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A Survey on Wireless Technologies for Biomedical Parameters

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Abstract: ***Wireless Sensor Networks (WSNs) are gaining popularity in our day-to-day lives because of its wide range of applications in health care monitoring, industrial applications, control networks, environmental sensing, etc. In this paper, we present a brief review on wireless technologies for choosing better, faster and reliable data transmission of medical parameters in health care monitoring systems of WSN. The sensors, which can be either wearable over body or implanted or embedded inside the body, help to monitor the health condition of a person in wireless body area networks (WBANs). WBAN assist in facilitating the on-demand services for patients at home (out-patients) and in clinic\hospital (in-patients), by providing the agile and better results of physiological status to nursing stations or monitoring sites with efficient utilization of wireless network technologies.***

Keywords: Healthcare, WSN, WPAN, WLAN, WMAN, WWAN

1. Introduction

Sensor is a device which allows us to detect the environmental parameters of any form of energy. Sensors provide output in the form of electrical or optical signal, whose values represent the changes or events in quantities of the environmental energy. Sensor applications include manufacturing and machinery, airplanes and aerospace, cars, medicine and robotics. Due to its diversified areas of applications, creating a network of sensors is essential to monitor and control the environmental parameters, for example, monitoring the temperature is necessary in theatres, school buildings, monitoring physiological status of human body, etc. Communicating with sensors within a network wirelessly reduces the complexity of wired networks and also wireless communication utilizes the frequency bandwidth efficiently [1]. The network of sensors constituently deploys Wireless Sensor Network (WSN).

The stable increase of elderly population in developed countries is one of the primary challenges currently being faced by world. As per Population Reference Bureau [2], it has been estimated that in coming 15 years, the population of age 65-and-over in developed countries will be approximately 20% of global population. Therefore the demand for delivering better health care for growing population of elder people is necessary while minimizing the costs included for health care systems [3]. Health care applications are evolving to newer heights within WSN technology. Integrating sensors with consumer electronics technology allow us to monitor elderly people, children, patients, etc. Biomedical parameters such as heart rate, electrocardiography (ECG), oxygen saturation, body temperature, etc, can be obtained by outfitting patients in hospital/clinic (in-patients) or patients away from hospital (out-patients) with tiny, wearable sensors either wired (Body Area Network (BAN)) or wireless (Wireless Body Area Networks (WBAN)) [4], which allow nurses, doctors and caretakers to monitor patient‟s physiological status continuously. The latest standard for WBANs is IEEE 802.15.6 [5] [6], which aims to provide low-power, short-range, reliable communication within the surrounding area of human body providing a broad range of data rates for various applications. During any emergency or calamity, this similar technology would provide medics to endeavor effectively towards huge numbers of casualties. Miniaturization trend allows developing smaller electronic devices so that these small sensor nodes provide a higher freedom of movement and grant doctors/nurses to diagnose predefined symptoms earlier [7].

Efficient utilization of wireless networks help in deploying faster, efficient health care monitoring system within BANs and WBANs. Depending upon geographic range [8] wireless networks are classified into 4 categories namely Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), and Wireless Wide Area Network (WWAN). Major wireless technologies involved in WPAN are Bluetooth Technology, ZigBee, and Ultra-Wideband (UWB). WLAN include IEEE 802.11 standards with Wi-Fi Alliance. WMAN constitutes IEEE 802.16 standards for Worldwide Interoperability for Microwave Access (WiMAX). And major WWANs are Global System for Mobile Communications (GSM), 2G (Second Generation), 3G (Third Generation), and 4G (Fourth Generation).

The details on design considerations involved in medical monitoring systems are given in section II. A brief review on the wireless networks, which can be implemented in either BANs or WBANs for health care monitoring systems, is provided in section III followed by conclusion.

2. Design Considerations

Current medical applications of WSN intent to advance the existing health care and monitoring services particularly for the children, elderly and chronically ill. In medical applications, the real-time is actually a soft real-time system, in which any latency is allowed [9]. Continuously monitoring health condition enables doctors or nurses or caregivers to identify emergency situations like sudden falls or heart

attacks in few minutes or even seconds is enough for saving lives, considering this special caregivers dependency will be minimized and without real-time systems it is not possible to identify these conditions. Hence, providing real-time monitoring and identification, and taking actions according to the situation are major benefits in pervasive healthcare systems.

In recent years, the demand for wireless sensor networks is growing at a rapid pace due to its wide range of application areas. This led the researchers to focus on functionality, definition and communication protocol standards for smart transducers. The IEEE and NIST have established IEEE 1451 set of standards for a Smart Transducer Interface for Sensors and Actuators in an effort to overcome the incompatibility problems that occur while interfacing smart transducers to controller devices, microprocessor-based systems, Fieldbus and control networks [10]. The key concept of these standards is to define an architecture that enables transducers to connect into any real-time distributed control network in a true „plug-and-play" manner, such that automatic system identification and configuration is aided.

