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MAC Layer Overview for Wireless Sensor Networks

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Abstract. Media access control (MAC) layer is a very important layer in wireless sensor networks (WSN) since this kind of network is self organizing and has different priorities than regular networks. Due to limited resources, WSN requires special MAC protocols. This work helps to explore some WSN MAC protocols and addresses the kind of problems that are solved by these protocols.

Keywords: Wireless sensor networks, WSN MAC layer, WSN technology

1. Introduction

Wireless sensor networks use a group of autonomous sensors for different purposes in a large variety of applications. Such networks have the ability to be self organized and failure-adaptive to provide an efficient and reliable network that carries the sensed data towards the sink successfully. To provide efficient and reliable services, many factors have to be considered such as the application environment requirement, reliability of the protocol used in the network and the network consistency. MAC layer is a major reason to provide the reliability and efficiency for WSN. MAC is responsible for channel access policies, scheduling, buffer management and error control. In WSN we need a MAC protocol to consider energy efficiency, reliability, low access delay and high throughput as major priorities to accommodate with sensor's limited resources and to avoid redundant power consumption [1].

2. Sources of energy waste in MAC

Energy waste in MAC protocols is attributed to the following [2, 3, 4]:

- Collision: when two nodes try to access the medium at the same time.
- Control packets: RTS, CTC and ACK.
- Overhearing: when the node receives a packet belonging to another node.
- Idle listening: this is the major source of energy waste, where the node keeps listening to medium because it does not know when it will be receiving data.

3. MAC families

a. Schedule based protocol: Usually it uses time division multiple access (TDMA). This type needs previous knowledge of network topology to establish schedule.
   Advantages: no collision, predictable delay, increases the overall throughput, fairness.
   Disadvantages: not good for large network, not scalable, works with stable topology, needs precise synchronization and previous knowledge of network topology which requires expensive hardware and large overhead.

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b. Contention based protocol [5, 6]: usually uses CSMA or ALOHA, there is no need for synchronization or topology knowledge because nodes compete to access the channel and only the winner will succeed.
Advantages: good for large scale, scalable.
Disadvantages: less performance for high load traffic, data packet size usually small, RTS and CTS are more energy consuming. RTS and CTS only used for uni-cast.

4. Some MAC protocols

- Sensor MAC (S-MAC)[1, 6, 2, 7]: uses a synchronized duty cycle and schedule periodic wake and sleep, and using very short SYNC packet to exchange periodically sleep schedules with neighbours. It contains transmitter address and the next sleep time. Advantages: reducing wasted energy by minimizing idle listening by making sleep and listen periods predefined and constant. Disadvantages: when a node lies between two awake clusters, the node has to follow two different schedules which consume more power. Furthermore, large message is divided into frames and sent in a burst to reduce overhead and latency, on the contrary it becomes unfair medium access. See Fig. 1.

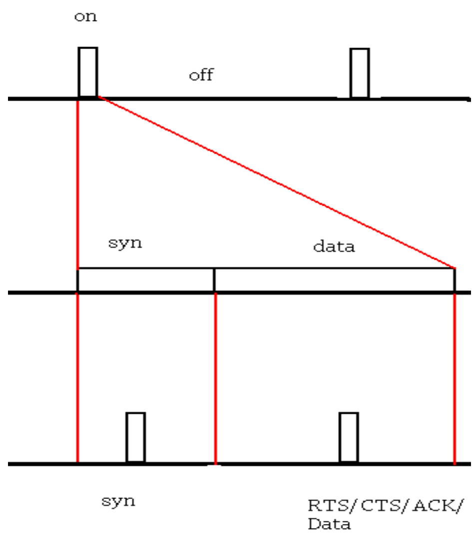

Figure 1: S-MAC

- Time out MAC (T-MAC)[2, 7]: uses sleep/active duty cycle but ends dynamically. Node in the active period sends or receives data but when there is no action for a certain time the active period ends. Advantages: increased efficiency of algorithm for variable traffic loads. Fig. 2 explains the difference between T-MAC and S-MAC [2]

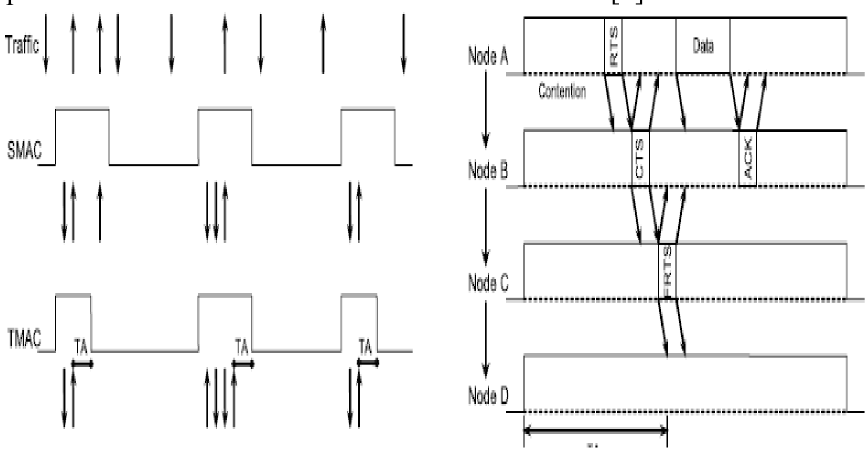

Figure 2: T-MAC and S-MAC

A problem of early sleep will occur when a third node supposed to be part of the next transmission process goes to sleep. This problem is solved in T-MAC by future RTS (FRTS), so the third node stays active to receive data instead of waiting for the next active period.

