MAC PROTOCOLS DEDICATED TO WSN/IoT

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Introduction

This report is written in the context of the 5th year ISS specialty module on Wireless Sensor Networks at INSA Toulouse and aims to present the main MAC layers protocols, their advantages and disadvantages, and their method of access. Firstly, we will approach the general notion of MAC layer and its use in a network, then we will present the main access methods used by MAC layer protocols, and finally we will present these protocols and the access method they use, but also their way of operating and their performances compared to one another.

Generalities about the MAC layer

The MAC (Medium Access Control) layer is a sub-layer of the Data Link layer, one of the seven layers of the OSI model that is in charge of the communication between two directly connected machines. The OSI (Open Systems Interconnection) model is a conceptual framework used to describe the functions of a networking system. This model is structured in seven different layers which correspond to different abstraction levels going from the lowest one, the physical layer, which concerns electrical or optical transmitting of raw data across the network, from the physical layer of the device sending the information to the physical device receiving it. The OSI model goes through the process of networking from this physical layer all the way to the last layer, the application layer, which is the entry of an application to the network where the user communicates directly through the software application.

A communication between two systems relies on protocols, which is a set of rules for formatting and processing data.
The use of protocols enables computers within a network to communicate with each other even if they are not using the same software or hardware, thus making standardized protocols a “common language” for them to be able to communicate anyway.
It is important to know to which OSI model layer a protocol belongs in order to really understand its usage.

As indicated by its name, the MAC layer is in charge of controlling the access to the physical transmission medium. It encapsulates higher-level

frames into frames appropriate for the communication medium and also adds a frame check sequence in order to identify if any transmission errors occurred. It also handles collision by compensating them by initiating retransmission if necessary.

The main MAC strategies

In order to be able to grant access to multiple actors to the collision medium of communication, which is a shared resource, the MAC layer uses coordinated access protocols among others, some of them are the following:

- SDMA (Space division multiple access): This access method allows the reception of more than one packet from spatially separated transmitters, as it separates the medium into several physical spatial pipes to allocate separate space to users and allow the sender can address the receiver as in a one-to-one channel. It allows a collision-free access to the medium. It has several advantages regarding wireless networks, but this protocol is still in research. [1]
- FDMA (Frequency Division Multiple Access): This access method allows ultiple users to send data through a single communication channel by dividing the bandwidth in distinct frequencies and assigning a unique frequency to each user, allowing the users to send data to a subchannel. It is used in satellite communication systems for example. [2]
- TDMA (Time Division Multiple Access): This access method allows multiple users to share the same frequency channel by dividing the signal into different time slots. It assigns the sending frequency to a sender-receiver pair for a certain amount of time. [3]
- CDMA (Code Division Multiple Access) : This access method assigns a code to each transmitter. There are many variants, to give an example, in the case of synchronous CDMA, it uses orthogonal codes to permit to the receiver to reconstruct the message.

The MAC layer can also use other strategies such as Random Access Protocols, CSMA CD/CA for example :

- CSMA CD (Carrier-sense Multiple Access with Collision Detection): This method consists in the sender listening to the medium all the time (carrier sensing) in order to be able to check that nothing is already being transmitted on the medium before it sends a message itself. If the medium is already in use it waits for the end of the transmission. This method also has a collision detector : if a collision

is detected the transmission stops and resumes later after a certain amount of time.

- CSMA CA (Carrier-sense Multiple Access with Collision Avoidance): This method uses carrier sensing as well but in this case nodes avoid collision by asking permission to the designated "master". They only transmits after authorization, which allows them to send the packets entirely.

MAC layer protocols for WSN

The communication of sensor nodes is destined to be more and more energy consuming and replacing or even charging flat batteries is very difficult, which is why the main challenge is to maximize their lifetime by using methods as low-consuming and efficient as possible, making this one of the main criteria to evaluate the efficiency and quality of a protocol.[4]

In this section we will present a few MAC layer protocols particularly used in Wireless Sensor Networks with their characteristics [5]:

- S-MAC (Sensor Media Access Control): This is a protocol for sensor networks in which the nodes alternatively switch from a listening to a sleeping mode periodically. The idea is for them to be sleeping while other nodes are transmitting. If nothing happens, the nodes go to sleep for a long time, since it is not necessary to keep them awaken and listening at all times and wake up later when the timer previously set expires and wakes them up so they can see if another node wants to communicate with them. If more than one neighbor wants to talk to a node, it will wait to have access to them medium, using as an access method a TDMA and CSMA-CA combination. For the nodes to be synchronized, in the beginning the first node, called the synchronizer defines for itself a random schedule and sends it to its neighbors, which then define a schedule following the one they received and send it to their neighbors and so on… To prevent a clock drift, they need to perform timer synchronization through periodic updating. This protocol allows a fair amount of energy savings thanks to the sleeping mode: the sleep-listen periods result in a lower throughput and perform higher latency.

- T-MAC (Timeout MAC): The advantage of this protocol is that it is quite energy efficient and easy to implement.[6] This protocol is derived from S-MAC: it has a similar synchronization and uses the same kind of access but does not have fixed sleep and active periods, the listening periods just end because it is capable of working under various traffic loads. It also saves more energy than S-MAC. [5]

- B-MAC (Berkeley MAC): [5]This protocol mainly aims to have a low power consumption and to avoid collisions effectively. It thus logically uses the CSMA-CA access method. This protocol is practical since it has a simple implementation, is reconfigurable by upper layers, is scalable to a large number of nodes and has a low power listening by using preamble sample. It adapts itself to the network at the beginning which optimizes the cycles by minimizing the listening times. This protocol generally performs better than the previous ones but it has an inconvenient: its system model can be difficult for developers but it is still widely used because its performances are still satisfying with default parameters.

- P-MAC (Pattern MAC): [5] This protocol is mostly performant in relatively stable traffic conditions. Its results, at least in simulation, seem to be better than S-MAC but it might be slow to adapt to changes on traffic.

- Z-MAC (Zebra MAC): [5] [7]The Z-MAC protocol combines TDMA and CSMA features to control the access to the medium and runs on top of the B-MAC protocol, with a better high-load handling but with a higher complexity, which can be an issue.

- TRAMA (Traffic-Adaptive Medium Access): [7] This protocol uses TDMA to access the medium. It is a schedule-based protocol, the nodes will synchronize and exchange their schedules and their neighborhood's schedule to their neighbors. An algorithm allows the nodes to select their slot.

- LEACH (Low-energy adaptive clustering hierarchy): This self-organizing protocol divides nodes into local clusters and designates a node head of the cluster (this role is randomly named and rotates among the nodes of a cluster in order to dissipate). This node will coordinate the cluster and forward the data of the cluster's nodes to the sink. It uses TDMA within the cluster (the node that is the cluster-

head creates the schedule that will be used by TDMA) and CDMA between the different clusters to avoid interference with a nearby cluster.

Conclusion

In this report, we have first reviewed what a MAC layer is, and what is its purpose, its main purpose being to control the access to the medium, as indicated by its name, then we have covered a few of the main strategies used by the MAC layer to grant access to the medium of communication, and finally we reviewed the main protocols used by the MAC layer, their advantages and their disadvantages one to another, and the access method they use.

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