A Study on Characterization and Challenges for Body Area Network

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Abstract – Body Area Network is the critical real time network in which sensors are attached in or on body to observe the patient health information. This smaller network form is defined with hybrid constraints in terms of sensor types, communication type and application type. In this paper, a study on WBAN network is provided under different aspects. The paper has identified the requirements and challenges associated to the network. The work also explored the WBAN network for patient monitoring along with placement of nodes in the network respective to different organs. The role of sensors and monitoring effect is also discussed in this paper.

Index Terms – WBAN, Hybrid Communication, Real-Time, Infrastructure Driven.

1. INTRODUCTION

WBAN demonstrates an intelligent and autonomous system for monitoring the activities of a person. It is a Smart network which offers promising and significant services in advanced application fields like research, business, industrial, defense, and viable lifestyles. A WBAN is consists of various type of low power sensor devices in the human centric network to serve a variety of applications including healthcare, personal entertainment, advance sports training, live events, aviation, special forces (i.e. military, air force, fire fighters, terrorist trackers, bomb diffusers, astronaut monitoring etc.), disasters, consumer electronics devices. WBAN provides a way to remotely monitor human vital signs, movements, activities using an intranet or an internet which save a lot of money. Now a day's demand of wearable wireless devices in each and every application is grown, and they need to fulfill reliability, security, fault assurance and quality of service aspect. Till now WBAN is not able to satisfy these requirements due to its dynamic topology, time-varying wireless channel, variation in channel bandwidth, limited resources like battery, processors and memory.

A Wireless Body Area Network consists of small, intelligent devices attached on or implanted in the body which are capable of establishing a wireless communication link. These devices provide continuous health monitoring and real-time feedback to the user or medical personnel. Furthermore, the measurements can be recorded over a longer period of time, improving the quality of the measured data

Two types of devices can be distinguished: sensors and actuators. The sensors are used to measure certain parameters of the human body, either externally or internally. Examples include measuring the heartbeat, body temperature or recording a prolonged electrocardiogram (ECG). The actuators (or actors) on the other hand take some specific actions according to the data they receive from the sensors or through interaction with the user.

In order to realize communication between devices, techniques from Wireless Sensor Networks(WSNs) and ad hoc networks could be used. However, because of the typical properties of a WBAN, current protocols designed for these networks are not always well suited to support a WBAN. The following illustrates the differences between a Wireless Sensor Network and a Wireless Body Area Network:

- The devices used have limited energy resources available as they have a very small form factor (often less than 1 cm3 [10]). Furthermore, for most devices it is impossible to recharge or change the batteries although a long lifetime of the device is wanted (upto several years or even decades for implanted devices). Hence, the energy resources and consequently the computational power and available memory of such devices will be limited
- All devices are equally important and devices are only added when they are needed for an application(i.e. no redundant devices are available)
- An extremely low transmit power per node is needed to minimize interference and to cope with health concerns
- The propagation of the waves takes place in or on a (very) lossy medium, the human body. As a result ,the

waves are attenuated considerably before they reach the receiver

- The devices are located on the human body that can be in motion. WBANs should therefore be robust against frequent changes in the network topology
- The data mostly consists of medical information. Hence, high reliability and low delay is required
- Stringent security mechanisms are required in order to ensure the strictly private and confidential character of the medical data
- And finally the devices are often very heterogeneous may have very different demands or may require different resources of the network in terms of data rates, power consumption and reliability.

When referring to a WBAN where each node comprises a biosensor or a medical device with sensing unit ,some researchers use the name Body Area Sensor Network (BASN) or in short Body Sensor Network (BSN) instead of WBAN. These networks are very similar to each other and share the same challenges and properties. In the following, we will use the term WBAN which is also the one used by the IEEE

In this paper, a study on WBAN network is provided under different associated aspects. The paper has explored the requirement and challenges to the WBAN network. In this section, the exploration to WBAN network is provided along with application requirement. In section II, the work defined by earlier researchers is presented. In section III, the Positioning of sensor nodes in patient monitoring system is provided along with identification of associated challenges. In section IV, the conclusion of work is presented.

