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The Role of Cross-Layered Designs in Wireless Body Area Network

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Abstract

With recent advancement, Wireless Body Area Network (WBAN) plays an important role to detect various diseases of a patient in advance and informs the medical team about the life threatening situation. WBAN comprises of small intelligent Biomedical sensors which are implanted inside patient body and attached on the surface of a patient to monitor different vital signs, namely; respiratory rate, ECG, EMG, temperature, blood pressure, glucose. The routing layer of WBAN has the same challenging problems as similarly faced in WSN but the unique challenge is the temperature-rise during monitoring of vital signs and data transmission. IEEE 802.15.6 MAC Superframe of WBAN is different from IEEE 802.15.4 MAC of WSN and provides channels to emergency and non-emergency data for transmission. As similarly seen in WSN, PHY layer of IEEE 802.15.4 and IEEE 802.15.6 provide various modulation techniques for data transmission. The purpose of this study is to familiar with routing layer, MAC layer and PHY layer in the cross-layer design of WBAN.

Keywords: WBAN, patient data, IEEE 802.15.4 MAC/PHY, IEEE 802.15.6 MAC/PHY

1.0 INTRODUCTION

WBAN has brought advancement to monitor the health condition of a patient without need of medical care team. Due to insufficient health resources to provide in time, various chronic diseases affect the health condition of people which increase the number of patients in millions each year [1][2]. These shorting coming in the healthcare domain, the WBAN has recently stimulated changes to monitor various diseases of a patient without affecting his/her daily activities [3]. There are three types of biomedical sensors (BMSs), namely; implantable, wearable and off-body BMSs, and are connected with a body area network coordinator (BANC) which are used to monitor various vital signs a patient body [4][5] as shown in Figure1. The implantable BMSs are installed inside the patient body, the wearable BMSs are also known as attachable BMSs which are attached on the skin surface of a patient body. Whereas, the off-body BMSs are placed near to the patient body to monitor audio/video based the health condition of a patient body such as sleeping position, RUN, WAKING, SIT. The purpose of deployment of implanted and wearable BMSs are to detect any type of uncertainty during monitoring of EEG, ECG, heartbeat, respiratory rate, blood pressure, glucose level, temperature [5][6] etc. Further, the vital signs reading are classified into four groups that are Critical data Packet (CP), Reliability data Packet (RP), Delay data Packet (DP) and Ordinary data Packet (OP) [7][8] and are also called as natured-of patient data. The CP and RP are emergency data while DP and OP are non-emergency data. The CP is the first priority data to allocate channel for transmission which contains low threshold values of vital signs. The RP is the second priority to allocate channel which contains high threshold values of vital signs. The DP is the non-emergency data and it is placed on third position to allocate channel for transmission. The DP contains audio/video streaming of a patient physical examination. The OP contains routine checkup of the patient's body such as temperature reading and is placed in the fourth position. The low threshold vital sign is in the life threatening situation and needs to transmit to the medical staff first as compared to the high threshold vital sign [9]. The reason is that the low threshold of a vital sign approaches towards zero value and high threshold value of a vital sign is far away from the low threshold value. The channel allocation to BMSs is the responsibility of a BANC which is the unique challenging problems due to resource constraints structure of BMSs, temperature-rise issues, detection of critical data and allocation of channel on the basis of priority, selection of suitable paths for data transmission, weak signal of an antenna, high energy consumption to verify and select the low temperature path for data transmission, update routing table, mobility, and security [6][10][11]. These are the prominent problems to work on them.

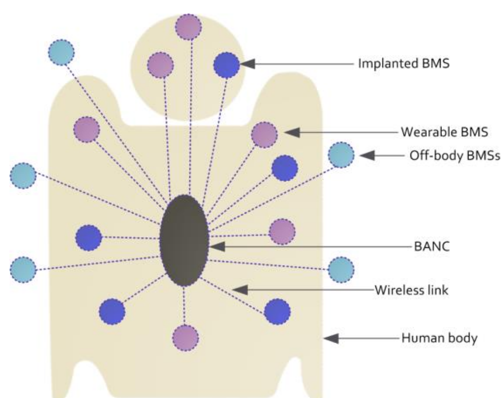

Figure 1 Typical structure of deployment of BMSs

Numerous research contributions have made for the aforementioned problems in WABN. The cross-layer is the capabilities to enhance the performance of the routing layer, Medium Access Control (MAC) layer, PHY layer which are required for a patient data [12]. Therefore, the application layer, and transport layer are associated with routing, MAC and PHY layers of the TCP/IP protocol suites which helps to establish a connection between layers for data transmission [13][14]. Each layer shares the status of the required services and provides information of it, and list of parameters that have been used and other information as depended on the application objectives. These types of information exchange with the remaining four layers to transmit data.

In wireless communication, the application layer provides the functionalities of data format, compression and encryption for end-to-end messages during transmission [13][15][16]. To achieve data reliability, the transport layer divides the large amount of data of a patient into several blocks of messages which helps to protect the network from congestion during transmission [13][16]. The source BMS selects those BMSs that have minimum temperature and consumes minimum energy consumption of the intermediated BMSs in the routing layer. The aim of verifying temperature and energy is to provide reliable data transmission [16]. The security is provided to messages during transmission with support of IPSec protocol [17]. IEEE 802.11, 802.15, and 802.16 families are associated with MAC layer and this layer plays a significant role to provide various scheduling access schemes, contention-based slots allocation, on the priority basis slots allocation to emergency and non-emergency based BMSs [13][16][18][12]. The similar families of IEEE are also used in PHY layer to provide different services such as transmission power strength, channel frequency modulation and data rate [12][13][16] [18].

