Research Article
Journal of Intelligent Systems: Theory and Applications 4(1) (2021) 1-7
DOI: 10.38016/jista.758312

Performance Evaluation of WBANs MAC Protocols in Different dBm and OMNet++

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Abstract

In present days, wireless sensor networks (WSN) have involved considerable attention of both academy and industry because of the varied range of contexts in which they could be used. The has wireless body area network (WBAN) become the most important standard for WSN, and several software and hardware platforms are built on it. The implementation and performance analysis of this standard is essential to understand the important limits of it. The simulation is one of the greatest valuable tools for protocol evaluation and prototyping design. Furthermore, network simulators play an important part to test new algorithms and other protocols built on this specification. In this paper, the performance of the WBAN MAC standard protocols has been tested. The performance of the protocols regarding power consumption, delay and packets congestion are compared using OMNet++ simulator.

Keywords: wireless, sensor network, WBANs, algorithm, simulation.

1 INTRODUCTION

The wireless connection is used to connect different devices without any physical connection like cables. The wireless type of connection reduces the cost and difficulties of using the traditional wired network. In wireless networks, the connected devices use the radio frequencies to send data between source and destination. The physical layer in the wireless network devices is responsible for getting connected to each other [1].

Current developments in micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics have allowed the progress of low-cost, low-energy, multiuse sensors that are minor and connect free in small areas. These little sensors, that contain sensing, data processing, and communicating gears, force the knowledge of sensor networks grounded on cooperative energy of several nodes [2].

The Institute of Electrical and Electronic Engineers (IEEE) confirmed the structure of a working collection for IEEE 802.15.4 (IEEE 2003) to outline a foundation to Body Area Network [3]. The 802.15.4 defines both the physical & media access control layer. The physical layer can work in different bandwidths, the first one is the frequency band 2.4 to 2.4835 GHz using 16 different channels, the second one is the frequency band from 902 to 928 MHz using ten different channels, and the third one is one channel in the frequency band 868.0 MHz to 868.6 MHz [4]. There are different features of the media access control layer managing. They are beacons, channel contact, managing of GTS, proof of the frames, and others. There are two methods of process of the media access control layer contingent on the topology that used and the need for certain bandwidth; they are beaconless approach and beacon approach. In the beaconless approach, the sink node is the only state waiting for information. The expedient that wants to send info, it will first check if the channel is empty. If it is empty, then it will send the info. If it is not empty, it will wait for an arbitrary time that defined in the ordinary. If the sink node has info that must be sent to an expedient, it will wait till the nodes demand for the information. After that, the sink node must send the acknowledgment to reaction of the demand. The sink node will transmit the info if they are pending, using the exact

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Recieved : 26 June 2020
Revision : 21 October 2020
Accepted : 27 October 2020

procedure of CSMA/CA. In the case of no info that waits, the sink node sends an empty info frame. The beaconless approach is naturally used in the nodes that sleep for a long time (99%). When an incident occurs, the nodes will wake-up and immediately will direct a frame of aware. In this kind of work, the sink node will not supply any synchronization for the nodes, no Guaranteed Time Slot (GTS) will be coming, and only arbitrary access is taken over for medium spreading because of no superframe and the space of synchronization. There are many kinds of sensors used in sensor networks: low sampling rate magnetic, thermal, seismic, visual, infrared, acoustic and radar, which can sense different environment circumstances such as humidity, temperature, lightning condition, vehicular movement, noise levels, pressure, soil makeup and the current features like speed, course, and size of an item.

Sensor nodes could be beneficial to place sensing, continuous sensing, control of actuators, and event recognition. The idea of wireless connection and micro-sensing of these nodes open the door for many different application zones [5]. In current times, there has been growing awareness from researchers, application developers and system designers, on a novel kind of network construction commonly known as wireless body area networks (WBANs) or body sensor networks (BSNs), made possible by new developments on frivolous, ultra-low-power, small-size, and smart monitoring wearable sensors. In WBANs, sensors constantly watch human’s physical actions and activities, like motion pattern and fitness situation [6].

We studied five different MAC layer protocols which are used broadly in WBANs. Two different scenarios were created using Castalia simulator under the OMNET++ platform. We calculate, delay, power consumption, and packets congestion with the using of two different sensor dBm.

The rest of the paper is organized as follows: In Section 2, we will review the literature. Section 3 contains MAC protocols in WBANs. Section 4 contains OMNET++ simulation framework of mac protocols and finally, section 5 concludes the paper.

