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The Emerging Wireless Body Area Network on Android Smartphones: A Review

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Abstract. Our society now has driven us into an era where almost everything can be digitally monitored and controlled including the human body. The growth of wireless body area network (WBAN), as a specific scope of sensor networks which mounted or attached to human body also developing rapidly. It allows people to monitor their health and several daily activities. This study is intended to review the trend of WBAN especially on Android, one of the most popular smartphone platforms. A systematic literature review is concerned to the following parameters: the purpose of the device and/or application, the type of sensors, the type of Android device, and its connectivity. Most of the studies were more concern to healthcare or medical monitoring systems: blood pressure, electro cardiograph, tremor detection, etc. On the other hand, the rest of them aimed for activity tracker, environment sensing, and epidemic control. After all, those studies shown that not only Android can be a powerful platform to process data from various sensors but also smartphones can be a good alternative to develop WBANs for medical and other daily applications.

1. Introduction

The rapid growth of digital communication has penetrated the society into every aspect of life. Wireless body area networks (WBAN) is one of the promising technology which is typically consists of a collection of low-power sensors and communication device which attached to human body. The device can be mounted in the body, stuck on the skin, or worn around the body [1]. Each of the sensors are usually called as nodes. The nodes monitor the information of the desired parameters, which can be any human vital signs, activities or environmental aspects, then it processed for the wireless transmission to the computer or computer networks for further analysis and use [2].

WBAN then enables new applications and opportunities related to the wireless sensor networks (WSN). The variety of possible applications span from medical care (e.g., monitoring of heart rate, blood pressure, etc) to the entertainment. This technology is standardised under IEEE 802.15.4, IEEE 802.15.6, and Bluetooth Low Energy which published in 2006, 2012, and 2010 respectively [3]. Those standards required low-power, low-cost, and low bit rate networks which specifically design to be placed in or on the human body. Figure 1 shows a simplified common WBAN network architecture [4].

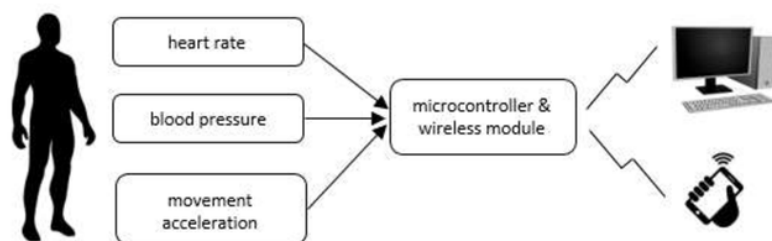


Figure 1. Simplified WBAN network architecture

At the same time, the development smartphones technology and its platform also support the mobility of WBAN technology. Smartphones can act as gateway or sink for the nodes (sensors), and connected to the server or further networks. Nowadays, smartphones can also act both as the nodes since most of them were already equipped with various sensors (e.g., heart rate sensor, accelerometer, gyroscope, etc.) [5]. Moreover, Android development as an open source platform makes it possible to make the smartphone as the data processor and also the end system at once. In addition to that, smartphones also can be the wireless module. Smartphones also have rich capabilities in communication, such as Bluetooth and/or Wi-Fi [6]. According to the WBAN standards, developers mostly use Bluetooth since it is low-power, low bitrate, and moderate distance (up to 15 m). Yet, they also can use the Wi-Fi to provide the need of a further transmission distance or a bigger bit rate (usually for entertainment purpose) [7].

This paper is intended to give a literature review of WBAN technology based on Android smartphones because of its promising development capabilities. The main aspects of this review are the category of each research (medical and non-medical), the purpose, the design focus, and the connectivity. The second aspect reviewed is the application features related to its purpose. By giving a resume of the related works, this paper can present insights for researchers who are interested in WBAN technology particularly for the smartphone-based implementation.

2. Android Based WBAN for Medical Purposes

WBANs technology has attracted many scientists to explore this field as it can give a new paradigm of telemedicine. Thus, most of the WBANs research are focused in medical purpose. Zhang et. all in 2013 proposed a cluster based epidemic control through smartphone-based BANs [8]. The main strategies were reading smartphone users' vital signs (e.g. heart rate, body temperature) and also their social interaction to predict the epidemic. This paper is then developed to a socialized WBANs for sensing the environment in 2016[9].

At the same year, M. Singh and N. Jain performed and evaluated a wireless blood pressure monitoring system using Bluetooth. They developed a prototype of an Oscillometric method which consisted of a pressure sensor, analogue signal conditioning circuitry, microcontroller, and a Bluetooth module. The blood pressure reading was then sent to an Android smartphone. The results had been compared to OMRON HEM-7111 and mercury sphygmomanometer with more than 97% accuracy [10].

On the other hand, Castillejo et al. came with the idea of integrating wearable devices in wireless sensor network for e-health application. In this paper, they did not only focus on smartphones, but the users/patients were also able to connect their smartwatches and tablets. It specifically used Android smartphones as the main requirements. The application could process the heart and breathing rate measurement, also core body temperature so that it can suggest the users, which had been tested to a group of sportsmen and women, about their workout plan according their personal vital parameters [11].

Furthermore, another development in term of WBAN in Android-based smartphone also gained the attention of B.R. Nandkishor et al., who interested in building an application for monitoring and evaluating medical parameters. The application was consisted of ECG, heart rate, and body temperature

sensor. Those sensors' data were processed and stored by a microcontroller, then transmitted to the smartphone via Bluetooth module. The application on the smartphone then read the received data and trigger an alert if there were any critical condition which already stored as the preset. The alert system can notify any patient's emergency situation by giving SMS, e-mail, and buzzer [12].

