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STUDY OF TOOLS AND TECHNOLOGY FOR WIRELESS BODY NETWORK

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***Abstract*— Wireless Body Area Network(WBAN) is a novel promising sub-field of wireless sensor network. A key application of Wireless Body Area Network is health monitoring. Wireless sensors are placed on the human body or implanted in the body to observe essential signs like blood pressure, body temperature, heart rate, glucose level etc. Use of Wireless Body Area Network technology to monitor health parameters significantly reduces the expenditures of patient in hospital. In this paper we study the different tools and techniques which are useful in wireless body area network.**

***Index Terms*— BAN, WSN, HBC, BLE.**

I. INTRODUCTION

BANs evolved from generic networks referred to as wireless sensor networks (WSNs), which belongs to a big network family known as PAN. BAN however may be described as a set of nodes that can be used to sense, actuate, compute and communicate in a multi-hub wireless channel with each other. BAN's operation around the human body allows it to be used to collect, process and store physiological, activity and environmental parameters from the host's body and it's immediate surroundings. The operation of BAN is not limited to only the outside of the human body. It can be used to implant in order to perform specific tasks.

The development of BAN became necessary since the existing low power and short- range standards such as PAN could not fulfil some of the requirements for medical applications. BAN standards are to support a combination of reliability, QoS, low power, data rate and must be non-interference. The proposed data rate for BAN is up to 10Mbps and it is to use existing industrial scientific medical bands or any frequency band approved by national medical and regulatory authority.

A. Architecture of BAN

The architectures of BAN can be summarized in the following categories:

- Hardware
- Network topology
- Communication technology
- Software
- Deployment
- Physical environment
- Energy source

BAN is a network of computing nodes that are used to perform operations to aid monitoring and actuation application in healthcare. BAN is not only applicable in healthcare but also in performance monitoring in sports and providing feedback in military and leisure applications.

B. The Hardware

The IEEE TG6 recommended and approved hardware components for BAN are as follows:

- A general purpose sensor (humidity, temperature and light)
- A medical device (pulse-oximeter)
- A data collector or aggregator (image collector)
- A controller or tuner (infusion-pump) and
- An access point or a gateway (smart phone)

A lot of platforms for sensing and processing specific signals have been developed.

II. TOOLS AND TECHNIQUES FOR WBAN

A. IEEE 802.15.6

The IEEE 802.15.6 is a standard developed specifically for WBANs [3]. The standard was released in February 2012. It addresses a broad range of applications in three separate frequency bands with separate physical layers (PHYs).

1. Narrowband (NB) PHY: It supports frequency bands ranging from 402-405 MHz, 420-450 MHz, 863-870 MHz, 902-928 MHz, 950-958 MHz, 2360-2400 MHz and 2400-2483.5 MHz. Some of these frequency bands may face coexistence issues with IEEE 802.15.4 (Low Power PANs), IEEE 802.11 (WIFI) etc.

2. Ultra-wideband (UWB) PHY: The UWB is divided into two frequency bands. The low band from 3.25-4.75 GHz and a high band from 6.6-10.25 GHz.

3. Human Body communication (HBC) PHY: The human body or the skin is used as a communication medium unlike the other two, in which, air is the communication medium. The HBC PHY has a central frequency of 21MHz with a bandwidth of 5.25MHz.

Some of the features of the IEEE 802.15.6 are discussed here. In 802.15.6, varied bit rates are supported with a range of 3m for the operation for on body network. The network topology supported is a star with a maximum of two-hops in a tree network. There is a single Medium Access Control (MAC) for all the three PHY layers which means it is very flexible and combines many access techniques. The MAC also provides 3 levels of security. The maximum possible achievable data rate is 10Mbps. IEEE802.15.6 standard is an extremely low power and reliable design which addresses all the WBAN requirements such as, emergency response, support for numerous sensors, sensitivity of the antenna to the human body, radiation patterns shaping to minimize the specific absorption rate(SAR) into the human body, considerations for the user's motion etc.

Unfortunately there was no hardware development board for IEEE 802.15.6 on the market and so the pursuit of this protocol for the thesis project had to be stopped. It would be interesting to find out why no silicon chip manufacturing company has invested in the IEEE 802.15.6 WBAN protocol. Although no hardware is currently available, it would be interesting to briefly study the differences and similarities with other protocols, which makes the future migration of the thesis project concepts to 802.15.6 easy.

