

Wearable Health Monitoring System (WHMS) using Wireless Sensor Network

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Abstract: The development in technologies has taken place in many sectors such as the Wearable Health Monitoring System (WHMS). It has been a remarkable revolution by the emerging of the Wireless Sensor Network (WSN) in performing the monitoring and recording of healthcare. Thus, the wearable wireless sensor based systems are intended to provide better personal health management, ubiquitous monitoring health condition, better quality treatment and care, along with to allow efficient circuit integrations, reliable vital signal measurements, low operation costs and optimum power usage. This paper therefore attempts to comprehensively review the basic concepts of Wearable Health Monitoring System (WHMS) using Wireless Sensor Network (WSN). A comparative study was carried out in various healthcare monitoring systems, which adapted different wireless technology. In addition, the challenges and limitations of WHMS systems are identified. The implication of this study is to minimize the challenges and limitations in the design, development and application of a wearable wireless sensor based systems. It is expected in the future that the information shared in this paper can serve similar scientific field and improve the system features.

Key words: Wearable Health Monitoring System (WHMS), Wireless Sensor Network (WSN), Wireless Wearable Health Monitoring System (WWHMS), Wireless Local Area Network (WLAN), Wireless Personal Area Network (WPAN).

INTRODUCTION

The current technology advancement in various sectors has led to many remarkable developments and novel inventions. By understanding the core of the problems and culture of the modern world, many conventional concepts have been interpreted and redeveloped by adopting current existing technologies, such as the wireless sensor network (WSN) in the Wearable Health Monitoring System (WHMS) for medical applications. For the past decade, numerous research and development efforts have been carried out in WHMS, inspired by the need to monitor a person's health condition outside of the hospitals (Lymberis, A., A. Dittmar, 2007; Troster, G., 2005; Gatzoulis, L., I. Iakovidis, 2007).

The whole system has been developed and known as the Wireless Wearable Health Monitoring System (WWHMS).

Basically, a wireless network is an infrastructure without wire and connected by the radio frequency (RF) through free space propagation. There are few types of wireless network such as Wireless Local Area Network (WLAN), Wireless Personal Area Network (WPAN) and Wireless Metropolitan Area Network (WMAN). Each type of these networks may be divided into a few standards of technologies such as IEEE 802.15.4 (ZigBee), IEEE 802.15.1 (Bluetooth), and IEEE 802.15.3a (UWB) for WPAN. The choice of network applied is based on its deployment in a system, for instance in applying the short-range or long-range communication system. Wireless networks have very convenient mobility and great flexibility to meet the demand of the untethered connectivity of the radio link.

The sensor network is an infrastructure consists of sensing, such as the ability to measure, compute, and communicate, which will provide an administrator capability to instrument, monitor and react to an event in a specific environment. This type of network is commonly used in data collection, monitoring, surveillance and

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medical telemetry. However, it is also quite popular in sensing control and activation. In the next few years, WSN is predicted to be an important technology that will experience major deployment, such as for the national security (Cayirci, E., 2003). The sensor network efficiency depends on the space and time, location, coverage and data synchronization. On the other hand, the challenges necessitate energy awareness at all layers of a communications protocol stack (Kemal Akkaya, Mohamed Younis, 2005).

There are many WHMS applications which adopt sensor network and wireless operation, such as the remote monitoring of physiological data, elderly assistance (Scanail, C., 2006), tracking and monitoring doctors and patients, sport-health, early-age detection of Autism Spectrum Disorders (ASD) (Picard, R., 2009), disaster relief medical care (Tia Gao, T. Massey, 2007), diabetes (Merrell, R., 2003) and many more. It is due to the increasing attention from researchers and corresponding industries in research and development efforts. Besides that, there are other various factors such as the increase of healthcare costs and world ageing population Hao, Y. and R. Foster, 2008), the limitation of conventional medical devices and the ambulatory system (Bonato, P., 2003), the need to get real-time feedback in long-term health monitoring (Pantelopoulos, A., N. Bourbakis, 2008), the ineffective managing and monitoring chronic diseases and so on. In order to meet these demands, numerous prototype and commercial products have been produced such as the Smart Vest (Pandian, P.S., 2008), Wearable Health Care System (WEALTHY) (Paradiso, R., 2005), My Heart (Luprano, J., 2006), Life Shirt (Heilman, K.J. and S.W. Porges, 2007) and many more.

