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A Cloud-Based WBAN System for Health Management

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Abstract: *In this paper, a novel cloud-based WBAN health management system is introduced to. This system can be used for people's health information collection, record, storage and transmission, health status monitoring and assessment, health education, telemedicine, and remote health management. Therefore it can provide health management services on-demand timely, appropriately and without boundaries.*

Keywords: cloud; Wireless Body Area Network; IoT; health management system

I. INTRODUCTION

With the improvement of people's living standard, people pay more attention to their health. But the aging population has become a trend all over the world, old people easily suffer from diseases such as diabetes, hypertension and cardiovascular and cerebrovascular disease. In the meantime, young and middle-aged patients with chronic disease are growing because of the rapid pace of life, the huge working pressure and the unhealthy lifestyle. According to the report published in 2013 by Chinese center for disease control and prevention, there are about 330 million hypertensive patients and 100 million diabetic patients in China, which have become the number one killer to Chinese people. Health management issues are facing a tremendous challenge.
Nowadays, information and communication technology are gradually entering the health service field. The health management applications for a large population, based on the combination of wireless body area network (WBAN), broadband mobile communication and cloud computing, are made possible. To sharply reduce the costs of health and medical treatment, to change the uneven allocation of medical resources and to improve the health care, developing digital medical technology turns out to be an important method. There are a lot researches on wireless body area network technology, cloud computing technology, health assessment system, telemedicine and home-care model at home and abroad, which have put forward a number of innovative theories and applications.

In this paper, a novel health management system is introduced which integrates wireless body area network, cloud computing, the Internet of things and other advanced information technology. This system can be used for people's health information collection, record and transmission, health status monitoring and assessment, health education, telemedicine, and remote health management. Therefore it can provide health management services timely, appropriately and without boundaries. The remainder of this paper is organized as follows. Section 2 presents an overview of the different researches in this field. In Section 3, we give a brief introduction of the technologies that is related to the sensor-cloud system. Section 4 presents a detailed description of the health management system. The conclusion and future work are shown in Section 5.

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II. Related Work

Firstly, a number of the largest IT corporates, such as IBM and Microsoft, propose some schemes for the digital health management based on cloud computing. IBM with ActiveHealth Management has created a new cloud computing and "Collaborative Care Solution" to help the doctors and patients get the health information which they need from the cloud and to improve medical service quality and cut costs [1]. Microsoft introduces a health management application platform for the individual and family, which called "HealthVault" [2]. This system is mainly used to share patients' electronic medical record (EMR) with hospitals and doctors in order to increase efficiency. In addition, there are many institutions and researchers working on the digital health management system. Carlos Oberdan Rolim et al. [3] propose a solution to automate the process from data collection to information delivery by using "sensors" attached to existing medical equipment which inter-connected to exchange service. Their proposal is based on the concepts of cloud computing and wireless sensor networks. Then the information becomes available in the "cloud", from where it can be processed by expert systems and/or distributed to medical staff for analysis. Upkar Varshney [4] presents pervasive healthcare, wireless networking solutions and several important and interesting research problems about the health monitoring system. The pervasive healthcare applications include pervasive health monitoring, intelligent emergency management system, pervasive healthcare data access, and ubiquitous mobile telemedicine. The wireless networking solutions included use of wireless LANs, ad hoc wireless networks, cellular/GSM/3G infrastructure-oriented networks and satellite-based systems. However only some related concepts are proposed without real-life implementation. B.Eswara Reddy et al. [5] focus on the design of a Cloud framework for Health Monitoring System (CHMS). The system collects patients' health data which can be stored in a Cloud information repository. This facilitates the data analysis using services hosted in the Cloud. Sudhamony et al. [6] propose a system which provides telemedicine and tele-Health services for cancer-care delivery in India. These services are based on Oncology Network (ONCONET), which can be utilized not only by doctors but also other researchers, professionals, decision makers to reduce the miseries of cancer patients. Jones et al. [7] propose an architecture for mobile health services based on body area networks. It focuses on defining a generic mobile solution which can be adapted to different clinical applications. An adaptive communication middleware for monitoring heart-patients at home is being developed by the operating systems group at Hasso-Plattner-Institute which is involved in the telemedicine research project Fontane [8]. UbiMon [9] designs a platform for patients' monitoring, which implant sensors into patients' bodies to get vital data. This platform uses nodes to carry out the acquisition, processing, and storage tasks. Hiroshi Nakajima et al. [10] establish a framework of Systems Health Care by employing the tools of Index, Criterion, and Causality. Cheng and Zhuang [11] implement a Bluetooth-enabled in-home patient monitoring system, making early detection of Alzheimer's disease easier. A medical practitioner is able to determine whether a target patient is developing Alzheimer's disease based on the movement pattern of the patient. A case study shows that this in-home patient monitoring system is feasible and practical in real-life application. Chen et al. [12] propose a novel e-healthcare management system based on the introduction of encoded rules which are dynamically stored in RFID tags, and explain how it can be employed to leverage the effectiveness of existing ones. Yang Xiao et al. [13] provide a comprehensive survey about wireless telemedicine including relevant wireless technologies, applications and research issues. A. Redondi et al. [14] design a module called LAURA which provides patient location, tracking and monitoring services in nursing institutes through a WSN. This system is composed of three functional blocks: a location and tracking engine; a personal monitoring module; a wireless communication infrastructure to deliver the information. A health monitoring and indoor localization system based in a shoe-mounted sensor module is presented by C. Mariotti et al. [15]. The shoe sole measures the body temperature which includes an NFC (Near Field Communication) technology. And this platform can be extended to other sensors applications in order to monitor the sport performances of the users. José-Fernán Martínez et al. [16] present some feasible e-health application scenarios based on a WSN: one is for firemen/women monitoring, and the other one for sports performance in an indoor scenario as a gymnasium. This system acquires the physiological data from a Bluetooth commercial device. And the system can be adapted to a wide variety of e-health applications with minimum changes and the user is able to interact using different devices.