2 RELATED WORK

Recently, many articles have reviewed and detailed the aspects of wireless sensor and WBANs.

In [7], a new frame structure design is proposed for a new MAC in WBAN by prioritizing patient data traffic. Later, critical patient data were measured effectively and threshold-based slot allocation technique was developed. Also, packet size, mark spacing, super frame time efficient frame design are presented.

Hybrid MAC protocols for WBAN are compared in [8]. First, the design challenges of WBAN MAC are listed. Second, hybrid MAC protocols are compared to standard MAC protocols. Third, a comprehensive comparison of hybrid MAC protocols is presented in terms of QoS and WBAN specific values. Finally, important open research areas neglected in hybrid MAC design have been identified.

A new QoS-based cross-layer MAC protocol is proposed in [9], capabile with the ISO / IEEE 11073 standard, using a socket allocation scheme, priority mechanism, multi-channel architecture, and cross-layer solution. The proposed MAC protocol has been modeled and simulated. The proposed method gives better results than other MAC protocols in terms of end-to-end delay, packet loss rate and throughput parameters.

In [10], a TDMA-based MAC protocol is proposed to dynamically adjust the transmission order and transmission time of the nodes according to the channel status of the WBAN and application context. The working slot allocation optimizes by minimizing the energy consumption of the nodes, subject to delivery probability and production constraints. It has also proposed a new synchronization scheme to reduce synchronization overhead.

In [11], reviewed protocols for sensor wireless networks and grants cataloguing for the several methods pursued. The Datacentric, the hierarchical and position-based are three important classifications that are inspected in this paper. In addition, the quality of network flow and service modeling is also discussed.

In [12], reviewed the synchronization of the time issue and the requirement for synchronization of the time in sensor networks, after that presents in detail, the synchronization of the time in the basic form approaches designed and proposed for sensor networks.

In [13], suggested the unwanted EA’s performance when dealing with grouped routing problem in WSN by framing a new fitness role that incorporates two clustering parts, viz. cohesion and separation error.

In [14], offers sensor-MAC (SMAC), a new medium access control protocol planned for the networks of the wireless sensors. While dropping power, feeding is the primary goal in the plan; the protocol has the decent ability to change the size and capable of escaping from the collision. It achieves these by using a collection of scheduling and contention scheme.

In [15], the availability of WSN nodes are considered that can be addressed by indulging the distant testing and fixing the substructure for separate sensor nodes using COTs components, they built and evaluated the system level examination interface for distant testing repair and software update. This also covers contents regarding the plan methods which were carried to explore the difficulty using the projected infrastructure. The wireless broadcast can be used efficiently in various testing with optimum cost.

In [16], the modified superframe structure of IEEE 802.15.4 based MAC protocol is proposed which addresses the problems and improves the energy consumption efficiency. Moreover, priority guaranteed CSMA/CA mechanism is used where different priorities are assigned to body nodes by adjusting the data type and size.

In [17], presented an energy-efficient cooperative MAC (EECO-MAC) protocol using power control in mobile ad hoc networks. Cooperative communications improve network performance by taking full advantage of the broadcast nature of wireless channels.

3 WBANs MAC PROTOCOLS

At the MAC layer, there is an interchange among latency, reliability, and energy feeding that must be fixed. The QoS needs, i.e., latency and reliability, create from applications, and power feeding mirrors the overall protocol complexity and appropriate duty cycle [18]. Resource efficiency is a very important factor when developing a MAC protocol for WBAN. Comparing to wireless networks for more wide areas, WBANs experience much fewer power consuming which explains into more long times by getting an actual little duty cycle and a basic protocol job. Regularly, the body sensor has a partial battery volume, particularly for these sensors that are located in the body. For raise, the lifetime of those sensors, power effective MAC protocols will be a significant part. In contrast, some WBANs grounded applications require a very dependable connection, little delays, and little energy feeding [19].

To report the serious problem of spreading sensor time, many low energy MAC protocols have been projected for general WSNs [20]. In those protocols, the radio is switched on and off occasionally to maintain power [21].

S-MAC usages three new methods to decrease power feeding and provision self-formation. To decrease power feeding in hearing to a silent network, nodes occasionally snooze. Adjacent nodes procedure practical groups to auto-match on snooze timetables. Enthused by PAMAS, SMAC likewise puts the radio to snooze through communications of further nodes. Different from PAMAS, it solitary utilizes in-network signing. Lastly, SMAC puts on note transitory to decrease argument dormancy for sensor-network applications which need to keep and advance dispensation as information transfer over the network [22].