2. RELATED WORK

Samaneh Movassaghi[1] has defined a survey based work on Body area network. Author explored the Aim of WBAN. In this paper, Author survey the current state-of-art of WBANs based on the latest standards and publications. Open issues and challenges within each area are also explored as a source of inspiration towards future developments in WBANs. Aung Aung Phyo Wai[2] has presented a work on reliability enhancement under visualization system for body area network. Author designed and developed a testbed with integrated hardware and software solution aiming to enhance data reliability and provide performance visualization of WBAN. In this demo, Author showcase Presented current works of improved hardware platform design and development, on-body wireless channel modeling and empirical network profiling, energy-efficient and reliable routing protocol, motion-aware reliability enhancement scheme and visualization of real-time WBAN operations. Zahoor Khan[3] presented a work on QoS aware peering for routing protocol in delay sensitive data in Body area network. In this paper a routing protocol is proposed by considering the Quality of Service requirements of the body area network data packets. The proposed algorithm provides better performance than other QoS-aware routing protocols in terms of higher successful transmission rates, lower overall network traffic load, and fewer number of packet timeouts in both the mobile and static patient scenarios.

Jocelyne Elias[4] has defined a topology based energy aware communication in Body area network. This work investigates the optimal design of wireless body area networks by studying the joint data routing and relay positioning problem in a WBAN, in order to increase the network lifetime. Author solve the proposed model in realistic WBAN scenarios, and discuss the effect of different parameters on the characteristics of the planned networks. Numerical results demonstrate that Presented model can design energy-efficient and cost-effective wireless body area networks in a very short computing time, thus representing an interesting framework for the WBAN planning problem. Hassine Moungla[5] has defined a Min-Max based approach for commodity flow model under dynamic topology generation. In this paper, Author propose a Min-Max multi-commodity flow model for WBSNs which allows to prevent sensor node saturation and take best action against reliability and the path loss, by imposing an equilibrium use of sensors during the routing process. Simulation results show that the algorithm balances the energy consumption of nodes effectively and maximize the network lifetime.

Christian H. W. Oey[6] defined an energy aware routing approach for Wireless Body area network. In this paper, Author introduce the issues in the design of energy-aware routing protocols in WBANs and review the existing protocols. The comparative discussion of the protocols and their perspectives are also covered. N. Javaid[7] has presented a measurement analysis for fatigue of soldiers using body area network. In this paper, Author propose a routing protocol for measuring fatigue of a soldier. Three sensors are attached to soldier's body that monitor specific parameters. Presented proposed protocol is an event driven protocol and takes three scenarios for measuring the fatigue of a soldier. Author evaluate Presented proposed work in terms of network lifetime, throughput, remaining energy of sensors and fatigue of a soldier.

Md. Tanvir Ishtaique ul Huque[8] has defined an energy adaptive routing approach under body area network. In this paper, Author propose an energy efficient cluster based routing protocol for WBANs, named as energy efficient adaptive routing in wireless body area network (EARBAN). Although EAR-BAN is a cluster based routing protocol, it also combines the benefits of direct and multi hop transmission methods, depending on the energy level and spatial information of body nodes, to formalize an energy efficient, adaptive and opportunistic routing. Muhannad Quwaider[9] has presented a physical context detection approach for wireless sensor network. This paper presents the architecture of a wearable sensor network and a Hidden Markov Model (HMM) processing framework for stochastic identification of body postures and physical contexts. The key idea is to collect multi-modal sensor data from strategically placed wireless sensors over a human subject's body segments, and to process that using HMM in order to identify the subject's instantaneous physical context. Lu Shi[10] has presented an authentication system under channel characteristics exploration for body area network. Author propose a lightweight body area network authentication scheme (BANA) that does not depend on prior-trust among the nodes and can be efficiently realized on commercial off-the-shelf low-end sensor devices. This is achieved by exploiting physical layer characteristics unique to a BAN, namely, the distinct re- ceived signal strength (RSS) variation behaviors between an on-body communication channel and an off-body channel. Presented main finding is that the latter is more unpredictable over time, especially under various body motion scenarios. Benoit Latre[11] has presented survey based work for body area network. This paper offers a survey of the concept of Wireless Body Area Networks. First, Author focus on some applications with special interest in patient monitoring. Then the communication in a WBAN and its positioning between the different technologies is discussed. An overview of the current research on the physical layer, existing MAC and network protocols is given. Further, cross layer and quality of service is discussed. JeongGil Ko[12] has defined a work health care system under sensor network. In this review, Author present some representative applications in the healthcare domain and describe the challenges they introduce to wireless sensor networks due to the required level of trustworthiness and the need to ensure the privacy and security ofmedical data. These challenges are exacerbated by the resource scarcity that is inherent with wireless sensor network platforms. Subir Biswas[13] has defined protocol and application specification approach for body area network. This paper provided a formulation of the network protocol-centric problems specific to Wireless Body Area Networks. It will also present a number of specific protocol level solutions for: 1) Transmission Power Assignment with Postural Position Inference for On-body Wireless Communication Links, 2) Probabilistic Routing in On-body Sensor Networks with Postural Disconnections, and 3) Physical Context Detection using Wearable Wireless Sensor Networks.