This paper is constructed as follows: section 2 presents different implantable and wearable BMSs with functionalities. Section 3 presents categorization of cross-layer design. The routing, MAC and PHY layers of WBAN present in section 4. Finally, the conclusion of this paper presents in section 5.

2.0 CATEGORIZATION of BMSs

The architecture of BMS consists of a physiological signal and radio transceiver [19]. The functionality of physiological signal is to monitor vital signs of a patient body and converts the sensed analog signals into a digitized pattern. The digitized signal forwards the converted data of patient's vital signs to radio transceiver which communicates the digital signal to a BANC. Further, the BANC forwards the findings of vital signs to the medical staff through internet [4] for necessary actions according to the condition of vital signs. Table 1 shows various functionalities of wearable and implantable BMSs [19][20] where they monitor different vital signs of a patient body such as blood pressure, EEG, ECG, EMG, Temperature and artificial retina, camera pill respectively.

The Star/mesh topology is used to connect BMSs with a BANC and BANC is subject to assign channels to the deployed BMSs as depends on the condition of vital signs. Now the question is: how a sensor can use the routing, MAC and PHY layers for heterogeneous natured of patient data in order to transmit the emergency data first to the BANC? For example: The respiratory rate sensor is detected a low threshold value and the glucose sensor is detected normal value. The low threshold value of a vital sign is in life-threatening situation and it should give the first priority to transmit [9]. These types of emergency and non-emergency patient traffic handle with the support of cross-layer architecture because BANC is responsible to allocate first slot to the respiratory sensor and then the glucose sensor [7][21][22][23] which is challenging problem in the cross-layer wireless communication. Therefore, the cross-layer architecture classifies the responsibilities of BMSs into Manager, Non-manager and centralized and distributed methods [12][16][24][25]. These methods help to allocate resources and shares among five layers of TCP/IP model.

Table 1 WBAN BMSs with their functions [19][20]

Sensor	Placement	Data Rate	Topology	Function
Blood Pressure	Wearable	High	Star	Measures Maximum and Minimum threshold values
EEG/ECG/EMG		High		Measure Voltage differences
Humidity		Very Low		Observe humidity changes
Blood Oxygen Saturation (CaO_2)		Very Low		Measure absorption ratio in blood oxygen saturation
Pressure		High		Measure Pressure values
Respiration		High		Measure breathing of the patient
Glucose		High		Measure the blood circulation rate in a body
Temperature		Very Low		Measure the coolness or hotness of a body
Artificial Retina	Implantable	High		Collect information from the environment and convert it to the electrical signals
Artificial Cochlea		High		Implant in ears and helps to convert voice signals into Pulses
Camera Pill		High		Swallow the pill in order to monitor various parts of a body

3.0 CROSS-LAYER DESIGN CATEGORIZATION IN WIRELESS COMMUNICATION

The five layers of TCP/IP protocol are implemented on BMSs and across the network. There are challenging problems for BMS (1) how can a BMS utilize and share the functionalities of five layers of TCP/IP internally? (2) how can BMSs use these five layers for information distribution across the network? For question (1): The Manager and Non-manager methods [12][16][24][25]. Whereas for question (2), The centralized and distributed methods [12][16]. The centralized and distributed methods are used to share information among BMSs in the whole network.

3.1 Manager Method

This method is also known as inter-layer method which proposes a vertical plane (VP) to share resource among layers [16]. Each layer does not communicate with other layers of TPC/IP for resource sharing but each layer stores the required functions in vertical plane as shown in Figure 2 (a) (re-drawn from [14][16]). The VP makes an association between layers for resource sharing.

3.2 Non-Manager Method

This method is also known as intra-layer method and each layer shares information with other layer as shown in Figure 2(b) (re-drawn from [14][16]). For example, the application layer shares data format, encryption information and communicates with other four layers of TP/IP model. These types of information are shared sequentially and through this way the transport layer shares information to network layer, MAC layer and PHY layer [26]. The information sharing is continued until to complete data transmission process.

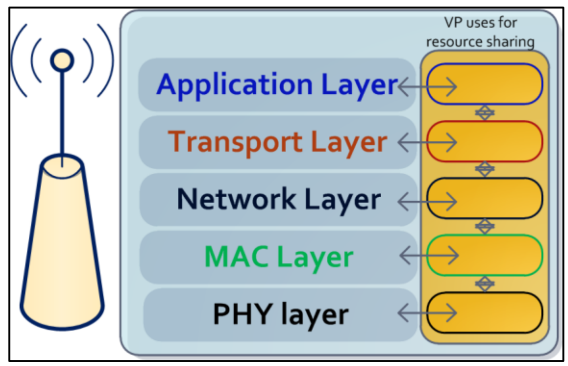

Figure 2.(a) Information sharing for manager method,

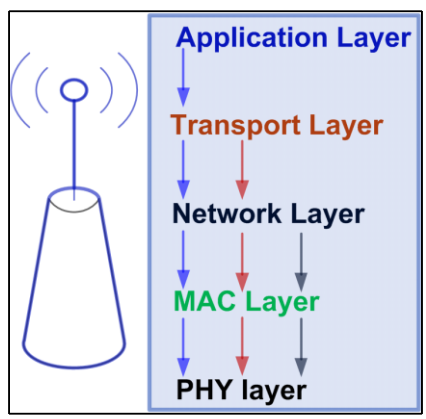

Figure 2 (b) Information sharing for non-manager method (re-drawn from [14][16]

3.3 Centralized Method

The centralized method is categorized into different multi-levels hierarchy where different types of required information and resources are shared among BMSs in the network as depicted in Figure 3(a) (re-drawn from [16] [14]. The level-0 is comprised of a Base station which is responsible to allocate channels to BMSs in the remaining levels (lower levels) of the network in real-time without delay. The level-1 is also comprised of BMSs, which are in direct communication range to Base station. In a similar way, the level-2 is comprised of BMSs that are connected with direct paths to the centralized node. The purpose of multi-levels classification is to ensure the resource distribution among the sensor nodes of the network.

