Wireless eHealth (WeHealth) --- From Concept to Practice

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Abstract—**Recently, the R&D and applications of M2M systems are booming in China, especially after it is written in the 2010 Government Work Report. In this paper, the R&D works of wireless eHealth (WeHealth) are overviewed, the concept of which was proposed by our group in 2005. Some key techniques of WeHealth system are discussed, and some practices based on the concept of WeHealth are introduced. Besides, a recent WeHealth pilot trial on chronic disease monitoring is also introduced, which is reported as "The First Wireless Healthcare Chronic Disease Monitoring Project in China Based on Internet of Things Technology". There are 30 community hospitals up to now applying our WeHealth blood pressure monitoring system for chronic disease management. The practical data clearly demonstrate the effectiveness of our WeHealth system in hypertension disease control.**

Keywords- M2M; healthcare; chronic disease; wireless

I. INTRODUCTION

Recently, there is growing interest worldwide in the R&D of M2M techniques and systems. While in China, there is booming interest in these topics, since it is already supported by the government. In the Chinese Government Work Report 2010, "to accelerate the R&D and applications of Internet of Things" is clearly written. After the sentence, more and more research institutes and companies show great interest to the integration of communications techniques into various industries.

However, there is another voice existed, which shows some conservative attitude to M2M applications: "Will M2M applications come soon as the government and many people expected?" People with this attitude think some key techniques of M2M, are not so matured as anticipated.

In this paper, we will introduce our concept and R&D works of WeHealth (Wireless eHealth). The concept of WeHealth was first proposed in 2005, in the first workshop of eHealth in China, i.e., "Beijing 2005 eHealth Workshop". And in the following 7 years, we have dedicated to the R&D of WeHealth to make this concept come true.

The whole paper is organized as follows: in Section II, the concept of WeHealth is introduced; in Section III, some key technologies of WeHealth are discussed; in Section IV, some major applications of WeHealth system are depicted, and in Section V, a pilot trial of our WeHealth system for chronic disease monitoring and management is elaborated. The whole paper is concluded in the Section VI.

II. THE CONCEPT OF WEHEALTH

In recent years, there are growing interest and activities of introducing wireless technologies into healthcare industry. On one hand, the demand of improving the efficiency and diversity of healthcare services is increasing. On the other hand, the fast development of wireless technologies, especially wireless sensor and heterogeneous networking techniques, has given sensors various functionalities [1-2], which allow sensors to be the end node in ubiquitous computing environment and which allow the sensors to link to the Internet Network everywhere seamlessly. WeHealth enables the wireless professional real-time patient monitoring and therapy support as well as private user access to monitoring, medical assistance and individual care services in future pervasive/ubiquitous computing environments.

Fig. 1 shows the infrastructure of our proposed WeHealth. The various matured wireless access techniques and networks can be applied to provide advanced and convenient healthcare services. In the home environment, the physical sensors (such as blood pressure sensor, heart rate sensor, etc.) or nonphysical sensors (such as the action detection sensor) are attached on the human body to collect the parameters of the patient-in-care.

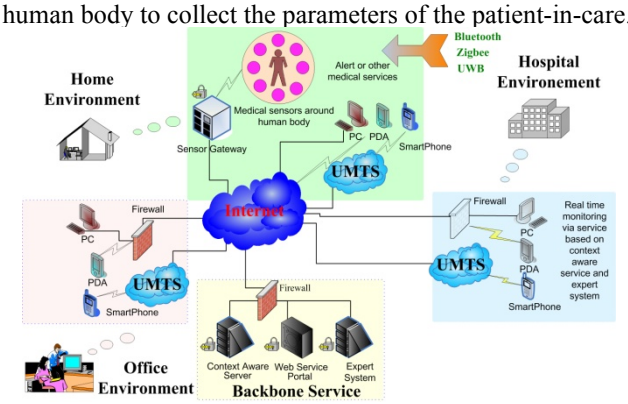

Figure 1. Infrastructure of WeHealth

The collected data are transmitted through short range wireless (Bluetooth, Zigbee or UWB) transmitter to the home gateway, which might be embedded into home ADSL, PC, mobile phone, PDA, etc. Through home gateway, the patient's daily data are sent to the hospital to implement the real-time monitoring and expert instruction to the patient. A variety of healthcare services can be developed through the platform of the home

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environment. A typical service is the monitoring of the chronic diseases (diabetes, heart diseases, etc.).