TMAC protocol is a medium access control protocol planned particularly for wireless sensor networks. TMAC allows wireless sensor node switch on its wireless at harmonized periods and switches it off later of a firm time-out once no message happens through some period. Messages are spread in bursts. This arrangement lets active alteration of the wireless-on period to altering message rates. TMAC protocol keeps additional power comparing to its predecessor SMAC in a network which message rates change. SMAC protocol allows the node to switch the wireless on for a static period. S-MAC needs change to the message rate, while T-MAC does not [23].

BMAC is a carrier sense media access (CSMA) protocol for wireless sensor networks. Driven by ecological monitoring applications, BMAC structures extreme low energy work, actual impact escaping, minor code scope, and expectable implementation. To reach little energy work, BMAC hires an adaptive little energy wireless selection arrangement to decrease working sequence, minimalize idle hearing, and remove the overhead of harmonization. BMAC lets facilities to rearrange the MAC protocol for the best act, whether it be for productivity, dormancy, or energy preservation [24].

BanMAC is IEEE 802.15.6 for wireless body area transportations. That standard aims to stipulate numerous physical layers (PHY) and medium access control (MAC) layer protocols for the diversity of requests with numerous QoS needs [25].

ZigBeeMAC is IEEE 802.15.4 standard stipulates that MAC layer is largely accountable for retrieving of the physical layer wireless channel, that is to reach networks active admission grounded on the physical layer interface purposes [26]. There are mostly two types of information sending style in ZigBee networks: with-beacon connection and without-beacon connection. In with-beacon networks, the network director occasionally transmits beacon frames, gear in PAN network is harmonized per the beacon frames from the director. For without-beacon networks, the network director arbitrarily broadcast beacon frames from period to period. When the node is around to transmit info, initially, it must pause for an arbitrary distance of time, and after that start to sense the network situation, if free, the node begins to transmit info; if not free, the node must pause for additional time, and re-sensing network till the network is free to transmit info. To shorten the understanding of the protocol, the plan utilizes without-beacon info sending model. Figure 1 shows the wireless body area networks' MAC protocols.

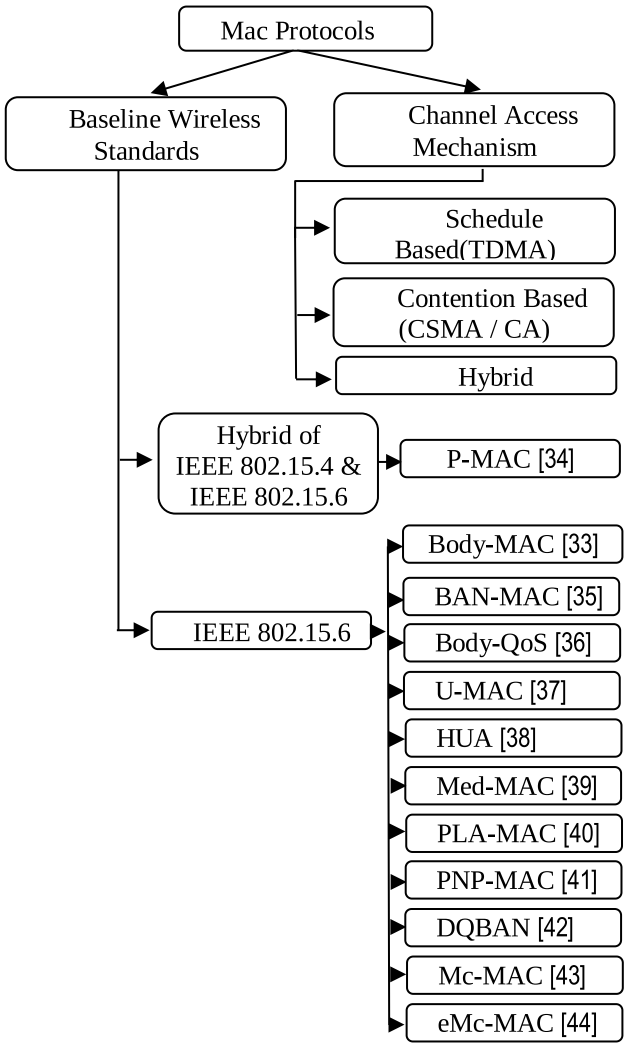

Figure 1. WBAN MAC Protocols.