B. Human Body communication

Human body communication (HBC) is a technology which uses the human body as a transmission medium for electrical signals. It has several other descriptive synonyms such as, Intra body communication, Body channel communication, Body-coupled communication etc. In HBC, by the methods of near-field communication, data can be exchanged between two devices on the human skin by capacitive or galvanic coupling of pico amp currents on the surface of the human body. Most of the energy remains in the skin without radiation into the environment and this makes the communication possible with low power, low frequency signals. There are two main coupling techniques which have been researched: Galvanic coupling and capacitive coupling.

In Galvanic coupling, there are two transmitting electrodes and two receiving electrodes attached to the skin. A differential signal is applied to the transmitting electrodes which induces the propagation of a very small galvanic current in the conductive body tissue. The receiving electrodes detect the differential signal and receive the data. This approach utilizes the dielectric characteristics of the human tissue which behaves like a transmission line for data. Since there is no external ground involved, galvanic coupling is independent of the environment.

In capacitive coupling, one of the two transmitting electrodes is attached to the skin while the other is kept floating. The electrodes for the receiver are also arranged in the same way. When the transmitter sends data by generating electric potential, inducing an electric field in the body, the receiver detects the change in electric potential and is able to receive the data sent by the transmitter [4]. The set of floating electrodes are coupled to the ground through air creating a return path, while the pair of electrodes connected to the skin create a forward path for the data signals [5]. Since there is an external path included in capacitive coupling, it is sensitive to the interference from the environment.

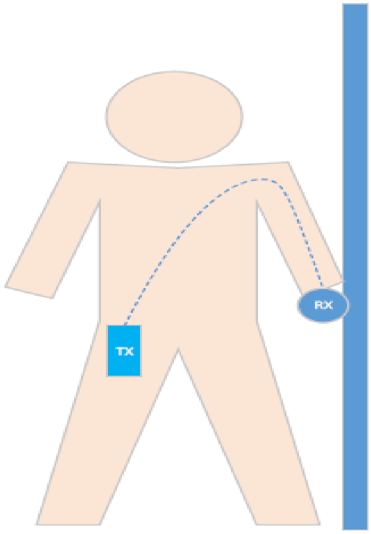

Figure 1: HBC technology used for access control with a pocket device as a transmitter (TX) and the door knob containing a receiver (RX)

As shown in Figure 1, HBC technology is being used for access control to a room. Here the person contains an active tag in the form of a transmitter which may lie inside the pocket of the person's garments. When the person touches the doorknob, the receiver in the door knob receives a signal. The receiver verifies that the person has access to the room behind the door and unlocks the door.

This technology is highly suitable for a wireless low power patient monitoring system that avoids RF interference that generally occur in transmission through air. Philips ADA project, EU Project eGo, Ericsson "Connected me" project, Microchip Body com technology, NTT's Red Tacton and the Swiss National Advisory Commission on Biomedical Ethics NEK-CNE1 – Galvanic coupling measurement system are some projects that have utilized this technology. Of all the above projects, Microchip's Bodycom technology was a readily available development kit which could be purchased, but these kits were now obsolete and out of production (In May 2016). There was no commercial hardware development or evaluation board available on the market and so the pursuit of the human body communication technology was stopped.

C. Bluetooth Low Energy

In June 2010, the Bluetooth SIG introduced Bluetooth Low Energy with version 4.0 of the Bluetooth Core Specification and Bluetooth 4.2, was released in December

2014. Bluetooth low energy wireless technology is a well-known short range communication protocol specialised for lower power, transmission range of up to 30m and lower cost. There are multiple devices, development boards, sensors, evaluation kits etc. on the market with the Bluetooth low power technology which can be bought commercially. BLE operates in the 2.4GHz ISM band which is divided into 40 channels or 2MHz each. The PHY modulation is Gaussian frequency shift keying (GFSK) and the bit rate supported is 1 Mbps. BLE supports only star topologies. BLE allocates two types of channels for operation: The advertisement channel and the data channel. For advertising, three channels are allocated for discovering nodes, associating with the nodes and for broadcasting data. For the data channel, the master node decides the time and sequence of the channel hopping procedures in the rest of the 37 channels. Channel hopping makes this protocol robust with respect to interference [6]. BLE also offers various security services for protecting wireless information exchange.