3.4 Distributed Method

The resources (channels) sharing in the distributed method are not similar as described in the centralized method but each node forwards data to the destination node directly or via use of multi-hops and links as shown in Figure 3 (b) (re-drawn from [16][14]). The distributed method reduces performance of the network in terms of high delay if two nodes use the same node for data transmission and reception which creates data congestion and drops data. The [27] focuses on delay problems for heterogeneous nodes of data while data congestion problem has been resolved in [28].

4.0 AIM OF CROSS-LAYER DESIGN IN WIRELESS BODY AREA NETWORK

The aim of cross-layer architecture is to investigate the challenging problems and follow them in routing, MAC and Physical layers of WBAN [6][29]. In the cross-layer communication, each layer contains various configuration steps to give the required services to the particular element and solve it. This study tries to show a generalized structure of the cross layer in WBAN as presented in Figure 4 where various BMSs are deployed inside the patient body and attached to the surface of a patient body. These BMSs are connected with a BANC in the star topology which monitor various vital signs such as heartbeat, respiratory rate, Blood pressure, temperature, glucose level, EEG, ECG, EMG [19][20][30]. The results of monitored vital signs are forwarded to BANC and BANC further forwards to medical staff via Base station. This paper classifies the cross-layer design for WBAN into three layers in the following sub-sections.

4.1 Network Layer

Various BMSs are deployed and connected with a BANC to transmit results of vital signs to medical staff for necessary actions as shown in Figure 4. All sensors are directly connected to a BANC during data transmission. The direct connectivity is granted under the criteria when there is no traffic and BMS is under the coverage area of a BANC then it can use a single-hop [30]. Use of Multi-hops, when a sensor is away from the coverage area of a BANC and/or sensor is minimum energy to transmit data [31].. The multi-hops BMSs consume minimum energy as compared to single-hop during data transmission [31].

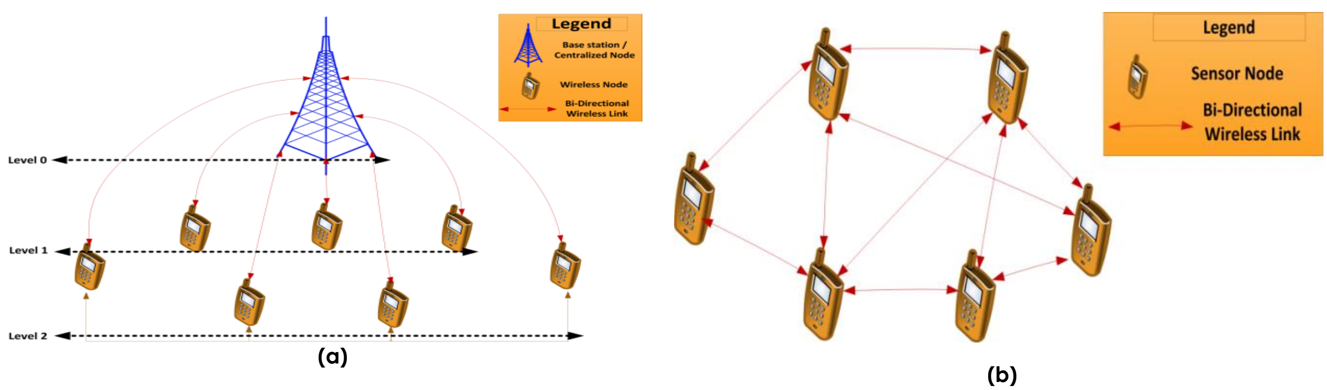

Figure 3 Sharing information and Resources in the network with the support of cross-layer **(a)**Centralized method is used to share information between sensor nodes in the network and **(b)** in Distributed method, each sensor node is used single/more than one path to transmit data to destination node.

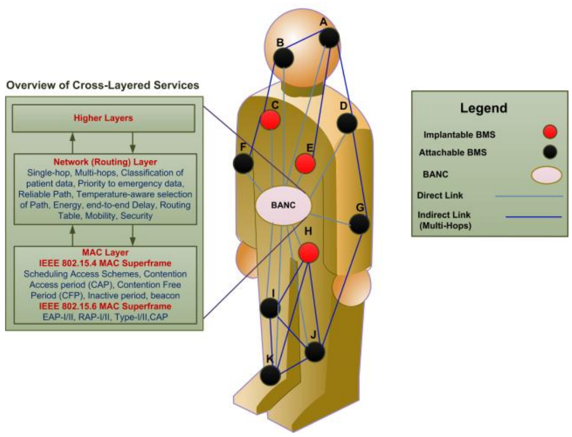

Figure 4 WBAN Cross-Layer designs

For data transmission, each BMS uses Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) and Time Division Multiple Access (TDMA) [21]. With CSMA/CA data transmission, each BMS performs Request-to-Send (RTS), Clear-To-Send (CTS) and Clear Channel Assessment (CCA) before data transmission which helps to avoid data collision. With TDMA transmission, the BANC divides the channel into fixed time period and assigns channels to sensors for transmitting data. Table 2 [32] compares the functionalities of TDMA and CSMA/CA.

