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A Multi-beam Directional MAC Approach for Wireless Body Area Networks

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Abstract: Wireless Body Area Networks (WBANs) designed for medical, sports, and entertainment applications, have drawn the attention of academia and industry alike. A WBAN is a special purpose network, designed to operate autonomously to connect various medical sensors and appliances, located inside and/or outside of a human body. This network enables physicians to remotely monitor vital signs of patients and provide real time feedback for medical diagnosis and consultations. The WBAN system can offer two significant advantages: patient mobility due to their use of portable monitoring devices and a location independent monitoring facility. With its appealing dimensions, it brings about a new set of challenges, which we do not normally consider in such small sensor networks. It requires a scalable network in terms of heterogeneous data traffic, low power consumption of sensor nodes, integration in and around the body networking and coexistence. This work presents a medium access control protocol for WBAN which tries to overcome the aforementioned challenges. We consider the use of multiple beam adaptive arrays (MBAA) at BAN Coordinator (BAN_C) node with superframe similar to IEEE 802.15.4. When used as a BAN_C, an MBAA can successfully receive two or more overlapping packets at the same time. Each beam captures a different packet by automatically pointing its pattern toward one packet while annulling other contending packets. This paper describes how an MBAA can be integrated with superframe structure to serve single hope star topology where BAN_C serves as coordinator. Simulation results show the performance of our proposed protocol.
Keywords: wireless body area network (WBAN); MAC; multi-beam adaptive arrays (MBAA); sensor node; Slotted Aloha

I. INTRODUCTION

According to aging estimates, there will be some 71 million elderly people in USA by the year 2030, more than twice the number in the year 2000 [1]. With this progressive rise of people living longer and the increasing segment of elderly in the population, there will be greater need for ways to monitor their medical status and keep them safe without forcing them to live at or near hospitals or healthcare facilities.

Recent advances in Wireless and Micro-Electro-Mechanical technologies and the proliferation of electronics gadgets in, on and around human body provide a unique opportunity for building the next generation of wireless BAN technology targeted at medical and consumer applications. WBAN is seen as the key technology that will provide a single unified solution for connectivity in and around the body, and which is intended to support a wide range of medical applications such as wellness monitoring, deep brain stimulation, electronic pills, and implanted drug delivery, as well as lifestyle applications including ambient intelligence (e.g., home, office, car), gaming, entertainment, and consumer electronics [2].

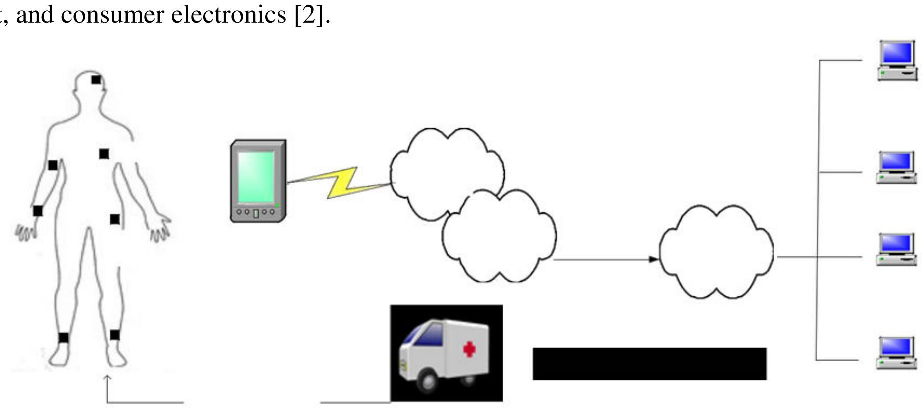

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Figure 1. WBAN's working scenario.

Figure 1 shows the general working scenario of a WBAN. Here all the data from a human body is collected and supplied to the appropriate destination using wireless communication. We are just concerned about the communication among the different sensors and BAN_C, which itself forms a small network. It has some distinctive properties which differentiate it from either a wireless sensor network or wireless personal area network. The close proximity of different sensors and BAN_C nodes to the body compels us to keep the electromagnetic pollution extremely low. The devices used (except BAN_C) are very small in their size (approx 1 cm3), which in turn put constraints on their energy consumption. Some of the devices are implanted inside the body with negligible option of renewing their energy source, so a long battery lifetime is needed (up to several years or even decades) [3].

Limitation on energy resources and available memory, consequently limits the computational power of such devices. Additionally, different sensors have different data rates and packet size. This small network may consist of numerous devices on a human body, which results into strong interferences. Electromagnetic waves are propagated through human body, so higher attenuation hampers the transmitted waves, before they reach their destination. It needs a simple and accurate propagation model as devices are quite heterogeneous in terms of data traffic, power consumption, delay and reliability. There is a large volume of ongoing work to develop the Medium Access Control (MAC) protocol for WBANs. Its distinctive property, which we discussed above, does not hold true for either Wireless Sensor Networks (WSNs) or Wireless Personnel Area Network (WPANs). This is why use of any of the set standard WSN or WPAN protocols does not meet the exact requirement of WBANs. In Table 1 we can see the IEEE draft WBAN specifications.

Table 1. IEEE WBAN specification.

