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A Review of WSN Technologies for the Design of u-Healthcare Systems

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Abstract: Wireless Sensor Networks (WSNs) refer to a network of intelligent sensor nodes that are capable of monitoring physical and environmental conditions and can be deployed anywhere and anytime. The technological advancement in the integration of low-power electronic devices in the area of sensing, networking, and processing is rapidly increasing thus it pervasively changes the trends in healthcare systems. Efficient utilization of this emerging technology simplifies the monitoring and treatment of patients and enables high-quality, reliable, and emergent medical services. This study presents a review of WSNs capable of uplifting the design of u-Healthcare Systems enabling remote and continuous monitoring and thus providing immediate and effective medical services for patients.

Keywords: Wireless Sensor Networks (WSNs), u-Healthcare, Self-monitoring, Sensors

1. Introduction

Recent u-Healthcare's progress has risen rapidly due to the emerging developments in Wireless Sensor Networks. People can now self-monitor or manage his own health even without visiting healthcare providers. Efficient medical services through computerized medical information systems and resources have been provided ubiquitously.

In the article written by Paddock in 2013 [1], she stated that in self-monitoring, individuals use intelligent tools including wearable sensors and mobile apps to allow the collection, processing, and displaying their personal data to enable them monitor and manage all aspects of their personal health. The number of people who self-monitors their own fitness and health is also increasing to improve wellbeing and personal efficiency [2].

The advances in telecommunication technology have made possible data transmission for healthcare systems over the wireless systems. The development of sensing, networking, processing and embedded system (*i.e.*, system on chip) technologies enabled health monitoring devices more intelligent and

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smaller that are able to measure various bio-signals and exchange information through connected networks. Wireless sensor networks (WSNs) have enabled remote, continuous and real-time patient monitoring which collects disease-specific bio-information from wireless biomedical devices used by patients even in their homes or other settings outside of a medical facility [3][4]. The remote monitoring devices (*i.e.*, bio-sensors) typically acquires health information from people's natural daily living in home, company and even when they are performing their exercise outside and transmits to a central server for storage and analysis by healthcare professionals.

This paper deals with the review of the various WSN technologies and its convergence with the medical services in order to provide a ubiquitous healthcare (u-Healthcare) system that enable people to receive medical services beyond time and distance. A discussion of the WSN technologies enable us to draw the framework for the communication of healthcare information more efficiently and provide a robust and effective collection of physiological information from the patients. It would also allow a real-time monitoring of the patients' conditions regardless of their location and environment.

The rest of this paper is organized as follows: Section 2 discusses the related works on the utilization of WSN technologies to healthcare services; Section 3 outlines the various WSN technologies utilized in the u-Healthcare systems; Sections 4 highlights the convergence of WSN and medical services; and finally, the concluding remarks are discussed in Section 5.

2. Related Works

Various researches have emerged for the development of infrastructures in the area of ubiquitous healthcare systems. Generally, providing more efficient utilization of physicians, shortened hospital stays, reducing the skill level and frequency of visits of home-care professionals, reducing hospital readmission rates, and promoting health education can all contribute to reduced healthcare costs [5].

The ubiquitous healthcare system allows healthcare personnel to remotely perform real-time monitoring, early diagnosis, and treatment for potential risky and chronic diseases [6]. In addition, it can be cheaper and more convenient for the elderly and infirm to get theor healthcare needs by staying in their own homes rather than in aged-care facilities [7]. Remote monitoring can be addressed using a personal digital assistant (PDA) and network management applications.

Touati and Tabish (2013) [8] have presented a comprehensive review of the requirements for the development of next-generation u-Health systems (*e.g.*, hardware, communication, and computing). Their study provides a comparison on the new technological and technical trends and their features to address u-Healthcare requirements. This study provides a holistic approach toward understanding u-Healthcare systems and their requirements.

According to Yao, *et al.* [9], a healthcare system must be wearable and easy to use in order to allow continuous monitoring. Their study discussed the standards for wireless communication, plug-and-play device interoperability, and medical information exchange in healthcare systems. Then, the design and implementation of a wearable, plug-and-play system for home care that uses Bluetooth as the wireless communication protocol were addressed.

