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IEEE802.15.6 NB Portable BAN Clinic and M2M International Standardization

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Abstract - **The increase of non communicable diseases (NCDs) will change the direction of health services to emphasize the role of preventive medicine in healthcare services. The first short-range medical body are network (BAN) standard IEEE802.15.6 is expected to be used for secure and user-friendly sensor devices for portable medical equipment. A BAN is an enabler for uploading medical data to a backend system for remote diagnoses and treatment. Machine-to-Machine (M2M) infrastructure is also a key technology for providing flexible and affordable services extending electronic health record (EHR) systems. This paper proposes a BAN-based portable clinic that collects health-check data from user-friendly medical devices and sensors and sends the data to a local backend server, and it evaluates the clinic in fields of actual usage. We discuss issues experienced from actual deployment of the system and focus on integrating it into upcoming healthcare M2M infrastructure to achieve affordable and dependable clinic services. We explain the components and workflow of the clinic and the system model. The system is set up at a temporary health center and has a network link to a remote medical help center. The paper concludes with our plan to introduce our system to contribute to internationally standardized preventive medicine.**

I. INTRODUCTION

The increase of noncommunicable diseases (NCDs) such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes in developing countries will change the direction of health services to emphasize the role of preventive medicine. By the year 2020, noncommunicable diseases will reportedly come to account for seven of every 10 deaths in developing regions [1]. Preventive medicine can reduce the costs of the social medical/healthcare system not only in developed but also in developing countries.

Electronic health record (EHR) systems, which make patients' medical records a meaningful component of care services, increase the efficiency of treatment at medical facilities. The systems, however, lack user-friendly features for retrieving health-related data, such being available everywhere and being adaptable to any local infrastructure. Portable medical/health-check devices and the system are expected to function as a close-to-user system. At the same time, they need to successively follow international and open standards to make the devices affordable.

The first short-range medical body area network (BAN standard IEEE802.15.6 [2]) was published in 2012. A BAN using narrow band (NB) technology is an enabler to upload medical data on a person who receives medical examinations to a backend system for remote diagnosis and treatment. Expectations are that it will be used for user-friendly and secure communication among portable medical equipment and the data collector.

Machine-to-Machine (M2M) technologies are also key components for providing flexible services, such as smart-house living for elderly people, by integrating EHR systems. The international standardization work for healthcare M2M service (FG M2M) began under the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) [3] in 2012 and the pace of this work on e-health standards and interoperability is being accelerated by collaboration with the World Health Organization (WHO) [4].

This paper explains a BAN-based portable clinic that collects health-check data from medical devices and sensors closest to the examinees and sends the data to a local backend server. We explain deployed components and the workflow of the clinic and the system model. The system is set up at a temporary health center and has a network link to a remote medical help center. We evaluate the system and discuss issues to make it available anywhere. We then focus on integration into a healthcare M2M platform. The paper concludes with our plan to provide affordable preventive medicine and applicability to cases such as healthcare in disaster-stricken areas and elderly living alone.

II. PORTABLE BAN CLINIC AND IEEE802.15.6

The portable health clinic (PHC) was introduced to reduce deaths caused by easily curable diseases [5]. It was prototyped as a portable-clinic box equipped with major diagnostic tools integrating a simple equation to categorize patients into four groups depending on the level of action or attention required. It also provides immediate consultation via video conferencing system with a remote physician at a remote healthcare call-center.

The first stage of the clinic uses a paper-based interview sheet for each examinee and copies measured data from the screen of medical devices to the sheet offline. The BAN-enabled clinic allows a coordinator to wirelessly and securely gather all measured data from medical devices and sensors. It removes mistakes in copying data and reduces time in copying. Once data are collected in the coordinator, they are sent to a backend local server for categorization and further remote diagnosis.