III. KEY TECHNOLOGIES OF WEHEALTH

We believe that for a successful application of M2M system, to investigate some cutting-edge technologies which could solve some special problems in the particular application is necessary. Here we would like to introduce one of the key technologies that we had investigated, i.e., the innovative frame structure design in order to guarantee the emergency access in the case of some alarm happens in healthcare monitoring.

Our innovation is initiated from IEEE 802.15.4 protocol. In IEEE 802.15.4, all nodes must use carrier-sense multiple access/collision avoidance (CSMA/CA) algorithm to obtain channel and transmit a periodic packets including alarming packets. However, there are still latency caused by contentions between nodes having emergent packets and normal packets to grab the channel.

Therefore, we propose a new Alarm Access (AAC) scheme to make use of the wasted bandwidth in contention free period (CFP) for emergency access in order to reduce transmission latency of alarming packets [3]. In the AAC superframe structure, a Listening Window with a length of T_A is inserted into time-slot called as Slot-A in the CFP as showed in Fig. 2. The beacon frame shall specify Slot-A allocation in the CFP based on both the traffic rate of the nodes and the assigned guaranteed time slots (GTSs) by PAN coordinator. The Listening Window begins at time T_F in each Slot-A. Once entering the Listening Window, the node called as data transfer node that owns this Slot-A enters inactive mode. But the coordinator should listen to alarming access frame from the other nodes. If one node in emergency conditions is to initialize an alarming access, it must start before the end of the Listening Window.

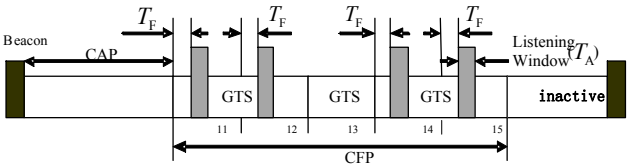

Figure 2. The Proposed Alarm Access (AAC) Superframe Structure

Fig. 3 shows alarming access process in the Slot-A. Data transfer node transmits the first data frame with a length of not more than T_F at the beginning of this Slot-A. Then it enters inactive mode in the Listening Window. Coordinator starts listening to the alarming access frame from the other nodes at the beginning of the Listening Window. When no other nodes initial alarming access as shown in Fig (a), Data transfer node can receive ACK frame from the coordinator at time τ_{ack} after the end of the Listening Window. It continues to transmit the remaining data to the coordinator in this Slot-A.