While the previous work mentioned were focused on application, G. Wolgast et al. were more concerned in antenna design in WBAN. Using an ECG sensor, they collected ECG signal to monitor if there was any myocardial infraction in the readings. This research was focused on the design of planar inverted F-antenna (PIFA) which integrated with the sensor and the application installed in an Android smartphone. The resulted antenna design was able to perform successful ECG signal transmission via Bluetooth. In addition, it also offered a low-cost surface wave propagation antenna which suitable for WBAN applications [13].

Up until 2016, many researchers were still interested in ECG signal analysis. V. Wahane et al. proposed a system for ECG monitoring in cardiac arrhythmia case. This research was focused on the system design using ECG sensor, microcontroller, and Android smartphone. They also expanded the system into some possible network, not only the monitored patient but also the medical server (it could be a hospital) and also the doctor(s). The data was transmitted through Bluetooth and Android's platform, while the doctor could access patient's data from the server. Moreover, the system could generate an alert for any critical condition [14].

Another innovation in this field then made by M.S. Mahmud et al. by designing a real time and non-contact multi parameter wearable device for health monitoring. Their prototype has a non-contact ECG sensor with fully integrated analogue front end (AFE), a temperature sensor, an accelerometer, and a Bluetooth low energy (BLE) module. This device can be used by inpatient, outpatient, or elderly. It could detect fall, temperature, and monitor ECG signal. In addition, the system can also generate an alert for the authorities [15].

While most of the previously mentioned research were using ECG sensor as their point of interest, R. Contreras et al. used accelerometers and gyroscope sensors which built in smartwatches to calculate the tremors in patients with Parkinson's disease. The system was developed with the use of several nodes (smartwatches) and one sink which is the Android smartphone. The result showed that it can quantify tremors which were presented in the form of linear acceleration and angular velocity in the time domain until it can detect patients with Parkinson's disease in stage 3 and 4 [16].

3. Non-Medical Android Based WBAN

As WBAN promises a new paradigm in healthcare services, it can be expanded to a wider use in our daily life. M.S. Pan and H.W. Lin were implemented a step counting algorithm by using the information gathered by an accelerometer sensor built in a smartphone. The algorithm was conducted in two steps. First, the accelerometer collected linear acceleration and gravity values. Then, the horizontal components of the perceived linear acceleration could be derived. The second phase was the adoption of correlation coefficient concept to identify the steps. They focused on made the algorithm so the users might carry their smartphones in a natural manner and allowed to move it arbitrarily [17].

Furthermore, in 2016 Al-Naffakh et al. proposed an activity recognition using wearable computing. They designed a system using smartwatch's accelerometer and gyroscope to read user's motion. Transparent authentication system (TAS) was also introduced to improve the security level and continuous authentication. The findings showed that Android smartwatch and smartphone were capable to capture information in order to perform activity recognition [18].

Same with the previous research mentioned above, B. Shin et al. also made use of smartphone's accelerometer for motion recognition for pedestrian dead-reckoning (PDR). Magnetometer, gyroscope, and barometric pressure sensor were also used to complete the analysis. The proposed algorithm offered a high positioning accuracy for 3D pedestrian navigation system using smartphone [19].

4. Results and discussion

The expansion of wireless body area networks technology which already captured the attention of many researchers can be categorized into two big groups: medical and non-medical purpose as mentioned above. Android itself has proven that this platform is sufficient to handle several network algorithm and strategies among nodes, the end user(s), and the server. Table 1 below sums up the works related to WBAN specifically in Android environment.

Table 1. Related works in WBAN technology based on Android Smartphone

Year	Author	Category	Purpose	Type of Sensor(s)	Device
2013	Z. Zhang et al.	Medical	Cluster-based epidemic control	Temperature, blood pressure, heart rate, blood oxygen saturation, accelerometer, GPS	Smartphone
2013	P. Castillejo et al.	Medical	E-health application with wearable devices	Heart rate, body temperature	Smartwatch, smartphone
2013	M. Sigh et al.	Medical	Wireless blood pressure monitoring system using Bluetooth	Pressure sensor	Smartphone
2014	Z. Zhang et al.	Medical & Non-medical	Socialized WBAN and environment sensing	Temperature, blood pressure, heart rate, blood oxygen saturation, accelerometer, GPS	Smartphone
2014	H. Wang et al.	Medical	Socialized WBAN with mobile sensing	Temperature, blood pressure, heart rate, blood oxygen saturation, accelerometer, GPS	Smartphone
2014	B.R. Nandkishor et al.	Medical	Monitoring and evaluating medical parameters	ECG, heart rate, temperature sensor	Smartphone
2014	M.S. Pan et al.	Non-medical	Design and implementation of step counting algorithm	Accelerometer, gyroscope	Smartphone
2016	R. Contreras et al.	Medical	Quantification of tremor in Parkinson's disease patients	Accelerometer, gyroscope	Smartwatch, smartphone
2016	M.S. Mahmud et al.	Medical	Real time and non-contact health monitoring	Accelerometer, temperature sensor, ECG.	Smartphone
2016	B. Shin et al.	Non-medical	Pedestrian navigation based on motion recognition	Accelerometer, gyroscope, magnetometer, barometric pressure	Smartphone
2016	V. Wahane	Medical	Wireless ECG monitoring	ECG sensor	Smartphone
2016	G. Wolgast	Medical	Antenna design for heart attack detection based on WBAN	ECG sensor	Smartphone
2016	N. Al-Naffakh et al.	Non-medical	Activity recognition	Accelerometer, gyroscope	Smartwatch, smartphone

5. Conclusion

Those data show that WBAN can bring a brand new paradigm in our healthcare services yet lifestyle. The integration with one of the most popular and open source smartphone platform, Android, can escalate the development of applications.

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