Distance	2 m Standard 5 m special use
Network Density	2–4 nets/m2
Network Size	Max: 100 devices/network
Power Consumption	~1mW/ Mbps
Startup Time	<100 s or <10% of Tx slot
Latency	10 ms
Network setup time	<1 s (Per device setup time excludes network initialization)
Effective sleep modes	
Operation in global, license-exempt band	
Peer to Peer, and Point to Multi-point communication	
Future proof	Upgradeable,scaleable, backwards compatible
Quality of Service & Guaranteed Bandwidth	
Concurrent availability of asynchronous and isochronous channels	
Very Low, Low, and High duty cycle modes	Allows device driven degradation of services

WSN has been the inspiration behind most of the designed WBAN protocols in the literature. The IEEE 802.15.4 standards for low rate WPAN have been analyzed extensively. Our proposal exploits the multibeam adaptive array technology with a slotted aloha scheme. We know that directional antenna have received attention for ad hoc network protocols, and recently, many directional antenna MAC protocols have been proposed for wireless ad hoc networks [4]. Use of directional antennas in communication offers many advantages such as increased gain, spatial reuse, reduced interference for signal detection, improved throughput, etc. Spatial reuse and simultaneous communication of a BAN coordinator with the different nodes is the key behind this proposal. In a medical care facility, in a critical patient, we are bound to provide a solution where more than one sensor can communicate with coordinator simultaneously. MAC design with the help of classic protocols like FDMA, TDMA, orIEEE 802.15.4 etc. cannot provide parallel communication between more than one sensor and a BAN coordinator. The use of multi beam or multi radio concept provides support to this kind of network. The use of MBAA in such small network is discussed in the related study part.

Our protocol is for WBAN, for which almost all of the works suggest a star topology incorporated with a coordinator at its center, hence we also considered this simplest topology with a maximum 25 sensor nodes in this work. The paper is further categorized in different sections. Section 2 has some related studies, Section 3 describes our MAC protocol, Section 4 deals with the simulation and results, and Section 5 concludes the work.

II. RELATED STUDIES

There are various works which have aimed to resolve the MAC requirement of WBAN. Its similarity with WSN and WPAN gave it a basis for comparison, so MAC protocols utilized by these two network types have been analyzed for use in WBANs, but their heterogeneous traffic and criticality related with their users (patients) makes them exclusive. In Table 2 we see some major differences between WSNs and WBANs [5].

Table 2. Difference between WSNs and WBANs.

WSNs	WBANs
Cover the environment	Cover the human body
Large number of nodes	Fewer sensor nodes
Multiple dedicated sensors	Single multitasking sensors
Lower accuracy	Robust and accurate
Resistant to noise	Predictable environment
Failure reversible	Failure irreversible
Fixed structure	Variable structure
Low level security	High security
Accessible power supply	Inaccessible power source
High power demand	Lower power availability
Solar, wind power	Thermal, piezoelectric energy
Replaceable/disposable	Biodegradable
No biocompatibility needed	Biocompatible
Wireless solutions available	Lower power wireless
Data loss less of an issue	Sensitive to data loss

Here we discuss some pros and cons of WSN-related MAC protocols, to verify whether they will smoothly match the vital specifications of WBANs. Existing MAC protocols, which are intended for WSNs can be broadly categorized as: (a) Low power listening based protocols; (b) Scheduled Contention based and (c) TDMA based protocols.

Low power listening based protocols like WiseMAC [6] and BMAC [7] are quite good for high traffic applications, but are not suited for the low duty cycle of in-body or on-body nodes. As far as STEM [8] is concerned, it seems good for periodic traffic, especially for low traffic applications. It is suitable for handling sporadic events due to a separate control sub channel, but not in the case of high traffic, which is one of the possibilities in WBANs.

Scheduled Contention based protocols such as SMAC [9] and TMAC [10] are good for high throughput applications. In TMAC early sleep problem causes the loss of synchronization, while SMAC does not suit a network where throughput is not a big concern. Both protocols with above limitation seem unfit for WBAN. DMAC [11] has better delay performance due to sleep schedules but this one is also loosely synchronized.

The TDMA based protocol FLAMA [12] is good in the case of low power applications and it is adaptable to high traffic applications. Both the LEACH [13] and HEED [14] protocols use a cluster head mechanism which switches as per requirement,, but in the case of WBANs, switching of cluster head is neither possible nor required.

In spite of these protocols there are different proposals exclusively for WBAN in IEEE 802.15.6. Table 3 is an overview of the proposed MAC by different parties of the TG6 working group [15]. Protocols like Heartbeat Driven MAC protocol (H-MAC) [16], Reservation Based Dynamic TDMA Protocol (DTDMA) [17], and Body MAC Protocol [18] are also worth discussing.

Table 3. MAC proposals for IEEE 802.15.6

MAC Proposal	Type	Brief Description
MedWin	Beacon	Star topology, time partitioning, beacon, channel migration, security

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NICT	Beacon/Non Beacon	Super frame, TDMA based, non-beacon mode, MICS for wakeup
IMEC	Beacon	Dual duty cycling, flexible & power efficient, enhanced slotted Aloha with QoS, wakeup receiver, priority-guaranteed
YNU	Not mentioned (Cluster based communication)	Protocol considering SAR or thermal influence to a body by switching cluster
Samsung	Polling	Piconet co-existence, network management and security, poll based access and Single MAC concept
Inha	Beacon	Wakeup by Traffic Patterns and Radio, Super frame, MAC frame structure, Security, Multiple PHY support, Bridging Function
Fujitsu	Beacon	Signaling covering emergency, reliability, congestion and stability and wake up concept
CSEM	Preamble based WiseMAC-HA	WiseMAC based proposal (WiseMAC-HA)

H-MAC is a TDMA based protocol, supported by an active synchronization recovery scheme where two resynchronization schemes are implemented. The proposal is based on a star topology and it exploits heartbeat rhythm information in order to synchronize the nodes and enhance the energy efficiency.

DTDMA is again a protocol based on the TDMA approach with a beacon enabled super frame structure. It is good for normal traffic. In this proposal time slots are assigned to the nodes, which has buffered some data to transmit and later these slots are released for other nodes.

