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A Survey on Energy-Efficient Mac Protocols for Wireless Body Area Networks

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ABSTRACT

In WBAN, a number of implantable, wearable and off-body biomedical sensors are utilized to monitor various vital signs of patient's body for early detection, and medication of grave diseases. In literature, a number of Medium Access Control(MAC) protocols for WBANs have been suggested for addressing the unique challenges related to reliability, delay, collision and energy in the new research area. The primary goal of MAC protocols in WBAN is to efficiently analyze their features and endure energy minimization . In this paper, we provide a comprehensive survey of energy-efficient MAC protocol for wireless body area networks.

Keywords: Wireless Body Area Networks (WBANs); Energy Efficiency; MAC protocols; Medium Access Control (MAC); Power Efficiency

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INTRODUCTION

Applications of sensor networks in healthcare nowadays are collectively called as body area networks(BAN) [1].

BAN structure figure is shown below.

A BAN usually has small network size and is scalable to support new devices. Since not all the networks need to send data, they can be in the idle state and hence can be put into the sleep state to conserve power. A BAN is managed and coordinated by a central device called the BAN network controller (BNC). From [2], it is enunciated that several performance characteristics of WBAN like power consumption, traffic level, network scalability, packet delay and time synchronization are discussed. It is evident from [3] that MBAN also measures body parameters as like WBAN and they have contributed mathematical model to enhance network lifetime and analyze their performance through simulation. Due to development in WBAN, e-health services can be utilized by people anytime in the world. WBAN becomes an emerging technology which provides a real-time health monitoring and IoT as explained in [4]. In [5] they have proposed a network coding approach for WBAN using decode-and-forward relays. The energy efficiency is minimized and stability period is enhanced in [6].

The Medium Access Control (MAC) protocol for a WBAN should allow body sensors to get quick access to the channel and send data to the hub, especially in emergency situations while reducing power consumption. Power consumption and delay are major concerns for MAC protocols in a BAN . The MAC layer aims to achieve maximum throughput, minimum delay, and to maximize network lifetime by controlling the main sources of energy waste.

Monitoring large number of patients in real time is their main application. It is found that the potential of WBAN system helps in reducing the healthcare cost as well as the workload of medical professions resulting in higher efficiency. In [7], it is evidently noted that WBAN sensor networks are clearly used for telemedicine and M-Health services and their security challenges and biometrics are discussed. Healthcare is one of the major fields employing sensor devices and networks. There are two types of applications involved under healthcare which includes medical and non-medical. The medical applications are either wearable or implanted. Non-medical applications include file transfer and real-time audio/video streaming. From [8], we could find many reasons related to MAC protocol that lead to energy waste. In [9], they have created MAC protocol named Quasi-Sleep-Preempt-Supported(QS-PS) that achieves energy efficiency. The main schemes of WBAN MAC and their performance like power consumption, traffic level, network scalability, bandwidth utilization, packet delay and time synchronization are characterized in a table in [10]. Although WBANs are offering many advantages to us, but they are still

