5ISS - Communication

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Assignment 2:

MAC layer protocols for WSN

1. Introduction

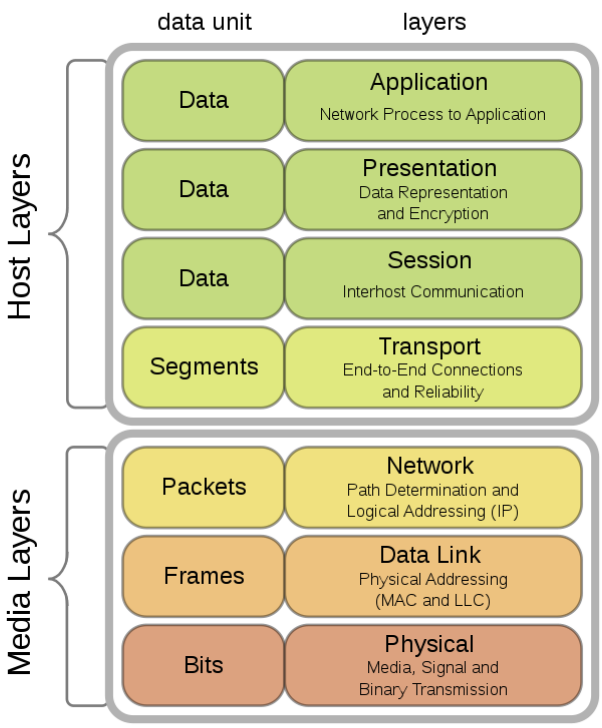
In the context of a wireless sensor network, maximizing the lifetime of the network is a common problem. Therefore, the MAC protocol must be energy efficient in the sense of avoiding waste as much as possible because when a node runs out of battery power it is essentially considered dead. In order to achieve that goal, regarding MAC layers, we must create algorithme that dictate behaviors and communication patterns used by the sensors.

In this report, we review some widespread MAC protocols and discuss their advantages and disadvantages regarding the following criterias: channel access type, synchronisation, localisation, security, node mobility and power consumption.

2. Definitions

MAC protocol is the first protocol layer above the Physical Layer .The primary task of any MAC protocol is to control the access of the nodes to the shared medium.

Media Access Control is a sublayer that controls the hardware responsible for the communication with the transmission medium. Paired with the logical link control layer (ILLC) they form the data link layer. LLC provides flow control and multiplexing for the logical link, whereas MAC provides the transmission medium.



The function of the MAC is to help each and every node to make a decision as to when and how to access the channel. In other words, when to send a frame, listen and sleep.

We can classify those protocols based on their channel access type. There are three categories, a category of protocols that uses CSMA that can again be splitted in two, synchronous and asynchronous, another category uses TDMA which can be centralized or distributed, and last, some MAC protocols use a combination of both, called hybrids.

CSMA: nodes attached to the network listen (carrier sense) before transmitting. If the channel is in use, devices wait before transmitting. MA (Multiple Access) indicates that many devices can connect to and share the same network. All devices have equal access to use the network when it is clear.

Even though devices attempt to sense whether the network is in use, there is a good chance that two stations will attempt to access it at the same time. This is called a collision, and if not properly dealt with, the two frames are discarded. With CSMA, two strategies can be adopted to deal with collision: CD (collision detection) when a collision occurs it is detected and senders stop transmitting, both frames have to be retransmitted after a random amount of time, since it is done after the collision actually occurred it is not very effective on large network. CA (Collision Avoidance) each node signals its intent to transmit before actually doing so.

TDMA allows several users to share the same frequency channel by dividing the signal into different time slots. The nodes transmit in rapid succession, one after the other, each using its own time slot. By definition, it prevents collisions.

It is important to note that TDMA allows a good synchronization between the nodes of a network, therefore giving the opportunity to do localisation via the MAC protocol.

3. Sources of energy waste

The energy consumption problematic is fundamental in WSN, most devices being battery power, their energy consumption defines their lifetime.[1]

The primary energy waste source is collisions, it basically neglects a transmission because frames have to be discarded when a collision occurs. hence the need to completely avoid them from happening.

Second, overhearing is very common. when a node receives a packet destined to other nodes it consumes energy without filling a purpose.

Third, you waste energy by using an excessive amount of control-packets.

[1] Iker Demirkol, Cem Ersoy, et Fatih Alagöz, « MAC Protocols for Wireless Sensor Networks: A Survey ».

Fourth, listening to idle channels obviously wastes energy as well, in WSN we try to have the shortest duty cycle possible.