The Body MAC protocol is also a TDMA based protocol having a superframe structure, identical to IEEE 802.15.4. But this superframe is divided into downlink and uplink frame, and the uplink frame is further subdivided into a contention access period and a contention free period.

We propose an idea which mixes the concept of multi beam adaptive array with a superframe based slotted aloha and contention free period (CFP) medium access protocol. The approach is almost identical to beacon enabled IEEE 802.15.4 MAC but in spite of CSMA/CA, S-Aloha with MBAA is used.This protocol is simple and effective to implement, if appropriate hardware is available. An important reasoning behind our proposal is to decrease the delay while accessing the BAN coordinator, enough time to sleep while no transmission is on the way, and simultaneous transmission by different nodes towards a BAN coordinator in case of urgency. Use of MBAA at the BAN coordinator provides the answer to the above problems pertinently because it gives enough room to scalability, adaptivity and flexibility in S-Aloha part of the superframe. Simultaneously it provides guaranteed slot in It is lacking in case of downlink transmission when some transmission is needed from BAN_C to sensor nodes. In the system model explanation section we describe the workings of MBAA with a slotted aloha scheme.

2.1. Relevance of MBAA in WBAN

As far as use of multi beam adaptive array in WBAN is concerned, several concerns come to mind. The first of these is that they are too big, impractical and expensive for WBANs. In response we recognize that this modern platform itself is an expensive tool and will be often used by the rich, so cost is not a big concern. Another concern is the impracticality, since frequency reuse is one of the crucial issues to cope up with. Ongoing work on antennas for enhanced spatial division multiplexing gives us confidence that sooner or later we are going to use multi beam antennas in all forms of wireless communication. Literature supports the notion of personal area networks using millimeter wave antennas as well as the multi beam antenna approach for gigabit wireless communication [20,21], which we could not have imagined in the 90s. In [22] Ramanathan reports that at 2.4 GHz, and the typical half wavelength element spacing, an eight element cylindrical array would have a radius of about 8 cm, making it quite unwieldy. As the operating frequencies continue to increase (as we know IEEE 802.11a uses 5 GHz), the antenna sizes will shrink. In the 5.8 GHz ISM band, the eight element cylindrical array will have a radius of only 3.3 cm, and

at the 2.4 GHz ISM band a mere 0.8 cm. thus the future for the beam forming techniques for such small network also looks bright.
Our network has a star topology which couples the entire sensor node with the BAN Coordinator. It is generally presumed that the size of the coordinator will be somewhat equal to that of a PDA. Use of MBAA at coordinator will increase all the parametric performance. Logically this approach divides the human body into a number of arrays. In that case simultaneous transmission of data will reduce the critical nature of the network. Medical care in urgent situations creates circumstances where we need uninterrupted communication from more than one bio sensor devices. Use of multi beam or multi radio does not seem suitable for now, but a more careful examination opens up a number of possibilities. Figure 2 shows the pattern for the antenna beam steering.

III. SYSTEM MODEL

In our approach of designing the MAC for WBAN, the slotted aloha multiple access method is merged with the MBAA. The human body is treated as a circular cell with its base station as the BAN coordinator, which is mounted with MBAA, while all the sensor nodes are using omni mode antennas. Sensors are fixed, so there is no mobility in the network but the whole network itself is mobile. In this fixed star topology network a slotted channel is shared by the sensor nodes in the uplink transmission (from node to coordinator). The BAN coordinator receives packets from the sensor nodes through N, (where N 1) different but spatially separated beams. Each beam is of radians, where 2 /N. If
< 2 /N, these beams are non-overlapping, and the BAN coordinator is in receiving mode. The BAN area is also partially covered, leaving holes in the coverage, as we can see in the Figure 2, when antenna beam = 4. Angular width of the non illuminated holes will be (2 /N–). This scenario provides the room for the BAN coordinator for beam steering towards specific node without interference to others. When = 2 /N, BAN coordinator can be used to broadcast by switching on all the antenna elements N.

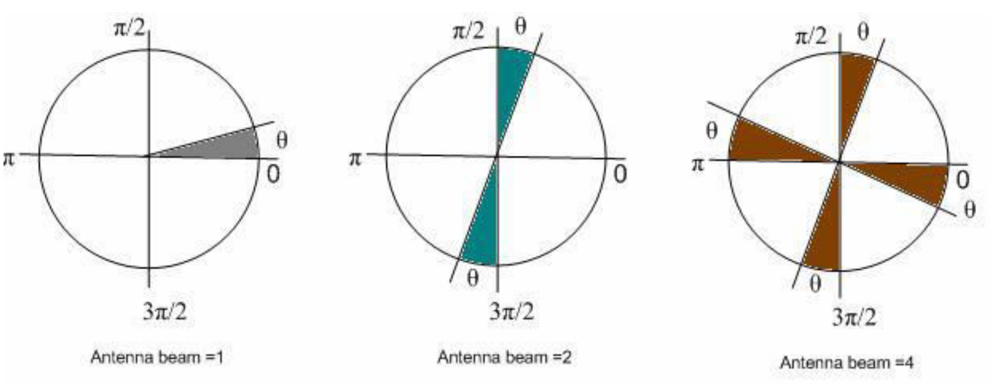

Figure 2. Beam pattern of antenna steering.

This small network notably has a very heterogeneous kind of traffic pattern with high risk urgent traffic situation. In case of any criticality to the patient it should be able to interact with BAN_C with very little delay. When sensors have nothing to transmit, they are in sleeping mode to save energy for longer lifetime. It has low traffic and low data rate. This network requires an efficient and simple MAC protocol to deal with its unique features. We reported some related studies in the previous section which elaborate different MAC and their capability to fulfill the requirements of WBAN. Due to the unique challenges posed by this small network each of those proposals has some drawbacks and cannot be used intact.