The WHMS is used to measure and monitor vital signals. It consists of various elements, such as miniature sensor, wireless communication module, processing unit, software, power supplies and so on. Therefore, WHMS will operate under a specific medical criteria application, certain ergonomic constrain and hardware resource limitation (Raskovic, D., 2004; Anliker, U., 2004). Thus, the required features must take into account the design and the development of the overall system. There are a few significant requirements, such as low power consumption, high reliability of data and system, and high range of usability and wearability. Consequently, designing such system is a very challenging task. Therefore, this paper briefly reviews the state of the art of WHMS including its basic system operation, wireless technologies involved and required features.

History of Sensor Networks:

In the past decade, the health monitoring system which were based on the RF transmission at a fixed distance with the use of a bulk wired equipment to transmit, receive and process the signals, were particularly invented to detect Electrocardiogram (ECG). Basically, these systems adopted the basic concept of the Doppler radar technique (Lubecke, O.B., 2002; Chioukh, L., 2011; Obeid, D., 2008; Sadek, S., 2010; Sekine, M., K. Maeno, 2011; Chioukh, L., 2009). Then, the application of healthcare monitoring system has gone through a drastic change with the deployment of wireless sensor network. Thus, WWHM systems exist with numerous wireless technology applications. However, the truth is wireless sensor networks have been applied over a few decades in many fields, such as in the military. In this section, a brief historical background of sensor networks is discussed and reviewed.

The historical background of the sensor network divided into four phases (Chong, C.Y., S.P. Kumar, 2003). The phase one, development of sensor nodes brings the date back to the Cold War around era military 1945's. An acoustic sensor network system developed by United States America (USA) for submarine surveillance to sense and tracks the Soviet submarines. During the same periods, the USA develops networks of air defense radar, which well know as Airborne Warning and Control System (AWACS) to protect its territory where some of these systems was applied in drug interdiction.

The second phase begins around 1980's, Distributed Sensor Networks (DSN) research based program in a sensor network, under the impetus by Defense Advanced Research Projects Agency (DARPA) where the ARPANET method approach was extended to sensor network for communication purpose. Slow and surely, progress in around 1980s resulted in the development of a multiple-hypothesis tracking algorithm to address difficult problems involving high target density, missing detections and false alarms (Sproull, R. F., D. Cohen, 1978). It is a current standard approach to challenging tracking problems.

The third phase is about the military deployment of sensor network technology application, which found out in the 1980s and 1990s. This period also called first generation commercial products. The military planner planned to use a network centric warfare from the DARPA-DSN research and testbeds developed. They use the network centric warfare to manage the weapon systems by the use of distributed sensors, which totally oppose from tradition warfare environments. Besides that, sensor networks can improve detection and tracking performance through multiple observations, geometric and phenomenological diversity, extended detection range, and faster response time (Chong, C.Y., S.P. Kumar, 2003). Evolving sensor networks represent a significant improvement over traditional sensors (Akyildiz, Ian F., 2002; Su, W., *et al.*, 2004).

The last, phase four is continued progress from the third phase. In late 1990s and early 2000s, advancement in computing and communication taken place, where it's implies the new generation of sensor network technology. Inexpensive and compact sensor, based on various high-density technologies such as Nanoscale Electromechanical Systems (NEMS), was appeared. The important method "standardization" in sensor network

leads wide scale deployment of technology such as WSNs. The main advantage such as a reliable network, ubiquitous connectivity, inexpensive component, low power-consumption makes possible deployment of sensors for a plethora of applications. Furthermore, the current direction of advancement more to mesh, peer-to-peer, and cluster-tree network topology where the enhancement in data security features and interoperable application profiles. The generations of commercial products and comparisons towards to a next-generation, third generation is simplified in Table 1.

Table 1: Comparisons in generations of commercial products.

Features	First Generation	Second Generation	Third Generation
Node Architecture (Sensor, process & communications)	Separated	Some integrated	Fully Integrated
Protocols	Proprietary	Proprietary	Standards
Topology	Point-to-point, multi-hop and star.	Peer-to-peer and client-server.	Fully peer-to-peer
Power source	Large or line feed	Batteries	Solar or nanotechnology based
Lifetime	Hours, days or longer	Day or weeks	Month or years
Deployment Methods	Physically installed	Hand-placed	Embedded
Size & Weight	Large & Pounds	Smaller & Ounces	Smallest & Grams or less

Wireless Sensor Node:

Researchers see WSNs as a current emerging field of tremendously based network systems of low-power wireless nodes consumption with a small amount of Central Processing Unit (CPU) and memory, and large merge networks for high resolution sensing of the environment (Welsh, M., 2004). A wireless sensor node may have more than one sensor for sensing the physical variance, a processing unit which consists of a microcontroller or processor, analog to digital converter (ADC) and flash memory, and a RF transceiver. Figure 1 below gives an idea about the basic components in a typical wireless sensor node.

