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MAC Protocols of Wireless Body Area Network: A Survey

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***Abstract*-Wireless Body Area Network (WBAN) is a promising technology compromise of number of intelligent sensors which can be integrated into a wearable wireless network, and can be used for computer-assisted rehabilitation or early detection of medical conditions. In this paper, we present a survey focusing on Medium Access Control (MAC) protocol developed for WBAN. We discuss the different type of data traffic emerged in WBAN. We further examine the existing MAC protocols with focus on their strengths and weaknesses.**

Keywords-Wireless body area network, medium access control protocol, energy- efficiency

1. INTRODUCTION

In today's era, technology is paying attention in how to apply it in keeping people healthy. It is clear that technology is giving the health care industry a much needed upgrade from medical translation tools to mobile applications that help patient live healthier lives. Wireless body area network (WBAN) is one of the dizzying technologies that could transform the health care industry.

WBAN emerges from wireless sensor network (WSN) in which sensors are deployed over human body. A wireless body area network (WBAN) is a radio frequency (RF)-based wireless networking technology that interconnects tiny nodes with sensor or actuator capabilities in, on, or around a human body [1]. WBAN connect local and wide area network too.

WBAN has its own characteristics as compared to WSN. These characteristics build new technical challenges for researchers. WBAN characteristic are discussed below:

- *Architecture:* WBAN mainly divided into two tiers. The intra-BAN network is simply comprised of the set of physiological sensors and the aggregator, whereas the extra-BAN network consists of the communication infrastructure used for communicating between the aggregator and destination database, computer or smart phone [2].
- *Density:* WBAN is not a dense network. According to the application, nodes are place in or on body. They are not deployed with high redundancy to tolerate node failures.
- *Data rates:* WBAN may occur in a more periodic manner and stable data rate.
- *Mobility:* Sensors are attached with human, and all movements are along in the same direction of the wearer. WBAN nodes are generally considered as stationary.
- *Latency:* It is easy to replace battery in WBAN compared to WSN as nodes in former are reachable. While energy conservation is definitely beneficial as node are miniature in size.

2. DATA TRAFFIC

WBAN data traffic is classified into three categories. They are: [3]

A. *Normal traffic*

Normal traffic is the data traffic in a normal condition with no time critical and on-demand events. This include unobtrusive and regular data gathering by sensor node. The normal data is collected and processed by the coordinator.

B. *On-demand traffic*

This type of data is initiated by coordinator to have some information. This is further divided into continuous (during surgical events) and discontinuous (when occasional data required).

C. *Emergency traffic*

This is having critical data which is initiated by sensor nodes when some predefined threshold value is crossed. This is unpredictable and not generated on regular intervals.

3. MAC PROTOCOLS

This section explains some well known existing MAC protocols proposed for WBAN. This discussion also includes the advantages and disadvantages of proposed protocols.

A. *IEEE 802.15.4 MAC PROTOCOL*

IEEE Standard 802.15.4 defines the physical layer (PHY) and medium access control (MAC) sub layer specifications for low data-rate communication [4]. It has two operational modes: a beacon-enabled mode and a non-beacon enabled mode. In beacon-enabled mode, the network is controlled by a coordinator, which is responsible for device synchronization and data transmission using periodic beacon. Optionally, the superframe can be subdivided into active and inactive periods. The channel is bounded by a superframe structure as illustrated in Fig. 1. The coordinator may enter in sleep mode during the inactive period. The active period contain three divisions: a beacon, a Contention Access Period (CAP), and a Contention Free Period (CFP). During the CAP period in beacon-enabled mode, devices compete for channel access using slotted CSMA/CA. While non- beacon enabled mode uses unslotted CSMA/CA.