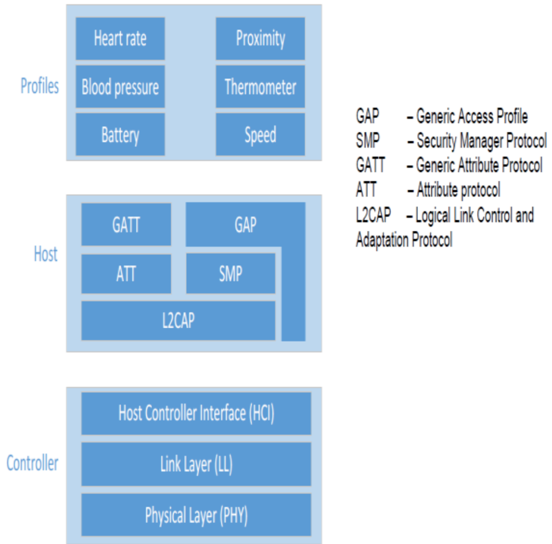

Figure 2: BLE protocol stack description

The Figure 2 is a figurative description of the Bluetooth protocol stack. There are three main building blocks in the BLE stack, mainly the user application consisting of several profiles which interfaces with the BLE stack, the host which constitutes the upper layers of the BLE stack and the controller which constitutes the lower layers of the BLE stack. All devices have either one of the roles: Central device which has more power and processing power and the peripheral device which is small, low power and resource constrained typically sensor end nodes. In BLE, the peripheral device advertises itself on every channel to find a central node in the vicinity by using the GAP services which are responsible for advertising and establishing a connection with a central node. Once the connection is established, GATT services and characteristics can be used to exchange data in both directions. The BLE technology is very low power but only supports a star topology, it is not optimized for a WBAN and was intended to be used for low power and low rate PANs while WBANs can have high bit rate requirements for sensors over 1Mbps for applications such as, ECG, Video streaming, and EMG.

D. IEEE 802.15.4 - Low Rate Wireless Personal Area Network

The IEEE 802.15.4 standard was released in 2003 and has seen several updates since then. It is the one of the most wide spread technologies for wireless sensor networks. It is a competitor for Bluetooth (IEEE 802.15.1) and is a low power, low complexity, low cost and low rate protocol for PANs. IEEE 802.15.4 only defines a PHY and a MAC layer. The rest of the upper layers can be user defined. Due to this feature, there have been several branches of wireless standards developed over the IEEE 802.15.4 such as, Zigbee, 6LowPAN, IEEE 802.15.4j etc.

IEEE 802.15.4 is a short range technology with a range of up to 100m [7]. In Zigbee, the network topologies supported are star, tree and mesh, the network layer is implemented on top of the IEEE802.15.4 MAC layer. IEEE 802.15.4 has multiple PHYs defined for a variety of frequency bands such as, 868 – 868.6MHz, 902 – 928MHz, 2400 – 2483.5 MHz, and more. It defines a total of 27 half duplex channels across three frequency bands: The 868MHz band has a single channel with a bit rate of 20kbps, The 915 MHz band has 10 channels with a bit rate of 40kbps and the 2400 MHz band with a bit rate of 250kbps. Modulation used in the PHY is Offset Quadrature Phase Shift Keying O-QPSK with a symbol rate of 62.5k symbols/s.

There are two types of roles for the devices: Full functional device (FFD) which has higher power supply and has a higher processing power and a reduced functional device (RFD) which is typically an end node with low power and resource constraints. At the MAC layer there are two possible channel access modes namely the Beacon Enabled mode and the Non-Beacon-enabled mode. In the Beacon mode, the FFD or the coordinator periodically emits beacons or packets with information about the network and about how to connect to the coordinator. End devices can follow specific association protocols to associate with the FFD and then send or receive data from the FFD in the contention free period (CFP) using slotted guaranteed time slots (GTS) mechanism or in the contention access period (CAP) using a slotted carrier sense multiple access with collision avoidance (CSMA/CA) protocol. CSMA is a mechanism in which the availability of a free channel/medium may be checked by sensing if there is a carrier in the channel or if there is a transaction occurring in the channel. By performing CSMA/CA, collisions can be avoided by a backoff mechanism. When a device senses that the channel is busy, the device does not transmit for a random time, called the backoff period. After the backoff period, the device may again check if the channel is busy. This is a mechanism to avoid collisions. In the non- beacon-enabled mode, the FFD waits for data request from end nodes. When an end device wants to exchange data with the FFD, it has to win the channel access via the CSMA/CA protocol and then exchange data using an un-slotted CSMA/CA protocol [8]. IEEE 802.15.4 defines an encryption algorithm but does not specify how the key exchange should take place or what authentication methods can be used. These issues have to be addressed by the upper layers. There are two options for the upper layers definition: ZigBee protocols, specified by the industrial consortia ZigBee Alliance, and 6LowPAN. There are multiple devices, development boards, sensors, evaluation kits etc. on the market with the Zigbee technology which can be bought commercially. The IEEE 802.15.4 technology is not optimized for WBANs: The throughput of IEEE 802.15.4 is low, the communication is limited to one channel and may cause channel coexistence issues, the power consumption is higher than BLE and IEEE802.15.6 and Zigbee is generally used with high node density with a mesh network over long distances.

