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Networking Aspects of Wireless Body Area Network

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Abstract—*The motivation for health monitoring system rises from the self-awareness that people ought to have of their physical activities and increase in chronic disease. As the worldwide population is growing and the area is becoming lesser, it has also become a challenge for the medical associates to take care of the patients by calling in the hospital and then personally checking them again and again. With the advancement in Micro electromechanical sensors (MEMS) technology this problem has got a solution by implementation of remote health monitoring system. Now, a person need not come to any hospital for regular checkups and can be taken care of at their residences with the help of Wireless Body Area Networks (WBAN). WBAN provides remote health monitoring. In this paper, we are going to present the types of body area networks, technique used for interoperability and their challenges*

Keywords*: MEMS; Sensors; WBAN; PAN; BAN; heterogeneous networks; coexistence.*

1. INTRODUCTION

The motivation for health monitoring system rises from the self-awareness that people ought to have of their physical activities. The other factors are the increase in chronic diseases. A report from Partnership for Solutions National Program Office (in 2004)[1] and a World Health Organization (WHO) report[2], [3] reveals the increase in the number of affected people. Another factor is population ageing. WHO[4] states that in 2008 the average life expectancy for the global population was 68 years with 80+ years in some developed countries (most European countries, Canada, Australia, Japan, New Zealand, etc.). And the last point relates to global projections of an increase in deaths related to cancer and heart diseases [5]. Other figures from WHO [6], [7] point to high Blood Pressure (BP) (leading cause), high blood glucose and physical inactivity as main attributable causes of mortality besides tobacco. In the same report, high BP and high blood glucose were in the top ten causes. Therefore to monitor and check the health issues WBANs were designed as an application to wireless sensor networks. WBAN consists of small, intelligent devices attached on or implanted in the body which are capable of establishing a wireless communication link. WBAN consists of wireless sensors which are attached to the human body and responsible for sensing, processing and communicating the physiological signal to the medical server for further analysis [8]. Sensors communicate to the medical server with the help of personal area networks/body area network (PAN/BAN) techniques, local area network (LAN) techniques and Wide Area Network (WAN) techniques. These wireless sensors, may be invasive or non invasive, are used for analyzing physiological changes in human body in a periodic manner. These devices have enabled our medical system to reach at different paradigm of health monitoring and in detection of life threatening events at quite an early stage [9]. In section 2 we will explore various existing wired as well as wireless body area networks. In section 3, we discuss different network architectures of WBAN. In Section 4, we review layered model for WBANs. We conclude in section 5 by stating a few open research issues.

2. BODY AREA NETWORK

Body area network consists of a sensing device and a network interfacing technique. Generally, the sensing device has sensors and actuators. The sensors are used to measure vital parameters of the human body. For example body temperature, electrocardiogram (ECG), electroencephalogram (EEG) etc. The actuators (or actors) on the other hand take some specific actions according to the data they receive from the sensors. For instance, the sensor senses the glucose level in the blood and the actuator manages to pump the correct dose of insulin to the patient. The network interfacing technique used in the device can be managed by a two or three tier heterogeneous network. The complete architecture of a three tier heterogeneous network is explained in section 3.

2.1. Existing body area networks

There are enormous BAN devices existing in the world. They are being used to monitor different health parameters for various applications and uses different network techniques. Such few devices are mentioned in table 1. The table fairly explains nine such devices for their networking methods used and physiological parameters monitored for different applied areas of human reach for an instance war field and space.

Among these nine mentioned devices eight devices use different wireless techniques for transmission of data ranging from PAN (Bluetooth and IEEE802.15.4) to WAN (Cellular devices). These devices generally give real time information about patient health. While the other device first stores the data and then the stored data is taken to the hospital in some sort of flash drive.

Table 1: BAN for health monitoring around the world

Sr. No.	Device Name	Networking method used	Parameters monitored
1	Smart Vest [10]	Wireless transmission geo-location of the wearer	Electrocardiogram (ECG), PPG, heart rate(HR), blood pressure(BP), body temperature (BTemp) and GSR
2	AMON [11]	Cellular connection to a medical centre	ECG, HR, BP, skin temperature for high-risk cardiac/respiratory patients
3	Life Guar [12]	Bluetooth	Monitor the health status of the astronauts in space
4	Smart Shirt, by The Georgia Tech [13]	Optical fibre communication	Soldier's vital signs-heart rate, temperature, respiration rate,
5	MagIC [14]	Wireless data transmission	Unobtrusive recording of cardio-respiratory and motion signals during daily life and in a clinical environment on cardiac patients
6	The WEALTHY [15]	mobile phone network GPRS transmitter	Monitoring of respiration, ECG, EMG, body posture and movement
7	Wearable health care system (knitted integrated sensors) [16]	A multi-channel, bidirectional and implantable bio-telemetric platform	For real time in-vivo monitoring of several physiological monitoring systems have been developed
8	The smart shirt [17]	IEEE 802.15.4 communication standard	ECG and acceleration signals
9	System based on 3G smart phone technologies [18]	Bluetooth technology and 3G mobile phone network	Continuous glucose monitoring

3. ARCHITECTURE OF WBAN

WBAN work in a three tier architecture as explained in Fig.1. In tier-1, we have the target area and the sensors. Here the inter-sensor communication is governed by PAN/BAN techniques like ZigBee, Bluetooth, IEEE802.15.4 standards, Bluetooth Low Energy and ANT etc. Tier-2 consists of local area network (LAN) for example Wi-Fi. Tier-3 includes Wide area network like GPRG, 3G and LTE technologies etc.