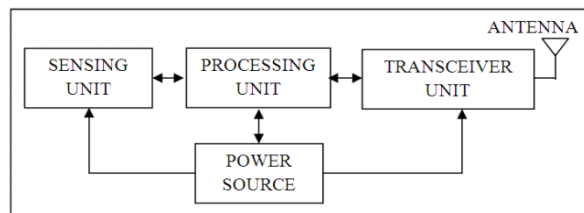


Fig. 1: Basic components in a typical wireless sensor node.

Basically the sensing unit senses the given entities or objects and communicated through sending the sensed data via wireless links. The sensor node, wireless node (WNs), mote, smart dust or commercial off the shelf (COTS) language term used interchangeably somewhat. Sensor devices, or wireless nodes (WNs), are also sometimes called motes (Deshpande, A., 2004). The sensor usages in WSN have variety reasons such as functionality and capabilities. Wireless Sensor nodes are able to perform some processing, gather sensor information or sources, and communicate with other connected nodes in a network. A mote can be a node, but a node not necessary always to be a mote.

The sensor is a hardware device that can measure changes in physical condition, which can monitor it. A sensor should be small in size, low energy consumption, function in high density, autonomous, easily adapt to environments around and can operate unattended. There are two types of sensor such as passive and active. Passive sensors are in elemental form; array and low-energy devices such as acoustic where it senses the signal without manipulate the environment. However, the active sensors tend to be high-energy system instance radar, where it's actively probing the environments around it and require continues energy source. Generally the WSN occupies with passive sensor with a certain coverage area that observing with high reliability and accuracy. Sensor node spatial density in the field may be high as 20 nodes per cubic meter.

The processing unit consists of ADC, controller, memory, amplifiers and filter. These elements may differ in types, which based on the signals processing method or techniques used. Any sensed signal from the sensor may in continue or period and will digitized by using ADC. As its name, the ADC converts the analog signal to digital data, and then sends it to the controller for processing. The controller used to perform the tasks, processes data and controls the function of other component in the sensor node. The most common controller is microcontroller, where it's often used in different type of embedded system operation because of its advantage in low power consumption, low cost, flexible connection to other devices and ease in programming.

The amplifier is used to amplify the signal current or voltage. A filter is used to perform signal-processing functions by removing the unwanted frequency components and enhanced the desired signals. Normally it can be categorized in low pass, high passed and the band passed filter. The transceiver is the combination of

transmits and receives functions. The transmitter used to transform the source signal so that it's suitable for transmission and receiver used to capture the signal from desired device. However, the transceiver also able operates in sleep mode or in idle mode. Transmitted data may via single or multi hop to the desired monitor station, base station, cell phone or Personal Digital Assistant (PDA), where it connects to another network by an Internet. Power source is used to supply an optimum energy, in order to operate the circuit or devices.

The power consumption is often an issue that requires to be taken in the accounts of WSNs system constraints. Mostly, the communication circuitry and antennas are the main elements that draw most of the energy (Xiaoyan, H., 2001; Haenggi, M., 2003; Zhu, J., S. Papavassiliou, 2003; Min, R., A. Chandrakasan, 2003; Lindsey, S., *et al.*, 2001). An antenna used to convert the electrical power into radio waves and vice versa. The wireless transmission medium assumed linear and time invariant or path over which information flow where it uses to connect communicating parties. Examples free spaces consist of RF, laser, infrared and so on. In WSNs, application the radio frequency based communication is most popular. It is because it have industrial, scientific and medical (ISM) band to use license free communication frequency such as 2.4GHz, 915MHz and many other frequency.

Technologies for Whms:

In the past decades, the development in wireless technology incorporated different disciples such as communication, computer, information, control, sensor and actuator engineering in an integrated way, lead to better performance, novel solution and an advanced complete system. Wireless communication is fast growing technologies to provide the flexibility and mobility (Willig, A., 2003). The wireless networks have the dynamic network formation, low cost, easy deployment and untethered connectivity to meet the user demand. They have implemented in numerous field such as industrial, medicals, defense and so on.

Generally there are two main types of wireless networks, instance mobile and fixed networks. The mobile wireless network can classified into two categories such as cellular and physicals, where the cellular categories consist of First-Generation (1G) to Fourth-Generation (4G) with various types of service package such as Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS) and many more. The fixed wireless networks can divide into three main individual standards such as Wireless Metropolitan Area Network (WMAN), Wireless Local Area Network (WLAN) and Wireless Personal Area Network (WPAN). Figure 2 below point up summarized of wireless networks categories and standards involved.