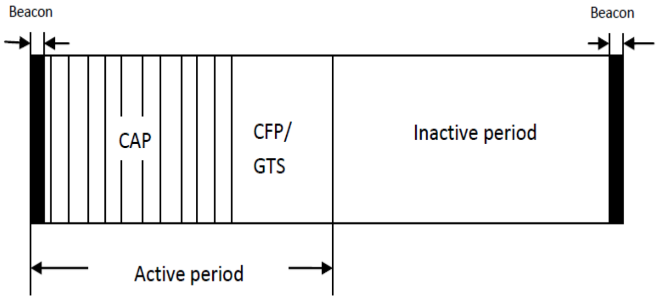

Fig. 1 Superframe structure of IEEE 802.15.4

IEEE 802.15.4 decreases collision and idle listening, leading to power savings. It features low complexity by Cross-layer optimization, so it reduces the power overhead of software implementations. But this protocol restricted with maximum of 7 Granted time slots (GTS) allocated. The use of clear channel assessment (CCA) leads to high energy consumption. IEEE 802.15.4 especially designed for low power consumption and low data rate communication.

B. *ENERGY EFFICIENT LOW DUTY CYCLE*

Low duty cycle MAC protocol is proposed in [5] for static natured topology of WBAN. TDMA approach is adopted for streaming large amount of data. This MAC protocol explain hierarchical topology consist of sensor nodes communicating with master node (MN) which in turn communicate with monitoring system (MS). Hierarchy removes the need for sensors to expands their power for transmitting to MS. Static topology and TDMA strategy maximize network life.

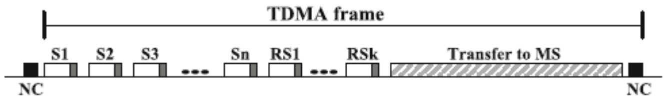

Fig. 2 TDMA frame of energy efficient low duty cycle MAC protocol [5]

Protocol divides each TDMA time frame into parts as shown in Fig. 2. Each sensor is allocated equal time slot for transmitting to MN. To avoid collision/overlapping due to clock drift, Guard time (T_g) is introduced between two consecutive time slots. T_g also reduces bandwidth wastage. Few times slots are reserved which are being assigned when requested. Number of these extra time slots depends upon packet loss rate (PLR), packet error rate (PER) and number of sensor nodes.

This protocol uses a Network Control (NC) packet for general network information. But main usage of NC is periodic synchronization after calculated number of time frames. Communication between MN to MS is discussed by two models. In first, MN has only one transceiver, so enough time is reserved for communication with MN to MS. In second, MN has two transceivers.

Energy efficient low duty cycle protocol results in reliable data transfer which is important for medical application. It performs best for high communication data rates as well as small burst of data. TDMA approach ensures collision free as well as minimization of idle listening but provides fixed frame structure. As static network topology, protocol may not respond well when topology is dynamic. It does not support on-demand traffic.

C. *BODY MAC*

For energy minimization, in [6] author proposed an energy efficient TDMA based MAC protocol. Three types of bandwidth allocation schemes i.e. Burst Bandwidth procedure, Periodic Bandwidth procedure and Adjust Bandwidth procedure are planned to cope with different types of data communications such as periodic data sensing and important event allocation. This efficient and flexible bandwidth management procedure improves network stability and control packets transmission.