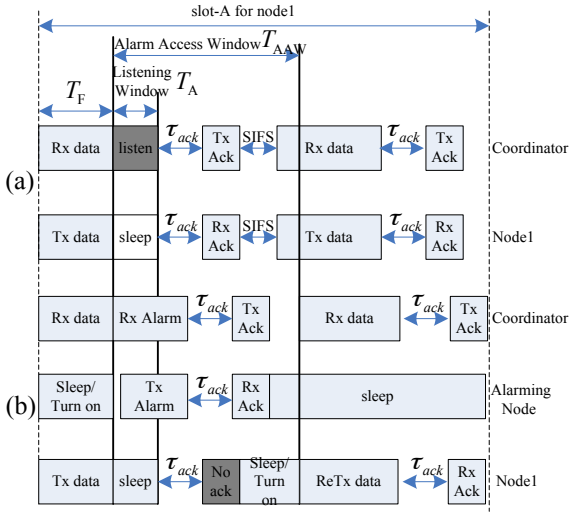

Figure 3. An Example of Emergency Data Transmission in Slot-A

If other one node wants to initiate its alarming access after the end of the CAP in the superframe as shown in Fig (b), it should select a latest time Slot-A in the CFP to start to send an alarming data frame in the Listening Window. The coordinator that detects the alarming frame in the Listening Window cancels the packet from the data transfer node and starts to process the alarming packet from the alarming node. In that case, the data transfer node and the coordinator shall wait for the end of the Alarm Access Window with a length of T_{AAW} and then restart to transmit and receive periodic traffic from data transfer node.

Of course, when considering the whole services of wireless applications in healthcare, there are some other key technologies such as context awareness [4], data security and privacy [5], etc. For limitation of space, these technologies will not be elaborated in this paper.

IV. SOME MAJOR APPLICATIONS OF WEHEALTH

Based on the infrastructure of WeHealth, we have investigated several M2M applications during the past several years.

Our major application of WeHealth is the chronic disease management, which is sometimes called “homecare”. More services can now be delivered in the patient’s home, but professional supervision and monitoring are still required, rural and less served urban patients also face travel and access problems. The application of WeHealth homecare strengthens the applications of short range and low power wearable/portable wireless sensor networks to monitor the physical parameters of the patient, e.g. blood pressure, body temperature and/or ECG on a relatively long-term basis for the aging people with chronic diseases, such as asthma, cardiovascular, and diabetes. Zigbee or some other communication techniques can be chosen as the technique for transmitting the patient’s physical data to the remote monitoring center in hospital. WeHealth system should be “self-closed”, and “smart” to some extent. Therefore, the system should not only strengthen the gathering of data from

various sensors, but also smart signal processing and analysis by some expert system.

Fig. 4 illustrates a chronic disease monitoring application of WeHealth, taking hypertension management as an example.

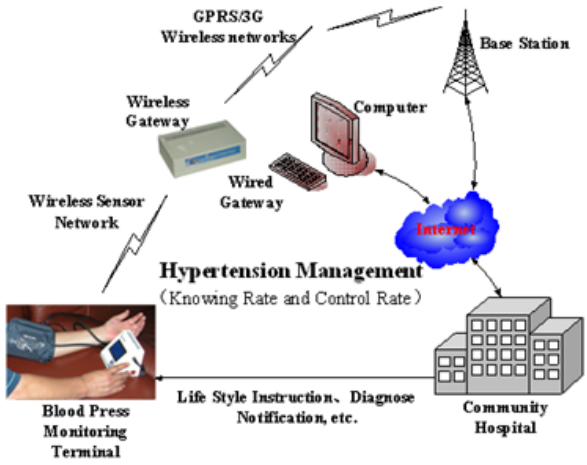

Figure 4. One Application Case of WeHealth for Hypertension Management

The daily health monitoring can be carried out at the community by the person himself, while the professional diagnosis should be provided by the hospital or through the expert system. The patient's data come from sensors or automation carried by person or set on certain place at home, e.g., embedded in bed, chair, and shoes. Wireless sensors collect the people's vital signs, and then relay to family sink/gateway. The whole system is used for hypertension management to increase the knowing rate and control rate of hypertension disease (which will be introduced in Section V).

Another key application of WeHealth is the remote rescue in disasters. The requirement of applying more wireless technologies into disaster rescue becomes impending after the tremendous earthquake happened in Wenchuan, Sichuan Province of China in May 2009. Due to the destroy of the communication infrastructure and roads, the first-time circumstance in the earthquake field could not be transmitted outside.

To meet the requirements and to provide more or better solutions to disaster rescue in future, we propose another WeHealth application as wireless remote medical emergency rescue in disasters. Medical wireless sensor network (such as with Zigbee protocol) is proposed to collect the vital life parameters of the injured people in disaster. Different nodes of wireless sensor network attached on the body of injured people are networking together. There is at least one node connected with a gateway, the multi-mode gateway guarantees that at least one network (such as satellite) is connected and the physical data of the injured people can be transmitted to the remote healthcare center to support the first-aid medical assistant. In the field of wireless sensor network, there is a mobile monitoring center to monitor the life status of the injured people in the disaster field.