3.1. Slotted Aloha

Slotted aloha divides the time into equal slots, and the data packets are also kept of equal length. Packets are transmitted in fresh slots after their arrival. If more than one transmission takes place in a single time slot, packets are destroyed. There is a scenario where simultaneous transmission of several packets does not necessarily result in destruction of all the transmitted information. Using capture effect, if power of one of the received packet is sufficiently high, compared to the other packetsinvolved in the collision, and then strongest packet can be correctly decoded while others will be lost [23].

3.2. Beam Convergence and Wakeup Radio

In general study of the MAC protocol for WBAN, issue of waking up a sleeping node while not disturbing others has got lot of attention. Most of the protocol which discusses the energy saving mechanism gives periodic opportunity to the sensor node to go in sleep mode while not in transmission. This is an approach which has solved the wireless sensor network energy consumption issue with the help of work like SMAC, WiseMAC etc.[][]. Unlike wireless sensor network, WBAN has unique sensor for each of its task to handle. In wireless sensor network hundreds, sometimes even thousands sensors are deployed to concentrate on single task/change in the environment. So absence of one sensor out of one cluster, due to their sleep schedule hardly matters to the network. But incase of WBAN, where each sensor has been assigned a unique task, absence of the required sensor from network can create a critical situation for its user. Especially in times of need their absence matters a lot. Further more, we can not keep them waking up most of the time, since it turns into more energy consumption. So there is a tradeoff between energy consumption and sleeping of the sensor to prolong their lifetime in the network. Some scholars have suggested the use of wake up radio mechanism as busy tone (BT) channel to wake up the destined node, incase of urgency/on demand data traffic from the BAN_C or Doctor. In the last part of the superframe's inactive period BAN_C is given opportunity of on demand data transmission. Worth noting is that whenever a node is finshed with its transmission it goes to sleep. As per its need it wakeup and listens to beacon, and try to transmit its data into S-Aloha part.if it wants to reserve the GTS it request for the same in S-aloha portion.

Use of busy tone channel is a good approach but its use results into wakeup of other unwanted sensor nodes, due their neighboring position. This drawback is also solved in our work through the use of beam forming approach. We have analyzed that if we are using a beam forming approach to resolve the issue of sleeping node, we must know the location (altitude, latitude, longitude using DoA), and also must cover the specific surface area of the sensor node through our beam. Absence of knowledge of location and accurate width of beam will hamper the benefit of the beam forming approach. Keeping location aside which we covered in above discussion, we concentrate how to guarantee the accurate beam forming for the specific sleeping node. Following is the table which shows that coverage of a beam depends on two things 1st the Angle of the beam (i.e. beam width) and 2nd the distance it travels. See the Figure 3. where dependence of beam width on these two variables has been shown. The table 4. is an output of the coverage of the surface area, incase of varying distance under different beam width. Here we found that taking small beam width may not give full cover to a close sensor node which is sleeping. A fix beam width which could cover the closest as well as farthest sensor node could be 40 degree. Because it is capable of covering a minimum surface area incase of minimum as well as maximum distance in WBAN. It should be noted that we have considered the average surface area ofsensor node 26 mm2. So we selected a proportionate beam width which is capable of giving precise coverage to a node. i.e. 400.

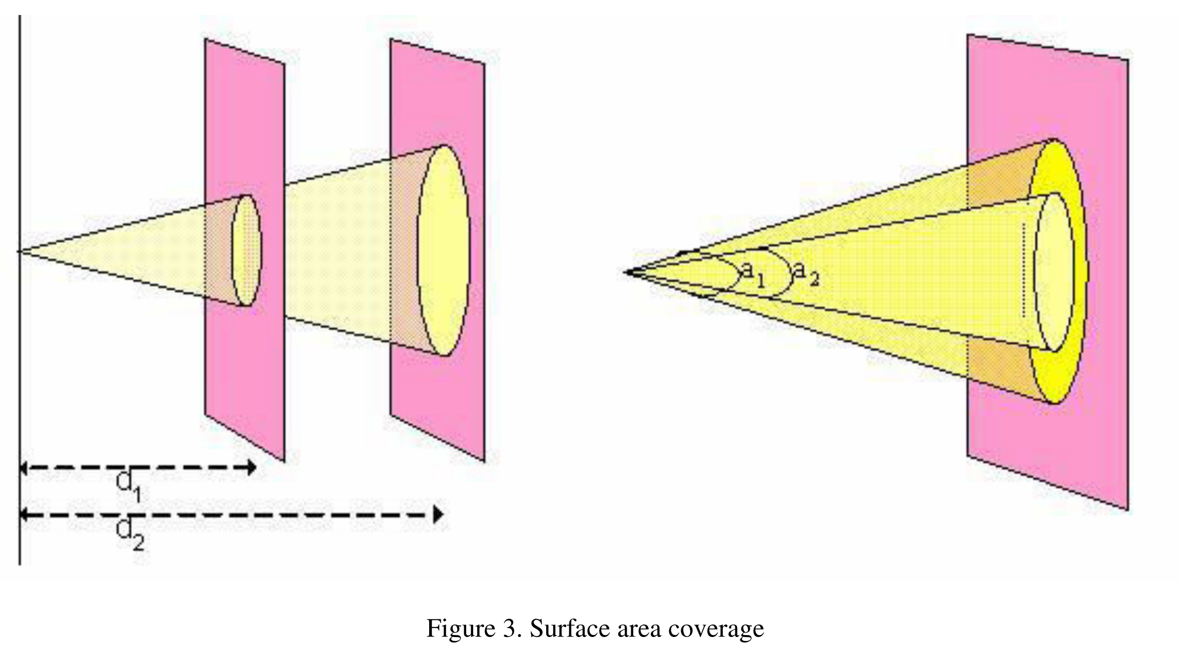

Figure 3. Surface area coverage

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Table 4 . Coverage Area on the base of Distance and Beam Angle