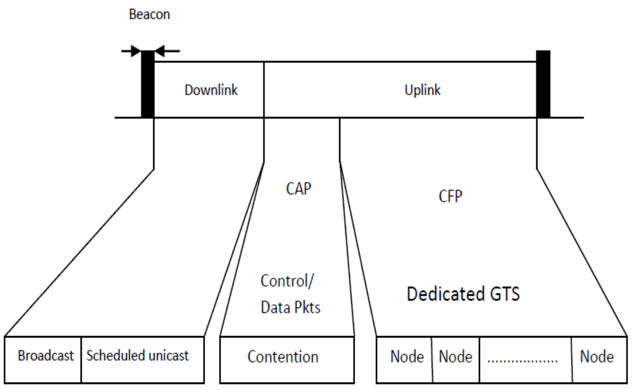

Fig. 3 Body MAC frame structure

Above Fig. 3 show Body MAC frame structure which is divided into beacon, downlink and uplink. Beacon is used for MAC layer synchronization. To accommodate on demand traffic, downlink is used for data communication between gateway (coordinator) and sensors. The uplink frame consists of two sub-parts: Contention Access Part (CAP) and Contention Free Part (CFP). CSMA/CA strategy is adopted in CAP where sensor nodes try to send control packet to gateway for Guaranteed Time Slots (GTS). However, nodes can also communicate for small data packets during CAP. To avoid collision, coordinator assigns GTS to sensor nodes. Nodes can enter into sleep mode and wake up only when they have to receive and transmit any data to the gateway. Body MAC protocol have a provision to support on-demand traffic. Allocation of 3 bandwidth management scheme reduces packet collision, idle listening and control packet overhead. However, protocol uses CSMA/CA in the uplink frame of CAP period, which is not well founded scheme due to its unreliable clear channel assessment (CCA) and collision issues and also CSMA/CA ends up with high energy consumption.

D. ENERGY EFFICIENT MAC PROTOCOL

O. Omeni et al. proposed this protocol in [7] supports star topology (single hop communication) which has centrally controlled wakeup and sleep mechanism to maximize energy efficiency. The centre node act as master having high computational power assign slots to each slave nodes which acquire data and transmit it to master for processing. This MAC protocol introduces three basic processes. First is link establishment process in which slave nodes join to the cluster. Wakeup service process is the second one which allows master slave communication. Last is exception process or alarm process which support communication for emergency data. For guaranteed and reliable communication, a novel concept of Wakeup Fallback Time (WFT) is introduced. It lessens the continuous time slot collision and overlapping. If failure occurs in assigned wakeup process, sensor node enters into sleep mode for a specific time interval calculated by WFT. During this sleep time, sensors node buffers data packets for future communication. Similarly, master node also goes into sleep mode set by WFT if it fails to communicate with slave nodes. Here, central control reduces energy consumption, idle listening and over hearing. This protocol support emergency traffic but no proper mechanism to handle on-demand traffic. It limits the entry of nodes in a cluster up to 8 only and only one node goes into network at a time. The implementation of energy efficient protocol is quite complex.

E. BATTERY-AWARE TDMA MAC PROTOCOL

The author of [8], proposed battery –aware TDMA based MAC protocol which consider parameter like electrochemical properties of battery, time varying wireless fading channel at physical layer and packet queuing characteristics at data link layer. TDMA with cross layer design technique is used. Its operation is similar to IEEE 802.15.4. Protocol intended to maximize the idle period for sensor nodes for recovery process of the batteries. Time frame of proposed protocol is divided into beacon, active time slots and inactive slots as shown in Fig. 4. Sensor nodes wake up at the beginning of beacon periods. The beacon is incorporated for indication of length of frame period and channel state information (CSI).

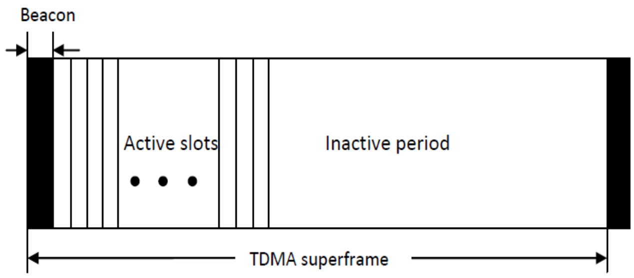

Fig. 4 Time frame structure of battery-aware MAC protocol

Each sensor node evaluates the number of packets that can be transmitted during each individual frame period. This estimation is done at beginning of each frame period. Sensors receive beacon periodically and know about their subsequent time slots to transmit in active period. No transmission is carried out in inactive period which reduces energy consumption. Packets in the buffer are transmitted by sensor node only if the channel is good and the buffer size is large enough. Time frame in the protocol is adaptive can be changed according to the application. This protocol prolongs the sensors life. Here, Reliable and timely delivery is achieved by GTS. But holding of packets in buffer for a long time leads to high average delay and packet loss rate (PLR). There is no mechanism for emergency data and not suitable for implants.

F. PRIORITY GUARANTEED MAC PROTOCOL

In [9], priority guaranteed MAC protocol proposes a new superframe structure in which beacon period are at boundaries and there is a combination of CAP and CFP periods.