3. PATIENT MONITORING

The main cause of death in the world is Cardio Vascular Disease (CVD), representing 30% of all global deaths. According to the World Health Organization, worldwide about 17.5 million people die of heart attacks or strokes each year; in 2015, almost 20 million people will die from CVD. These deaths can often be prevented with proper health care. Worldwide, more than 246 million people suffer from diabetes, a number that is expected to rise to 380 million by 2025. Frequent monitoring enables proper dosing and reduces the risk of fainting and in later life blindness, loss of circulation and other complications .These two examples already illustrate the need for continuous monitoring and the usefulness of WBANs.

Numerous other examples of diseases would benefit from continuous or prolonged monitoring, such as hypertension, asthma, Alzheimer's disease, Parkinson's disease,renal failure, post-operative monitoring, stress-monitoring. An example of a medical WBAN used for patient monitoring is shown in Figure 1. Several sensors are placed in clothes, directly on the body or under the skin of a person and measure the temperature, blood pressure, heart rate, ECG, EEG, respiration rate, SpO2-levels etc. Next to sensing devices, the patient has actuators which act as drug delivery systems. The medicine can be delivered on predetermined moments, triggered by an external source (i.e. a doctor who analyzes the data) or immediately when a sensor notices a problem. Example of an actuator is a spinal cord stimulator implanted in the body for long-term pain relief.

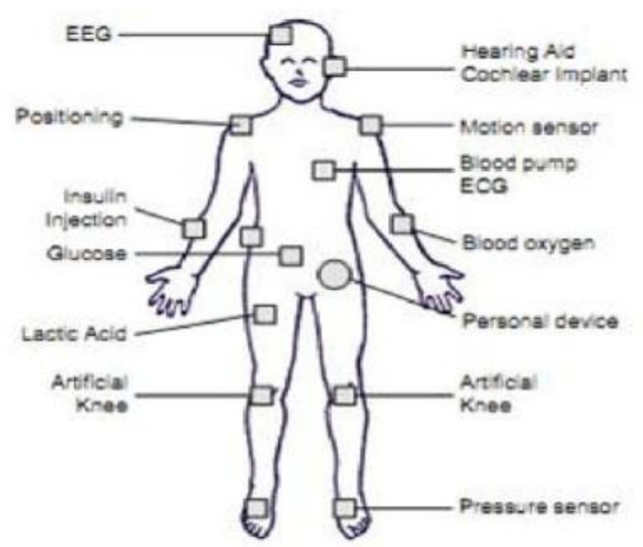

Fig. 1 Example of patient monitoring in a Wireless Body Area Network

Positioning in WBAN

In literature, protocols developed for WBANs can span from communication between the sensors on the body to communication from a body node to a data center connected to the Internet. In order to have clear understanding, we propose the following definitions: intra-body communication and extra-body communication. An example is shown on Figure 2. The former controls the information handling on the body between the sensors or actuators and the personal device the latter ensures communication between the personal device and an external network.