Different from the above works, the health management system in this paper has completed integrating nearly all health applications into a whole system. Several latest technologies, especially the cloud computing and Internet of things technologies, have been applied to this system. It makes large-scale deployment and mass data storage and processing possible, not just a theoretical study or lab test in small scale.

III. Integrated Technology

This paper mainly involves three latest technologies which are integrated seamlessly in one single platform. These are WBAN to collect and transmit health data, a cloud service for data storage, processing, and distribution and IoT (Internet of Things) technology.

3.1 WBAN (Wireless Body Area Network). A WBAN consists of multiple sensor nodes, and each node can sample, process and communicate one or more vital signs (heart rate, blood pressure, oxygen saturation) or environmental parameters (location, temperature, light). Typically, these sensors are placed strategically on the human body as tiny patches or hidden in users' clothes allowing ubiquitous health information collecting and monitoring. By using WBAN, people can communicate with some portable electronic equipment (such as PAD, mobile phone) and synchronize the data employing Bluetooth technologies. Furthermore, WBAN can be a part of the whole communication network with other communication networks such as WIFI and mobile Internet. And then it can communicate with any terminal (such as PC, mobile phone, PAD) just on the network [17]. WBAN technology helps collect health data and deliver them to the "cloud".

3.2 Cloud. Cloud computing service refers to a variety of applications delivered as services from the datacenters. The advantage is that service providers enjoy greatly simplified software installation and maintenance and centralized control, and an end user can access the

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service "anytime, anywhere", can share data and collaborate with other more easily, and can keep their data stored safely in the infrastructure [18]. Specific to our health management system, after receiving people's health data, the cloud computing platform will store them, and update them when new data comes. The data can be accessed "anytime and anywhere" from the cloud by the owner and his/her authorized doctors or family members. At the same time, the health management system running on top of the cloud infrastructure facilitates the analysis of the personal electronic health record and identifies some high-risk person who might develop a number of specific diseases using a number of mathematical models. Finally the cloud health management system will send an alert to the doctors or health-care professionals for immediate actions based on the results of the data analysis [5].

3.3 IoT (Internet of Things). Sensors, motes, Wireless Sensor Networks, semantic middleware architecture, ontologies, etc. are part of the Internet of Things, have already become a very popular research topics. The number of applications based on the IoT has boomed in recent years. And these applications have some unique characteristics. They are autonomous in their data capture patterns, have event transferring capabilities and provide strong interoperability or network connectivity [16]. Due to these specific features (ubiquity, pervasiveness, miniaturization of components, etc.), it makes the health monitoring and management "timely" possible.

IV. Health Management System Based on Cloud

The overall health management system based on cloud computing and WBAN includes three different logic layers: hardware, software and service shown in figure 1.

Fig. 1. **Three different layers of health management platform**

4.1. Hardware layer

The hardware layer has multiple functionalities: terminal, channel and cloud.

The terminal includes a large number of sensors, such as blood pressure monitor, digital Oximeter, the digital ECG monitor and so on. It is used to collect people's daily health parameters. After collecting health information by these sensors, the information then can be transferred to some gateway such as intelligent mobile phone and computers through WIFI, Bluetooth or RFID. And the gateway can forward the data to the cloud computing data center via the Internet or 3G or the private network. Figure 2 describes the hardware layer of the health management system, which is a foundation for upper software layer.

