



Review on Energy Efficient Contention Based MAC Protocols for Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies. This technology has introduced a new flux in diversified fields like medical, military, environment, home, agriculture, etc. Since the sensor nodes in WSN are battery operated hence energy awareness is one of the most important issues in WSNs. To achieve minimum energy consumption, several MAC protocols have already been proposed. In this paper, we provide a comprehensive review on some of the common contention based energy efficient MAC protocols for wireless sensor networks.

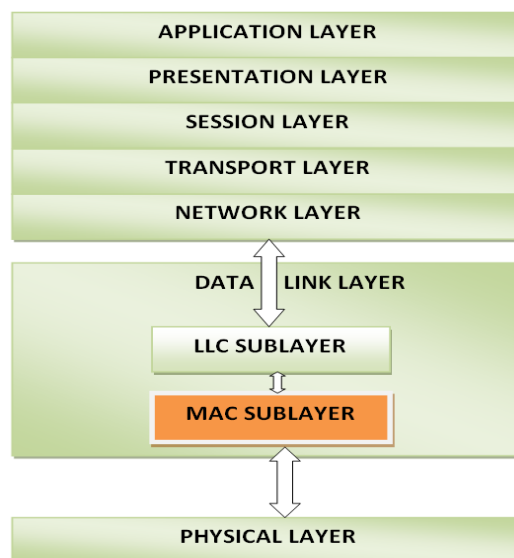
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I. Introduction

Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for the present era. A WSN consists of a large number of low cost and low powered sensor nodes which are powered by small batteries and can be deployed within or near the region of interest [1]. Since the sensor nodes are required to operate under remote conditions without fresh supply of power to replenish itself, energy conservation becomes the major constraint. WSNs have acquired many different applications in areas such as health monitoring, industrial automation, military operations, building automation, agriculture, environmental monitoring, and multimedia [2].

In the OSI Model the Data Link Layer is divided into two sub-layers to satisfy the need to manage access to a shared communication medium. The lower sub-layer provides the functions of MAC protocol and the higher sub-layer (Link Control Layer) supports several MAC options Fig.1. depicts the same [3]. Apart from transferring of data from upper layers, other important functions of the MAC layer are frame delimiting and recognition, addressing, prevention of errors, adjudication of channels shared by nodes and buffer management [4].

Figure1. OSI Reference model in the context of MAC protocol



II. Reasons of energy wastage

Following are the major causes of energy wastage in MAC protocols for wireless sensor networks [5] [6].

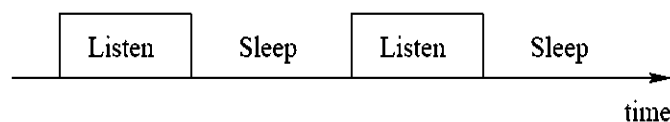
- **Collisions:** When two or more nodes try to access the same medium at same time, the packets get corrupted during the transmission and need to be discarded. This results in wastage of energy resources.
- **Protocol Overhead:** Control packets like RTS, CTS and ACK consume more energy. Since these do not directly transmit data, throughput is also reduced.
- **Idle Listening:** It results when a node is in idle state and is ready to receive a packet but is not receiving any packet. This elevates energy wastage in WSNs.
- **Overhearing:** Overhearing of packet occurs when a node receives the packet that is not addressed to it.
- **Over emitting:** Over emitting occurs when a sensor node sends packet data to a receiver which is not ready to receive the packet.

III. Medium access control Protocols

The purpose of MAC protocol is to control the access to the shared wireless medium in a manner that the execution needs of the underlying application are fulfilled. For different applications of wireless sensor networks, researchers have developed a variety of different MAC protocols. MAC protocols in WSN can be categorized as Contention based, Schedule based, Hybrid and Cross Layer protocols [5][7]. Contention based protocols are based on Carrier sense multiple access (CSMA) technique in which the wireless nodes sense the medium before transmitting to detect whether the medium is idle or not. The main objective of contention-based MAC layer protocols is to minimize rather than completely avoid the occurrence of collisions. Following are few of the widely known contention based protocol.

A. Sensor MAC (S-MAC): S-MAC is a contention based protocol in which each node periodically sleeps and wakes up. The time frame in S-MAC is divided into two modes-listen and sleep mode as shown in figure 2 [8]. In listen mode the SYNC, RTS, CTS, Data and ACK packets are transmitted. In sleep mode the node turns off its radio and sets a timer to wake it up.

Figure 2. Periodic listen and sleep schedule.

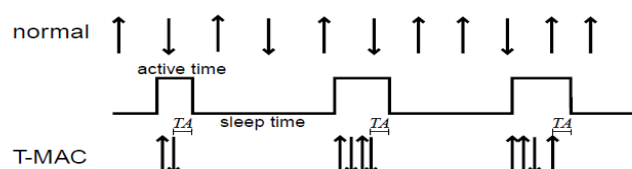


Since the S-MAC protocol has fixed duty cycles so substantial amount of energy is wasted when the communicating node is active or even when there is no packet to transmit or receive. This also sometimes results in high latency and lower throughput [9].

3.2. Timeout MAC (T-MAC): T-MAC protocol is the advancement of S-MAC protocol which removes the flaws of S-MAC. Instead of fixed duty cycles like in S-MAC, T-MAC has dynamic duty cycles which reduce the idle listening problem. In T-MAC all the messages are sent in variable length bursts and a node listens to the channel only for a short interval of time period T_A as shown in figure 3 [10]. If node does not hear any data packet within the T_A time interval it goes to sleep.

T-MAC is more energy efficient than S-MAC as it reduces the idle listening problem by using dynamic duty cycle [10]. But T-MAC protocol suffers from the early sleep problem. This problem is solved in T-MAC by future RTS (FRTS).