V. PILOT TRIAL OF WEHEALTH

With the major applications of WeHealth, we have initiated some pilot trials. The first pilot trial is with the WeHealth system for hypertension management, which was started since April 15, 2010 in Beijing and still in continuing. The pilot trial is organized by the Haidian Healthcare Bureau currently, and in total 30 community hospitals are involved. Among the 30 hospitals, 15 are university hospitals. In total more than 5,000 users are assigned our WeHealth terminals now. This pilot trial is reported as the "The First Wireless Healthcare Chronic Disease Monitoring Project in China Based on Internet of Things Technology" [6].

A. *Benefits of WeHealth System*

After deploying our WeHealth terminals and the related hypertension management system (in abbreviation WeHealth system in the following) for several months, we receive very active feedback from the patients, the hospitals and the health-care bureau. For the hypertension patients, they can self-measure blood pressure at home and receive the feedback from hospital about the blood pressure evaluation result and healthcare suggestion immediately. For doctors, they can manage hundreds or thousands of chronic disease patients at the same time, which save a lot of time and energy for them in the disease management. For the healthcare bureaus, currently the number of patients with hypertension disease exceeds 200 million in China, how to effectively control the disease is an unbelievable arduous task. While WeHealth system makes it possible to grasp the real everyday blood pressure data of each patient, which gives a way for future data analysis and statistics, and gives the fundamental reference for future policy making. It can be predicted that, future community hospital in China will have not only the 'scattered' health information of the patient through in-hospital diagnosing, body-checking, etc., but also the 'continuous' health information through WeHealth system or some other similar M2M systems.

B. *Effect of WeHealth System*

After a period of time of deploying our WeHealth system, we overview the blood pressure data in the database transmitted every day by the patients. It is a delighted thing for us to see some hypertension patient's blood pressure is changing as a tendency. The blood pressure (BP) of the patient is collected everyday through WeHealth system. In our software, we record of each patient's value for each measurement. Meanwhile, we mark a different color to each value. Different colors mean different blood pressure status. Therefore, we can see changes of the disease by changes in color.

Although this gives us a very intuitionistic feeling that WeHealth system is effective probably, a more scientific evaluation should be carried out based on some statistic method. We will introduce our statistic method in the following.

According to the 2009 Hypertension Prevention and Treatment Guide of China [7], the evaluation on the effect of hypertension prevention and treatment is based on three guidelines, i.e., the knowing rate, the treatment rate and the control rate, in abbreviation, 'three rates'. Knowing rate is defined as the percentage of people who know themselves they

are hypertension patients. Treatment rate is defined as the percentage of patients who are taking hypertension medicine in recent two weeks over all the hypertension patients in the community. Control rate is defined as the percentage of patients whose blood pressure is already controlled (through taking medicine or some other treatment method) below 140/90mmHg over all the hypertension patients.

Among the three rates, the control rate seems to be the only guideline which is suitable for the effect evaluation for systems such as WeHealth. Therefore, we use this rate to make the effect evaluation for our WeHealth system. The earliest pilot trial of our WeHealth blood pressure monitoring system was in April, 2010. The users who have the blood pressure record of more than one month are selected to do the evaluation.