A. IEEE802.15.6 NB

The IEEE802.15.6 standard is a candidate for simultaneously collecting measured data from different types

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of medical devices/sensors to a data collector (hereafter a "coordinator"). The coordinator automatically configures devices securely as a component of a BAN and the health-check provider needs not manually manage the relationship between the coordinator and devices/sensors. The IEEE802.15.6 NB supports several narrow band frequencies: 400MHz, 900MHz, 2.36GHz (US only), and 2.4GHz to follow the spectrum regulations of each country. Our BAN-enabled portal clinic at first uses the 2.4GHz band because of its usability and in the near future will switch to medical 400MHz bands or other regulated bands with no modification to the application.

The communication between a sensor and the coordinator requires less power consumption in data transfer and maintains data ordering among sensors involved in a BAN for future analytical data use. Notably, less traffic from the coordinator to sensors, such as timing beacons, is foreseen for reducing the burden of receive-wait states for a small sensor. We have implemented a BAN requiring less traffic from the coordinator to sensors in the sensor radio frequency (RF) module and allowing plug-in of sensors, such as an SpO2, at the setup or a later time. A beaconless time synchronization mechanism is deployed and the mechanism with mutual authentication protects wireless communications from eavesdroppers and attacks [6]. The interface is defined on IEEE802.15.6 by the Quality-of-Life Sensing Network (QoL-SN) association [7].

Other short-range wireless communication, such as Bluetooth, is used for peer-to-peer services like hands-free voice communication and does not satisfy requirements for user-friendly and secure medical uses.

B. Portable BAN Clinic Components and Configuration

The portable BAN clinic consists of an attaché case equipped with measurement devices/sensors, its coordinator, a local backend server, and a remote database (Fig. 1). The devices/sensors are used to measure height, weight, waist and hip size, body temperature, pulse rate, oxygenation of blood, blood pressure, blood glucose, urinary protein, urinary glucose and urinary urobilinogen. Blood tests and urinalysis are managed by paramedics in a healthcare center team to maintain the operation and measurement quality.

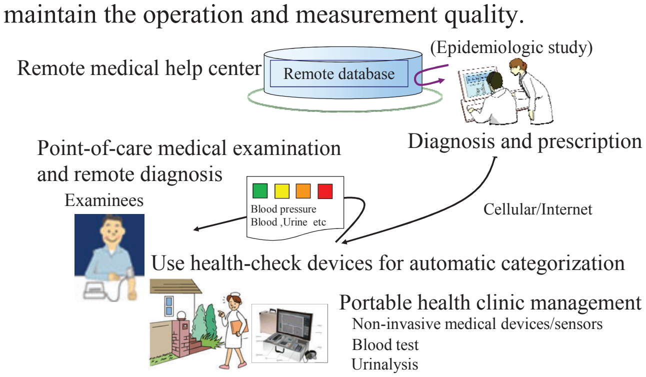

Fig. 1. Portable BAN clinic model

Fig.2 shows the typical clinic workflow. The clinic is comprised not only of equipment but also a well-trained health center team. This team is important for maintaining the quality of measured data for remote diagnoses and managing the system under unstable power condition.

Each device/sensor is equipped with a BAN sensor with a unique ID, which it uses as part of the encryption seed and then establishes a secure communication with the coordinator [8]. The coordinator is a USB dongle to send/receive data to/from devices/sensors with an automatically assigned timeslot by time domain multiple access (TDMA) to maintain the quality of service in wireless communication. Some short-range wireless communication adopts carrier sense multiple access with collision avoidance (CSMA/CA) to compete wireless channel connection, such as a wireless LAN for high channel utilization, but in the area of medical/healthcare applications, some sensors, such as SpO2 and ECG, need to continuously send data to a coordinator with a pre-assigned timeslot for accurate data retrieval. We use a terminal running the Android operating system to plug in the USB dongle as a coordinator and to manage measured data checks and upload them to a remote database system for medical doctors to diagnose remote examinees (Fig. 3).