Table 2 Comparison of TDMA and CSMA/CA access schemes [32]

Function	TDMA	CSMA/CA
Power consumption	Low	High
Bandwidth Utilization	Maximum	Low
Preferred Traffic Level	High	Low
Dynamic Network	Average	Good
Effect of Packet failure	Latency	Low
Synchronization	Essential	N/A

The TDMA based sensors consume less energy as compared to CSMA/CA. The reason is that TDMA allocates predefined timeslots to sensors in which they transmit data. Whereas, the CSMA/CA based BMSs perform contention to access channel all the time which degrades the network performance in terms of high energy consumption, high delay, and low data reliability [21]. These degradations do not allow to use for emergency data.

4.1.1 Classification of Patient Data

The patient data are classified into CP, RP, DP and OP [7][8]. The CP and RP are the most critical data of a patient whereas DP and OP are the non-critical data of a patient. The CP data comprises of a low threshold value of a vital sign such as low heartbeat, low respiratory rate; and RP data comprise of a high threshold value of a vital sign such as high heartbeat, high respiratory rate. The OP and DP comprise of temperature, glucose level etc of the patient's body. The CP and RP data require the first highest priority to transmit data as compared to DP and OP. It has been noticed in WBAN that CP and RP-based BMSs use TDMA scheme to access channel while DP and OP-based BMSs use CSMA/CA scheme to access channel [21]. In an emergency situation, the BMSs transmit an alert signal to a BANC and BANC allocates channels to the particular BMSs without interruption of other sensors contentions [21].

4.1.2 Temperature-based Path Selection

The routing table of each BMS keeps updated information of the whole network which comprise of number of hops-count to destination, energy, and temperature level of intermediate BMSs. During data transmission, the sender BMS verifies the aforementioned three parameters if the temperature of that BMS is high from threshold values then that particular BMS (the whole path) is not used as intermediate path for data transmission. The high Radio Frequency (RF), Biosensors antenna, and sensor circuitry are the main causes of heating up BMSs during monitoring of vital signs and transmission of results of vital signs which damages the tissues and skin of the patient body [33]. The [33] uses Specific Absorption Rate (SAR) which measures the temperature of BMSs before transmitting data on them as shown in Eq. 1.

$$\text{SAR} = \frac{\sigma\,|E|^2}{\rho}\ (W/kg) \qquad (1)$$

Where σ is used to transmit the electrical heat. The ρ is used to find the density level of the tissues and E is used to measure the electric field radiation in a patient body.

If the temperature level of a sensor node is minimum and energy is not enough to transmit data. With this uncertainty, the transmitter node updates the routing table and selects another node to transmit data [34]. Examples are DMQoS [8] uses routing and MAC layers, Framework of QoS-aware routing protocol [35], and [36]. They focus on the classification of patient data, packet classifier, transmission power, MAC transmitter/Receiver, QoS, and Routing table.

4.2 MAC Layer

IEEE 802.11, IEEE 802.15, and IEEE 802.15.1 [37] are not capable to monitor vital signs of a patient body. IEEE 802.15.4 MAC Superframe structure has the capabilities to monitor various vital signs [38] and uses reduced-duty cycle to consume minimum energy of BMSs during contention to access channel [39]. This paper discusses MAC Superframe structures of IEEE 802.15.4 and IEEE 802.15.6 in the subsections.

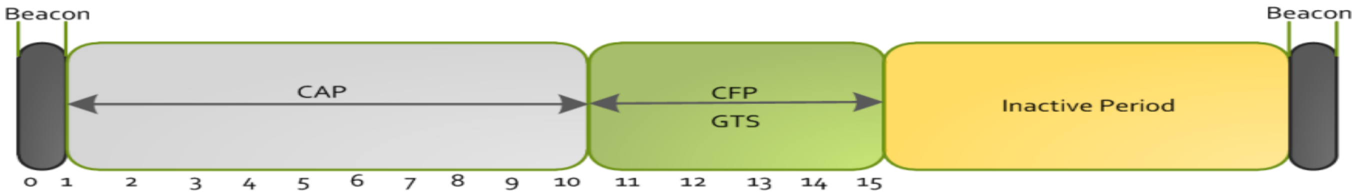

Figure 5 Superframe structure of 802.15.4 MAC (re-drawn from [38])

4.2.1 Superframe Structure of IEEE 802.15.4 MAC

The Superframe structure of IEEE 802.15.4 MAC comprises a beacon, contention access period (CAP), contention free period (CFP) and inactive period (IP) as depicted in Figure 5 (re-drawn from [38]). Various BMSs are implanted or attached to the patient body and connected to the BANC as depicted in Fig 4. The patient data is classified into normal, periodic, and emergency data. These data are represented as natured-of patient data in WBAN [40]. Usually, the normal data comprises of temperature and glucose level. The periodic data comprises of blood pressure recording whereas emergency data comprises of low and high threshold values of vital signs.At the beginning of communication, the BANC broadcasts a beacon message to all BMSs in the network and it includes information of BANC energy, and synchronization. The CAP period is implemented on CSMA/CA access scheme and CFP period is implemented on the TDMA access scheme.