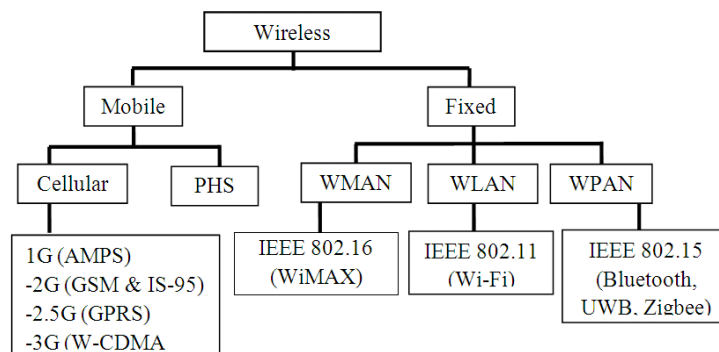


Fig. 2: Wireless networks categories and standards.

The differences between WLAN, WPAN and WMAN take place from the different design aim and goals. First, WPAN is intended for short range communication, normally up to 10 meters where it devices consumes a very small amount of power. Second, WLAN invented to operate up to 100 meter distance coverage area and have intermediate of power consume requirement. The third is WMAN, whereas the data rate for devices is not that important as it's for WLAN devices, but the cost and battery lifetime are. Thus WPAN devices have lower data rates and cost when compared with WLAN. However, nowadays WPAN technologies being developed with the aim for high data rate in very short distance application. The devices of WLAN and WPAN operate in unlicensed bands. The large distance covered up to several kilometers is main characteristic of WMAN application. It not only can operate in unlicensed bands, but also over the licensed frequency band. Because of that, WMAN devices not intended in battery powered devices for extensive periods of time.

Current Healthcare Applications:

Commonly, there are three types use of WHMS systems such as motion and activity, physiological monitoring and large-scale physiological and behavioral studies (Ko, J.G., 2010). Based on the past decade, the WHMS can identify in term research prototype, commercial product, and hardware configuration such as Body Area Network (BAN), microcontroller, customized hardware and textile based. This study review was based on

research prototype such as systems-based microcontroller or custom designed platforms, systems based on smart textiles, Mote-Based BAN, WHMS based on commercial Bluetooth sensors and cell phones and other related WHMS application. For information, an idea of embedding sensors into garments was firstly pursued by the researcher team at the Georgia Institute of Technology (Park, S., 1999). The works of this team lead to Smart Shirt invention where it is referred to as wearable system. The discussed WHMS system was simplified and compared in Table 2 below.

Table 2: Selected application system.

Project Title	Hardware / Power	Wireless Technology	*Measured Parameters	Application	Network Topology / Size
AMON [41]	Wrist-worn unit / 1.25 AH LiION	GSM/UMTS-Link	Pulse, SpO ₂ , BP, ECG, T, A.	High-risk cardiac/respiratory patients.	Mobile phone link / Medium
MagIC [43]	Vest based textile woven sensors, custom electronic board and PDA / Unknown	Bluetooth	ECG, R, A, HR, other vital signal.	Recording cardiorespiratory and motion signals.	One sensor to remote computer. (Study in progress to validate the use of the system) / Tiny
Wearable ECG-recording System [45]	Microcontroller board and PDA / Battery	Wires, ZigBee and GPRS	ECG	Remote detection of cardiac arrhythmia, tele-home-care	One sensor to HHD / Tiny
CodeBlue [46]	Sensor motes (with the custom processing board) / Lithium polymer battery	ZigBee (compliant MicaZ and Telos motes)	ECG, SpO ₂ , A	Real-time physiological status monitoring with wearable sensor	Multihop Routing Network / Large
HeartToGo [50]	Cell phone and communication available BT bio-sensors / Cell phone battery	Bluetooth, GPRS	ECG, A	Individualized remote cardiovascular disease (CVD) detection.	An artificial neural network (based machine learning technique)
AUBADE [51]	Mask, glove, chest sensors / Unknown	Wires, Bluetooth, Wi-Fi	ECG, GSR, EMG, R	Evolutions of an emotional state of an individual	Wireless LAN / large
Bioharness [53]	Chest Belt / 4.2V Li-Ion rechargeable	Bluetooth or ISM RF	ECG, R, T, A, P	Remote monitoring of human performance and state in the real-world.	GPS, RAELink3

*Abbreviation: Oxygen Saturation (SpO₂), Blood Pressure (BP), Galvanic Skin Response (GSR), Electrocardiogram (ECG), Blood Pressure (BP), Temperature (T), Respiration (R), Activity (A), Posture (P), Electromyogram (EMG), Heart Rate (HR)

Advanced Care and Alert Portable Telemedical Monitor (AMON Project):