Challenges	Wireless Body Area Network
Scale	Human body (centimeters / meters)
Node Number	Fewer, limited in space
Result Accuracy	Through node accuracy and robustness
Node Task	Node performs multiple tasks
Node Size	Small is essential
Network Topology	More variable due to body movement
Data Rates	Most often heterogeneous
Node Replacement	Replacement of implanted nodes difficult
Node Lifetime	Several years / months, smaller battery capacity
Power Supply	Inaccessible and difficult to replaced in an implantable setting
Power Demand	Likely to be lower, energy supply more difficult
Energy Scavenging Source	Most likely motion (vibration) and thermal (body heat)
Biocompatibility	A must for implants and some external sensors
Security Level	Higher, to protect patient information
Impact Of Data Loss	More significant, may require additional measures to ensure QoS and real-time data delivery.
Wireless Technology	Low power technology required

TABLE 1: Charactersitics of WBAN

Doing so, the medical data from the patient at home can be consulted by a physician or stored in a medical database. This segmentation is similar to a multi-tiered telemedicine system is presented. Tier 1 encompasses the intra-body communication, tier 2 the extra-body communication between the personal device and the Internet and tier 3 represents the extra-body communication from the Internet to the medical server. The combination of intra-body and extra-body communication can be seen as an enabler for ubiquitous health care service provisioning. An example can be found in where Utility Grid Computing is combined with a WBAN. Doing so, the data extracted from the WBAN is sent to the grid that provides access to appropriate computational services with high bandwidth and to a large collection of distributed time-varying resources.

In Figure 3, a WBAN is compared with other types of wireless networks, such as Wireless Personal (WPAN),Wireless Local (WLAN),Wireless Metropolitan (WMAN) and Wide Area Networks (WAN). A WBAN is operated close to the human body and its communication range will be restricted to a few meters, with typical values around 1-2 meters. While a WBAN is devoted to interconnection of one person's wearable devices, a WPAN is a network in the environment around the person.

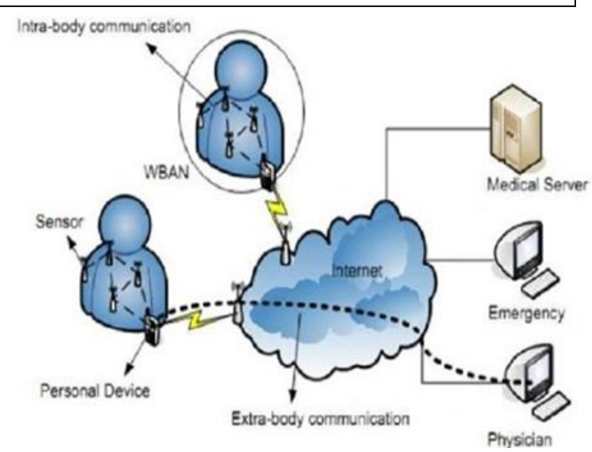

Fig. 2 Example of intra-body and extra-body communication in WBAN

The communication range can reach up to 10 meters for high data rate applications and up to several dozens of meters for low data rate applications. A WLAN has a typical communication range up to hundreds of meters. Each type of network has its typical enabling technology, defined by the IEEE. A WPAN uses IEEE 802.15.1 (Bluetooth) or IEEE 802.15.4 (Zig-Bee), a WLAN uses IEEE 802.11(Wi-Fi) and

WMAN IEEE 802.16 (WiMax). The communication in a WAN can be established via satellite links.

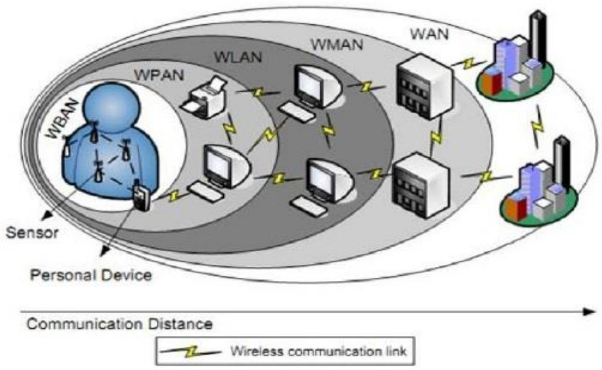

Fig. 3 Positioning of a Wireless Body Area Network in the realm of Wireless Network

4. CONCLUSION

In this paper, a study on WBAN network is provided under different integrated aspects and in relation to the patient monitoring. The paper has explored the application requirement and the architectural formation of the network. The paper identified the scope and requirement of WBAN network in association to relative challenges.

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