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Analogous Research on Pursuance Assessment of MAC Protocols in WSNs

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Abstract

A Wireless Sensor Network (WSN) consists of tiny sensor nodes capable of sensing some physical attribute, processing and communicating to other nodes in the network. WSNs are very much applicable for health tracking, environmental monitoring, soil monitoring etc. Energy is a major constraint in Wireless Sensor Networks. Medium Access layer is one of the means to conserve the limited energy. This paper analyzes and compares different types of MAC protocols in Wireless Sensor Networks.

Keywords: WSNs, MAC, S-MAC; D-MAC, Wise-MAC, X-MAC, TMAC, TRAMA.

1. Introduction

Wireless Sensor Networks play a major role in catering the needs of people in today's world. Wireless Sensor Networks are deployed in the physical phenomena of their interest. A sensor node consists of a transceiver for receiving and transmitting a signal, Analog-to-Digital converter to convert the Analog signal to Digital, a processor to process the signal, and a battery for power- supply to all these components. Since battery is exhaustible source of energy, network life time of a node is limited. MAC is one of the possible means to preserve the finite energy of battery. The purpose of MAC is to avoid collisions, to control the status of radio transceiver, etc.

Section II gives characteristics of Wireless Sensor Networks. MAC layer is briefly discussed in Section III. Classification of MAC protocols are discussed in section IV. MAC protocols are briefly discussed in Section V. Finally this paper is concluded in Section VI.

2. Characteristics of WSNs

- Attribute-based addressing: The address format in WSN is attributing –valued pairs. For example (New York, temperature<35) means the sensor nodes located at New York which sensed the temperature less than 35 must respond to this query.
- Location Awareness: The nodes must know their position since data is collected based on their position
- The sensors must immediately respond to the drastic changes in the environment
- Query handling: Users must be able to respond to request data from the network through some base station or any of the nodes whichever is closer.

3. Medium Access Control (MAC)

3.1 Characteristics of Good MAC Protocol

The MAC layer main functions are frame delimiting and recognition, addressing, transfer of data from upper layers, error protection (generally using frame check sequences), and arbitration of access to one channel shared by all nodes [15].

The reasons for wastage of energy in MAC layer are:

- *Idle listening*— Nodes try to listen the packets that were yet to be sent.
- *Overhearing*— Nodes try to listen to the packets that were sent to the neighboring nodes.
- *Collisions*— it two nodes try to send the packets at the same time, they may collide.

3.2 Performance Metrics in MAC Protocols

- *Packet Delivery Ratio:* The ration of no of packets received by no of packets sent.
- *Average End-to-End Delay:* The end-to-end delay is averaged over all Surviving data Packets from the Source to Destination [17].
- *Average Energy-Consumption:* It is the average energy Utilized by all nodes in transmitting, receiving and forward operations [17].

4. Classification of MAC Protocols for WSN

For WSN's MAC protocols are classified as:
1. Contention **B**ased: It is widely used because of its simplicity and robustness to the hidden terminal problem. But the problem with this scheme is idle listening, over hearing, and collision [2].
2. TDMA-Based: Here the duty cycle of the radio is reduced and there is no contention-introduced overhead and collisions. But scalability is not good as contention-based protocols [2].

5. MAC Protocols

5.1 S-MAC: Sensor MAC [1] is Contention –based Protocol. The main disadvantage of Sensor MAC is that because of Periodic Sleeping latency increases [18].
Periodic Sleeping— Node must first listen to their neighboring nodes before starting their own listen and sleep schedules. There are two options for the Sensor Node

1. If the sensor node listens the schedule of any of the neighboring node, then it becomes follower
2. If the sensor node doesn't listen to any schedule from the neighboring nodes then it frames its own schedule and becomes Synchronizer. It broadcasts its own schedule Due to Periodic Sleeping there is Reduction in Energy Consumption.

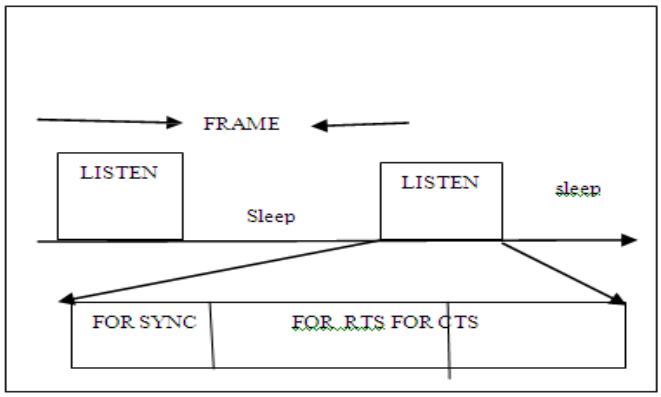

Figure 1: Low Duty Cycle Operation of S-MAC [3]

Adaptive Listening— Adaptive Listening reduces the delay caused by Periodic Sleeping. In this technique, if the node overhears its neighbor's transmission, it wakes up at the end of transmission for a short period of time. If the sensor node is the next hop node, its neighbor is able to pass the data immediately. If it does not receive any it goes back to sleep [18].

S-MAC without Periodic Sleeping: In this mode the parameter Sync flag will be kept Zero. All the nodes work without periodic sleep and runs in fully Active mode. But node goes to sleep when it overhears its

neighbor's transmission. So overhearing is also avoided in this mode [16]. If the nodes are not aware of each other, Periodic Neighboring node discovery solves the problem [15].