- S-MACL (global sleeping schedule)[6, 7]: this protocol solves the SMAC border node problem. S-MAC considers the whole network as one cluster and each node has a unique ID, in this protocol we have two kinds of nodes: synchronizers and followers.
- When nodes do not receive a SYNC frame after the first listening period, arbitrarily the network chooses one node to use its schedule as a reference for the network (synchronizer node).
- When node receives a schedule different than the neighbours, it compares the current ID with the new one and follows the higher ID. If the new one has a lower ID the node will announce its own schedule in the next listening time.
- Pattern MAC (P-MAC) [7]: it is used in a dynamic sleep/wake up schedule according to the node traffic and its neighbours. Nodes get information from its neighbour before it sends the communication packets (pattern), in other words the node derives its schedule according to its own pattern and neighbour pattern.
- Traffic adaptive MAC (TRAMA) [7]: using single time slotted channel access divided into random and scheduled access period. Consists of neighbour protocol (NP), scheduling exchange protocol (SEP) and adaptive election algorithm (AEA). NP: uses the random access period for signalling, synchronizing and updating two hops neighbour information. It uses the schedule of the target node for future transmission, where the node schedule is established according to its current traffic and propagated to the neighbours. AEA: use the information from SEP and neighbours information to elect transmitter, receiver and stand by nodes for current time slot and the not selected for Trans/Receive data is removed from election and goes to sleep.
- B-MAC (versatile low power MAC) [2, 7]: uses the CSMA protocol. The node wakes up every check interval, where the radio samples the channel and checks if there is an activity during the preamble period. It stays on for receiving data but if there is no data the time out forces the node to sleep. To transmit data the node adds a preamble that is slightly longer than the sleep period of the receiver. During the preamble the Rx will wake up and wait to receive data after the preamble. Disadvantages: overhearing and excess latency at each hop, so this implies that Rx will have to wait until the end of the preamble period to start receive data. Other nodes have to stay in wake up status as well until the end of the preamble. All the waiting leads to pre-hop latency and for multi-hop network the accumulated latency will have effect on overall network performance.
- X-MAX (short preamble MAC) [7]: solves the P-MAC problems by embedding the target ID in the preamble so other node can go back to sleep. Embedding short pauses between preamble packets so if the Rx wakes up it can send an ACK during this pause and cut the preamble to start sending data.
- TSMP [7]: uses TDMA and frequency division multiplex FDMA over 16 frequency channels divided into time slots so more than one node can access the medium at the same slot but with different frequency. The TSMP works under this rules: never put two transmissions in the same time and frequency, for a given node it should not receive or transmit two times. Disadvantages: complexity, tight synchronization, scalability, broadcast communication, memory. Fig. 3 explains the TSMP protocol[2]

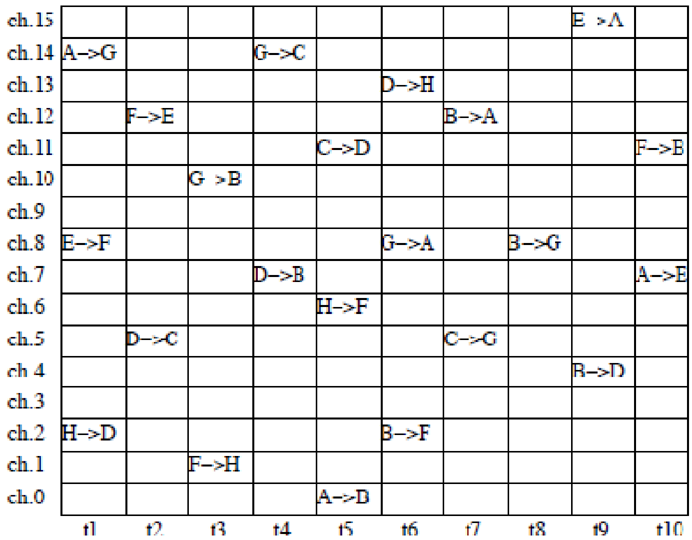

Figure 3: TSMP protocol

5. Conclusion

This paper conducts an overview of the MAC layer for wireless sensor networks, the problems, protocols with their advantages and disadvantages. This paper helps toward the effort to explore MAC ideas and protocols suggested for wireless sensor networks.

6. Acknowledgements

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