In healthcare monitoring systems there are four other categories of characters are present other than developers and administrators. Those are Children, Elderly and chronically ill, Caregivers, and Healthcare professionals. These characters continuously communicates with WSN healthcare systems by utilizing different subsystems, these are 1. Body Area Network (BAN) – the sensors which are embedded or implanted on body constitute a network. 2. Personal Area Network (PAN) Subsystem – a network subsystem is created with using smart phone sensors, video sensors, and etc. 3. Gateway to the Wide Area Networks – for transmitting the data beyond hospitals or home (out-patients) for further processing and monitoring biomedical parameters by healthcare professionals or caregivers. 4. Wide Area Networks – for transmitting data across hospitals, cities, etc. 5. End-user healthcare monitoring application – caregivers or healthcare professionals get real-time physiological status of in-patients and out-patients to personal digital assistants (PDA), or smartphone. The design considerations of these subsystems in healthcare monitoring of WSN are provided in table 1 [3].

Table 1: Design Considertaions of healthcare monitoring systems

Subsystem	*Design consideration*
Body Area Network Subsystem	Power consumption, Transmission power, Unobtrusiveness, Portability, Real-time availability, Reliable communications, Multi-hop routing, Security
Personal Area Network Subsystem	Energy efficiency, Scalability, Self-organization between the nodes
Gateway to the Wide Area Networks	Security, Congestion prevention
Wide Area Networks	Data rate, Reliable communication protocols, Secure data transmission, Coverage
End-user healthcare monitoring Application	Privacy, Security, Reliability, User-friendliness, Middleware design, Scalability, Interoperability, Context-awareness

3. Review on Wireless Networks

Constant increase of wireless systems in healthcare applications, important corporate and academic resources is being conducted towards improvement of standards. Compelling advancement in issuing industrial standards has been formed by organizations, such as Institute of Electrical and Electronics Engineers (IEEE), Bluetooth Special Interest Group (SIG), International Organization for Standardization (ISO), American Society for Testing and Materials (ASTM), etc. For any wireless communication the necessity to use the limited frequency bandwidth efficiently depends on the range within which transmissions occur, number of bytes to be transferred and how often the transmission occurs, and life-time of the system.

Wireless links for accessing wireless networks are Terrestrial microwave, Communications satellites, Cellular and PCS systems , Radio and spread spectrum technologies, and Free-space optical communication. Wireless networks classified based on geographical range are categorized into WPAN, WLAN, WMAN, and WWAN. Wireless networks utilization in healthcare applications of WSN to monitor physiological status of children, elderly and chronically ill for both in-patients and out-patients are shown in Fig. 1. A brief review of these wireless networks is discussed below:

3.1 Wireless Personal Area Network (WPAN)

The major task in healthcare monitoring is to gather biomedical parameters such as ECG, oxygen saturation in blood, heart rate, etc. from the sensors which are either implanted inside the human body or wore over the body or embedded onto the body. WPANs are responsible for collecting the data from BAN due to its short range of data transmission and reception of approximately within 100 meters. WPANs constitute of ZigBee, Bluetooth, Infrared, Near Field Communication (NFC), and UWB. However infrared require exact line of sight with short range communication and NFC has the proximity of practical 4cm range. Connections made through WPAN require less or no infrastructure. This grants small, inexpensive and power efficient solutions to be implemented for a wide range of devices [11].

Bluetooth - Bluetooth is extensively used WPAN technology. IEEE 802.15.1 standard specifies the operation and architecture of Bluetooth devices, but the operation is concerned only for physical layer and medium access control (MAC) layer. The protocol layers and applications are standardized by Bluetooth SIG. Bluetooth Low Energy (BLE) is the latest version of Bluetooth i.e. V 4.0 and data rate is 24Mbits/s [4], [11], [12].

ZigBee - Compared to Bluetooth, ZigBee is less expensive than Bluetooth. ZigBee comes under Low-Rate Wireless Personal Area Networks (LRWPANs) with the ease of installation, efficient data transfer, extremely low cost, short-range operation, and a reasonable battery life while maintaining uncomplicated and flexible protocol. ZigBee provides raw data of 250 Kbits/s but is scalable down to sensor and automation needs of 20Kbits/s using wires communication [11], [13], [14].

