission, and message alerts. Therefore, this study focuses on ensuring the privacy of data by use of multi-communication network integration technology. The final aim is to develop a remote healthcare system that is secure and reliable.

3. System-related technologies

Relevant technologies support the remote healthcare system, including a communication system, physiological signal processing system, cloud system, and PSO scheme.

3.1. Communication system

Wireless sensor network technology is extensively used in consumer electronics, hospitals, houses, factories, agricultural autocontrol, and monitoring. Taiwan is currently confronted with an aging population, and wireless sensor network technology is very promising in terms of medical care.

In 2012, scholars proposed using ZigBee technology to develop a noninvasive wearable physiological parameter monitoring device that users who recently left a hospital could use for self-monitoring at home, thereby reducing the consumption of medical resources [9]. In 2011, scholars proposed combining ZigBee with GPRS to transfer data to a medical center for further analysis [10]. Researchers then proposed a mesh topology constructed using ZigBee wireless sensor network technology, and implementing patient positioning and emergency call services at a hospital, such that medical personnel could identify the location of patients [11]. ZigBee is an emerging short-range wireless network communication technology. When interference from an external environment is minor, it is considered applicable among current and emerging wireless transmission technologies for medical treatment.

ZigBee technology uses IEEE 802.15.4 as its standard; it also defines the Physical (PHY) Layer and Media Access Control (MAC) Layer, and the structure of Network (NWK), the Security Layer, data link layer, and Application (APL) according to the standard by the ZigBee Alliance. The APL contains the Application Support Sub-layer (APS), ZigBee-driven object layer (ZDO) and ZigBee communication stack [12,13]. The ZigBee network architecture is classified according to two patterns: the Full-Function Device (FFD); and the Reduced-Function Device (RFD). The FFD has a routing function; it can be applied to a star, tree, or mesh network topology, and provides data exchange. The RFD differs from the FFD as it lacks