And finally, we call overmitting when a node transmits to a node that is not listening.

4. Some important MAC protocols

a. Aloha Protocol

This is the first introduced MAC protocol for general use in networks (1970). It went on to see several upgrades throughout the years. In its early stages, it was extremely simple, every node can send data whenever it wants to, and if a data packet is lost due to collision, it will be retransmitted later after a random amount of time. which limits the number of nodes on a network since a greater number of nodes is synonymous with a lot more collisions occurring.

Then, it was decided that the time would be slotted (Slotted Aloha Protocol), nodes can now transmit in divided time slots from a channel. A node waits for the beginning of a time slot to transmit, then collisions are less likely to occur. But it still may happen at the beginning of a transmission.

Aloha can also be seen with preamble sampling, in which nodes can go to sleep or wake up depending on if the channel is free during the next time slot. A dummy packet can be sent to keep a node awake and thus avoid missing the wake up schedule of its neighbors, it then continues listening until it receives the acknowledgement frame.

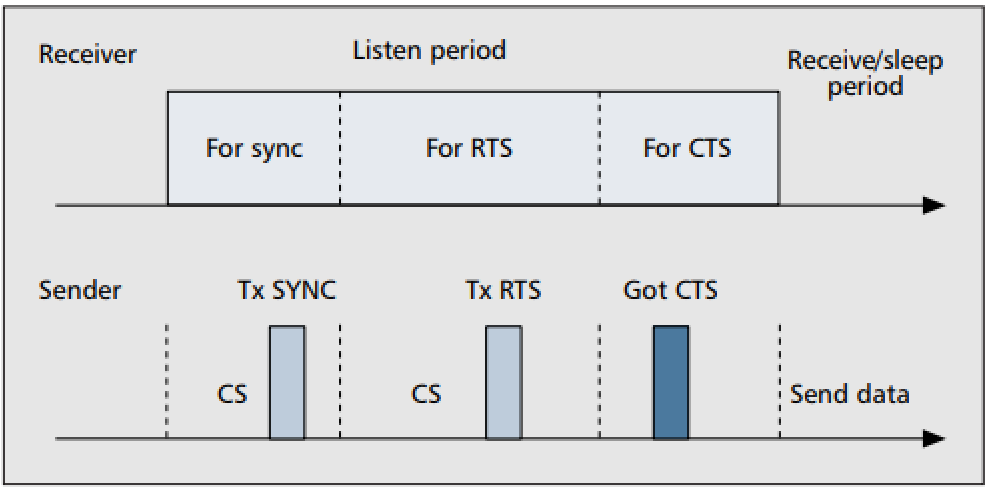
b. S-MAC (Sensor-MAC)

This protocol is based on Carrier Sense Multiple Access (CSMA) and uses RTS and CTS. With S-MAC, neighboring nodes are grouped in virtual clusters allowing to set up a common sleep schedule. This is the idea behind this protocol, nodes are locally synchronised and managed.

The S-MAC protocol works with a periodic sleep/listening mechanism and a low duty cycle in order to reduce the energy consumption of nodes. Each node is in control of its own sleep/duty cycle and is designed to be in a sleeping state as much as possible. When a node wakes up it listens to the channel and determines whether to send or receive data packets.

The synchronous feature makes the protocols more appropriate for delay-sensitive applications compared to asynchronous protocols. The latter involve additional delay for the sender to meet the receiver's active period, which is eliminated with synchronous approach where nodes sleep and wake up all together.If the neighboring nodes belong in two different virtual clusters they will wake up at the listening period of both virtual clusters. But as a consequence, it is possible to follow two different schedules which can lead to idle listening and overhearing inducing more power consumption.

Neighboring nodes share their schedule using SYNC packets broadcasted periodically (synchronization period). A collision avoidance mechanism is used, this is achieved by a carrier sense (CS) .



c. T-MAC (Timeout MAC)

T-MAC is proposed to improve the poor performances of the S-MAC protocol under variable traffic loads, in fact, the static sleep/listen period of the S-MAC leads to high latency and lower throughput. Here in T-MAC, a time threshold TA is set up, the listening period ends when no event has occurred in the time TA. [2]

Here all messages are transmitted in bursts of variable lengths and sleep between bursts, the synchronisation via virtual clusters is similar to S-MAC.