Fig. 2. **The hardware layer of the health management system**

4.2. Software layer

The software layer has been implemented in two different Operating Systems: one is conventional desktop version based on Windows and another is mobility version based on Android.

4.2.1. Desktop version

The Cloud health management system includes six subsystems, which are electronic health records system, Health Information Collection System, health risk assessment system, health intervention system, health education system and telemedicine system shown in Figure 3. Moreover, an Internet of Things system for health is part of the overall platform with the sensors for information

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collection. The interfaces of the platform follow the technology and industry standards at home and abroad, and they can be interconnected.

Next, the functions and services supplied by this platform are introduced in detail.

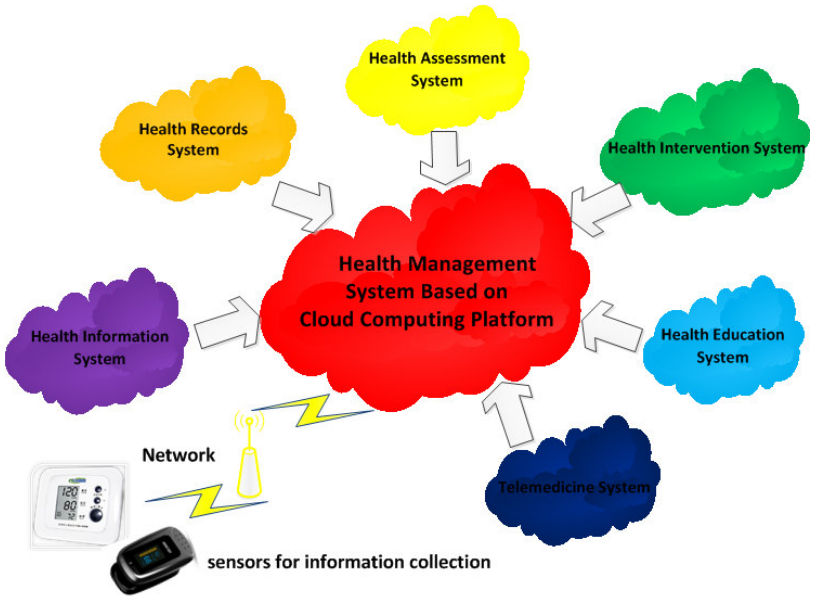

Fig. 3. **The architecture of software layer in the health management system**

A. Electronic Health Records System.

This system is a large-scale database designed and implemented based on the "Basic framework and data standard for electronic health record" authorized by the Chinese national health ministry. It contains the person's basic information, the person's diseases record and the abstract of his/her health problems, and the person's main health service records within his/her life cycle shown in Figures 4 and 5. In addition, the system can collect the real-time health data generated by the health information collection system which will be described in the next section. Therefore a person owns the comprehensive and centralized electronic health record which can help doctors, health professionals and his/herself analyze the current health status and estimate the probability of conducting some diseases in the next few years.