Angle = 10

Distance = 0.25 m	Area = 1.501 mm2
Distance = 0.50 m	Area = 6.002 mm2
Distance = 1.00 m	Area = 24.010 mm2
Distance = 2.00 m	Area = 96.040 mm2

Angle = 20

Distance = 0.25 m	Area = 6.095 mm2
Distance = 0.50 m	Area = 24.381 mm2
Distance = 1.00 m	Area = 97.525 mm2
Distance = 2.00 m	Area = 390.102 mm2

Angle = 30

Distance = 0.25 m	Area = 14.075 mm2
Distance = 0.50 m	Area = 56.301 mm2
Distance = 1.00 m	Area = 225.203 mm2
Distance = 2.00 m	Area = 900.810 mm2

Angle = 40

Distance = 0.25 m	Area = 25.969 mm2
Distance = 0.50 m	Area = 103.878 mm2
Distance = 1.00 m	Area = 415.512 mm2
Distance = 2.00 m	Area = 1662.046 mm2

3.3. Array Resolution in Beam forming

One of the most important factors which may affect the performance of adaptive array while forming a beam is its angular resolution. Array resolution is important in a packet system because if the arrival angles of an interfering packet and the desired packet are too close, the array cannot simultaneously null the interference and form a beam pattern maximum on the desired packet. [25] So we should becareful in forming the beam pattern in that direction where already some transmission is ongoing. We will form beam which is apart enough from the ongoing transmission with the help of following pseudo code, where we have not fixed the angular resolution for each new beam pattern but we have kept away the new beam pattern on the base of AoA of the new approaching sensor node.

In the following pseudo-code the first loop checks the possibility of creation of a beam in some ongoing transmission's direction. According to the condition if new beam pattern is able to overlap the ongoing beam pattern, then that beam pattern formation is discarded. Further if it above condition assures that there won't be any overlap of the beams then second part works to assign the first free beam towards the approaching sensor node.

```
/* To check, whether new beam forming is viable or not */
Loop ( i = 1, max no. of Beam)
IF (Beami  is engaged)
```

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Then

IF ((AOA of Approached Beam < AOA of Beami + Beam_width) OR

(AOA of Approached Beami> AOA of Beami – Beam_width))

Then

Beam Formation is Canceled

Exit

End IF

End IF

End Loop

/* Pointing the 1st free beam towards the approaching sensor node */

Loop (i = 1, max no. of Beam)
IF (Beami is free)

Then
Beami = AOA of Approached Beam

Beam Form towards the AOA of Approached Beam

Exit

End IF

End Loop

Print ("no beam is free")

Beam Formation is canceled

End

3.4. Working of our model

In the previous section, we summarized the working of WBAN. The following points can constitute a guideline for the principles that governs the design of our MAC protocol in order to coordinate the communication in WBAN environments. We are outlining them here.

Our BAN_C is mounted with multi-beam adaptive array which itself is capable of transmitting and receiving from different direction concurrently.

All sensor nodes are in omni mode with lesser transmitting power to save energy, because BAN_C receiving beam is ought to approach them.

Super frame structure is same as IEEE 802.15.4, but for on demand data transmission we propose a modification in inactive part of the super frame. According to that BAN_C will transmit wakeup radio call for specific sensor node and after its wakeup it will transmit back the data.

The entire three important part Beacon, S-Aloha CPR has replaced (CAP), CFP is same as IEEE 802.15.4. BAN_C sends Beacon in omni mode, through all the antenna array. Then BAN_C is in receiving mode in the S-Aloha CPR which uses slotted aloha technique instead of CSMA/CA approach. In CFP BAN_C has its bidirectional capability, it means in this period it can receive and if required can transmit but not simultaneously. For transmission, BAN_C will reserve the GTS in transmitting mode. This GTS can be shared by other three beams if the destination node is more than one. These different beams will approach their respective destinations in transmitting mode. Since we know concurrent transmission and reception is not possible so none of other (if unused) beam will unfold themselves in receiving mode. Even if any beam is not being used they are not given any reception activity in a situation where BAN_C is supposed to transmit data.

Acknowledgments from BAN_C to the sensor nodes are sent using different frequency so that simultaneous transmission could carry on. See the superframe structure in figure x.

As we discussed above the two most important things in our approach 1) accurate analysis of the beam angle so that it can cover the surface area of the node. 2) Virtual angular separation of the nodes through BAN_C maintained table so that BAN_C would give opportunity of transmission to them who are separate enough to not to hamper the others transmission.

