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Energy Efficient and Priority Based MAC Protocols for Wireless Body Area Network: A Survey

M.Ambigavathi[1], Dr. D. Sridharan[2]

[1]Research Scholar, [2]Professor

Department of ECE, CEG Campus, Anna University, Chennai, (India)

ABSTRACT

Recent developments in Wireless Body Area Network (WBAN) provides many opportunities for researches on remote health monitoring to improve the quality of life in hospitals and homes. Also, it is a crucial factor to monitor and transmit the data from sensor nodes to coordinator node. Since, transmission of time critical data over the network has served under various issues like Collisions, Energy consumption, Reliability, and Delay. To enhance these strategies, WBAN should incorporate with Inter of Things (IoT), Fog computing, Cloud computing and Big data for providing massive storage, high security and cost-effective quality healthcare services. The most important challenges in WBAN is to refine and maintain the Quality of Service (QoS). This paper reviews the recent MAC protocols and identify the issues in order to achieve better performance over energy consumption and delay. In future, these problems will be resolvedby considering priority based effective data transmission mechanisms to enhance the overall performance of the WBAN.

Keywords: Body Area Network, Energy Consumption, Delay, Priority based data transmission

I. INTRODUCTION

Wireless Body Area Network connects the independent nodes like sensors and actuators that are situated in the clothes, on the body or under the skin. The network typically expands over the whole human body that should be used in various applications such as indoor and outdoor health monitoring system [1]. The overall architecture of WBAN system is presented in Fig.1. The network coordinator is connected in between the network provider and WBAN. Wireless connections such as Bluetooth, GPRS, Wi-Fi, ZigBee, IoT, WLAN are connected to the network provider for the coordination of sensing nodes. The major concern is to provide an international standard for low power, short range, and high reliable communication, and supporting a vast range of data rates for different applications [2]. WBAN offers [3] many new applications in the area of remote health monitoring, home based healthcare, medicine, multimedia, sports and many others all of which makes advantage of the uncontrolled freedom of movement. The main benefit of using WBAN is that, patient doesn't need to stay in bed itself, but they can able to move freely across the room and even leave the hospital for a while which reduces hospital costs and improves the quality of life for the patient. IEEE 802 has established a low power and excellent communication standard called IEEE 802.15.6 for WBAN, the main purpose of such standardization is to optimize low power in body [4].

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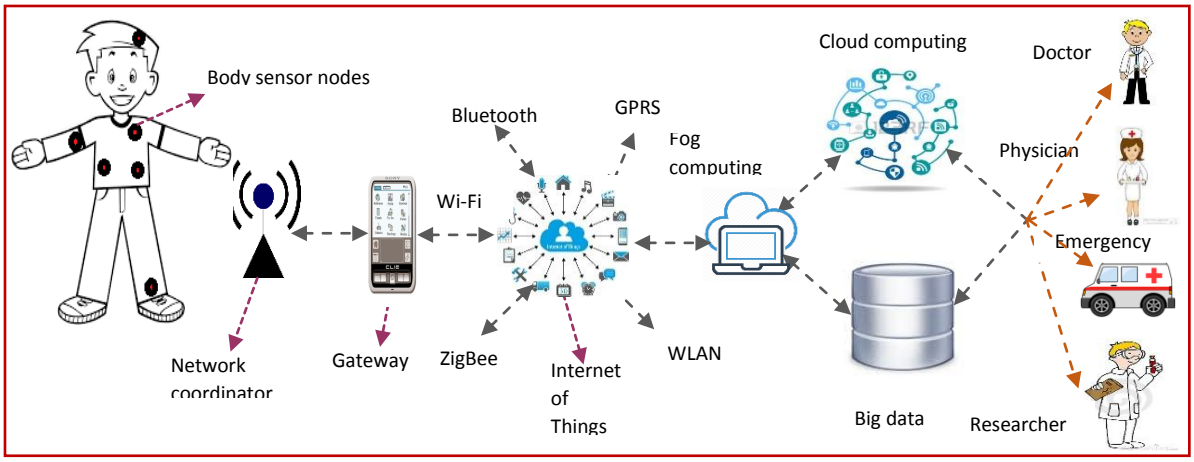

Fig.1 Overall schematic representation of WBAN system.