During data transmission, each BMS performs RTS, CTS and CCA along with contention to access channel in CAP period. The BANC allocates channels of CFP period to those BMSs who obtain channel access in the contention. The IP is used to save energy during sleep period of BMSs. However, the drawback of IEEE 802.15.4 MAC is that it provides limited 16 slots which are not enough for heterogeneous natured-of patient data. Further, each BMS whether it is emergency-based or non-emergency based BMS perform contention to access channel and there is no dedicated channel allocated for emergency data without performing contention. During channel allocation, each BMS performs RTS, CTS and CCA which degrades the network performance in terms of high delay and low data reliability with high energy consumption. These elements reduce performance of MAC protocol therefore numerous research contributions have been performed to design and enhance the Superframe structure of MAC protocol. The examples are R-MAC [41], H-MAC [42], HEH-BMAC [43], [21], FCMA [44], PLA-MAC [7], and PNP [45] etc.

4.2.2 Superframe Structure of IEEE 802.15.6 MAC

IEEE 802.15 working group decided in 2006 to design low power sensors. Therefore, they made a group, is known as Task Group 6 (TG6) is to develop sensors that can monitor vital signs of a patient and sportsman during their activities. In 2012, the first draft was publicized which provided the guidelines of functionalities of MAC and PHY layers with their Superframe structures [5][46].

Figure 6 depicts Superframe structure of IEEE 802.15.6 MAC which comprises of beacon, exclusive access phase (EAP-I/II), random access phase (RAP-I/II), type-I/II and contention access period (CAP) [5][46]. During data transmission, each BMS synchronizes clock with a BANC when BMS receives a beacon. IEEE 802.15.6 MAC is used CSMA/CA and slot Aloha access schemes for the proposed MAC. The EAP-I and EAP-II are dedicated to carry emergency data. Whereas, the RAP-I, RAP-II and CAP are used to are dedicated to carry normal data such as temperature readings, glucose level and blood pressure of a patient body. The type-I traffic is represented as emergency data and type-II is represented as normal data to a BANC.

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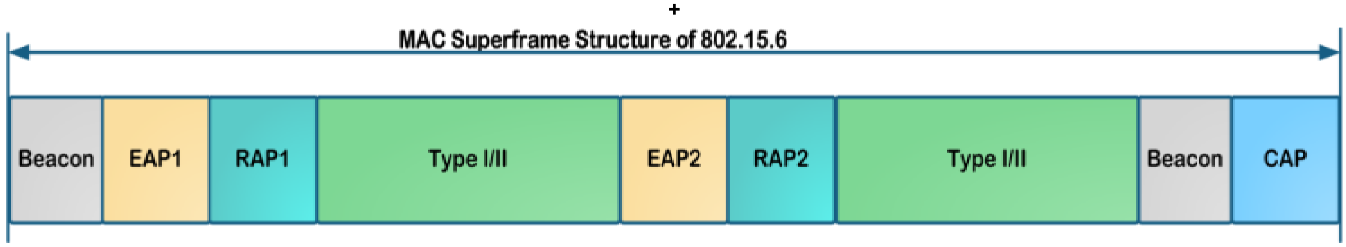

Figure 6 Superframe structure of 802.15.6 MAC (re-drawn from [5][46])

4.3 MACs Comparison Of IEEE 802.15.4 and IEEE 802.15.6

The application of IEEE 802.15.4 is to monitor specific environment such as temperature of a room, battlefield for detection mines. Whereas, IEEE 802.15.6 is specially designed to monitor health condition of a patient, sportsman and can be used for entertainment purposes such as 3D movies, and adventure actions in movies as shown in Table 3. The maximum network coverage area of IEEE 802.15.6 supports 6 meters and IEEE 802.15.4 supports 100 meters as aforementioned according to the applications characteristics. The network scalability means add more sensors to the network and extends the coverage area. IEEE 802.15.4 supports 65000 sensors in the network while IEEE 802.15.6 supports 256 sensors. The reason is that IEEE 802.15.6 has been designed for a human body as compared to IEEE 802.15.4 has been designed for environmental applications. The energy consumption of IEEE 802.15.6 is high due to heterogeneous applications as compared to IEEE 802.15.4 monitors homogeneous types of applications such as temperature of a room. The medium of data transmission in IEEE 802.15.6 is air, on-body and in-body while IEEE 802.15.4 uses an air as presented in Table 3. The disadvantage for in-body and on-body as medium for data transmission damage the skin and tissues during monitoring and transmission of results of vital signs as compared to air as medium. However, this type of situation is handled with SAR [33] which measures the temperature of skin and tissues before data transmission. The patient, and sportsman data are very significant and it does not bear higher delay with lower data reliability as compared to data of IEEE 802.15.4. Due to this reason, IEEE 802.15.6 provides higher transmission rate as compared to IEEE 802.15.4. Both standards use same types of channel access schemes. The controls overhead are high in IEEE 802.15.6 as compared to IEEE 802.15.4 due to its application sensitive data such as emergency and non-emergency data, dedicated channels allocation. The conclusion ends that IEEE 802.15.4 provides all those types of functionalities which require from IEEE 802.15.6.

Table 3 Functionalities comparison of IEEE 802.15.4 and IEEE 802.15.6 [47]

Objectives	IEEE 802.15.6	IEEE 802.15.4
Applications	Patient, Sportsman, entertainment	monitoring of environments such as temperature, air pollution, Automatic operations
Network coverage	1 to 6 Meter	10 to100 Meter
No. of Sensors support	3 to 256	10 to 65000
Energy Consumption	High	Average
Data transmission medium	Air, on-body, in-body	Air
Data transmission rate	50Kb/sec to 10 Mb/sec	20 Kb/sec to 250 Kb/sec
Channel access mechanism	CSMA/CA, TDMA, Aloha	CSMA/CA, TDMA, FDMA, Aloha
Controls Overhead	High	Low