Lin *et al.* [10] has proposed a mobile patient monitoring system which integrates a personal digital assistant (PDA) technology (*i.e.*, a wireless PDA-based monitor is used to acquire continuously the patient's vital signs) and wireless local area network (WLAN) technology (*i.e.*, used for the transmission and communicating real-time bio-signals).

Although ubiquitous health technologies were not yet ubiquitous in the true sense, Rigby [11] encourages the application of emergent ubiquitous in health and a paradigm shift of moving a monitoring system for at-risk patient from the health facility to the patient's daily living environment (*i.e.*, remote

and real-time monitoring). He suggested that there is a need for an interaction between the developers and health policy makers to identify and respond to the future issues, challenges, opportunities, and benefits.

Currently, various wireless and pervasive technologies exist for medical and healthcare services. Leveraging their advantages and their effective utilization delivers an efficient healthcare service among the society. This paper aims at identifying the qualities of an ideal home based and mobile healthcare system that could lead for a truly high quality ubiquitous healthcare service.

3. Wireless Sensor Networks for u-Healthcare Systems

The u-healthcare systems nowadays are primarily designed to patients of heart, glucose and dementia disease, *etc.*, and elderly people at home or mobile environment. Wireless sensors around users (*i.e.*, patients) monitor and measure their various bio-information (*e.g.*, blood, pulse, glucose, *etc.*) which enables them to do self-management through u-Healthcare applications as shown to them on a mobile device. These users could be managed by a central healthcare center while continuously monitoring the bio-information transferred from the sensors. The bio-information can be measured by implantable, wearable, portable sensors, and transferred to a mobile device via wireless networks (*e.g.*, Bluetooth, Zigbee, RFID, *etc.*) and to a central server through mobile or wired networks. The wireless network for a u-Healthcare system is depicted in Figure 1.