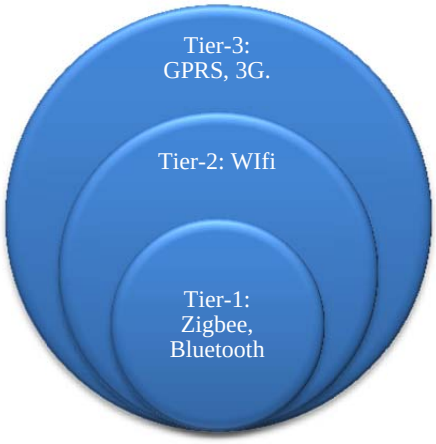

Fig. 1: Three Tier Structure of WBAN

Further, depending on the location of application , the architecture of the WBANs can also be classified as patient centers and hospital centered BANs. This classification model was given by IBM [19].

3.1. Patient Centered Body area networks

A patient-centered system uses three-tier architecture as shown in Fig. 2. First tier have body-worn or implanted sensors for physiological monitoring of multiple parameters; in tier 3 Hospital Information System (HIS) is present for storage and management of health data and in tier 2 a mobile device is used as a personal gateway between tier1 and tier3.

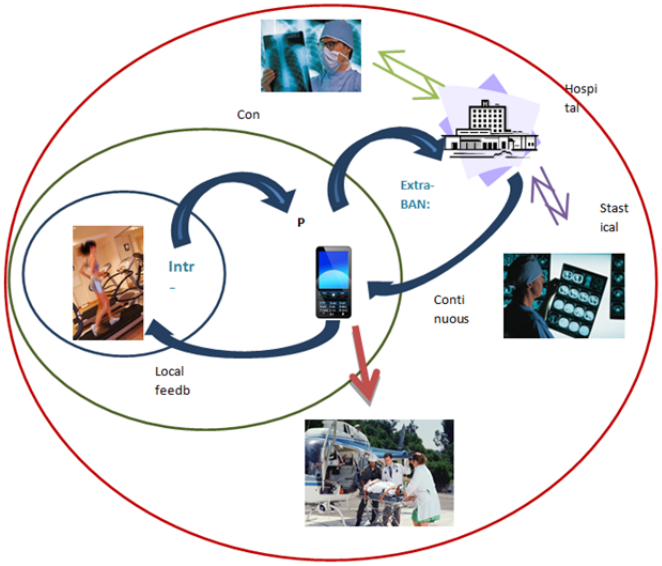

Fig. 2: Patient centered Body area sensor network [20]

3.2. Hospital Centered Body area networks

A hospital-centered system is designed to support medical professionals in carrying their usual activities in an easy way as depicted in Fig. 3. This system contributes to improve efficiency and productivity of care professionals by increasing data access, and is used as an instrument that can help reduce the number of medical errors [21]. Here, tier 1 consists of HIS, in tier two it has wifi module and in tier three RFID/Cellular systems which is present with the health care professional.

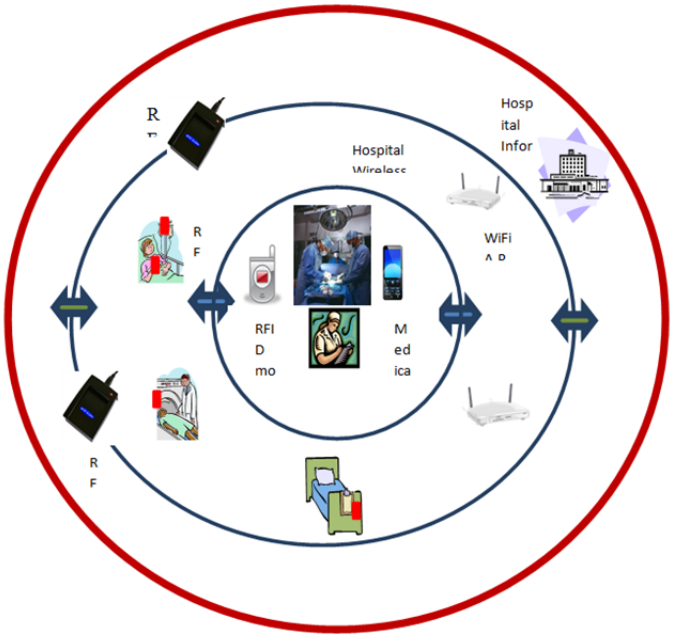

Fig. 3: Hospital centered Body area sensor network [21]