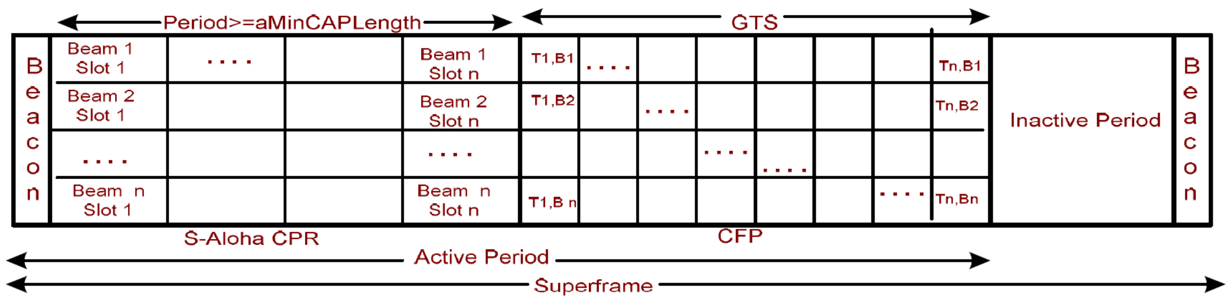

Figure 4. Superframe Structure

The slotted aloha divides the time in equal slots, and the data packets are also kept in equal length. Packets are transmitted in fresh slots after their arrival. If more than one transmission takes place in a single time slot, packets are destroyed. There is scenario where simultaneous transmission of several packets does not necessarily result in destruction of all the transmitted information. Using capture effect, if power of one of the received packet is sufficiently high, compared to the other packets involved in the collision, then strongest packet can be correctly decoded others will be lost. [7]

Mixing MBAA with slotted aloha makes it capable of receiving data from more than one sensor node in a single time slot without the prior discussed capture effect. Every packet from different nodes transmitted in a slot is captured by different beam of the MBAA simultaneously. It nullifies the other transmission which may occur in the same beam pattern. This technology allows BAN_C to receive more than one data packet in the same slot without any scheduling algorithm or reservation based protocol. Figure 3a show the data transmission flow.

In our model we assume, in a human body various kind of biosensors are implanted inbody or onbody as per the different requirement. These sensor nodes send their data to BAN coordinator. when some sensor node sends data to BAN_C, it is demodulated and error is checked with the use of error detection code. If packet is error free it is successfully accepted, otherwise it is discarded.

When packet is successfully received an ACK is sent by the BAN_C to the sensor. This ACK is always sent on other frequency so that BAN_C and sensor nodes can transmit and receive simultaneously.

Main obstacle in the use of MBAA in WBAN network is acquisition of packet, i.e. the problem of locking each beam onto a different packet, while nulling all other packets in the slot. For this we have adapted the following technique for acquisition from Ward et al[].

In each of the slot we add a preamble. This preamble keeps three period of a known pseudo noise sequence [25 of aloha ppr]. Slot width is increased as compared to the data packet with uncertain time period. Within this time period, packet transmission is randomized so that each packet reaches to BAN_C at slightly different time.

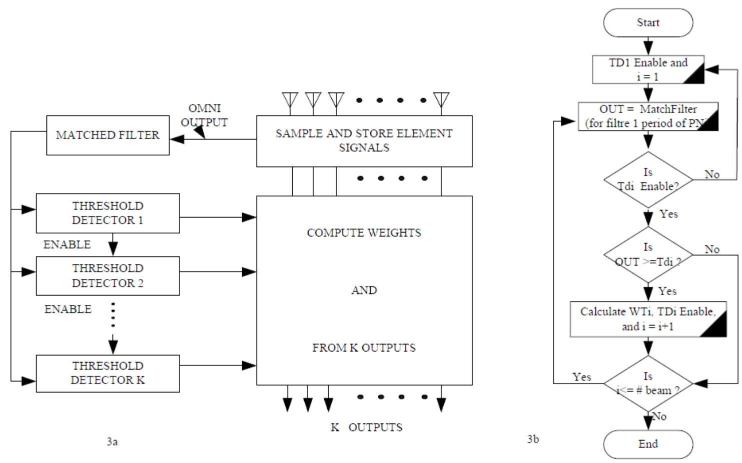

Figure. 5. Flow chart and block diagram of MBAA and the signal acquisition signal processing [24].

Packets are acquired as follows, if at first only one beam is to be formed. The goal is to point the beam toward the first packet to arrive in each slot with nulls on any other packet to arrive in each slot with nulls on any other packets in that slot. For packet acquisition, a single array element with an omni directional pattern will be used as the receiving antenna, so any packet can access the system. When second packet arrives in same slot first packet will be received successfully, conditioned that second packet should reach there with at least one bit delay. If condition is not met, array will loose both the packets. In Figure 3a, we see that if multiple packets are coming in one slot from different beam then packet with slight delay is being acknowledged successfully. Multiple packets are received simultaneously with the use of packet acquisition technique. A separate threshold detector and weight calculation is used by each adaptive array beam. Arrival of packet triggers the threshold detector for next incoming packet. For example if first packet arrives, it triggers threshold detector one (TD1), when TD1 is triggered it will enable TD2 so that it can receive the next packet if arrives. (TD2 will not operate until after TD1 has been triggered).Same approach is taken onward for new packet arrival until maximum number of beam pattern is reached. Figure 3b is the block diagram of a multi-beam adaptive array and the acquisition signal processing. Packet acquisition technique is much elaborated in [aloha ppr].
Similarly in CFP part o the superframe the same approach of increasing the width of the time slot compared to the data packet with uncertain time period is used.

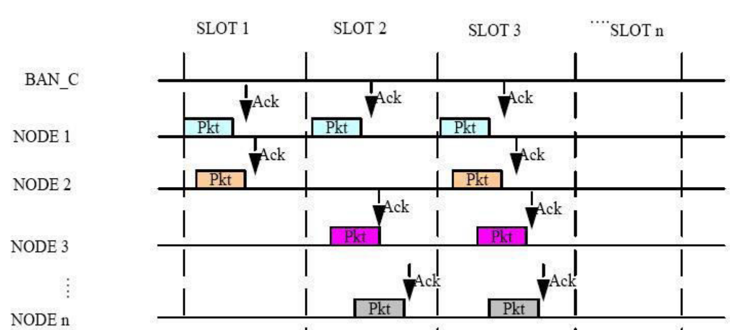

Figure. 6. Diagram of transmission between BAN_C and nodes acquisition signal processing.