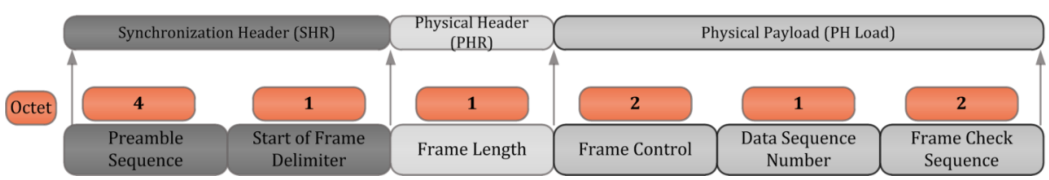

Figure 7 Physical frame structure of IEEE 802.15.4 (re-drawn from [48])

4.4 Physical Layer

To activate and de-active the radio signal of a sensor, signals modulation, frame control, data transmission are the responsibilities of the physical layer. IEEE 802.15.4 [48] and IEEE 802.15.6 [4][5] physical frame structure are presented in the following subsections.

4.4.1 Physical Layer frame structure of IEEE 802.15.4.

The physical frame structure of IEEE 802.15.4 is consisted of SHR, PHR and PH load as described in Figure 7 [48]). The SHR header comprises of a 'preamble sequence' and 'start of frame delimiter'. The PHR consists of a 'frame length' and in a similar way, the PH load includes 'frame control', 'data sequence number' and 'frame check sequence'.
The preamble-sequence reserves four bytes and uses to synchronize a BANC with BMSs when it broadcasts in the network. The Start of Frame-Delimiter uses one byte and demonstrates the start of frame to the receivers when it receives data. IEEE 802.15.4 PHY reserves one byte for Frame length and shows the total length of a frame to receiver. The frame control uses two bytes and updates whether the channel is under congestion or it is not congested. With this assistance, the BMSs transmit data without collision. Further, during data transmission, all BMSs use single channel with De-MUX key which differentiates data of all BMSs on the receiver side with the support of data sequence number header. The frame check sequence (FCS) protects data during transmission from third party from violation and generates a hash value of messages. The hash value with original messages is sent to receiver and receiver applies the same method to generate a hash value. If the hash value of receiver is matched to the sender hash values, the receiver accepts the messages and believes that messages

has not tempered during transmission. Otherwise, the messages are dropped.

4.4.2 Physical Layer Frame Structure of IEEE 802.15.6

IEEE 802.15.6 physical layer provides assistance to activate and de-activate the radio signals of antenna and uses CCA to assure channel availability. Further, IEEE 802.15.6 is divided into Narrow Band (NB), Human Body Communication (HBC), and Ultra Wide Band (UWB) [4] [5]. These three methods have been used to transmit patient data in WBAN as described in the following sub-sections.

IEEE 802.15.6 NB Physical Layer

The NB PHY layer is constructed of the Physical Layer Convergence Procedure (PLCP) preamble, PLCP header and Physical Layer Service Data Unit (PSDU) [5] [49]. The PCLP preamble recovers the damaged contents of a message, packet detection and provides synchronization at receiver side. The PCLP header employs various techniques for signals modulation and demodulation such as Differential 8-Phase-shift Keying (D8PSK), Differential Binary Phase-shift Keying (DBPSK) and Differential Quadrature Phase- shift Keying (DQPSK) [5]. The NB PHY layer is connected to MAC layer via PSDU header.

IEEE 802.15.6 HBC Physical Layer

The packet structure of HBC is comprised of PLCP preamble, Start Frame Delimiter (SFD), PLCP header and PSDU [5] [49]. Further, HBC uses Electrostatic Field Communication (EFC). With EFC supports, the HBC generates 64-bit code for PLCP preamble and SFD. The preamble helps for synchronization between BANC and BMSs whereas SFD detects the start of a new frame at the receiver side. The PCLP header provides two types of services as seen similarly in SFD and FCS.

IEEE 802.15.6 UWB Physical Layer

The UWB is the third type of a physical layer which is the most beneficial technology for short range communication for on-body sensors. The UWB provides low complexity, high performance and consumes minimum energy [5] [49]. The detailed structure is comprised of synchronization header (SHR), PHY header (PHR) and PSDU [5] [49]. The SHR provides preamble and SFD sub-headers. The PHR protects data during transmission for integrity violation and PSDU transmits the whole message to the receiver.

5.0 CONCLUSION

The routing layer is the same challenging problems as seen in WSN but the unique requirements are temperature issues and selection of efficient path for emergency data. The MAC layer is also challenging problems such as contention-based channel allocation to emergency and non-emergency data, no dedicated channel allocation to emergency data without performing contention and higher delay during contention with higher data collision. Numerous research contributions have been made for these challenging problems and have been tried resolved according to the need of patient data. Different signal modulation and de-modulation techniques have been shown in PHY layer. This paper draws attention towards understanding the routing, MAC and PHY layers in WBAN which is different from WSN routing protocols.

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References

[1] G. Acampora, D. J. Cook, P. Rashidi, and A. V Vasilakos. 2013. A Survey on Ambient Intelligence in Health Care. *Proceedings of the IEEE. Institute of Electrical and Electronics Engineers*. 101(12): 2470–2494.

[2] H. Cao, V. Leung, C. Chow, and H., Chan. 2009. Enabling technologies for wireless body area networks: A survey and outlook. *Communications Magazine, IEEE*. 47(12): 84-93.

[3] G. Fortino, D. Parisi, V. Pirrone, and G. Di Fatta, 2014. BodyCloud: A SaaS approach for community body sensor networks. *Future Generation Computer Systems*. 35 (2014): 62-79.