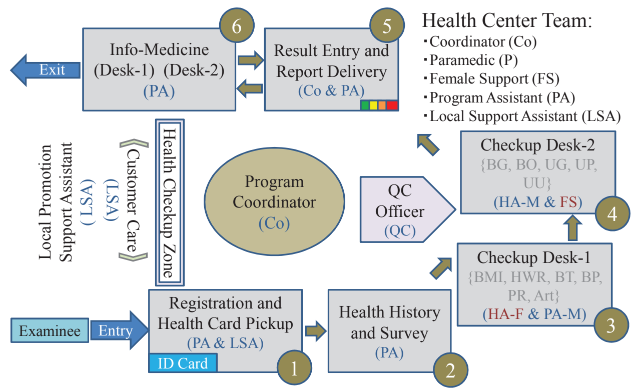

Fig. 2. Typical portable health clinic workflow

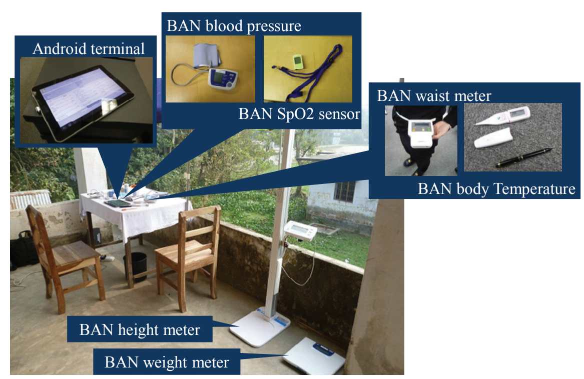

Fig. 3. BAN-enabled devices and Android terminal

	Green	Yellow	Orange	Red
・・・				
Blood Pressure (mmHg)	<140 mmHg <90 mmHg	140≦ <160 mmHg 90≦ <100 mmHg	160≦ <180 100≦ <110	180≦ 110≦
Blood Sugar	<100mg/dl	100≦ <126mg/dl	126≦ < 200mg/dl	≧200mg/dl
Postprandial Blood Sugar	<140mg/dl	140≦ <200mg/dl	200≦ < 300mg/dl	≧300mg/dl
Urine test				
Urine Protein	-	±	≧+	
Urine Sugar	-	±	≧+	
Urobilinogen	±		≧+	
・・・				
SpO2	≧96%	93≦ <96%	90≦ <93%	<90%

Red: Emergent -***Telemedicine*** + Encouragement to visit clinic
Orange: Affected -***Telemedicine***
Yellow: Caution -***Provide a leaflet*** about healthcare in Bengal
Green: Normal

Designed by Naoki Nakashima, M.D., Kyushu University Hospital and Kunihisa Kobayashi, M.D., Fukuoka University Chikushi Hospital

Fig. 4. B-logic

Data are sent from the Android terminal to a local server, in which a paramedic examines the measurement result with an automatic health-check result based on B-logic, which is a triage-like stratification process to determine the priority of subjects' treatments based on the risk determined by the health check-up result (Fig.4). The color of each subject is automatically determined by an application using B-logic after input of all health checkup data without a doctor's assistance.

After the determination, a program assistant in the health center team prints out and explains the result and gives advice when the risk is gauged as yellow or green. If the risk is orange or red, the examinee goes to a remote medical diagnosis site in the clinic and consults with a medical doctor using an available remote communication tool, such as Skype, with satellite/cellular communications (Fig. 5).

Fig. 5. Remoter diagnosis scene

C. *Issues*

The portable BAN clinic gives rise to the following issues. These need resolving if we are to conduct health checks with a smaller health center team.