AMON or the advanced care and alert portable telemedical monitor was a project financed by the EUFP5 IST program (Anliker, U., *et al.*, 2004). The AMON prototype is a wrist-worn device which wirelessly connected to the stationary unit Telemedicine Centre (TMC) by using GSM link. The AMON as showed in Figure 3 below is designed to continuously monitor high-risk cardiac patients. The system comprised of collecting and evaluating multiple vital signal, intelligent various parameter medical emergency detection, and a cellular network connection to Medical Mission Control (MMC) center. Besides that, it can wirelessly transmit raw data, extract value and send the detected alarm to medical center (Anliker, U., *et al.*, 2004). The unobtrusive ergonomic enclose wrist-worn and low power design technique is applied in the system designed for long term monitoring without interfering or restrict mobility of patients day life activity. The main challenges in AMON system design faced are, the ability to derive various information from wrist-worn sensor beside keeps the size and power consumption in minimum level. A medical study has been carried out on 33 patients to validate the system performance. Although the conducted validation study revealed problems regarding the reliability of the measured data and the wearability of the device, the general idea of the device was very well received by the users (Pantelopoulous, A., N.G. Bourbakis, 2010).



Fig. 3: Prototype AMON wrist-worn device (Anliker, U., *et al.*, 2004).

Maglietta Interattiva Computerizzata (MagIC):

MagIC, is washable woven sensitized textile as emphasizes at Figure 4 below, and it's developed by researchers in Milan, Italy. MagIC or MagliettaInterattivaComputerizzata (Di Rienzo, M., 2005). MagIC is composed of a vest, including textile sensors for detecting ECG, posture and respiratory activity, and a portable electronic board for motion detection, signal pre-processing and wireless data transmission to a remote monitoring station (Di Rienzo, M., 2005). This textile-based wearable system (Meng, Y., H.C. Kim, 2011) used Bluetooth technology in data transmission from portable electronic board to local Personal Computer (PC) or PDA. The system was tested in recording unobtrusive cardio respiratory and motion signal while the subjects freely moving. The recording results on the subject during on the bed and physical exercise showed good signal quality over monitored time, correct identification arrhythmic incident and average estimation heart rate. The tested evaluations also correctly identify atrial fibrillation episodes and atrial and ventricular ectopic beats. Further development of MagIC will focus on normal routine clinical practice and daily life use.

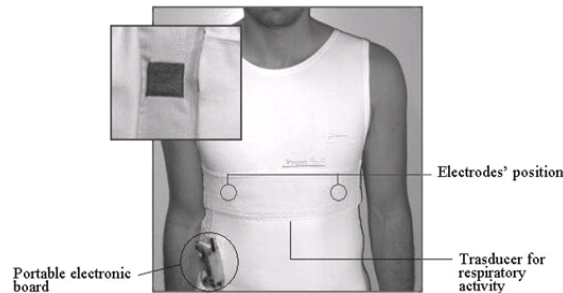


Fig. 4: The MagIC system with inset details of textile electrodes (Di Rienzo, M., 2005).

Wearable ECG-recording System:

Wearable ECG-recording system for the continuous arrhythmia monitoring and detection was developed (Fensli, R., 2005). The ECG sensor constantly transmits the measured signal to the receiver module in Hand Held Device (HHD) by using modulated RF-radio link. This design is an alternative to conventional Holter monitoring systems. The HDD as in Figure 5 below, also known as Personal Digital Assistant (PDA) devices serve as an intelligent of the system where it processes, analyzes and saves the recorded ECG measurements. The PDA was implemented with an arrhythmia algorithm detecting events with true detection rate of 99.2% (Pantelopoulos, A., N.G. Bourbakis, 2010). The HDD/PDA transmitting alarm signal and recorded ECG waveform through GPRS/GSM link to remote clinical station. HHD will record 1 min of the ECG signal when an abnormal ECG activity detected and transmit it to the base station with some other parameters. The transmitted signal using File-Transfer- Protocol (FTP) and database are used to store the recorded data. The actual alarm limits are defined by a doctor in setup configuration. This system implements several alarms such as bradycardia, tachycardia, and arrhythmia, where it's variations in RR intervals. The advantage of this system is easy use and no technical skill required to operate.

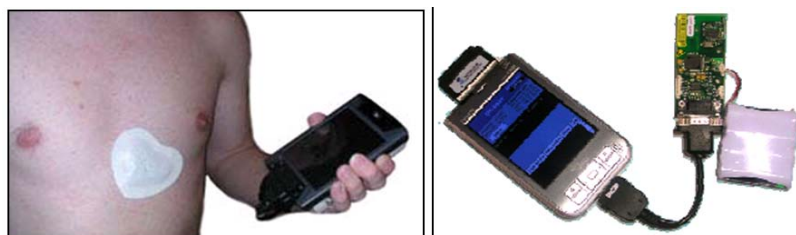


Fig. 5: A sensor applied on subject chest while holding assembled HHD (left) and a unit of PDA connected to the receiver circuit with battery (right) (Fensli, R., 2005).