[4] B. Latré, B. Braem, I. Moerman, C. Blondia, and P. Demeester. 2010. A survey on wireless body area networks. *Wireless Networks*. 17(1): 1–18.

[5] S. Movassaghi, S. Member, M. Abolhasan, and S. Member. 2014. Wireless Body Area Networks : A Survey. *Ieee Communications Surveys And Tutorials*. 16(3): 1658–1686.

[6] Ben Elhadj, H., S. Boudjit, and L. C. Fourati. 2013. A cross-layer based data dissemination algorithm for IEEE 802.15.6 WBANs. in *2013 International Conference on Smart Communications in Network Technologies, SaCoNeT 2013*. Paris. 17-19 June 2013. 1-6

[7] Anjum, I., N. Alam, M. A. Razzaque, M. Mehedi Hassan, and A. Alamri. 2013. Traffic Priority and Load Adaptive MAC Protocol for QoS Provisioning in Body Sensor Networks. *International Journal of Distributed Sensor Networks*, 2013: 1–9.

[8] Razzaque, M. A., C. S. Hong, and S. Lee. 2011. Data-centric multiobjective QoS-aware routing protocol for body sensor networks. *Sensors (Basel, Switzerland)*. 11(1): 917–37.

[9] Ullah, F. A. Khelil, A. a. Sheikh, E. Felemban, and H. M. a. Bojan. 2013. Towards automated self-tagging in emergency health cases. *2013 IEEE 15th International Conference on e-Health Networking, Applications and Services (Healthcom 2013)*, no. Healthcom. 658–663.

[10] Rajput, O., S. Qureshi, A. R. Solangi, Z. Aziz, and F. K. Shaikh. 2013. Applicable Operational Mechanisms To Assist Visually impaired People-A WSN Perspective. *2013 5th International Conference on Information and Communication Technology for the Muslim World (ICT4M)*. 1–6.

[11] Qadri, S. F. S. A. Awan, M. Amjad, M. Anwar, and S. Shehzad. 2013. Applications , Challenges , Security of Wireless Body Area Networks (Wbans) and Functionality of. *Science International Lahore*. 25(4): 697–702.

[12] Fotis Foukalas, N. A. and Vangelis Gazis. 2008. Cross-Layer Design Proposals for Wireless Mobile Networks: A Survey and Taxonomy. *IEEE Communications Surveys*. 10(1): 70–85.

[13] L. D. P. Mendes and J. J. P. C. Rodrigues. 2011. A survey on cross-layer solutions for wireless sensor networks. *Journal of Network and Computer Applications*. 34(2): 523–534.

[14] Fu, B., Y. Xiao, H. J. Deng, and H. Zeng.2014. A survey of cross-layer designs in wireless networks. *IEEE Communications Surveys and Tutorials*. 16(1): 110–126.

[15] Xiao, M. X. M., X. W. X. Wang, and G. Y. G. Yang. 2006. Cross-Layer Design for the Security of Wireless Sensor Networks. *2006 6th World Congress on Intelligent Control and Automation*. 1(2006);104–108.

[16] H. Zeng, K. Joon, J. Deng, B. Fu, Y. Xiao, and J. Jeski. 2012. Proactive and Adaptive Reconfiguration for Reliable Communication in Tactical networks. in *Defense Transformation and Net-Centric Systems*, 2012. 8405(2012): 1–9.

[17] Chuang, I. C. Hsieh, and Y. Kuo. 2011. An Adaptive Cross-Layer Design Approach for Network Security Management. *Advanced Communication Technology (ICACT), 2011 13th International Conference*. Seoul, Korea. 13-16 February 2011. 1085–1089.

[18] Wang, J., and G. L., Smith. 2010. A Cross-Layer Authentication Design For Secure Video Transportation In Wireless Sensor Network. *International Journal of Security and Networks*. 5(1): 63-67.

[19] Chen, M. S. Gonzalez, A. Vasilakos, H. Cao, and V. C. M. Leung. 2010. Body Area Networks: A Survey. *Mobile Networks and Applications*. 16(2): 171–193.

[20] Lai, X., Q. Liu, X. Wei, W. Wang, G. Zhou, and G. Han. 2013. *A Survey Of Body Sensor Networks. Sensors.* 13(5): 5406-5447

[21] Khan, Z. a., M. B. Rasheed, N. Javaid, and B. Robertson. 2014. Effect of Packet Inter-arrival Time on the Energy Consumption of Beacon Enabled MAC Protocol for Body Area Networks. *Procedia Computer Science*. 32(2014): 579-586

[22] Kim, B., and J. Cho. 2012. A novel priority-based channel access algorithm for contention-based MAC protocol in WBANs. *Proceedings of the 6th International Conference on Ubiquitous Information Management and Communication - ICUIMC '12*, p. 1.

[23] Pantelopoulos, a., and N. G. Bourbakis. 2010. A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*. 40(1): 1–12.

[24] Srivastava, V., and M., Motani. 2005. Cross-layer design: A survey and the road ahead. *IEEE Communications Magazine*.43(12): 112–119.

[25] Carneiro, G., J., Ruela, and M. Ricardo. 2004. Cross-Layer Design In 4G Wireless Terminals. *IEEE Wireless Communications*. 11(2): 7–13.

[26] Kwon, T., H. Lee, S. Choi, J. Kim, D. H. Cho, S. Cho, S. Yun, W. H. Park, and K. Kim. 2005. Design And Implementation Of A Simulator Based On A Cross-Layer Protocol Between MAC And PHY Layers In A Wibro Compatible IEEE 802.16e OFDMA system. *IEEE Communications Magazine*. 43(12): 136–146.