(1) Unstable power supply and batteries may not be charged
(2) Data transfer via cellular phone may not be available
(3) Limited space/location is available in setting up the clinic
(4) User-friendly interface for examiners not for engineers

Power supply is a problem when we use a portable BAN clinic in rural areas of developing countries. We use a wireless LAN to send data from an Android terminal to a local server. The server is comprised of note PCs and operable even in sudden power loss, but some components, such as a wireless LAN access point, are not battery-operable. Once power loss occurs, the system will not work because of a single-point failure. All components should be battery-operable and support offline operations. The system should work for about eight hours. Measurement devices also need to last eight hours. Small sensors, such as an SpO2 sensor and body temperature measuring device, are light weight and easy-to use, but they may not last long because of power consumption for the short-range wireless communication.

Recent Android terminals expect battery charge via a micro-USB connection and share the same interface with a short-range wireless communication device. We are unable to charge the terminal during health-check operations. Once a BAN is configured among all the devices and the coordinator, it is difficult to switch over to another coordinator keeping the BAN network configuration with measured data stored in the terminal. Assuming several Android terminals that will become the coordinator, a type of service handover feature is required between coordinators in BANs. The same is also expected for measurement devices. The IEEE802.15.6 specification has basic BAN identification features and a control format, but its actual operability has not been well investigated. We need to investigate this feature.

III. Healthcare M2M and Portable BAN Clinic

It is over a decade since the idea beyond humans was introduced to wirelessly connect to network. M2M international standardization is becoming actively discussed at the ITU-T and several industry-oriented organizations. The M2M focus group (FG) is focusing on requirements for healthcare M2M. The FG is the first group to look at healthcare applications using a BAN no broader than Internet of Things (IoT) applications.

The primary purpose of the portable BAN clinic is health checks and remote diagnoses. The examinee's data should be carefully managed under medical institutes, such as a hospital database, and maintained under established security functions and policies. The M2M framework is an emerging platform and issues in maintain the quality of personal medical-/health- related data received from a BAN are still not well investigated.

There are issues to be considered regarding healthcare M2M applications using BAN technologies. One is the standardization of the data format for handing BAN data. There is an international standard handling medical data used in medical institutes, such as a hospital, under sufficient power supply, but it is difficult to deal with sensor data in a BAN environment. Another issue is the quality of data measured by a sensor in a BAN. M2M services expect a large number of devices and use appropriate networks, such as one by a mobile virtual network operator (MVNO) and a sensor device not provided by a medical institute. The measured data go up to a M2M platform with no measured environmental information. The following section addresses these issues.

A. *BAN requirements beyond ISO/IEEE 11073 standards*

The ISO/IEEE Standard 11073 defines an object-oriented information model and is a good candidate for abstract data format and industry-driven protocols for health device communication, which are proliferating in hospitals. Legacy medical devices have sufficient power supply and can follow the standard even in a wireless environment. The ISO/IEEE 11703-20601:2010 defines a common framework for making an abstract model of personal health data available in transport-independent transfer syntax required to establish logical connections between systems and to provide presentation capabilities and services needed to perform communication tasks. The protocol is optimized to personal health usage requirements and leverages commonly used methods and tools wherever possible.

Short-range wireless sensors, on the other hand, do not utilize the standard for data exchange, but uses industry-driven standards, such as Bluetooth low-energy profiles, because of constraints in power supply for wireless sensors. We used the simplest type-length-value (TLV) format to reduce power consumption in wireless communication. Emerging and user-friendly medical/healthcare sensors require efficient data representation consistent with ISO/IEEE 11073 compatibility and an efficient format for healthcare M2M devices, such as small sensors, when plug in directly and wirelessly to an M2M infrastructure.

We suggest defining a reference model including the BAN data reference model for sensors and an interface to the M2M framework. The reference model consists of the healthcare M2M interface model, domain information model supporting legacy medical devices, and BAN data reference model.

The healthcare M2M interface model accommodates highly useful devices not only in hospitals but also mobile environments, and the BAN data reference model is expected to be compact and extendable to accommodate new sensors and should be transferable to a legacy data information model (Fig. 7). The BAN data reference supports the TLV format and deals with different types of BAN sensors that are expected to be small for short-range wireless transfer using a small rechargeable battery.