IV. SIMULATION SECTION

We have used the OPNET modeler wireless suite to characterize the network performance [25]. This tool facilitates antenna modeling in its antenna pattern editor and its editor supports the creation of the arbitrary 3D gain patterns. The beam can be pointed at desired points in three dimensions, and the energy received at every node is computed automatically by the OPNET kernel procedures. With addition of a child process in a contributed slotted aloha model we modeled our scenario [26].

With the adoption of the IPP Hurray lab contributed model for IEEE 802.15.4 and Vikram et al [] for adaptive array antenna, we have modified the model to suit the S-aloha, inspite of CSMA/CA and MBAA.

Figure 7, shows the modified node model for the adaptation/implementation of multi beam forming approach. Since we have limit ourselves to max four beam patterns so we have added four antennas with four different transmitters and receivers. Each of them has 45 degree directionality and 10 dB gain. They are programmed to track the node position with the help of AoA, and point toward the aimed transmission. This node model includes traffic generating sources of both kind GTS as well as s-aloha, Battery module, Synchronization module for GTS traffic, Antenna Controller module. Our addition is the Antenna controller module which incorporates process models for antenna control, transmission, reception and null formation.

The process model for the antenna controller is shown in Figure 8. This process maintains two lists, “transmit_weight_list_ptr” and “receive_weight_list_ptr,” which are stored as state variables. When ever an upper layer gives the command to form a transmit or receive beam, the weights are calculated in accordance of the antenna.

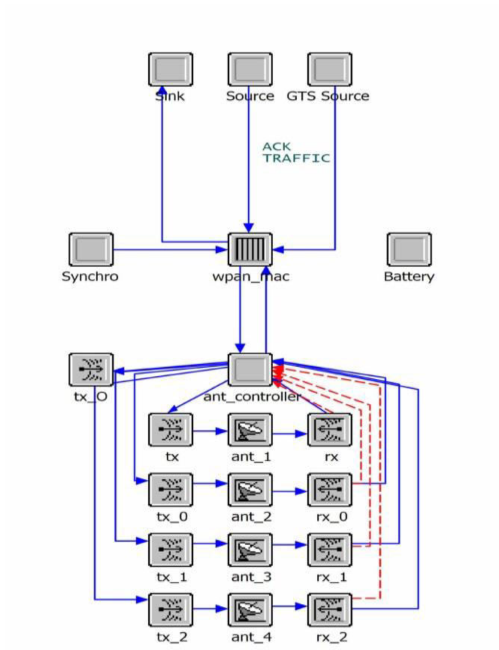

Figure. 7. Node and process model for MBAA implementation.

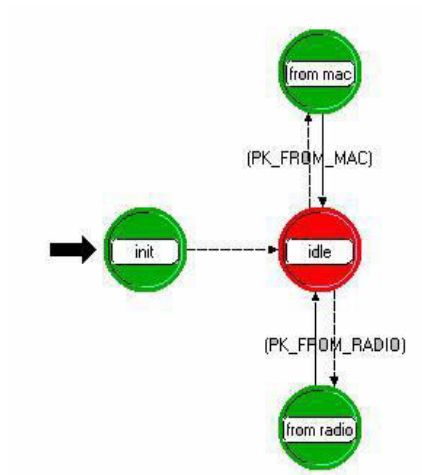

Figure. 8. Antenna Controller process model

Once the desired direction of the beam and the algorithm type are determined using the previous algorithm, the appropriate process for beam forming is invoked. Any of the following three processes is invoked.

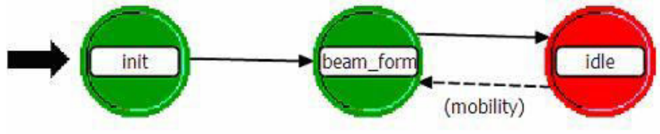

Figure. 9. Transmission process model

The process model for the transmission is shown in Figure 9. This process is used to accurately form a beam pattern for transmission in specific directions. This model is invoked when the antenna controller process is interrupted due to mobility of a target node.

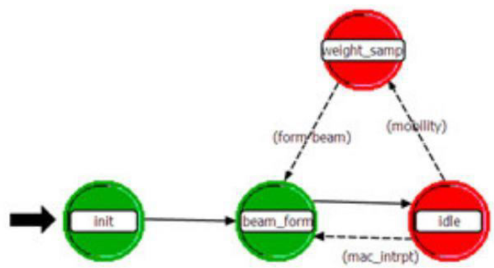

Figure. 10. Receiving process model

The receive process model is shown in Figure.10, it increases the sensitivity of the receiver towards a desired signal by steering the maxima (main lobe) of the gain pattern towards the AoA of the signal ofinterest. The receiving beam is formed in the direction of the strongest signal received, or it can be configured to form the beam towards a given user as directed by MAC sub layer

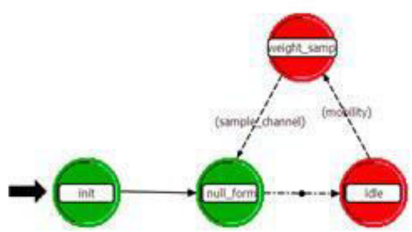

Figure. 11. Null forming process model

The null forming process model is used to from a null towards the strongest interfering signal and maximized the gain towards the desired users.

Table 5. Simulation parameters.