The standard describes the MAC layer that supports several physical (PHY) layers with the bandwidth efficiency of IEEE 802.15.6 to improve the security specification, energy efficiency of the sensor nodes and delivery tasks by using various advanced wireless technologies. Furthermore, WBAN application is coordinated with IoT (Internet of Things) for medical services [5] which provides one of the most significant solution to take care of aging people in the rapid growth, tracking of patients and biomedical devices within the hospitals and clinical institutes. Additionally, WBAN concentrated on fog computing [6] which is a new architecture to regulate some data center's tasks to the edge of the server. The primary objective of fog computing is to analyze the low and predictable latency in the applications such as healthcare services. Cloudlet framework provides scalable storage and processing infrastructure to accomplish the efficient data collection. Also, it supports large scale BAN systems which is capable to handle the Big data generated by WBAN users. Based on such technology the consumed power and packet delay of the collected data has decreased by increasing the number of Cloudlets [7]. Hence, the transmission of life critical data over the network becomes more decisive challenge. The remaining sections of this paper has organized as follows: Section II presents some of the existing medium access techniques in terms of energy and delay in WBAN. Section III discusses about the open research problems with feasible solution. Finally, the paper is concluded and the future work is stated in Section IV.

Energy efficient and Priority based MAC Protocols for WBAN

Low power communication technologies are used in between the body area nodes and a network coordinator [8]. The specialized IEEE 802.15.6 standard [9] has been designed for WBAN, to overcome various issues like energy consumption, latency and reliability. Furthermore, many authors were implemented a UWB based MAC protocols for effective data delivery and energy usage [10]. The effect of user priority scheme for various kinds of data for MAC layer adopted theslotted ALOHA channel access. ALOHA is the network that provided the first demonstration of a wireless data packet network. Authors were considered the back off scheme scenarios only in high priority medical data, however in such scenarios both the medical and low-priority non-medical data transmission offered the superior performance in throughput and packet delivery ratio provided for medical applications [11]. In WBAN, various data resources can be able to generate the time varying traffic. The large traffic volume might result in heavier latency to tackle those efficiency and reliability, authors were concentrated on the development of WBAN MAC design [12]. Furthermore, consideration of the traffic nature

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and channel status, they were introduced a context-aware MAC protocol and demonstrated that the proposed protocol has an ability to minimize the latency, energy consumption, and the packet loss rate [13]. The CSMA/CA protocol in IEEE 802.15.6 [14] allows the quick and prioritized access to the channels using differentiation contention window bounds of nodes with various priorities. With the help of CSMA/CA protocol, the throughput, delay and energy consumption have been evaluated. The different MAC protocols including S-MAC, TMAC, ZigBee, Baseline-MAC have also considered in [15] to predict the factors that affects the throughput, latency, delay and energy efficiency. Hence, the design of MAC protocols with high priority energy efficiency, and minimum delay for WBAN are the prime consideration.

1.1 Energy Consumption

Due to continuous transmission of data from the body sensors to base station, energy consumption of each node leads faster. Since, the effective MAC protocols are needed to improve the node's life time**.**Dynamic delayed Medium Access Control (D^2MAC) has implemented [16] using fuzzy logic technique that combined both application and protocol related parameters of the real-time traffic to adapt traffic loads with back-off time generated in IEEE 802.15.4 MAC protocol. The overall results validate a substantial reliability in data transmissions and minimize the latency without change in energy consumption of the sensor nodes.

In [17], a novel Token based Two Round Reservation MAC (TTR-MAC) protocol has employed based on IEEE 802.15.6 standard. In this technique, one round reservation scheme is focused for periodic data and two round reservations is created adaptively change the burst data to reduce the energy. Furthermore, this protocol distributes suitable number of allocation time slots to nodes in different data arrival rates. A token is a key to assign the user priority and critical data index is indicated to the transmission order of nodes, which extremely decreases the average delay. Authors in [18], evaluated the QoS parameters such as Delay, Reliability, Throughput (DRT) is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) channel access using IEEE 802.15.4 and IEEE 802.15.6.

However, using CSMA/CA, the data that informs the patient's emergency situation could not be transmitted to the coordinator, it is because CSMA/CA impairs network efficiency. To overcome such problems, they are concentrated on the prediction of network delay and collisions. A Back-off Counter Reservation (BCR-MAC) MAC technique has proposed to add the next back-off value to the payload of each transmitted data frame in order to the network coordinator could know their future back-off period. If the data frame does not arrive at the predicted time slot, a Guaranteed Time Slot (GTS) is allocated to the node in the next frame. In this scheme, a sensor node can reserve a back-off counter for next packet transmission [19]. The proposed results are evaluated and thus significantly improves the throughput, delay and collision probability. Table I describes the protocols served for energy efficient data transmission in WBAN.In [20], a Heuristic Self-adapt MAC (HS-MAC) approach has developed to reconfigure the wake-up schedule of the nodes in WBAN. Based on an adaptive algorithm that allows sensor nodes to adapt their wake up and sleep periods proficiently in static and dynamic traffic variations. Combined CSMA/CA with Flexible TDMA scheme for Interference Mitigation in relay-assisted intra-WBAN MAC (CFTIM-MAC) has presented [21] to communicate with network coordinator through using reliable channels. This method is used to extend the sensor node's lifetime as well as improved the throughput.