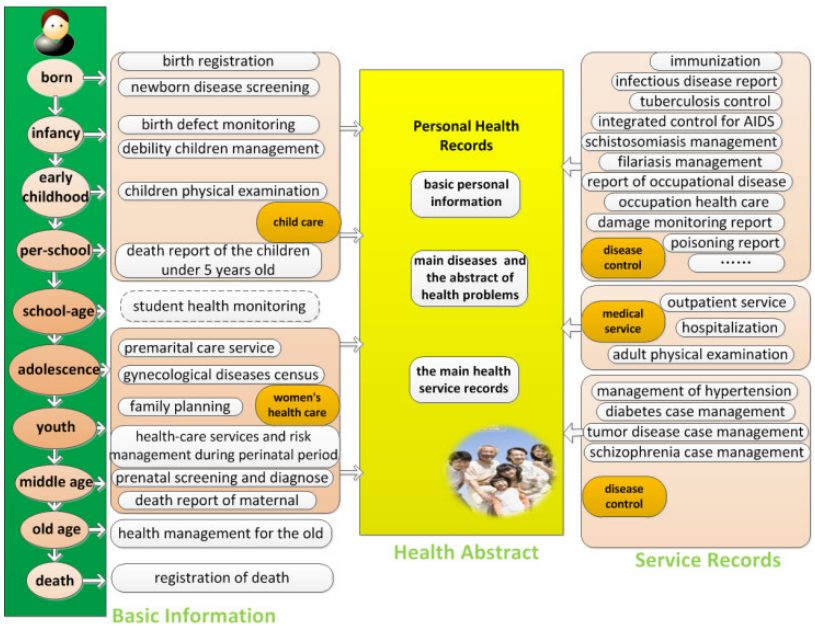

Fig. 4. **The basic framework for personal electronic health record**

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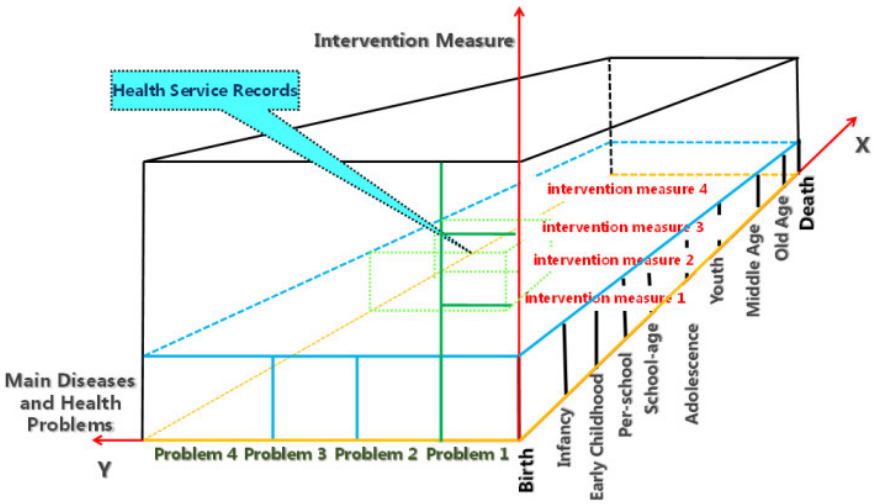

Fig. 5. **The architecture of the personal electronic health record**

B. Health Information Collection System.

This system is designed specially to collect person's health information, such as blood pressure, blood sugar, electrocardio, blood oxygen and body fat testing device using a variety of Wireless-enabled sensors (Figure 6).

Fig. 6. **Some sensors used for health information collection**

C. Health Risk Assessment System.

This is the most important part of the health management. This system can be used to analyze the data of a person's own electronic health record system, specify the personal health risk factors and predict the probability of developing some chronic diseases in the next few years using some disease-specific mathematical models. In addition to the conventional Health Risk Assessment methods [19], these models take a number of health risk factors stored in the personal health record into account. They are tested by using more than 20,000 real-life case studies which have been shown more than 90% accuracy, and have passed the examination of Chinese Health Management Association. This health assessment system can find the high-risk individuals who will be possibly developing some chronic diseases in the near future, however have not appeared any clinical signs. If the person is willing to change behavior in order to improve health, then it can avoid or delay the occurrence of chronic diseases by taking some interventions described in the next section. This prediction model for health risk assessment includes following chronic diseases: coronary disease, diabetes mellitus, stroke, chronic obstructive pulmonary disease, prostate cancer, hypertension and obesity, etc.

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D. Health Intervention and Promotion System.

This system is divided into two parts, one is nutrition catering system, and the other is exercise prescription system.

Nutrition Catering System is designed to improve personal health by providing nutritious diets. In this system, there are nearly all ingredients, kinds of recipes, detailed composition table of foods, and different meals for different physiological states and different diseases. Five functions have been built in this system shown in Figure 7.

Fig. 7. **Five functions in nutrition catering system**

Exercise Prescription System is designed to improve personal health by formulating personalized exercise programs according to his/her own age, sex and health status. The exercise program includes exercise type, exercise event, amount of exercise, exercise time, notes and so on. Besides, it can evaluate people's exercise effect in one period so that people can make some adjustments based on the results shown in Figure 8.

Fig. 8. **Exercise prescription system**

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E. Health Education System.

Terminal devices, such as TV, mobiles, ipad and computers, can be linked to the health management system via Cable TV, mobile Internet and Internet which can offer comprehensive health education video records, health knowledge and health guidance shown in Figure 9. By using this system, people can gain more professional and accurate health knowledge suitable for them.