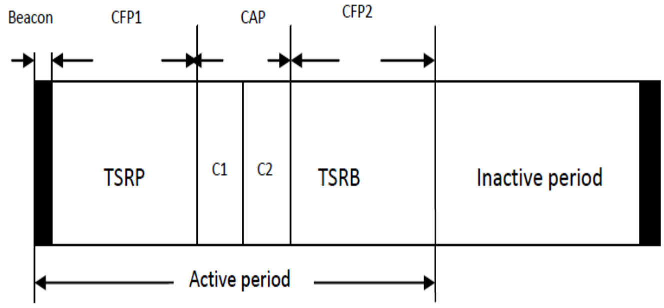

Fig. 5 Superframe structure

Superframe structure is shown in Fig. 5. The active period is divided into five parts: Beacon, Control Channel C1, Control Channel C2, Time Slot Reserved for Periodic (TSRP) traffic, and Time Slot Reserved for Bursty (TSRB) traffic. C1 is used for uplink control of life-critical medical application while C2 is used for uplink control of Consumer Electronics (CE) applications. Randomised ALOHA is used for these control channel. Proposed protocol is based upon TDMA approach to assign Guaranteed Time Slots (GTS) within two data channels TSRP and TSRB. The TDMA slots in the TSRP and TSRB periods are allocated on demand using the control periods. This protocol outperforms IEEE 802.15.4 in term of energy consumption. However, the superframe structure of protocol is complex and there is inadaptability to emergency traffic.

G. HEARTBEAT DRIVEN MAC PROTOCOL

In [10], author uses heartbeat rhythm information for synchronization of nodes. It is a TDMA based approach in which central node coordinates the network. H-MAC assigns dedicated time slots to sensor nodes for communication to avoid collision. Heart beat rhythm avoids the use of external clock and thus reducing the power consumption. It also reduces the control message overhead.

Each biosensor extracts Heartbeat Rhythm information (peek) from its sensory data. These peek intervals are used by sensors node and coordinator for data communication. Frame cycle and time slot assignment is calculated by coordinator. H-MAC protocol prolongs the network life. It reduces idle listening and avoids collision. Due to use of heartbeat rhythm, overhead related to control message is reduced. This reduces energy consumption. But the use of TDMA strategy makes this protocol static, dedicated and not adaptive for traffic. Drawback of protocol continues with the heartbeat rhythm information which varies depending on patient's condition. It may not reveal valid information for synchronization all the time and does not support events at irregular events. All sensors may not access heartbeat rhythm so synchronisation cannot be achieved always with heartbeat rhythm information. Guard time is included to avoid collision but it leads to reduce bandwidth utilization.

H. *MEDMAC PROTOCOL*

The medical medium access control protocol proposed in [11], is an adaptive TDMA based protocol for WBAN which support star topology focuses to improve channel access mechanism and power saving. A TDMA approach is adopted to assign time slots to sensors which are of variable length and vary according to the sensor requirements. MedMAC uses multi-superframe structure, where beacons are used for synchronization as shown in Fig. 6.

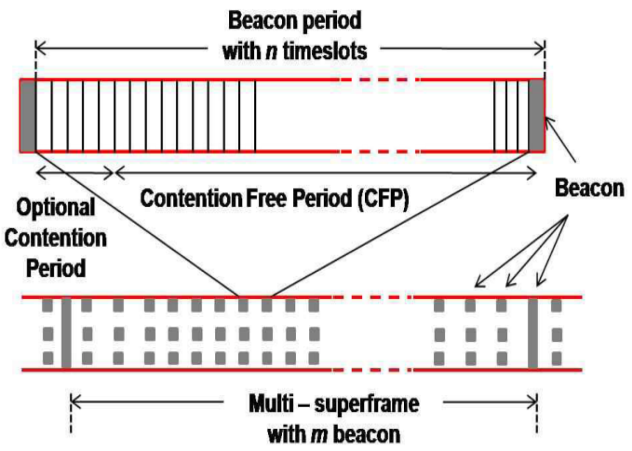

Fig. 6 Multi-superframe structure [11]