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Table 1:Protocols Assisted for Energy Efficient Data Transmission

Protocols	Literature	Techniquesused	Advantages	Drawbacks
D^2MAC (2013)	[16]	CSMA Scheduling	Reduced the latency with no change in energy consumption	No priority based data transmission exists
TTR-MAC (2016)	[17]	TDMA Scheduling	Highly decreases the average delay	No priority based reservation technique has been considered
DRT-MAC (2016)	[18]	CSMA Listening	Improved Delay, Reliability and Throughput	It does not support emergency data traffic
BCR-MAC (2015)	[19]	CSMA Listening	Good throughput, delay and collision probability	The waiting time of each time slot leads to high delay
HS-MAC (2016)	[20]	TDMA Scheduling	Idle listening problem is minimized	Unnecessary wake up beacon transmission
CFTIM-MAC (2016)	[21]	CSMA Scheduling	Extend the node's lifetime and high throughput	There is no mechanism to consider emergency data

1.2 Priority based data transmission

The huge amount of data is transmitted from the multiple sensor nodes for the purpose of monitoring patient's health related data in hospitals and homes. Delay and collision may occur in the presence of heterogeneous traffic loads, interruption of signals and so on. The most significant challenges for WBAN is to transmit the time critical data without any delay and maintain the QoS under the dynamic environment. The Latency-Energy Consumption-Timeout MAC (LEC-TMAC) protocol [22] has developed to minimize the energy consumption and latency in WBAN by reducing the activation timeout value with the support of listening timeout. Also, it practices flexible duty cycles for improving energy efficiency. In T-MAC, node depends on the concept of sleep and wakeup, the node wakes up after every time slot assignment, send remaining packets. This approach is more active with energy consumption and latency. This protocol could not provide throughput, PDR and network lifetime.

In [23], the authors have proposed a Priority-based Adaptive MAC (PA-MAC) protocol for better band width utilization. The proposed PA-MAC uses both CAP and CFP. The CFP is used to transfer continuous data packets to the coordinator. Also, the time slots have been allocated dynamically, based on the traffic priorities. Further, multiple channels are resourcefully utilized and reduced the average delay in WBAN, in the presence of coexisting systems. Priority Based Adaptive Timeslot Allocation (PTA MAC) has introduced [24] to prioritize the data using adaptive time slot allocation scheme. The CAP is divided C1 and C2 type of data and remaining

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phase used to transmit all types of data traffic. The emergency data are forwarded during CAP period through CSMA/CA approach. This protocol is also able to manage with dynamic network.

Data channels are parted from control channels to avoid collision using Priority Guaranteed MAC (PG-MAC) protocol in [25]. Only the priority based control channels are adopted to provide priority guarantee to life critical data. Normal data traffic channels are arrayed to improve resource efficiency and latency. Moreover, to minimize energy consumption and average delay, an asynchronous wakeup trigger mode has introduced for the priority traffic. Human Energy Harvesting Medium Access Control MAC (HEH-BMAC) protocol [26] has developed by combining two different medium access methods including Polling and Probabilistic contention to adjust the active and inactive states. This protocol reduces the average time delay and the energy consumption of each sensor node based on different priority levels. This method achieves better throughput and energy trade-off. Table II presents the protocols served for priority data transmission in WBAN. Context-aware MAC (CA-MAC) protocol uses hybrid super frame structure. In this, the traffic aware adjustment of priority data transmission and channel-aware adjustment of access mechanisms leads to desired energy efficiency and reliability. CA-MAC dynamically changes the sampling rate and scheduled based slots of each sensor nodes. However, a new polling based access schemes are necessary to manage the time critical data [27].

II. OPEN RESEARCH PROBLEMS AND FUTURE SCOPE

Many challenges and open research issues are still existing in different aspects of WBAN that needs to be considered. In future, the huge volume of data will be collected from multiple WBAN systems, also data can be in different formats such as audio, video, text, image and so on. To transmit these critical data at the right time and take necessary actions for the right patient are the major goals in healthcare monitoring applications. Since, designing a suitable MAC protocols for achieving better energy and the channel utilization is very important concern in WBAN. In this section, the open research problems are described in terms of energy efficiency, delay and priority based data transmission.