Advantages

1. By using RTS/CTS collision rate is reduced
2. It is easy to implement compared to other protocols
3. Energy is saved by sleep schedules

Disadvantages

1. S-MAC has fixed duty cycle
2. Due to broadcast packets collision increases. Because they do not use RTS/CTS packets

5.2 T-MAC: In T-MAC the node listens to the channel for only a short period after synchronization phase. If the data is not received it goes to sleep. If data is received it remains awake, till completion of data or awake period ends.

5.3 WISE MAC: Wise-MAC [12] is designed to optimize the downlink in terms of energy consumption and delay. It is based on preamble sampling like many other MAC protocols. If a base station wants to transmit data to one of its subscriber nodes, it starts to transmit the wake-up preamble right before the wake-up period of the subscriber node. The transmission of a data frame is started as soon as the base station is assured that the subscriber is listening. Note that a frame may contain one or more data packets. The frame starts with the address of the subscriber. Thus, other subscribers can switch off their transceivers in order to avoid idle listening caused by overlapping wake-up intervals; the address field is followed by a data field which holds one data packet. Each frame ends with a frame pending bit to signalize to the subscriber station whether the base station has additional data frames pending for it. As a result, the energy efficiency of the protocol is increased since the subscriber is able to switch off its transceiver as soon as possible. The subscriber node responds with an acknowledgment to the base station in the case that the base station has indicated that no additional frames are pending. The acknowledgment of the subscriber contains the information about the remaining time until the subscriber senses the medium again. This information is then used by the base station to keep its sampling scheduling information table up-to-date. The base station also stores the time when the acknowledgment was received in order to take the clock drift of the oscillator of the micro controller into account [11].

Advantages

1. It provides good throughput in changeable traffic rates
2. It increases the lifetime of a battery due to its low power utilization
3. Wise-MAC can be combined with other MAC protocols to work with diversified applications

Disadvantages

1. It is still having some latency
2. The nodes suffer with hidden terminal problem

5.4 D-MAC: Data Gathering Medium Access control protocol [10]. It is used to delivery data in real-time with high energy efficiency. D-MAC avoids Data interruption forwarding problem. To receive the data, nodes at one level wake up simultaneously. The nodes forward data to higher level in transmitting period (μ) followed to receiving period (μ). The nodes wake up just after the receiving period of lower-level. The Active period looks like a staggered wake-up pattern. This pattern minimizes latency as data packet reaches from root to leaves in one cycle only. If multiple children need to send data in one cycle then D- MAC apply Data prediction method. In data prediction method the parent wakes up at 3μ hoping that another child will send the data packet. A more-to-Send phenomenon is used when same child sends multiple packets to same or different parent. MTS flag is set in last packet [9].

Advantages
1. D-MAC is useful where latency is critical factor [13].

Disadvantages
1. D-MAC is not suitable for high traffic load due to small μ time
2. In D-MAC RTS-CTS handshaking is not used as only few nodes of network remain active at given time.
3. D-MAC achieves data aggregation by receiving packets from all children before forwarding them
4. Each node must know its depth level because it follows staggered wake-up schedule.

5.5 TRAMA: Traffic adaptive medium access protocol [14] is TDMA based protocol. In this energy-efficiency is achieved by reducing collisions and switching nodes to idle state when they are not transmitting or receiving. In TRAMA the time is divided into slots. It will not assign the slots to the nodes which are not having traffic. It also allows nodes to determine when they can become idle and not listen to the channel using traffic information. The TRAMA consists of three phases:

(i) Neighborhood discovery through Neighborhood protocol
(ii) Schedule Exchange Protocol is for exchanging two hop neighbor information and their schedule
(iii) Distributed Election scheme decides at a particular time slot which node can transmit based on available traffic

Advantages
1. TRAMA gives high throughput and energy- efficiency than S-MAC.

Disadvantages
1. In TRAMA there is end-to-end latency.
2. TRAMA decides when a node to transmit based on one hop information. So there occurs hidden terminal problem.

5.6 X-MAC: The design goals of the X-MAC protocol for duty- cycled WSNs are [8] (i)Energy-efficiency (ii) Simple, low-overhead, distributed implementation (iii)Low latency for data (iv) High throughput for data In X- MAC the sender node first sends a series of preamble packets to the receiver during fixed intervals. The preamble contains the destination address and the remaining no of preamble packets. When the receiver node receives any of preamble packets, it sends an acknowledgement. When the sender receives an acknowledgement, it stops further sending preamble packets and sends data packet. This will reduce the energy consumption and end-to-end latency. If the receiver node is busy in receiving data from another node, when the sender node waits for a clear channel to send data, it will wait till the completion. After completion the sender node immediately sends data packets without sending preamble packets. These two techniques reduce energy consumption and latency.

Advantages
1. Because of asynchronous duty cycled approach, it avoids synchronization overhead
2. No need to share schedule information with neighbors
3. Avoids overhearing due to short preamble. Energy efficient for light traffic loads

Disadvantages
1. Series of short preamble consumes most of channel time.

6. Conclusion

Researchers have developed various MAC protocols in Wireless Sensor Networks. This paper analyses frequently used MAC protocols in real world. Wise-MAC outperforms in energy-efficiency than S-MAC, D-MAC, X-MAC etc. D-MAC outperforms in other protocols in throughput. D-MAC and TRAMA outperforms other protocols in Latency. So it is suggested to use the MAC protocol depending on application. The future scope of this research is to simulate all these protocols.

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A Brief Author Biography

Dr. K. Sunil Manohar Reddy – Dr. K. Sunil Manohar Reddy is currently working as an Assistant Professor in the Department of Computer Science and Engineering at Matrusri Engineering College, Hyderabad, India. His areas of interest are Neural Networks, Artificial Intelligence, Software Engineering, Cloud Computing, Computer Graphics and Data Warehousing and Data Mining. He has published and presented about 30 papers in National and International Conferences and Journals.