[27] Bourse, D., M. Muck, O. Simon, N. Alonistioti, K. Moessner, E. Nicollet, D. Bateman, E. Buracchini, G. Chengeleroyen, and P. Demestichas. 2006. End-To-End Reconfigurability (E2R II): Management And Control Of Adaptive Communication Systems. *IST Mobile Summit*.

[28] Setton, E. T. Y. T. Yoo, X. Z. X. Zhu, A. Goldsmith, and B. Girod. 2005. Cross-Layer Design Of Ad Hoc Networks For Real-Time Video Streaming. *IEEE Wireless Communications*. 12(4): 59-65.

[29] Elias., J. 2014. Optimal Design Of Energy-Efficient And Cost-Effective Wireless Body Area Networks. *Ad Hoc Networks*. 13(B): 560–574.

[30] Alam, M.M., and E. Ben Hamida. 2014. Surveying Wearable Human Assistive Technology For Life And Safety Critical Applications: Standards, Challenges And Opportunities. *Sensors (Switzerland)*. 14(5): 9153–9209.

[31] Braem, B. B. Latré, C. Blondia, I. Moerman, and P. Demeester. 2008. Improving Reliability in Multi-hop Body Sensor Networks. *2008 Second International Conference on Sensor Technologies and Applications (sensorcomm 2008)*. Cap Esterel. 25-31 August 2008. 342–347.

[32] Marinkovic, S., C. Spagnol, and E. Popovici. 2009. Energy-Efficient TDMA-Based MAC Protocol for Wireless Body Area Networks. *2009 Third International Conference on Sensor Technologies and Applications*. Athens, Glyfada. 18-23 June 2009. 604–609.

[33] [33] Tang, Q. N. Tummala, S. K. S. Gupta, S. Member, and L. Schwiebert. 2005. Communication Scheduling to Minimize Thermal Effects of Implanted Biosensor Networks in Homogeneous Tissue. *Ieee Transcation On Biomedical Engineering*. 52(7): 1285–1294.

[34] Ahourai, F. M. Tabandeh, M. Jahed, and S. Moradi. 2009. A Thermal-aware Shortest Hop Routing Algorithm for in vivo Biomedical Sensor Networks. *2009 Sixth International Conference on Information Technology: New Generations*. 1612–1613.

[35] Liang, X. and I. Balasingham,. 2007. A QoS-aware Routing Service Framework for Biomedical Sensor Networks. *2007 4th International Symposium on Wireless Communication Systems*. Trondheim, Norway. 17-19 October 2007. 342–345.

[36] Khan, Z. A., S. Sivakumar, W. Phillips, and B. Robertson. 2014. ZEQoS: A New Energy and QoS-Aware Routing Protocol for Communication of Sensor Devices in Healthcare System. *International Journal of Distributed Sensor Networks*. 2014: 1–18.

[37] Cavallari, R. F. Martelli, R. Rosini, C. Buratti, and R. Verdone. 2014. A Survey on Wireless Body Area Networks: Technologies and Design Challenges. *IEEE Communications Surveys & Tutorials*. 16(3): 1–23.

[38] Li, C. B. Hao, K. Zhang, Y. Liu, and J. Li. 201. A Novel Medium Access Control Protocol With Low Delay And Traffic Adaptivity For Wireless Body Area Networks. *Journal Of Medical Systems*. 35(5): 1265–75.

[39] H. W. Tseng and Y. R. Chuang. 2013. A Cross-Layer Judgment Scheme For Solving Retransmission Problem In Ieee 802.15.4-Based Wireless Body Sensor Networks. *IEEE Sensors Journal*. 13(8): 3124–3135.

[40] Watteyne, T., I. Augé-Blum, M. Dohler, and D. Barthel. 2007. Anybody: A Self-Organization Protocol For Body Area Networks. in *Proceedings of the Second International Conference on Body Area Networks BodyNets*.

[41] Ullah, S. 2013. RFID-enabled MAC Protocol for WBAN. pp. 6030–6034.

[42] Li, H., S. Member, and J. Tan. 2010. Heartbeat-Driven Medium-Access Control for Body Sensor Networks. 14(1): 44–51.

[43] Ibarra, E. A. Antonopoulos, E. Kartsakli, and C. Verikoukis. 2014. HEH-BMAC: Hybrid Polling MAC protocol for WBANs Operated By Human Energy Harvesting. *Telecommunication Systems*. 58(2): 111-124

[44] Zhou, J., A. Guo, J. Xu, and S. Su. 2014. An Optimal Fuzzy Control Medium Access In Wireless Body Area Networks. *Neurocomputing*. 142: 107–114.

[45] Yoon, J. S., G. S. Ahn, S. S. Joo, and M. J. Lee. 2010. PNP-MAC: Preemptive Slot Allocation And Non-Preemptive Transmission For Providing Qos In Body Area Networks. in *2010 7th IEEE Consumer Communications and Networking Conference, CCNC 2010*. Las Vegas, NV. 9-12 January 2010. 1 - 5

[46] S. Ullah, M. Mohaisen, and M. A. Alnuem. 2013. Security Specifications,". 2013.

[47] Thanh, N. A. Vernhet, and Z. Rosenzweig. 2005. Gold Nanoparticles in Bioanalytical Assays and Sensors. *Frontiers in Chemical Sensors*. 3(2013): 261-277.

[48] IEEE Standard. 2006. IEEE Standard for Part 15 . 4 : Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs). *IEEE Standard*. 1–26

[49] Ullah, S. M. Mohaisen, and M. a Alnuem. 2013. Security Specifications,".