Figure 3. T-MAC protocol scheme, with adaptive active times



3.3. Berkeley MAC (B-MAC):- B-MAC is also a contention based MAC protocol which applies an adaptive preamble sampling technique to reduce idle listening [4]. There are no RTS, CTS, ACK packets used in B-MAC. To transmit data the node adds a preamble that is slightly longer than the sleep period of the receiver. During the preamble the receiver will wake up and wait to receive the data after receiving the preamble [11]. When a node has a data packet to send, it waits for a back off time before checking the channel. If the channel is idle, the node will transmit the data else it again waits for a back off time [4]. Since B-MAC is free from control packet overheads so it gives better results in terms of latency, throughput and energy efficiency than S-MAC [12].

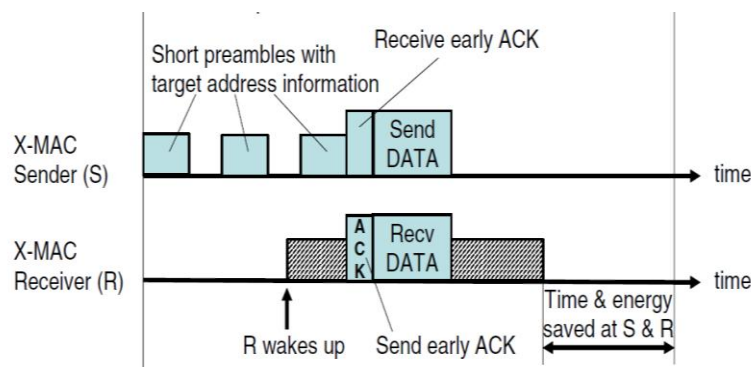
3.4. Wise MAC: - The technique behind wise MAC protocol is non-persistent CSMA with preamble sampling [13]. In preamble sampling all the sensor nodes have bi-communication channels. One channel is for accessing data and the other for control [12]. The schedule of the node is made through the table maintained by the node of the sleep schedules of its neighbors. Wise MAC provides a dynamic method to calculate the length of the preamble. During low traffic, wise MAC renders low power consumption and during high traffic, it renders high energy efficiency [12]. This helps in reducing the power consumption incurred by the predetermined fixed length preamble.

Wise MAC has a disadvantage that in broadcast type communication, it faces different sleep and wake up times for the neighbors of its nodes because of its decentralized sleep listen scheduling. It also faces the hidden terminal problem because it is based on the non-persistent CSMA [13].

3.5. X-MAC: - A series of short preamble packets is presented by X-MAC as shown in figure 4 [14]. Each of these packets avoids the overhearing problem of low power listening as they contain destination address information and remaining number of preambles. This elevates energy savings on non-target receivers [14].

X-MAC requires accurate clock synchronization. Wise MAC is the basis on which X-MAC alleviates the length of preamble sequence. This further alleviates the energy cost of sending preamble sequence by bringing in hand shake mechanism.

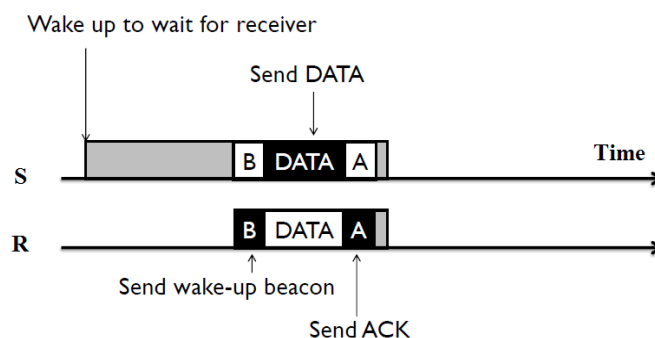
Figure4. X-MAC short preamble approach



X-MAC provides better energy efficiency and lower latency operations by decreasing the transmission energy and transmission period burdens [15].

3.6. Receiver Initiated MAC (RI-MAC):- Receiver-initiated MAC protocol is an asynchronous MAC protocol. Unlike other contention based protocols like S-MAC, T-MAC, X-MAC, etc. in which sender is responsible for initiating the communication process in RI-MAC data transmission is initiated by the receiver [16]. Whenever receiver is active it broadcasts a beacon as shown in Figure 5, which indicates that the receiver is awake and is ready to receive data.

Figure 5. RI-MAC data transmission scheme



The node with the pending data on receiving the beacon starts transmitting the data packet immediately. On the completion of the data transmission the receiver sends another beacon. This second beacon performs two roles: first, it acts as an acknowledgement for the data frame received by it, and second, it indicates that the receiver node is ready to receive more data packets [16].

3.7. Predictive Wakeup MAC (PW-MAC):-Predictive wakeup MAC protocol is an energy-efficient MAC protocol based on asynchronous duty cycling. PW-MAC is also a receiver-initiated protocol but proposes the use of an independently generated pseudo-random sequence which is used to control each node's wakeup schedules, thus allowing senders to accurately predict the time at which a receiver will wake up. PW-MAC also introduces a novel on-demand prediction-error correction mechanism in order to prevent senders from missing the wakeup of receivers due to factors such as hardware and operating system latency. PW-MAC achieves very high energy efficiency by minimizing idle listening and overhearing both at sender's side and receiver's side as well.

IV. Conclusion

The challenge in designing a MAC protocol is to make a balance between energy conservation and flexibility of the network. Several medium access control protocols for the wireless sensor networks have been proposed by many researchers but, there is no protocol accepted as a standard. This is because MAC protocols are application dependent. This paper conducts an overview to WSNs and contention based MAC protocols. This paper would help towards exploring the contention based MAC protocols for WSNs.

VI. References

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