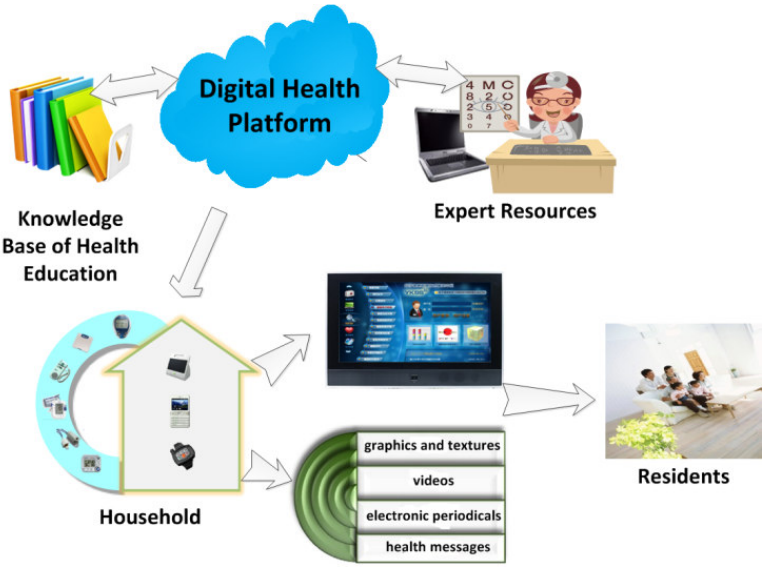

Fig. 9. **The highlight of health education system**

F. Telemedicine System.

The telemedicine system described in Figure 10 has following features.

- ☐remote consultation of doctors based on the Internet
- ☐online clinical interactive consultation
- ☐distance learning for special health management courses
- ☐online data transmission supporting document scanning, transfer CT image, PPT and Word document, etc.
- ☐teleconference for doctors and patients, both parties can be on the same page based on the patient's personal health record

Fig. 10. **The real-life scenario of telemedicine**

4.2.2. Mobility version

The mobile health management system can be treated as a simplified personal health management running on the intelligent mobile phone using Android specifically designed for managing chronic diseases like diabetes mellitus and cardiovascular disease, etc. Some functional modules have been built into these mobile phones including risk assessment module, health care and health management

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module and daily life management module. The healthy mobile phone can not only achieve health data acquisition from a variety of wireless-enabled sensors and forward them to the cloud computing platform for storage, but also can monitor people's health information in real time and can make warnings even automatically when an anomaly occurs. In addition, a number of functions have been integrated into the system such as personal health status monitoring, communication, GPS positioning, emergency call and entertainment together. Seven health apps are installed in the mobile phone shown in Figure 11.

Health toolbox includes six functions, can realize health self-test, hospital and doctor inquiry, nutritious diet and high risk assessment to some diseases.

Early warning is applied to remind people when to take medicine, take the blood pressure measure, have an exercise and have a break, etc.

On-click call helps people click only one pre-defined button on the screen to send "SOS" message to the five pre-scheduled contacts and share his/her current geographic location in emergency condition.

Health monitoring will help people know the current status of his/her own health status, the data are stored in the mobile phone and are periodically downloaded and updated from the health management cloud computing platform.

Health adviser will offer professional and accurate health management related consultancy using the knowledge of nutriology, kinematics, medical science, psychology, and so on.

Location-tracking can show his/her geographic location by using WIFI or GPS. Moreover, the family members or nurse can set an electronic fence for vulnerable people such as patients, disables and the old, as long as he/she is going out of the range, they will be alerted and the location of vulnerable people will be shown in their mobile phone.

One-click registration provides a faster, easier and more convenient way to fill in one's own information for system registration.

Fig. 11. **Seven health management mobile apps**

4.3. Service layer

A comprehensive service layer has been established in the health management system, which will be packaged as a service product in the future. Starting from collecting basic health data and establishing the person health record, the system will then be used for health risk assessment and a health risk report will be produced. Based on this, the system will formulate a health management scheme according to the people's health status including daily/weekly/monthly meal and exercise plan. And both the person and health professionals can use this system guide the behavior change in order to reduce the probability of developing some kind of chronic diseases. Telemedicine service facilitates the consultation of doctors to overcome the distance limit and save a lot of time and expense for travelling. As in Figure 12, health managers/ professionals and doctors play a very important role by providing the comprehensive health management service aiming to monitor people's health status, response to people's health inquiry and to provide health guidance for high-risk behavior change. In the process, the system can make some appropriate adjustments according to his/her doings. Naturally, it can be used for self health management as well.

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Fig. 12. **The procedure for health management service layer**

V. Conclusions

In this paper, we design and implement a comprehensive health management system integrating WBAN technology, cloud computing technology, the technology of the Internet of things and other advanced information technology together. As far as we know, this is a first innovative system integrating a number of functionalities including personal health information collection, record, storage and transmission, health status real-time monitoring, personal health assessment, health education, telemedicine and remote health management. In this way, this system can provide health management services on-demand, timely, appropriately and without geographical boundaries, which can benefit to the health care industry and individuals.

As future works, we intend to focus on the development of securing health information database and building a single-sign-on access control mechanism using finger-print technology to avoid data breaches, tampering and loss. At that time, the system could be deployed in the practical scenario for performance testing.

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