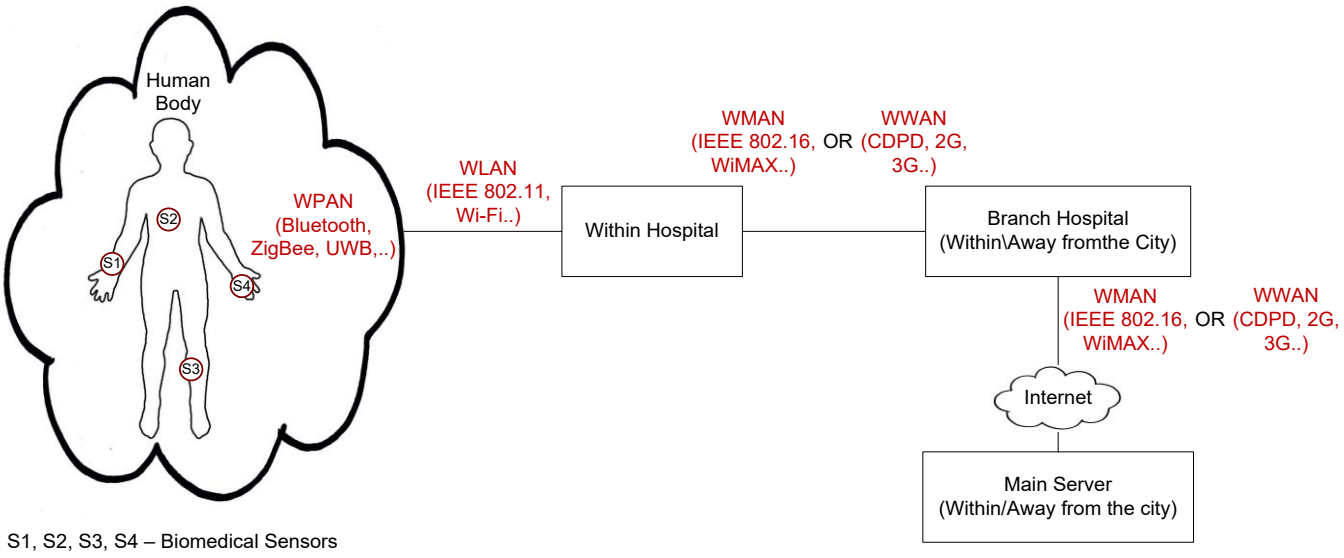

Figure 1: Wireless networks in medical applications

UWB - UWB is short-range high-speed wireless communication standard which has attracted much attention in recent years. Bandwidth of UWB is over 110Mbps (and up to 480 Mbps), which is sufficient for most of the multimedia applications, for e.g. delivering video and audio in home networking. UWB technology can also act as replacement for high speed serial bus such as USB 2.0. [4], [11], [15].

3.2 Wireless Local Area Network (WLAN)

WLAN allows users in local area, such as hospital, university or library to design a network or benefit connection to the internet. Once the physiological status of the patients is collected within BAN using WPAN, this data has to be sent to the doctors or nurses within a hospital, which requires transmission range of more than 100 meters hence WLANs allow us to transmit the data within hospital locality by providing higher range than short-range transmissions. Two standard bodies are mainly responsible for deploying WLANs [11], [14], [15], [16].

IEEE 802.11 – IEEE is a non-profit organization that implements actions to coordinate, produce and develop data networking standards. Vendors can produce compatible products according to IEEE 802.11 standards by the definition of mechanical process of how WLANs are implemented. This standard specifies key management, data confidentiality, access control, security association management and data integrity. Protocols developed by IEEE 802.11 physical (PHY) layer standards are 802.11-1997, 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac, and 802.11ad. The segment of radio frequency spectrum usage by 802.11 standards varies between countries [11], [17].

The Wi-Fi Alliance – This alliance certifies companies by assuring that their product pursue the 802.11 standards, thus allowing consumers to purchase WLAN products from various vendors without having to be worried about any compatibility problems. Transmission methods used in WLAN are Direct Sequence Spread Spectrum (DSSS), Orthogonal Frequency Division Multiplexing (OFDM), and Multiple Input Multiple Output (MIMO) [11], [14], [16].

3.3 Wireless Metropolitan Area Network (WMAN)

The biomedical parameters collected from the children, elderly or chronically ill people should be available to professional doctors within a city for providing better medication. WMAN establishes the connection between multiple networks in metropolitan area such as various buildings in a city. WMANs are an alternative or backup to laying fiber or copper cabling. IEEE 802.16 WiMAX is the major standard body responsible for implementing WMANs [11].

IEEE 802.16 WiMAX – Worldwide Interoperability for Microwave Access (WiMAX) is a wireless broadband standard that has high bandwidth over long-range transmission. WiMAX is a radio frequency technology that uses licensed and unlicensed bands to support wireless connections. In the line of sight, WiMAX can establish link distance of up to 50 kilometers and for non line of sight applications with speed up to 40 mbps per channel and a cell radius of up to 10 kilometers for portable and fixed access situations. This standard specifies the air interface, including the medium access control (MAC) and physical layers of Broadband Wireless Access (BWA). Orthogonal frequency-division multiplexing (OFDM) is the major development in PHY layer, in which multiple accesses is attained by assigning a subset of subcarriers to every user [17]. The data is divided into multiple parallel sub streams at a minimized data rate in OFDM, and each sub stream is modulated and transmitted on a isolated orthogonal sub carrier. By this way symbol duration increases and improves robustness [11], [14].