4. LAYERED STRUCTURE OF WBAN

WBAN follows its own five layered structure, which is named as ISO/IEEE 11073 (aka X73) [22], [23]. It is slightly different form that we have always used, the OSI layered model for networking devices. It proposes a set of standards corresponding to different layers of the protocol stack [21]. Specifically, it defines a general stack that matches the seven-layer ISO/OSI model by providing, for each layer, a set of sub-standards optimized for eHealth systems as shown in Fig. 4. Its lowest two layers (Physical layer and Transport and Physical Profiles & Networking support layers) provide interface and protocols to interact with all the PAN, LAN, and WAN technologies, used for communication in WBANs. Layer three and four are split into two categories. One is dedicated to medical device (MD) present in the hospital premises works with medical information bus (MIB). The second category is Personal Health Device (PHD) present with remote patient at home or office area uses the optimized Exchange Protocol to exchange data among Personal Health Devices. Finally, the fifth layer provides a common standard for MD and PHD for data models and format based on the Medical Device Data Language (MDDL), a common nomenclature, and the Domain Information Model (DIM) used to specify objects, attributes, events, and all that information that may be used to configure devices and exchange data.

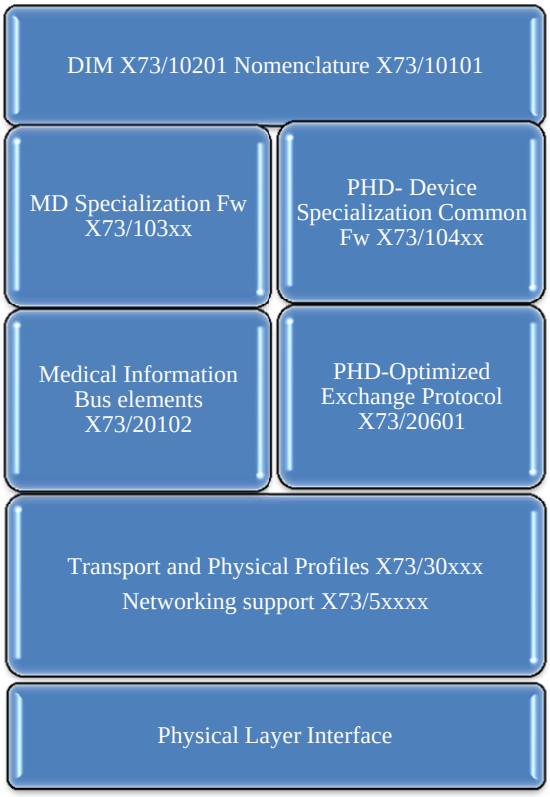

Fig. 4: Layered Models ISO/IEEE11073 std

5. CHALLENGES IN WBANS

WBAN is a very promising technique to raise the quality of human life expectancy. It is a continuously improving area of research and has much scope to improvise further. In this series of continuous improvement this paper presents the following areas of improvement and challenges in WBAN design.

5.1 Energy Efficiency

Energy consumption is crucial for the device which require long lifetime. Conventional methods used in WBAN for energy conservation includes use low-power processors for example MSP430, and low power consuming networking device for an instance ZigBee. Energy harvesting technique is the latest breakthrough in the energy conservation and generation for such wearable and hand held devices. In [24] a few power management and energy harvesting techniques are explained that include photovoltaic cells, mechanical vibrations and thermoelectric generators. Further work can be done on body temperature, body potential and breathing pressure as a source for energy harvesting.

5.2 Medium Access Control (MAC) protocols

Existing MAC protocols such as CSMA, CSMA/CD and CSMA/CA etc do not consider the heating issue in their routing decision metrics which is important for human safety. The second criterion is the link between nodes is assumed to be bidirectional while in fact; the link between nodes is likely to be unidirectional due to the node heterogeneity. To improve the MAC protocols for WBANs, these two aspects should be taken into account.

5.3 Heterogeneous Network Coexistence

While we are using the WBAN for metropolitan cities, it should be in a situation to configure itself to any existing network. As most of the available communication techniques for WBANs, are using ISM band's ultra wideband (UWB) spectrum, it causes issues for coexistence for various devices in the same pane, for an instance IEEE802.11 (Wi-Fi) and IEEE802.15.4 (backbone of ZigBee) standards uses 2.45GHz band for communication; it causes issues in terms of Bit error rate and channel interference. These issues need to be optimized. Work has to be done on interoperability among heterogeneous networks. Also Wi-Fi is an IP based network while ZigBee is not, so their connectivity needs a proper gateway [25].

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