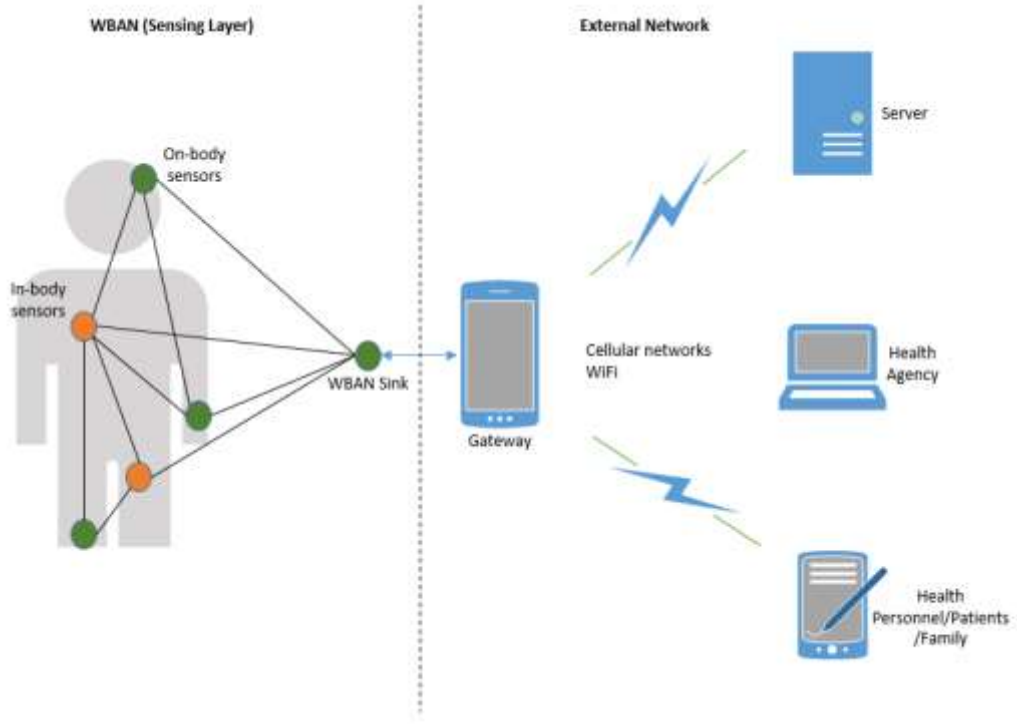

Figure 1. Wireless Networks for u-Healthcare

The Wireless Sensors should be robust, self-configuring, self-monitoring, self-healing and can withstand unpredictable environments with noise, signal loss and failures. These devices can be mobile (*e.g.*, wearable, emergency devices, *etc.*) or fixed (*e.g.*, temperature sensors, *etc.*).

Some of the characteristics of a WSN include:

- small physical size;

- Power consumption constrains for nodes using batteries or energy harvesting (*i.e.*, low power consumption, limited processing power);
- Ability to cope with node failures;
- Small storage capacity;
- Mobility of nodes;
- Dynamic network topology;
- Communication failures (*i.e.*, short-range communication capability);
- Heterogeneity of nodes;
- Scalability to large scale of deployment;
- Ability to withstand harsh environmental conditions;
- Ease of use;
- Unattended operation.

Wireless networks applicable for u-healthcare systems can be classified into three groups [12]:

- *In-body network*. This network is comprised of implanted body sensors that collects physiological information from individuals and a receiver to process its communication outside the body and to healthcare management applications. These sensors can include implantable pacemakers and implantable cardioverter defibrillators (ICDs) to collect physiological information in the body, and smart capsules to transfer to an external device.

Table 1. Wireless Networks for u-Healthcare

Classification of Wireless Networks in u-Healthcare	**Wireless Network Technology**
In-Body	Low-frequency inductive coupling, Industrial, Scientific, and Medical (ISM) bands, Medical Implant Communication Services (MICS)
On-Body	Wireless Medical Telemetry Service (WMTS), Radio frequency identification (RFID), Bluetooth, ZigBee, WLAN (Wi-Fi)
External Network	Cellular Networks (CDMA/HSDPA/GPRS/EDGE/ UMTS/LTE), Wibro, Satellite

- *On-body network*. This network is comprised of bio-sensors that can be attached to the body or on the devices that can be wearable. These devices collect physiological information of the individual wearing them. They may include bio-shirts, and wrist watches that collects and transfer physiological information to devices that are capable of local processing.

- *External Network*. This network is comprised of technologies that are capable of receiving, communicating, and processing physiological information collected from bio-sensors. These technologies are capable of wirelessly transmitting the collected information to processing devices and to a remote server.

Figure 2. Wearable Sensors

The increasingly advances in sensor technology allow continuous, real-time monitoring of multiple physiological bio-signals for users, including ECG, body temperature, respiration rate, blood pressure and acceleration. Figure 1 show wearable sensors capable of obtaining physiological data and then transfers the data wirelessly via Bluetooth, Zigbee, or RFID into base-station represented by a mobile device.

Figure 3. In-Body Sensors

In a u-Healthcare service model, the framework of its wireless network can be divided into layers and each classification plays significant roles. Both in-body and on-body bio-sensors measures and collects physiological information in the sensing layer and transfer it to a gateway or directly to an external server. Then, the gateway delivers the preprocessed physiological information to a local server or to a central server through the external networks.

4. Convergence of WSNs and Medical Services

u-Healthcare Systems keep track, manage, interpret an individual's health history and offer health maintenance advice and service. The basic service model for u-Health consists of 3 layers: Sensing, analysis and service [12].

- The sensing layer measures health condition of people, recognizes living patterns including food and exercise, and measures environmental values around people.
- The analyzing layer gathers basic information issued from the sensing layers and analyzes them.
- The service layer provides people with intelligent health services based on information stored in the analyzing layer.