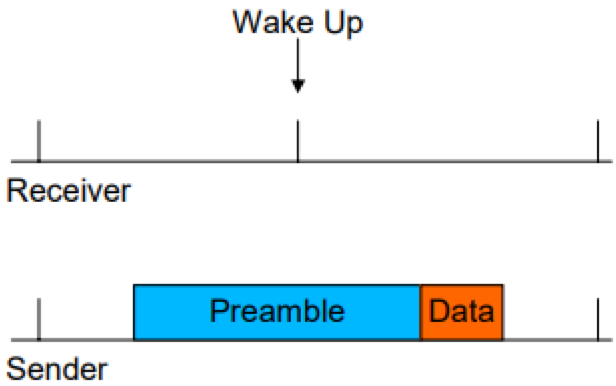
As a consequence, T-MAC saves energy compared to S-MAC.

[2] Youssouf Zatout, Eric Campo, et Jean-François Llibre, « T-TMAC: Energy Aware Sensor MAC Protocol for Health-care Monitoring ».

d. B-MAC (Berkeley MAC)

B-MAC is based on CSMA-CA (collision avoidance). The main difference with T-MAC is that this protocol is asynchronous, the nodes are not asleep and awake at the same time. To address that, the sender node has to send a long preamble frame in order to notify the receivers that a transmission is coming. When a node awakes it checks for channel activity using CCA. This behavior minimizes duty-cycle and reduces idle listening, But having to send such long frames to awake neighboring nodes raises the energy consumption.

Like S-MAC and T-MAC, B-MAC does not require clock synchronization or topology information, and dynamic node join/leave is handled without any extra cost.



e. E-MAC (Emergence MAC)

E-MAC is a very simplistic MAC protocol that allows nodes to achieve high throughput through multi-hop networks under a variety of situations without the need to tune system parameters[3]

This protocol uses TDMA in a distributed manner. This means that some nodes are managers of a limited sub cluster of devices.

The goal of E-MAC is to provide good performance with very low complexity. The protocol is based on a simple implementation inspired by the biological social metaphor of swarm reactions to an environment. The bare minimum amount of data is shared during each data packet transmission. No additional transmissions are made and there is no need for carrier sensing

[3] Tautvydas Mickus, Paul Mitchell, et Tim Clarke, « The Emergence MAC (E-MAC) protocol for wireless sensor networks ».

f. Z-MAC (Zebra MAC)

Z-MAC is a hybrid MAC protocol for wireless sensor networks. It combines the strengths of TDMA and CSMA while offsetting their weaknesses. Nodes are assigned time slots using a distributed implementation of RAND. Unlike TDMA where a node is allowed to transmit only during its own assigned slots, a node can transmit in both its own time slots and slots assigned to other nodes. In other words, every time slot from the TDMA has its own CSMA. Every node has an attributed time slot but it can have more than one if necessary, or if the node doesn't need the time slot it is redistributed to others who need more.

5. Comparison and critique

Although there are various MAC layer protocols proposed for sensor networks, there is no protocol accepted as a standard. One of the reasons for this is that the MAC protocol choice will, in general, be application dependent, which means that there will not be one standard MAC for sensor networks.

TDMA has a natural advantage of collision free medium access. However, CSMA methods have a lower delay and promising throughput potential at lower traffic loads, which generally happens to be the case in wireless sensor networks. However, additional collision avoidance or collision detection methods should be employed.

The question of energy consumption is hard to discuss and very few address it in literature, but comparison can be made to give an outline of the situation .[4]

[4] Bhavana Narain et al., « Energy Efficient MAC Protocols for Wireless Sensor Networks: A Survey ».

Name of protocol	Scheme used	Energy Saving	Advantages	Disadvantages
SMAC	Fixed duty cycle, virtual cluster, CSMA	Power savings over standard CSMA/CAMAC	Low energy consumption when traffic is low	Sleep latency, problem with Broadcast
BMAC	LPL, channel assessment software interface	Better power savings, latency, and throughput than S-MAC	Low overhead when network is idle, imple to implement Consumes less power	Overhearing, bad performance at heavy traffic. Long transmission latency
TMAC	Adaptive duty cycle, overhearing, FRTS	Uses 20% of energy used in S-MAC.	Adaptive active time	Early sleeping problem
WISE MAC	Minimized preamble sampling, schedule	Better than SMAC and Low Power Listening	Energy Consumption both at sender And receiver, and at non target receiver, increase latency at each hop.	Low power for low traffic, Do not incur overhead due to synchronization.
TRAMA	TDMA	Utilization of classical TDMA	Higher energy efficiency & throughput	time is divided into random access period
DMAC	Converge cast communication	Low latency	Energy saving and low letency	Aggregate rate is larger