Code Blue:

CodeBlue (Shnayder, V., 2005) is a medical prototype of the sensor network platform. These systems provide standard protocols for discovery and subscribe multihop routing of device, such as simple query interface that's tailored for medical monitoring. The system consists of motion sensor, two leads ECG and oximeter as demonstrate in Figure 6 below. Various medical sensors based on MicaZ and Telos mote designs have been developed as well as pulse oximeter, EKG and motion-activity sensor. The idea of CodeBlue developments is from researchers at Harvard University (Malan, D., 2004). The lack of reliable communication among medical sensors, multiple receivers (PDA's) and various high data rates have been addressed. However, a software framework has implemented, where it provides protocols for device discovery, publish/subscribe

multihop routing (Kambourakis, G., 2007), and a simple query interface allowed users to dynamically request specific data from a particular network node. On the other hand, CodeBlue use an RF-based localization system (Lorincz, K., 2004), to track patients and caregiver's location. CodeBlue system was evaluated among 30-node testbed in term network metrics, like packet loss, fairness across multiple paths and so on. Based on that, the future work improvement in reliable communication, bandwidth limitation issues and security are suggested.

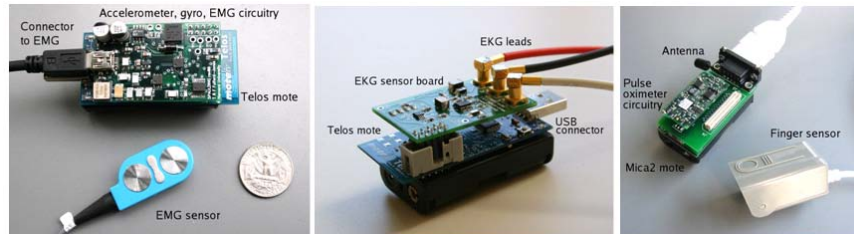


Fig. 6: Motion sensor (left), two leads ECG (middle) and pulse oximeter (right) (Shnayder, V., 2005).

HeartToGo:

HeartToGo is a cell phone-based personalized medicine technology as illustrate in Figure 7 below for Cardiovascular Disease (CVD), capable of performing continuous monitoring and recording of ECG in real time, generating individualized cardiac health summary report in layman's language, automatically detecting abnormal CVD conditions and classifying them at any place and anytime (Zhanpeng, J., 2009). The system applies an artificial neural network (ANN) based machine learning technique which combines individualized medical information and clinical ECG database data together, where it train cell phone to learn adapt to its user physiological environment to realize better ECG feature extraction and very accurate cardiovascular disease classification results. Various beat finding was performed for normal, premature ventricular expansion, sinus bradycardia, ventricular flutter and left branch beats. In addition, the statistics ECG report window was implemented such as average heart rate and number of detecting beats for each situation. The addition feature extraction discoveries will able reveal more diagnose signal condition, for example T wave and P wave locations and durations.



Fig. 7: HeartToGo Platform Prototype, in cooperation with a Microsoft Windows Mobile cell phone with a wearable 2-lead Alive Heart Activity Monitor and a built-in 3-axis accelerometer (Zhanpeng, J., 2009).

Aubade:

The usefulness measurement of an individual's by integrating various platforms is known as AUBADE (Katsis, C.D., 2006) system. The systems developed by researchers from University of Ioannina in Greece with the aim to evaluate an emotional state which is classified by vector feature extraction from facial electromyogram (EMG), respiration, ECG and electrodermal activity (ED). The system prototype contain of a mask with sixteen EMG textile fireproof sensors, a three lead ECG and respiration rate sensors where it locates on subject chest and textile sensor measuring electrodermal activity (or GSR or skin conductance activity) which place inside the glove. An individual's psychological condition is classified from a set of emotions by the 3-D facial representation mechanism as presented in Figure 8 below, and an intelligent emotion recognition module in real time. Importance finding has described that, motion artifacts or distortion can detect and body movement activity can classify by using a wearable ECG device system (Pawar, T. and S. Chaudhuri, 2007). The AUBADE system databases will acquire signals along with the subject's animation video is saved. The design system aimed to apply on human subjects, who operate under extreme stress situation or conditions such as in car racing driver, patients under suffering from neurological and psychological disorder. The system not

only can apply in multiple application fields but it is also an ergonomic, non-invasive, easy to wear and comfortable to use.