4 SIMULATION FRAMEWORK

Network simulators attempt to model the actual networks [27]. The main knowledge is that if a system could be modelled, structures of the model could be altered, and the conforming outcomes could be examined. As the procedure of model adjustment is inexpensive comparing the whole actual operation, an extensive variety of scenarios could be examined at small charge [28] [29].

Presently there are a lot of network simulators which have various structures in dissimilar features [30]. A small list of the present network simulators contains OPNET, NS-2, NS-3, REAL, OMNet++, J-Sim, SSFNet, and QualNet. Though, in this chapter, we do not aim to shelter all the presented network simulators. We only choice some characteristic ones and do some study and compare some from the others a little to grow a good opinion of the key structures of a specific network simulator. OMNet++ is widely used WBANs open-source network simulator that has an influential modular core design and graphical interface [31] [32].

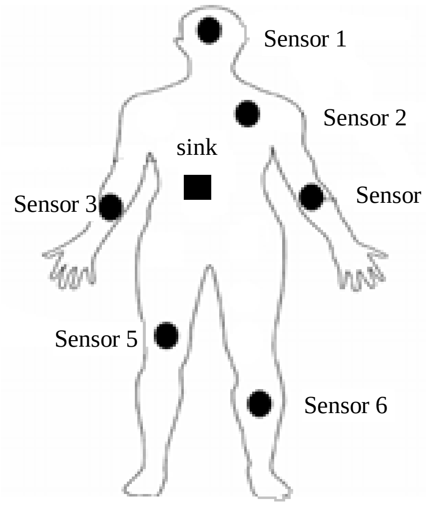

Figure 2. Distribution of the sensors.

We take four different considerations to compare among; delay, the power consumed, and collision. To evaluate the performance of the wireless sensor network; we created a simulation scenario using Castalia simulator based on OMNet++ platform We created two different scenarios in Castalia simulator, the first scenario with six nodes and one sink node and the second scenario with 24 nodes and one sink node. The simulation parameters that we used are shown in table 1. In 6 nodes scenario, we assumed that all the 6 nodes are attached to one person only plus the sink node. as shown in Figure 22. For the 24 nodes scenario, we assumed that there are 4 persons in one room and every person have 6 nodes plus sink node attached for each one. We applied five different MAC layer protocols; TMAC, SMAC, BMAC, BANMAC (802.15.6), and ZigBeeMAC (802.15.4). In both scenarios, the application in each node generate 10 packets per second, and each packet size is 105 Byte as listed in table 1. We calculated the average delay from the delayed histogram by taking the average time for each interval in the histogram and multiply it by the number of packets received during this interval, then we take the summation of them and divided it by the total number of the received packets.

Table 1. Simulation parameters

Parameters	Scenario 1	Scenario 2
Topology	Star	
Number of Nodes	6 + 1	24 + 1
Field Area	2 x 2 meter	6 x 4 meter
Mobility	Static Nodes	
Simulation Time	60 s	
Startup Delay Time	1 s	
Application Packets Rate	10 packets per second	
Application Packets Size	105 Byte	
Node TX Power	-10 dBm, -20 dBm	
MAC Protocols	TMAC, SMAC, BMAC, BANMAC, and ZigBeeMAC	
Max Packet Size for MAC	No Limit	
Buffer Size for MAC	32 Packets	
Packet Overhead for MAC	11 Byte	

We calculated the power consumption for the nodes by assuming that each node will consume 3.0 mW per second during the transmission and receiving with -10dBm sensor power and 2.9 mW per second during the transmission and receiving with -20dBm sensor power. Then calculate the time the consumed to transmit and receive all the packets in each node and multiply it by the power rate for each sensor power that assumed above.

We calculated the packets congestion by computing the number of packets that failed to be reached the sink node from each sensor due to the interference.

The average power consumed for six and twenty-four nodes. -10 dBm and -20 dBm power is shown in figure 3 and figure 4. In the six nodes, the SMAC protocol gives the least average power consumption level in both -20 dBm and -10 dBm power. While in the 24 nodes, the BMAC protocol gives the least average power consumption level in both -20 dBm and -10 dBm power. This is because BMAC does not have the RTS-CTS mechanism or synchronization requirements of other MAC protocols like SMAC and TMAC, the implementation is both simpler and smaller.