Given the total number of patients who are under the hypertension management $N_{\_total}$, the total number of patients among $N_{\_total}$ whose blood pressure are satisfactorily controlled (below 140/90mmHg) $N_{\_control}$, the hypertension control rate $R_{\_control}$ is calculated as [7]:

$$R_{\_control} = N_{\_control} / N_{\_total} * 100\% \quad (1)$$

For the term of 'satisfactorily controlled' below 140/90 mmHg, there are two kinds of definition, one is time-point satisfactory, the other is time-period satisfactory. Since with WeHeath system, we have the blood pressure data of at least two times per day, we prefer to use the time-period satisfactory evaluation. Therefore, the statistic method to evaluate the effect of WeHealth is given below:

1) to take the time-period satisfactory calculation method, and to use the blood pressure data of one week for the calculation;

2) if more than 70% of the blood pressure values of a patient are below 140/90 mmHg within one week, then the blood pressure of that patient is evaluated as satisfactorily controlled [7];

3) to calculate the blood pressure control status as 2) for each patient at the beginning one week of using WeHealth system and the one week of one month later of using WeHealth system;

4) to calculate the blood pressure control rates as Formula (1) for all WeHealth users for the beginning one week and the one week of one month later, respectively, and to make the comparison.

Based on the relatively long term (at least one month) monitoring data of patients using our WeHealth system, we have calculated and compared $R_{\_control}$ according to above evaluation method. For those patients who adhered to use WeHealth system for more than one month and self-measured the blood pressure at least twice everyday according to the doctor's suggestion, the result is: $R_{\_control}$ at the beginning one week: 22.2%, $R_{\_control}$ at the one week of one month later: 38.9%.

It is observed that using WeHealth system, the hypertension control rate is increased 16.7%, which clearly shows the effect of using our WeHealth system.

VI. CONCLUSION

In this paper, the R&D works in recent five years for the self-proposed concept WeHealth are introduced. We hope to answer the question "Can wireless communications be widely applied to healthcare industry". Based on the infrastructure of WeHealth, our research work focuses on some applications outside hospitals, such as at home for chronic disease monitoring/ management and at disaster field for first-aid rescue. Although through our solid research and development work, WeHealth system has clearly demonstrated its advantages, for example in the chronic disease management pilot trial, there is still a long way to go for a successful business deployment, since the industry chain of M2M is much longer than traditional industries such as communications or healthcare industries.

ACKNOWLEDGMENT

As the summary of our R&D work, there should be a long list of acknowledgement**.** First of all, we would like to thank our students. Without their R&D work, WeHealth might probably still rest on the concept stage. Second, we would like to appreciate our hospital, industry and other partners. They provide the fundamental requirements to us, which make our WeHealth investigation more and more clear and concrete. Besides, our special appreciation is given to Haidian Healthcare Bureau of Beijing. They give us strong support for the pilot trial of our WeHelath system.

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REFERENCES

[1] J. Yao, R. Schmitz, and S. Warren, "A wearable point-of-care system for home use that incorporates plug-and-play and wireless standards", IEEE Transactions on Information Technology in Biomedicine,pp363-371, Volume: 9, Issue: 3,Sept. 2005.

[2] Smalls J., Yue Wang, Xi Li, "Health monitoring systems for massive emergency situations", Systems, Applications and Technology Conference, 2009. LISAT '09. IEEE Long Island 1-1 May 2009 Page(s):1 – 11.

[3] Yanyan Guo, Guixia Kang, Yu Cao, Ping Zhang, "Emergency Access Mechanism in IEEE 802.15.4 for Wireless Body Area Sensor Networks", Chinese University Journal of Posts and Telecommunications, Vol.6, p24-31, Dec. 2009.

[4] Copetti, A., O. Loques, et al.. "Intelligent context-aware monitoring of hypertensive patients." 3rd International Conference on Pervasive Health., 2009.

[5] Ming Li, Wenjing Lou and Kui Ren, "Data security and privacy in wireless body area networks, " IEEE Wireless Communications, Feb. 2010, pp.51-58.

[6] http://www.bjhb.gov.cn/news.do?dispatch=readById&id=31502

[7] Lisheng Liu, Wen Wang, Conghua Yao, "2009 Hypertension Prevention and Treatment Guide of China", Chinese Journal of Hypertension, pp. 11-30, Jan. 2010.