E. IEEE 802.15.4j

In 2013, the IEEE 802.15.4j standard was released which was an alternative physical layer extension to support Medical Body Area Network services operating in 2360 to 2400 MHz frequency band [6]. The only difference between IEEE 802.15.4 and IEEE 802.15.4j is the additional PHY definition and MAC support for an additional PHY definition in a newly allocated frequency band for secondary usage specifically for medical devices compliant in the United States of America region, this band is protected from widespread interference experienced in other ISM bands. There was one development board commercially available which claimed to have the IEEE 802.15.4j support of MBAN. It must be noted that although the IEEE 802.15.4j PHY supports the medical band, there are no special improvements or provisions in the MAC to suit the requirements of a WBAN.

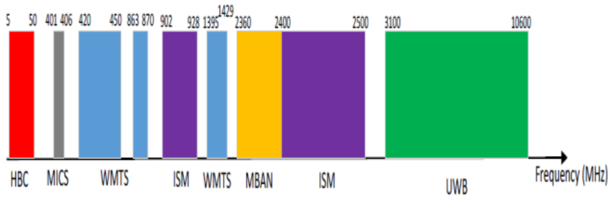

Figure 2.3: FCC allocated MBAN description in the frequency spectrum

F. Near-field communication (NFC)

Near-field communication (NFC) is promoted and maintained by the NFC Forum. NFC is a short-range wireless technology for a bidirectional interaction between electronic devices and is based on the same principles as radio-frequency identification (RFID) but NFC has an additional set of specifications to ensure interoperability between NFC equipment. Two NFC devices communicate by modulating information in an electromagnetic field at a frequency of 13.56 MHz. Small devices can be powered by the received electromagnetic field from the initiating NFC device and this property enables some NFC devices to take the form of very small battery less devices such as, tags, stickers or cards. There are several types of NFC tags defined by the NFC Forum. The tags are differentiated based on memory storage, data rates, capabilities, anti-collision support etc.

There are two modes of operation in NFC. In the Passive mode, the transmitting NFC device generates the RF field and the second NFC device receives the RF waves and interprets the modulation of the RF field as data and replies by load-modulating the intensity of the received field. The transmitting NFC device detects the incoming field and interprets that as the reply of the second device. In this setup the transmitting NFC device is active while the second device is passive. This method is generally used to read contactless cards or smartcards to be read from a range of up to 10 cm with a data rate ranging from 106 kbps to 848 kbps. In the Active mode, both NFC devices can generate the RF field. But the two NFC devices do not speak simultaneously, to prevent collisions, making the radio channel half- duplex. Larger operating distance of up to 20 cm are achievable and the data bit rate reaches up to 6.78 Mbps. Since there is two way exchange of information, one of the applications where active NFC can be used is a mobile phone to mobile phone data exchange. In this thesis project Passive NFC mode can be utilized as a side channel for association. Although each technology has its own unique discovery or association procedure, either the end node has to search for the coordinator in all the channels or the coordinator has to find the end nodes in all the channels. This increases the time taken for the association procedure. Also there is a possibility that sensor which do not belong to the PAN get falsely associated to the master or coordinator because of the proximity of the end node to master or coordinator. Using the NFC technology to associate devices to the coordinator makes it fast, intuitive and easy. If a nurse physical taps the required sensor end nodes on the master, the master can ensure that only the tapped sensor end nodes join the PAN. This idea will be further discussed in the design and implementation section.

III. Conclusion

One area of innovation is the patient monitoring system in hospitals using wireless body area networks (WBANs). In a WBAN, various sensors can be attached to clothing, placed on the skin of a person or even implanted inside a person's body. All the sensors monitor the vital signs of the patient and by using different wireless technologies, send the sensor data to the medical staff and administration for remote monitoring. The WBANs have the potential for real time response, timely management of diseases, monitored recovery and an improved patient experience.

Now that some technologies have been explored and the requirements have been discussed, it is important to find literature and state of the art work to understand which technology best fits the requirements presented.

In this paper we explored the different technologies used for WBN and also discussed their requirements.

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