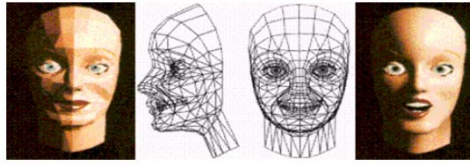


Fig. 8: The AUBADE system 3-D generic model of a user (Katsis, C.D., 2006).

BioHarness:

The BioHarness (Zephyr Inc., 2009) chest belt as showed in Figure 9 below is one of the current commercially available Zephyr products, which fabricated from smart sensor technology. It's wirelessly enabled system that used to observe ECG, skin temperature and activity, respiration rate. It is a comfortable and unobtrusive garment belt, which constructed with unique power consumption and Bluetooth technology. The system not only enables capture and transmission inclusive physiological data on the wearer via mobile and fixed data networks, but it also enabling actual remote monitoring of human performance and situation or status in the real world. The BioHarness system applied in many fields such as research, training and tele-health situations. The main advantage this system is offered diverse range of use sector, fast, accurate collection and analysis of high-quality and in-depth data. It also can be connected to any Smartphone.



Fig. 9: BioHarness chest belt (Zephyr Inc., 2009).

Challenges:

There are several challenges issue related to design and develop a WHMS was identified. Commonly, went mention a wearable healthcare system, the “wearable” term itself gives some general characteristic of a system that should meet the basic needs based on its identity. A wearable healthcare system implementation must meet the features of portability, easy to wear, minimum in size and light in weight. If the system is integrated with wireless sensor networks, so it must achieve the features of reliability, network efficiency, safety and privacy and validation. However, in reviewing some previous works there has been some frequently existing issue in this topic area.

The critical and most challenged issue in WHMS is the reliability of the system. It can be considered in three main stages of type. Stage one refers to reliability in data measurement, stage two regarding to reliability in data communication and third stage considered reliability in data analysis (Lee, H., 2008). The issue in stage one and three is more about hardware and software, in order to sensing and analysing data without any occurrence of errors. The second stage is more difficult and need more consideration compared with others two because, it related to wireless communication among sensor node and coordinator base station or central monitoring server. The reliable communication can realize by using a combination of wireless networks that count in WSNs, cellular networks, ad-hoc wireless networks, WLAN and satellite networks (Varshney, U., 2007). By using of retransmission protocol technique can fulfil the reliable data transmission (Juyng, J, and J. Lee, 2008), where an ACK (Acknowledgement) request and received within ACK wait duration between sensor device and coordinator is applied. On the other hand, compression algorithm technique was applied in wireless machine health monitoring for achieve much fast and reliable data transmission (Chan, J.C., P.W. Tse, 2009).

Second, the power related issues for the long life WSNs system is one of most significant challenge. Since, most of its devices based on battery operated, optimize power usage became one of its necessity criteria. PassiveRadio-frequency Identification (RFID) (Hande, A., 2007) is one of WSNs applications, which didn't require battery because it's using reader power. However, that system is limited in range of communication with small data size. Some recent applications, deployed Energy Harvest System (EHS) for WSNs like solar cell, wind fan (Qiu, J., 2011), vibration using piezoelectric devices (Roundy, S. and P.K. Wright, 2004), temperature difference (Stark, I., 2006), and shoes insert (Paradiso, J.A. and T. Starner, 2005). However, these EHS applications face some problems for real life WSNs applications such as power produce depends to environments and oversized. Rather than that, an energy-efficient Medium Access Control (MAC) protocols was designed to efficiently use energy in MAC protocols for WPMS application (Van Dam, T. and K. Langendoen, 2003; Zheng, T., 2005; Omeni, O.C., 2007; Ramakrishnan, S., 2004; Miller, M.J., N.H. Vaidya,

2005), and the sensor nodes standby or sleep mode periods are controlled to reduce energy consumption. Regarding to that, three major communication processes are proposed by they based MAC protocol operations such as link establishment process, wake-up service process and an alarm process. All that process only can be initiated by the master node.