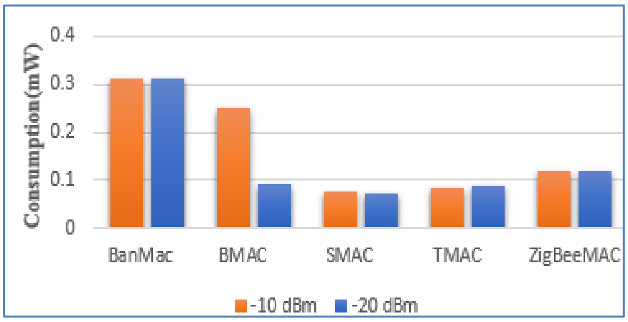

Figure 3. Average power consumption for six nodes.

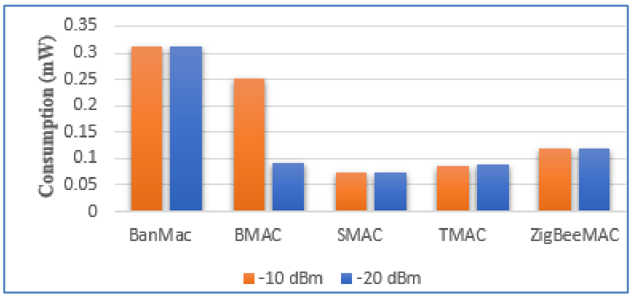

Figure 4. Average power consumption for twenty-four nodes.

The average delay for six nodes, -10 dBm and -20 dBm power is shown in figure 5 and The average delay for twenty-four nodes, -10 dBm and -20 dBm power is shown in figure 6. In the six nodes, the BanMAC and ZigBeeMAC protocols give the least delay in application level in both -20 dBm and -10 dBm power. While in the 24 nodes, the BanMAC protocol gives the least delay in application level in both -20 dBm and -10 dBm power. This is because BanMAC standard in a beacon mode with superframe boundaries, a hub divides the time into multiple superframes.

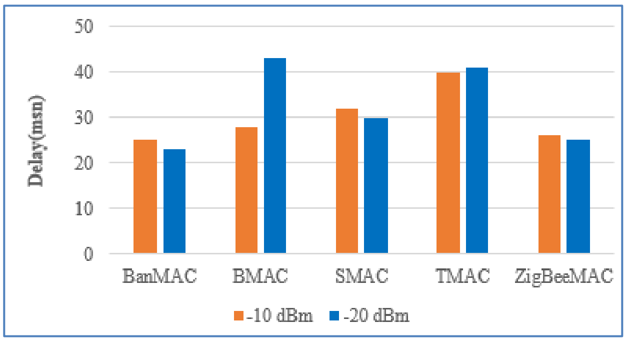

Figure 5. Average delay for six nodes

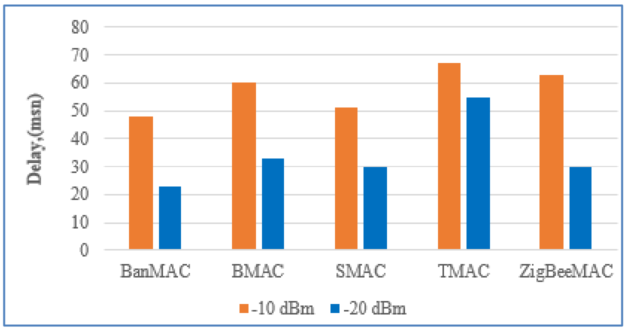

Figure 6. Average delay for twenty-four nodes

The congestion of the packets for six and twenty-four nodes, -10 dBm and -20 dBm power is shown in figure 7. In the six nodes, the TMAC protocol gives the least average packets congestion level in both -20 dBm and -10 dBm power. While in the 24 nodes, the TMAC and BMAC protocols give the least average packets congestion level in both -20 dBm and -10 dBm power. This is because T-MAC allows wireless sensor node switch on its wireless at harmonized periods and switch it off later of a firm time-out once no message happens through some period.