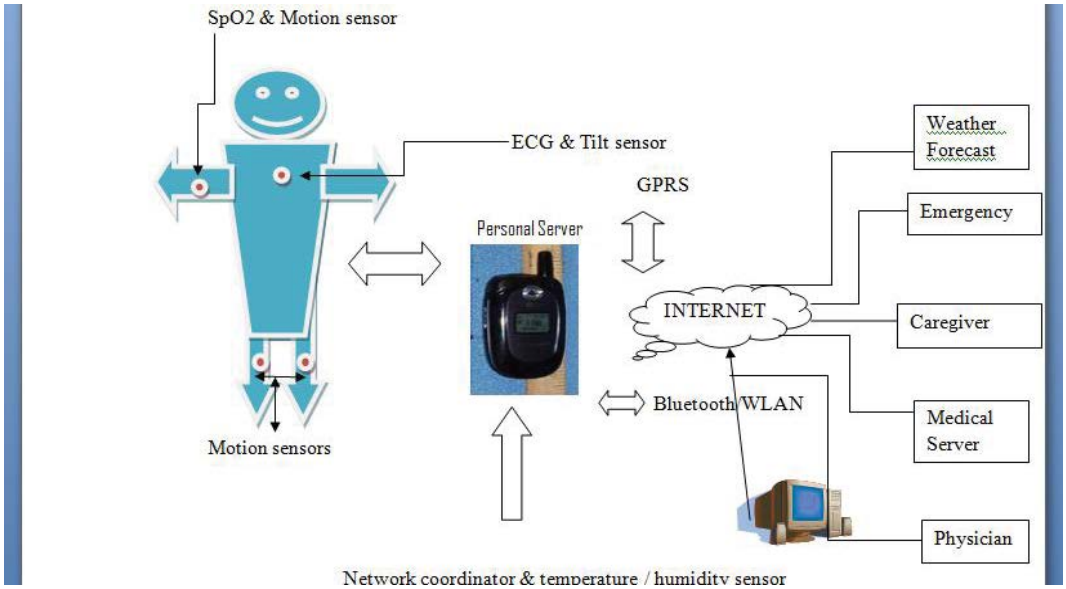

Fig .1 BAN Structure

facing a lot of technical issues like high QOS , power source miniaturization, secure data transfer, biocompatibility, small power transceivers and less communication delay. Power control plays an important role in reducing network interference and resource management in wban.

MAC

MAC protocols mostly deal with packet collision, idle listening, overhearing and packet overhead. Being enhanced with these primary operations in WBAN it is tough to save energy. Hence we hereby survey different MAC protocols to efficiently conserve energy consumption. The basic function of MAC is to provide an addressing mechanism and channel access so that each node available on a network can communicate with other nodes available on the same or other networks. The medium access layer was made necessary by systems that share a common communications medium. The MAC layer is the "low" part of the second OSI layer, the layer of the "data link". There are three ranges of MAC protocols that are considered for medical applications. They are clipping protocol, TDMA (Time Division Multiple Access) and the random access protocol.

Following protocols are used by Medium Access Layer:

1. ALOHA
2. Carrier Sensed Multiple Access(CSMA)
3. CSMA/CD (Carrier Sensed Multiple Access/ Collision Detection)
4. CSMA/CA (Carrier Sensed Multiple Access/ Collision Avoidance)
5. Ethernet

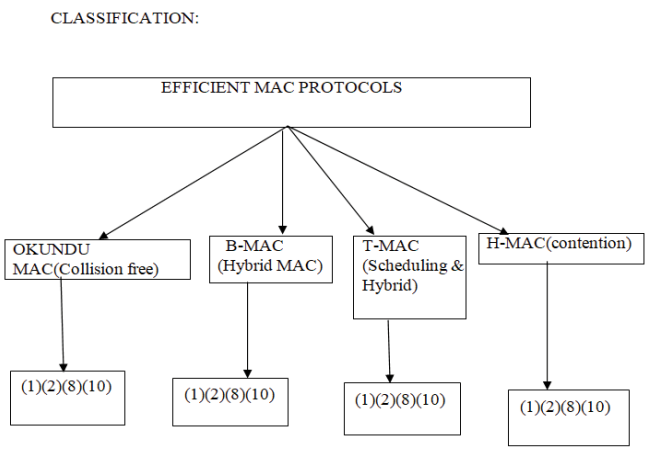

Fig .2 Classification of MAC protocol

Among the above mentioned protocols ALOHA and CSMA are used for many low power sensor network applications. They are noted together as random access protocol which is also termed as contention based protocol. The dual combination of clipping protocol and CSMA/CA to transmit the sensor data from multiple sensors to the Central Control Unit(CCU) that could be a good mechanism for power saving and reliable communication of critical medical data. The CSMA/CA protocol is a contention based protocol which could offer lower delay and reliable transmission of packets.

ENERGY EFFICIENT MAC PROTOCOLS

Okundu MAC Protocol

- This energy efficient MAC protocol was proposed by Okundu et al. (2)

- Hereby there are 3 main process involved here
  - Link establishment
  - Wakeup service
  - Alarm process
- Wakeup/sleep time and Wakeup Fall-back time (WFT) together constitutes basic energy saving mechanism.
- WFT consists of continuous time slots and hence is used to avoid collision.
- According to WFT mechanism, if the communication between slave node and member node (MN) fails due to MN's other activities, then it goes back to sleep mode for a specific time.
- WFT concept ensures that a guaranteed time slot is maintained by every slave node even if it is failed to communicate with MN.
- Also problems like idle listening and over-hearing can be reduced in this protocol.