The beacon period consists of a contention free period (CFP) and optional contention access period (CAP) which are made up of 2-256 timeslots. An optional contention period is also available for low-grade data, emergency operation and network initialization procedures. The duration of the multi-super frame is defined by synchronization mechanism. Timestamp scavenging with Adaptive Guard Band Algorithm (AGBA) is used by MedMAC to maintain synchronization between nodes and coordinator. AGBA guard band time is inserted between two consecutive time slots; avoid collision due to clocks drift. Guard band time is adjustable and Drift Adjustment Factor (DAF) monitors guard band and avoid waste of bandwidth using extra guard bands. Each node has a dedicated time slot which means no collision occurrences. This protocol outperforms IEEE 802.15.4 with respect to energy consumption and support emergency traffic.

I. *POWER EFFICIENT MAC PROTOCOL*

Power efficient MAC protocol proposed in [12]. This protocol introduces two wakeup mechanisms for reliable transmission. These are: traffic based mechanism which is for normal traffic and wakeup radio mechanism accommodates on demand and emergency traffic by using wakeup radio.

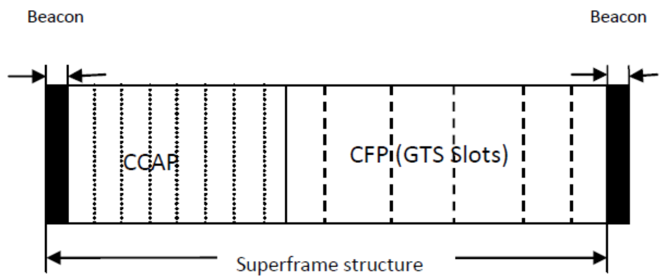

Fig. 7 Superframe structure

Protocol introduces a new superframe structure for WBAN as shown in Fig 7. Time axis is divided into three parts: a beacon message, a Configurable Contention Access Period (CCAP) to accommodate short burst of data, and a Contention Free Period (CFP) where Guaranteed Time Slots (GTS) are assigned to end nodes for collision free communication. In CCAP, slotted ALOHA is used and is for resource allocation. The protocol accommodates normal, emergency, and on-demand traffic. The traffic patterns of all nodes are organized into a table called traffic-based wakeup table**.** For energy minimization, a node wakes up only whenever it has a packet to send/receive. It introduces reasonable delay. This protocol uses Low Power Listening (LPL) which is not an optimal choice for implanted and on-body sensor nodes communication due to strict power capabilities.

J. *RESERVATION BASED DYNAMIC TDMA(DTDMA) PROTOCOL*

DTDMA is proposed in [13] for normal traffic for WBAN in which slots are only allocated to sensor nodes when they have data buffered and are released and assigned to other nodes when data transmission is over. Superframe structure of protocol is shown in Fig. 8.

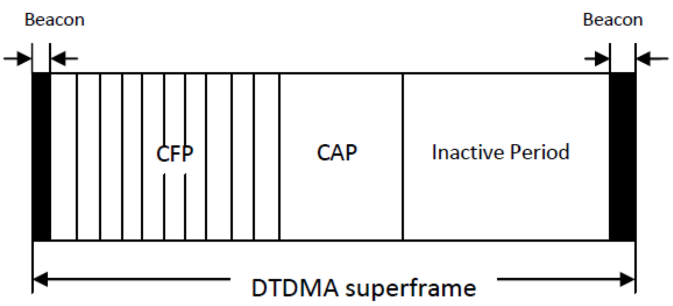

Fig. 8 Superframe structure of DTDMA.

Each superframe consists of a beacon which carries control information including slot allocation information. A CFP period is a configurable period used for data transmission. A CAP period is a fixed period used for short command packets using slotted-ALOHA protocol, and a configurable inactive period is used to save energy. In DTDMA protocol, the CFP duration is followed by CAP duration in order to enable the nodes to send CFP traffic earlier than CAP traffic. The duration of an inactive period is configurable based on the CFP slot duration. If there is no CFP traffic, the inactive period will be increased.