Wake-up interval and wake-up time are the most two fundamental design parameters to establish synchronization between sensor nodes and coordinator node. In [20], coordinator node adapts the wake-up schedule based on the traffic variations. Two access phases are introduced to transmit the data to a coordinator node. In first phase, each node waits for a beacon message before its data transmission. There is no specific mechanism to handle critical data packet, also extra control messages may degrade the result and increases the energy usage. Therefore, the reduction of extra listening periods during emergency data transmission is still a main challenge because it is difficult to predict which node will transmit critical data in the next cycle. To avoid interference and energy consumption of sensor nodes, authors proposed [21] CSMA/CA mechanism for non-interfering relay nodes and flexible TDMA mechanism for high interfering relay nodes to communicate with a coordinator node. In the first part, each node listens to the beacon message if node finds its ID in the beacon, then it transmits data in the assigned time slots. If not, node again synchronizes its time clock with coordinator node. Then, coordinator node selects one of the free slots and then transmits its beacon message in that corresponding time slot. Since, these empty slots are not assigned to any other nodes that may increase collision ratio with other nodes or newly incoming nodes. Hence, node keeps trying to listen for its beacon message that may chance to extra energy wastage and idle listening problem.

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Table 2:Protocols Served for Priority based Data Transmission

Protocols	Literature	Techniquesused	Advantages	Disadvantages
LEC-TMAC (2015)	[22]	TDMA Scheduling	Energy consumption and Latency	Less packet delivery ratio and throughput
PA-MAC (2016)	[23]	TDMA Listening	Less delay	Collision problem due to heterogeneous traffic loads
PTA-MAC (2013)	[24]	CSMA Listening	Improved QoS with dynamic network size	No guaranteed transmission of critical data packets
PG-MAC (2011)	[25]	CSMA Listening	High throughput	Adaptation in duty cycles might be slow and support only for delay sensitive data applications
HEH-MAC (2015)	[26]	CSMA Scheduling	Better in energy efficiency and throughput	Mode of operation leads to high delay
CA-MAC (2011)	[27]	TDMA Scheduling	Collision is omitted and delay, energy is improved	Emergency data is not considered

Also, it has used many unused timeslots and not considered any special mechanism to handle priority data. Authors have implemented two types of channel access methods to improve energy efficiency and throughput in [26]. In contention-free ID-polling, coordinator node assigns a monitoring interval ID to each node. Node transmits data packet to the coordinator node and then it confirms with ACK packet. These intervals are stored and updated in a dynamic table. Based on the updated schedule, coordinator node regulates the energy level of each and every sensor node. Once the communication is done, node turns again its radio to the sleep mode until it starts the next round. This channel access method uses a special ACK message after reception of successful data packet. In this, sender keeps on storing and updating the interval information may provide extra overhead and energy consumption due to extra control messages.

The highly coexistent interferences might be affected by beacon drops, data collisions, packet delays, and extreme energy consumption. To eliminate these issues, authors designed [23] a fixed time slot allocation technique for the control channel and the rest of the time slots is allocated to the data channel respectively. The superframe structure has divided into two phases such as CAP and CFP. In CAP access mode, each node transmits its packets to a coordinator node. But in CFP, each and every time node sends the GTS request to the coordinator. After successful packet reception, the GTS request packet has allocated to the nodes. The number of GTS requests and heterogenous traffic load may result the high collision ratio. All these methods are used both CSMA/CA and TDMA channel access method to effectively minimize the collision, energy and delay

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problems. From the overall analysis, nodes should extremely save their energy usage as much as possible. In addition, most of the data generated by the sensor nodes areredundant, it also causes a significant amount of energysurplus. Time critical data gathered from many WBANs are stored in the form of packets. Many researches have been focused some techniques to reduce the latency issues and few proposed scheduling methods to prioritize the critical packets in a queue. Since, the priority based scheduling, extremely energy efficient and intelligent packet reservation MAC protocols are necessary to eliminate the delay and energy issues. Also, a WBAN positioned on one patient's body may be connected with other patient in different data rates and power usage. However, this network must have to ensure consistent data transfer using specific set of MAC protocols to improve the data exchange, interact with other applications. In future, maintenance of data over the network fully depends on the prediction of challenges in QoS.

III. CONCLUSION

WBANhas several challenges due to continuous monitoring of patients in medical applications. Energy consumption and delay are the substantial issues in WBAN for the transmission of life time critical data from sensor nodes to the coordinator node. Many research works have fixated in designing the energy and delay-aware MAC protocols for WBAN. This paper reviewed about the recent protocols with main focus on energy consumption, delay, and priority based data transmission. Further, this paper explored the advantages and disadvantages of recent MAC protocols and highlighted some feasible solutions to eliminate the collisions, control overhead, delay and energy wastage. These issues should be reduced with the help of refining the existing techniques or using intelligent priority based scheduling MAC protocols in future.

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