Bandwidth MAC (B-MAC) Protocol

- In B-MAC protocol, energy efficiency is achieved by the management of bandwidth.
- There are 3 bandwidth management schemes available as noted below
  - Burst Bandwidth
  - Periodic Bandwidth
  - Adjust Bandwidth
- In the burst bandwidth scheme, bandwidth is reduced to half if it does not fully utilized by the nodes, which is also informed about reduction of bandwidth.
- Periodic bandwidth enhances energy potency.
- Adjust bandwidth defines the amount of bandwidth to be added or reduced from previous periodic bandwidth.
- BMAC performance could be analyzed through simulation which was explained in three states: packet transmission state, channel verification state and sleep state that was proposed in (8).

Time-out MAC (T-MAC) Protocol

- This MAC protocol was developed by Mihai et al for wireless BAN.
- Hereby, in T-MAC duty cycle issue changes the time slot assignment.
- The node goes back to sleep mode if there is no activation event for time interval.
- If there is an issue as node does not receive CTS even after sending RTS then it sends RTS two more times before going to sleep.
- It should be understood that packets are sent in bursts in T-MAC, as a result delay is minimized.
- T-MAC suffers from sleeping problem.

H-MAC Protocol

- H-MAC avoids external clock and thus reduces power consumption.
- In order to avoid collision, it uses GTS(Guaranteed time slot).
- By using heartbeat rhythm information it aims to improve BSN's energy efficiency.
- Depending on patient's condition, heartbeat rhythm information changes which may not reveal valid information.
- In case of low traffic, it encounters low spectral/ bandwidth efficiency.

ENERGY MINIMIZATION TECHNIQUES IN MAC PROTOCOLS

1. LPL

- LPL is expanded as Low Power Listening.

Table 1: Comparison of Mac Protocols.

MAC PROTOCOL	DESIGN APPROACHES	MERITS	LIMITATION
Okundu MAC	Collision free MAC protocol	Idle listening and overhearing can be reduced and it also avoids collision	Failure in communication between slave node and member node.
B-MAC	Hybrid Mac protocol	Improved energy potency, increased stability and efficient bandwidth management procedure.	Unreliable since depending on CSMA/CA.
T-MAC	Scheduling and hybrid based Mac protocol	Increases energy efficiency.	Early sleep problem.
H-MAC	Hybrid Mac protocol	Reduces extra energy cost of synchronization.	Low spectral/ bandwidth efficiency.

- Certain node remains in active state to receive data and other nodes go back to sleeping mode, this occurs when the channel is not idle and hence this is termed channel polling.
- Wise-MAC is one of the MAC protocols, which is based on LPL.
- This protocol uses non-persistent CSMA and preamble sampling technique and hereby reduces idle listening.

2. DUEL CHECKLIST

- This is called duel checklist to cope with scalability & collision problems.
- In duel mode protocols, contending nodes try to access the channels for data transmission. Therefore probability of packet collision is high.

Example: Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) in which CCA is performed by nodes before transmitting data.

- In terms of checklist, one can find TDMA,

CDMA & FDMA, but CDMA & FDMA are not suitable for WBAN because of large overhead and frequency limitations.

- Based on duel checklist, S-MAC is one of a MAC protocol.
- In this protocol, low duty mode is set as default mode.
- The energy wastage due to collision, idle listening, overhearing whereby wastage is minimized because node is turned on only for transmission of data and remains in sleep mode, otherwise.

3. TIME ALLOCATION/TDMA

- In this methodology, a super frame is used which possess number of nine slots.
- In order to allocate time for each contending node, traffic rate is used.
- The node gets time for transmission of data & remains in sleep mode for the rest of the time hence this scheme is power efficient.

Example: PB-TDMA(Preamble based Time division multiple access), B-MAC, Med-MAC.

CONCLUSION AND FUTURE WORK

In this survey, we have reviewed the energy minimization of wireless body area networks. Hereby, we come across several MAC protocols that are used for energy consumption. WBANs will allow for continuous monitoring of patients and early detection of possible problems. With current evaluating changes, idle listening and over-hearing problems can be avoided. We truly believe this research to be a source of inspiration towards future developments in WBANs.

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