The protocol provides more dependability in terms of low packet loss rate or packet dropping rate and low energy consumption. In this slot allocation is based on the CAP and CFP traffic information. But it does not support emergency and on-demand traffic. Its drawback include that protocol cannot operate on ten sub-channels simultaneously with respect to MICS band. And also not support the sub-channel allocation mechanism in the MICS band.

4. CONCLUSION

This paper present a survey on different Mac layer protocol proposed for WBAN with their advantages and disadvantages. Paper tries to cover proposed model of each protocol. We discussed classification of different data traffic in WBAN including characteristics of it. WBAN is a system that provides smooth, less expensive and ambulatory inspection during routine functions works in close association with wireless network. It also provides better and cheap substitutions for achieving good health conditions. These systems reduce the enormous costs as patient can connect with their doctor more easily, for instance, won't need to make expensive and perhaps unnecessary trips as monitoring can take place in real-time even at home and over a longer period. Thus a great benefit goes to patients, physicians as well as the whole society. WBAN expands the horizons of medical interaction; it's becoming clear that we are entering in a new era of health care.

REFERENCES

[1] Huasong Cao, Victor Leung, Cupid Chow and Henry Chan, "Enabling Technologies for Wireless Body Area Networks: A Survey and Outlook", in IEEE Communications Magazine, December 2009.

[2] Elisabeth Reusens, Wout Joseph, et. al, "Characterization of On-Body Communication Channel and Energy Efficient Topology Design for Wireless Body Area Networks" IEEE Transaction on Information Technology in Biomedicine, vol. 13, no. 6, November 2009, pp 1089-7771.

[3] Sana Ullah , Henry Higgins, Bart Braem , Benoit Latre, Chris Blondia, Ingrid Moerman, Shahnaz Saleem , Ziaur Rahman, Kyung Sup Kwak, "A Comprehensive Survey of Wireless Body Area Networks On PHY, MAC, and Network Layers Solutions", in conf Springer Science Business Media, pp. 1065–1094, Aug 2010.

[4] IEEE Std.802.15.4, Wireless medium accesses control (MAC) and physical layer (PHY) specifications for low data rate wireless personal area networks (WPAN). IEEE: Piscataway, USA, 2006.

[5] Marinkovi, S. J., Popovici, E. M., Spagnol, C., Faul, S., and Marnane, W. P., "Energy-efficient low duty cycle MAC protocol for wireless body area networks," IEEE Trans. Inf. Technol. Biomed. 13(6):915925, 2009.

[6] Timmons, NF and Scanlon, WG., "An adaptive energy efficient MAC protocol for the medical body area network", VITAE, 2009.

[7] O. Omeni, A. C. W. Wong, A. J. Burdett, and C. Toumazou, "Energy efficient medium access protocol for wireless medical body area sensor networks," IEEE Transactions on Biomedical Circuits and Systems. vol.2, no. 4, pp. 251-259, Dec. 2008.

[8] G. Fang and E. Dutkiewicz, "BodyMAC: Energy efficient TDMA-based MAC protocol for wireless body area networks," 9th International Symposium on Communications and Information Technology, ISCIT, pp. 1455-1459, 2009.

[9] Zhang, Y., and Dolmans, G., "A new priority-guaranteed MAC protocol for emerging body area networks," in the Proc. of Fifth International Conference on Wireless and Mobile Communications (ICWMC 2009), pp.140-145, 2009.

[10] Huaming L., and Jindong T., "Heartbeat-Driven Medium-Access Control for Body Sensor Networks," IEEE Transactions on Information Technology in Biomedicine, vol. 14, no. 1, January 2010.

[11] N.F. Timmons and W.G. Scanlon, "An adaptive energy efficient MAC protocol for the medical body area networks," 1st International Conference on Wireless communication VITAE, pp. 587-593, 2009.

[12] Kwak, K. S., Ullah, S., Kwak, D. H., Lee, C. H., and Lee, H. S., "A power-efficient MAC protocol for WBAN," Journal of Korean Institute of Intelligent Transport Systems 8(6):131140, 2009.

[13] Ullah, S. and Shen, B. and Riazul Islam and Saleem, S. and Sup Kwak, K., "A study of MAC protocols for WBANs", sensor, 2009.