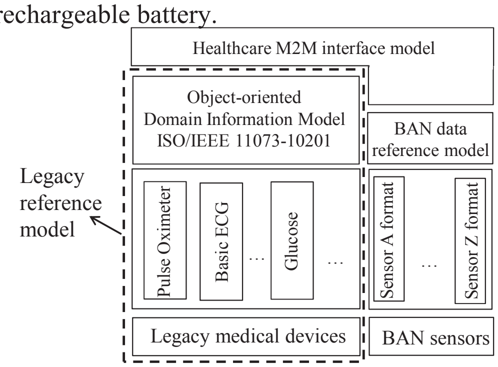

Fig. 7. BAN integration model in healthcare M2M

B. *BAN Data Identification in Healthcare M2M*

In a BAN configuration, measured data are basically not linked to personal information, since a medical device or sensor is shared by many people during health checks. The measured data are temporary linked to a local ID card or by another method, such as a barcode, and personal information is not stored in the device. Once a coordinator gathers the data, they are summarized as personal data following the secure requirements of a backend system. The coordinator has a role of compiling them as a record for the remote database. The quality of data measured by a sensor depends on the quality of the sensor and once it is uploaded without any information of the measured device, such as the manufacturer's name, it creates another risk for diagnoses by referencing the data, since accuracy of measured data depends on the quality of the device and it is difficult to know once the measured data are separated from the measured device. We require the sensed data with measurement information, such as a manufacturer number, to know the characteristics of the device. This is a requirement for healthcare M2M using BAN technologies.

IV. Evaluation

We have implemented a portable BAN clinic and partly introduced it in a primary healthcare (PHC) program. A healthcare center team had high praise for the portable clinic system using a BAN-enabled Android terminal. The PHC system without a BAN needs a special space for a PC and typing personnel since measurements must be input via a PC keyboard. The BAN-enabled terminal, however, enables paramedics to enter the result on site because most of the results are automatically entered using a BAN and the terminal is easy to use for paramedics inexperienced with PCs. Moreover, the terminal is easy to move and does not interfere with measuring in a limited space.

The current BAN-based PHC system uses a barcode for identification of examinees with each user having a barcode-printed registration card. There are some cases that a team member needs to reattempt reading the barcode into the terminal. Android terminals equipped with a near-field communication (NFC) reader sell for under $200. We have a plan to change the identification method to smart cards.

In the present BAN-based PHC system, checkup throughput is decreasing compared with the former system. This is not only because personnel are still unfamiliar with the new BAN-system yet but because the present system has little flexibility for sensor plug ins. For example, the former system temporally records measurements on paper and an examinee uses a sensor freely even if other people using other sensors because checkup personnel link measurements and their IDs with flexibility. On the other hand, in the present BAN system, a sensor is assuredly assigned to a specified terminal. If multiple sensors are assigned to a coordinator, they are exclusively used for one person even if another coordinator is not in use. The service switch-over issue described in section II still remains, so we need to implement this with the IEEE802.15.6 specification.

V. Conclusion and Future Work

This paper proposed a BAN-based portable clinic that collects health-check data from user-friendly medical devices and sensors and sends the data to a local backend server and has been evaluated at actual fields as the first trial. The former PHC system, whose measured data are manually entered, induces input errors.

The quantitative evaluation has not yet been performed, but we expect a BAN will greatly decrease input error because most of the results are entered automatically. The former PHC system has measured over 5,000 people as of December 2012 and the BAN-enabled was used partly during December. From June 2013, we will fully introduce the BAN-based PHC system and conduct health checkups targeting 15,000 people.

We will continue to improve on the BAN-based clinic and to work on standardization of a BAN-enabled healthcare M2M framework.

Acknowledgments

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