Next, portability is another challenge requirement in WSNs environments. An integration of sensors sensing component in a WSNs must in small in size, light weight, functional, robust and low in cost. To achieve that, mostly for WPAN used a tiny chip system such as system on chip (SOC), which consists a microcontroller unit (MCU) with RF transceiver or single microcontroller with external transceiver. Recently, some biomedical system suits the needs of easy-wear or attach on body for monitoring physiological signals (Barth, A.T., 2009; Jung, J., 2008). Thus, a system assume have a good portability. Following that, the network interference issues are an important challenge in wireless settings. Commonly, wireless connection is very sensitive to interferences, compared with wired connection link. Generally, the WPAN and WLAN coexists use the similar Industrial, Science and Medical (ISM) band. As the results, they can cause to a network interference problem. The data collision or network interference problems lead to cause an intermittent network connection, packet loss and ultimately result in low network throughput and increased energy consumptions. Therefore, an interference and coexistence problems among Bluetooth and WLAN have presented (Jo, J.H., H. Jayant, 2003; Sakal, I., D. Simunic, 2003; Howitt, I., 2001; Feng, W., 2002). Furthermore, interference issues amongst IEEE 802.15.4/ZigBee and WLAN also illustrated (Kim, S.M., 2005; Kang, M.S., 2007; Yang, G., Y. Yu, 2009; Hauer, J., 2009). The Packet Error Rate (PER), Bit Error Rate(BER), Radio Signal Strength Indicator(RSSI) and Signal Interference Noise Ratio (SINR) for interference avoidance are measured and analysed.

Based on the above discussions, the challenge in WHMS and WSN is not limited. There are many challenges of features that were not covered completely which it may currently exist problems in the advancement process such as the complexity in the computation of algorithms for computer or software usage.

Limitations:

In relation to above section, some current researchers' project, prototype or commercial product in medical application for healthcare monitoring are well presented. Based on this reviews, there are plenty of design and development in attendance. Most of the applications are well adopted MCU as a control unit, indirectly achieves low power consumption, long life time and minimized the overall size of the devices. The power sources to operate these devices generally are from battery but different scales and type. Instance AAA, AA, and Li-ion. By that, the weight and size of the overall system are determined from those batteries, otherwise the size of devices is directly proportional to battery capacity. Different and variety types of battery was deployed in WHMS based on its device consumption and operation, such as two AA or two AAA batteries (Oliver, N., 2006; Gyselinckx, B., 2007; Milenkovic, A., 2006) and Li-ion or Li-P battery (Monton, E., 2008). The lifetime of small Li-P batteries is an approximately 6 hours and for AA or AAA battery's lifetime severing several days or to 3 months in full active mode. Therefore, the battery selection is an important decision and it can control or limits the features of design such as portability, power consumption and wearability in healthcare applications.

There are also versatile wireless infrastructures architecture and technology for health monitoring systems. Researchers and developers apply the Bluetooth technologies to WPMS with PDA (Chakravorty, R., 2006; Chien, J.R.C. and C.C. Tai, 2006), Cell phone or WLAN. On the other hand, the ZigBee technology is applied to BAN with PDA or WLAN extensive network size (Yau, C.L. and W.Y. Chung, 2007). Consequently, interference and data collision may occur by overlapped channels if several types of wireless infrastructures are used in a same network area. Different health data applications and different network topology must be considered for achieving better performance and efficiency of the system, such as star, peer-to-peer, and mesh network topology. This is not an easy job, but not impossible to design a system with better features, like the famous phrase says killing two birds with one stone. In previous discussions, there are some sums up of certain criteria, system and several wireless options in platforms for healthcare physiological data sensing and monitoring. Each prototype or product system has achieved some mentioned issue and features such as reliability, power, portability and network interference. All systems doesn't completely satisfy all listed features, but each every system has the certain advantages, such as some appliances have good reliability, portability, and Quality of Service (QoS) but the power usage is not suitable for real life application. Same goes to others system, whereas it has good performance, but too bulky in devices equipment. In FireFly project, the voice data can send continuously over real time, but have weight and big devices, poor power consumption, and small size network. All that issue and limitation have to highlight and considered, in the way find some solution and improve on these weak points for real life application with better advanced system.

Based on the discussion above, the limitation of this system operation overall not stop until what have been discussed. In future advancement of WSN, WHMS and other cooperative system limitation may identify and will discuss more briefly later in other papers.

Conclusion:

The paper reviewed the state-of-the-art in Wireless Wearable Health Monitoring System (WWHMS) which cooperated with Wireless Sensor Network (WSN). This system is very important, especially in the field of health monitoring which leads to better understanding about wireless technology and medical healthcare. By deploying such a system, it not only save our valuable time and cost of treatment, but prevent and protect us from chronic disease. Besides that, it spurs the technology advancement and novel invention which lead the world to a better and healthy lifestyle. There are many wireless technology standards and to choose which one is better, it totally depends on a system operation, system requirements and implementation entirely. The WHMS system design is based on the needs to fulfil specific and by choosing correct technique or method will reduce the common challenging issues and limitation. Normally, a system with optimum power consumption, small in size, light in weight, reliability, efficient operation and friendly user are more desired.

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