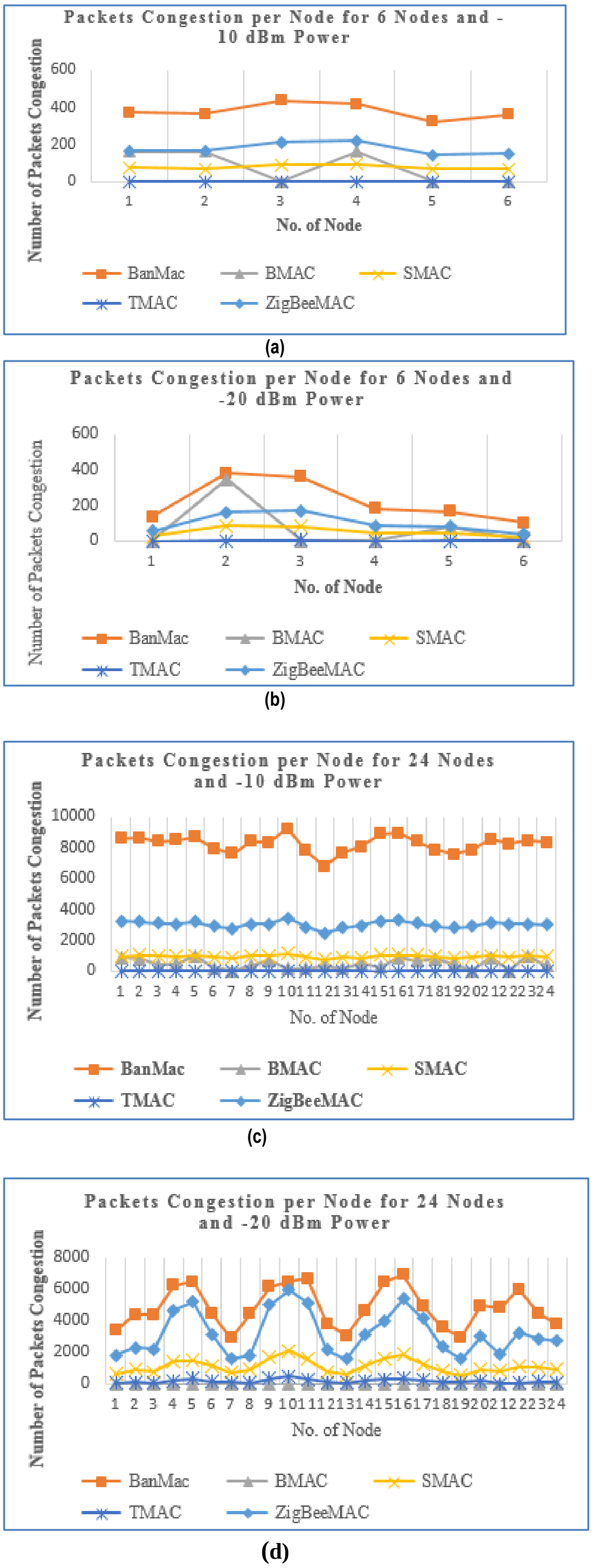

Figure 7. Congestion of the packets

To be clearer to understand the performance differences between the MAC protocols, we make a comparison as shown in table 2.

Table 2. Comparison of MAC Protocols

	Average Delay				Power Consumption				Packets Congestion			
Power	**-10 dBm**		**-20 dBm**		**-10 dBm**		**-20 dBm**		**-10 dBm**		**-20 dBm**	
Number of Nodes	**6**	**24**	**6**	**24**	**6**	**24**	**6**	**24**	**6**	**24**	**6**	**24**
BanMAC	Very Good	Good	Very Good	Very Good	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Mid
BMAC	Mid	Mid	Mid	Good	Bad	Very Good	Good	Very Good	Good	Good	Mid	Very Good
SMAC	Good	Good	Good	Mid	Good	Good	Very Good	Good	Good	Good	Good	Good
TMAC	Very Bad	Very Bad	Very Bad	Very Bad	Very Good	Good	Very Good	Good	Very Good	Very Good	Very Good	Very Good
ZigBee MAC	Very Good	Very Good	Very Good	Good	Very Good	Good	Good	Good	Mid	Mid	Mid	Mid

5 CONCLUSION

WBANs deliver talented applications in health monitoring systems to amount stated physiological information and deliver position-based info. In this paper, we offered an overview of the present MAC protocols for Body Area Network namely ZigBee (IEEE 802.15.4), BanMAC (IEEE 802.15.6), TMAC, SMAC, and BMAC. We also studied the performance of these protocols under two different numbers of nodes in terms of power consumption, packets congestion, and average delay using Castalia under OMNET++ simulator.

The analysis shows that ZigBeeMAC and SMAC show the high number of delays in high traffic. TMAC and SMAC show better average power consumption than the other protocols. TMAC gives the best results of congestion avoidance in different traffic load comparing to the rest four protocols.

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