Network Area	8 × 5 feet
Topology	Star
Number of nodes	25
BAN Coordinator	Directional Mode
Sensor nodes	Omni directional mode
Directional gain	10 dB
Packet Inter-arrival time	Exponential (0.1 to 0.01)
Packet size	1,024 bits (mean outcome)
Simulation Time	600 Sec
Number of Seeds	128
Frequency Band	2.4 GHz
Data Rate	250 kbps

V. SIMULATION RESULT

Simulations results of the IEEE 802.15.4 and Dir_BAN (MBAA with slotted aloha) are presented under varying number of inter arrival times to the network and number of nodes. The performance metrics concerned in this research work are energy consumption and delay. Fig 12 represents the delay of all the packets received by the MACs of all nodes in the network and forwarded to the higher layer. Figure 13 represents the energy consumption against the increasing number of nodes. The Figure14. Shows the delay against the number of nodes. In Figure 12, we see that decreasing inter arrival time is (frequency of data arrival is increasing) causing more data frames generation, which causes more delay and it goes up exponentially with the decrease in inter arrival time. The proposed approach is effective in reducing the delay. In Figure 14. also delay is increased when we are increasing the number of nodes, but our approach results in better performance. Similarly energy consumption is also reduced using our approach.

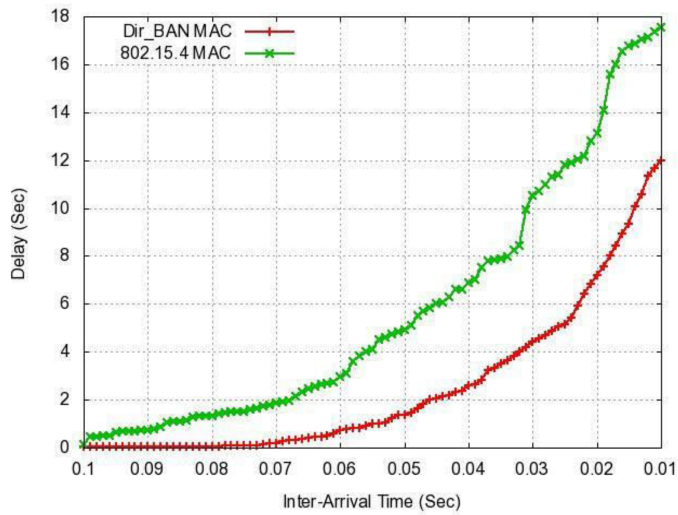

Figure 12 Delayvs.Inter arrival Time

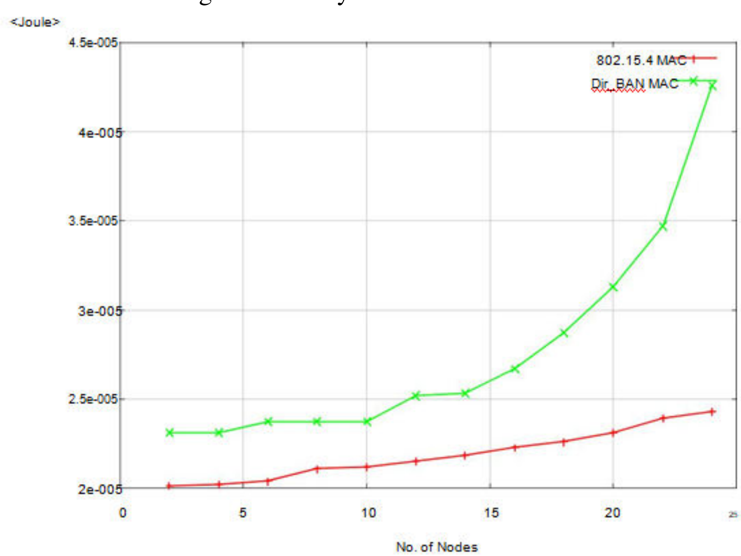

Figure 13. Energy Consumptionvs.Number of Nodes

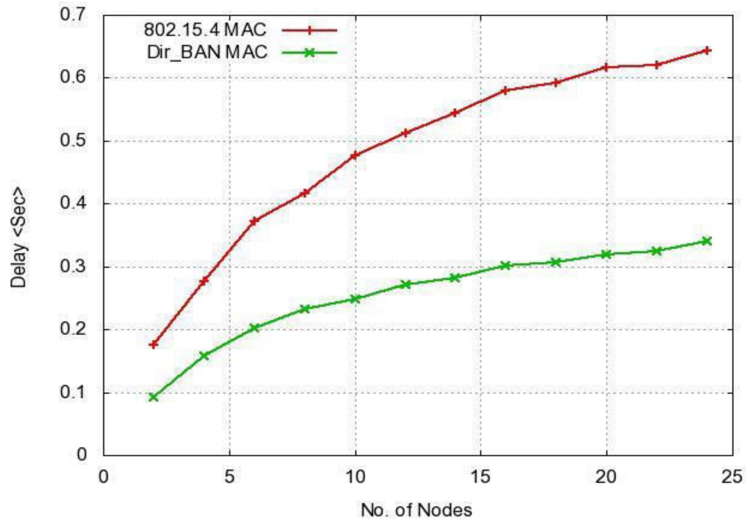

Figure 14. Delayvs.Number of Nodes

VI. CONCLUSIONS

This paper introduces a new approach for a WBAN MAC protocol. The simulation results of the proposed MAC with MBAA are presented and compared with those of a regular IEEE 802.15.4 omni directional mode. It also aims to find a way of applying smart antenna technology the smallest networks. By just mounting an adaptive array on the BAN coordinator we are capable of enhancing the performance. We have discussed the relevance of the use of MBAA in WBAN and packet acquisition technique in case of simultaneous transmission. In future work we plan to include prioritization of different sensor nodes with unique inter-arrival time, packet size and data rate.

VII. ACKNOWLEDGMENT

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VIII. REFERENCES AND NOTES

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