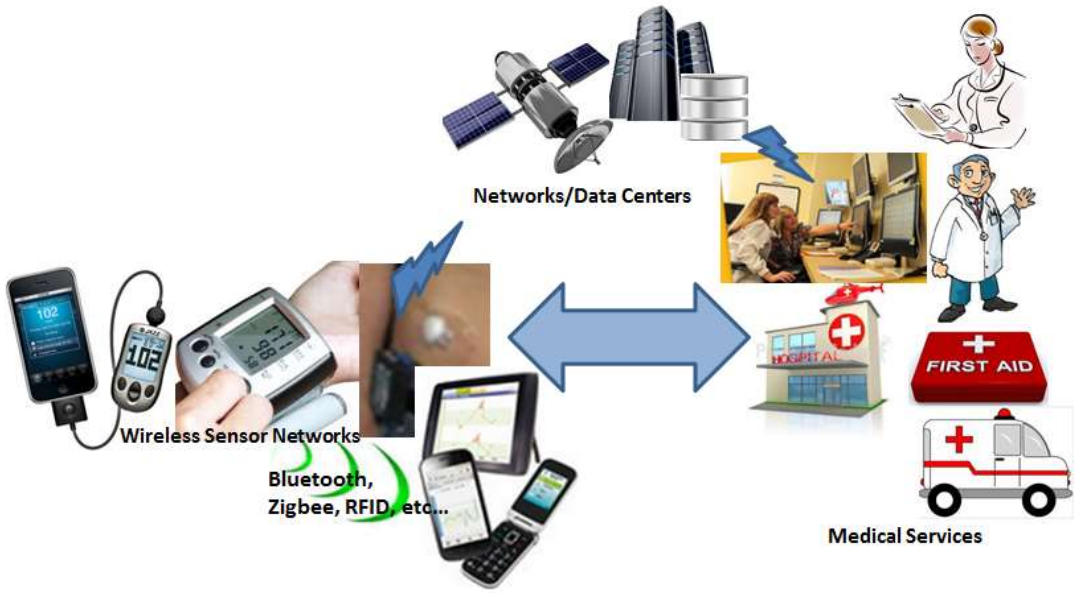

Figure 4. Convergence of Wireless Sensor Networks and Medical Services

The convergence of these technologies performs such important functions outlined as follows:

- It collects an individual's current health data. Various bio-signals are checked through sensors as blood sugar, blood pressure, pulse, active mass, weight, muscle quantity, body fat quantity, body fat rate, basal metabolic rate, body mass index, *etc.* These sensors are in the form of in-body or on-body networks.
- The health data that are collected through sensors are transmitted through wireless sensor networks (*e.g.*, Bluetooth, Zigbee, RFID, *etc.*).

- The transmitted health data are stored, interpreted and analyzed based on the medical relevant facts.
- The healthcare system monitors in real-time the individual's health status and analyze it based on their personalized health plans. The system then feedback a medically-relevant diagnosis and possible treatment to maintain their healthy lifestyle.
- The healthcare system also provides reminders for scheduled therapy and appointments and allow the scheduling of medical consultation appointments.
- The healthcare system also alerts healthcare agencies for emergency situations. Emergency calls can be placed by medical personnel who are monitoring the physiological information in case of detected abnormal symptoms.

In a simple scenario, health data are collected using wireless sensor networks – sensing layer. Collected health data are transmitted to the analyzing layer for storage, analysis and monitoring. Healthcare personnel are notified with the status of monitored patients. Efficient medical services based on patient's status and condition are provided ubiquitously.

5. Conclusion

The application of emerging advancements in Wireless Sensor Networks has led to efficient, reliable, and emergent healthcare systems. The technology advancement in integration of low-power electronic devices in the area of sensing, networking and processing is rapidly uprising thus it pervasively change the trends in healthcare systems. An efficient utilization of this emerging technology simplifies the monitoring and treatment of patients and enables a high quality, reliable and emergent medical services. This study presents a review of WSNs capable of uplifting the design of u-Healthcare Systems enabling remote and continuous monitoring that can keep track, manage, interpret an individual's health history and offer health maintenance advice and service tailored accordingly and thus could provide immediate and effective medical services for patients.

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