3.4 Wireless Wide Area Network (WWAN)

Patients who needs medication for more days than general patients for example patients in coma who may require more than a week or more than a month or even years to lead a normal life, for these kind of patients a database must be maintained at the main database server and should be updated on regular intervals of time. And this data should be made available to be monitored by professional doctors from

anywhere in the world. WWAN is a long-range communication that allows doctors and caregivers to monitor the patient's data by using cellular network data anywhere and also with the utilization of internet. WWANs establish connection over large areas, like cities or countries, via multiple satellite systems or antenna sites looked after by an Internet Service Provider (ISP). These systems are referred to as 2G systems. These networks require high cost to deployment since they cover a large geographical area. WWANs include mobile telecommunication cellular networks such as Long Term Evolution (LTE), GSM, CDMA 2000, cellular digital packet data (CDPD) and Mobitex to transfer data[11],[14],[18].

CDPD – Cellular Digital Packet Data (CDPD) technique is used for transmitting small units of data, called as packets, over the cellular network in stable manner. This technique allows sending and receiving data from anywhere and anytime within cellular coverage area quickly and reliably. It provides pervasive, high capacity, high speed, cost effective services to mobile users. Even voice can also be transmitted over existing cellular channels. To efficiently combine voice and data traffic on the cellular system without degrading the level of service maintained to the voice customer, CDPD network implements channel hopping technique [11].

2G – GSM belongs to 2G mobile systems. First GSM I standard was developed in 1992 and it provided voice and basic data services, for e.g. short-message- service (SMS), multi media messages (MMS). Most GSM networks operate in the 900 MHz or 1800 MHz bands. Maximum bit rate of 9.6kbit/s can be achieved by GSM systems. General Packet Radio Service (GPRS) belongs to 2.5G mobile systems. In GPRS the transfer medium can be shared by several users at the same time. Bit rate of 80kbit/s is reached in GPRS. Enhanced Data rates for GSM Evolution (EDGE) is part of 2.75 generation of mobile systems. EDGE offers various improvements which allow reaching high values of bit rate and bandwidth efficiency. EDGE system provides bit rate of 200kbit/s for downlink direction and 10kbit/s for uplink direction [11], [14], [19].

3G – Universal Mobile Telecommunication System (UMTS) is a system of third generation of mobile services, which establish voice communications and high-speed data connectivity, including access to the Internet, mobile data applications, and multimedia content. International Telecommunications Union (ITU), together with industry-standards groups from over the world, has specified the technical requirements and standards also the spectrum for 3G systems under the International Mobile Telecommunications-2000 (IMT-2000) program. High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) belong to 3.5 and 3.75 generation of mobile systems respectively. HSDPA possessing bitrates of 2Mbit/s for downlink and 384kbit/s for uplink direction and HSUPA allows sending data at a bit rate of 1.45Mbit/s for the uplink direction [11], [14], [19].

4G – Fourth generation of mobile telecommunication technology provides mobile broadband internet access to wireless modems, smartphones, and also to other mobile systems. International Mobile Telecommunications Advanced (IMT-Advanced) specifications are used for 4G standards. Theoretical downlink speed is between 100Mbit/s to 1Gbits/s for mobile and fixed transmission and uplink speed is 60Mbit/s [11].

Comparison between types of wireless networks in terms of transmission range, performance, speed, applications [11], is given in Table 2.

Table 2: Comparison between wireless networks

Type	*Technologies*	*Range*	*Performance*	*Speed*	*Applications*
WPAN	Bluetooth, ZigBee, UWB, Infrared	Less than100 m	Moderate	< 1Mbps	Cable replacement for peripherals
WLAN	Wi-Fi	Up to 1 km (Within a building)	High	11 to 54Mbps	Wireless extension of wired network
WMAN	WiMAX	1km to 10 km (Within a city)	High	11 to 100+ Mbps	Wireless inter-network connectivity
WWAN	CDPD, LTE, 2G, 3G, 4G	More than 25 km (Worldwide)	Moderate	10 to 384 Kbps, 1.8, 3.6-7.2 Mbps	Wireless network access

4. Conclusion

This paper reviews the types of wireless networks such as WPANs, WLANs, WMANs, and WWANs which can be utilized efficiently for health care monitoring systems in WSNs. By choosing the appropriate wireless network type for the specific application, deployment cost can be minimized and also challenges related to wireless data transmission are also reduced. Depending upon the transmission range, speed, deployment cost, and power consumption, any efficient and reliable network can be selected. The need for wireless technology in medical applications is anticipated to become more substantial with growth in deployment of mobile devices and wireless networks.

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