MAC protocols dedicated to WSN

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1 Introduction

In a sensor network, the communication needs are different than in more traditional networks. In classic networks such as home networks or cellular, we need high speed and a large amount of data. In a sensor network, we need to have minimal energy consumption, long-range transmissions, and the possibility to connect a large number of nodes. That is why we designed wireless sensor networks (WSN).

We can classify WSN protocols into four categories. First, we can divide the MAC protocols by if they are single layer or cross layer. Then we can divide the single layer protocols into three categories: synchronous, asynchronous, and hybrid. In this document, we are going to study the characteristics of each category of MAC protocols.

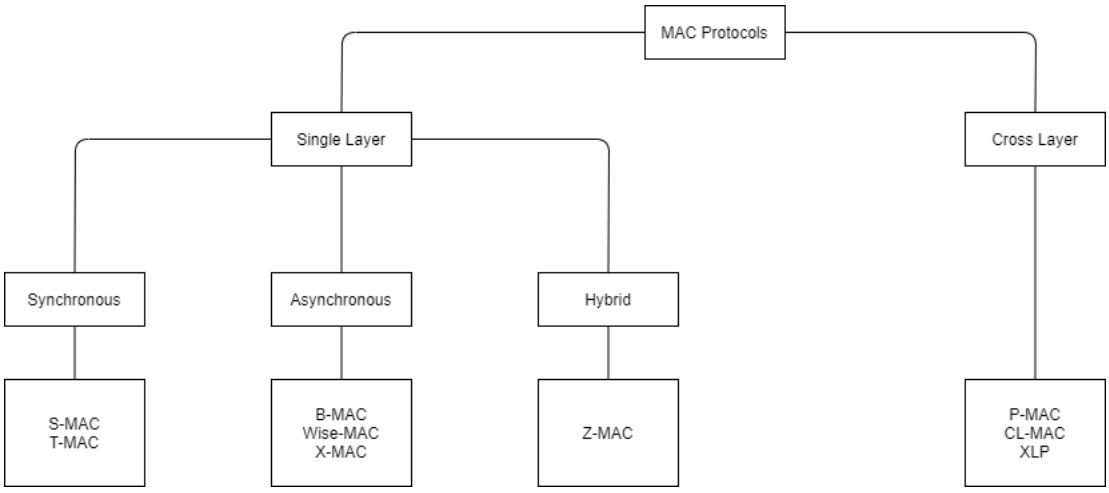

Figure 1: Classification of the MAC protocols based on their type

2 Single layer protocols

2.1 Synchronous protocols

Synchronous WSN protocols, use a clock to synchronize them and speak. S-MAC is a single layer synchronous protocol [2]. In this protocol, we can identify two kinds of nodes: cluster nodes and none cluster nodes. Cluster nodes can talk to each other. The other nodes are connected to a single cluster node to form a virtual cluster. In a virtual cluster, nodes are synchronized following a schedule. When it is their time to speak a node wakes up and transmits its message to its neighbors or to the cluster node if the message needs to leave the virtual cluster.

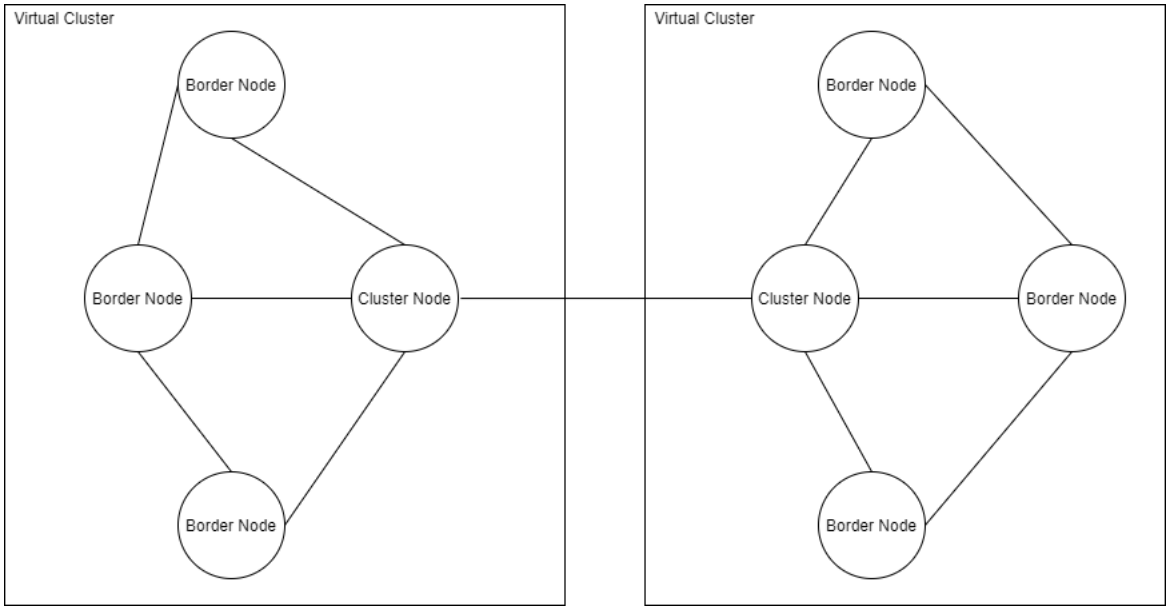

Figure 2: S-MAC node network with two virtual cluster

To synchronize nodes, SYNC packets are periodically sent via broadcast. A system of neighbor detection is also in place, it allows to add and remove nodes dynamically. The neighbor detection is expensive and a node without neighbors will perform it more often than with neighbors.

Using the cluster nodes, a message can reach any nodes of the network. The data will be transmitted over multiple hopes in the sensor network. To reduce latency, when a node overhears a neighbor transmission, it will wake up a short time before the end of the transmission to prepare the forwarding action. Fragmentation is also supported by S-MAC.

T-MAC is also a synchronous WSN protocol that is placed as the evolution of S-MAC [7]. The idea behind T-MAC is to replace the static idling cycle of S-MAC with a dynamic one. So, T-MAC (Time-out MAC) introduces an adaptive duty cycle.

In the T-MAC protocol, the duty cycle of a node can end earlier if no activities have been detected in a given time. This allows minimizing the latency inside the network. A node near the sink will receive more traffic than a border node. By minimizing the waking time of the border node we grant more time to the node placed at the center to transmit the data inside the network. Reducing the duty cycle also improves the energy consumption since a node is awake less often than in S-MAC.

2.2 Asynchronous Protocols

Asynchronous protocols use, like synchronous one, sleep/wake-up cycle, but in their case, the sleeping time can differ between each node. B-MAC is an asynchronous protocol design for networks with N-senders and 1-receiver [2].

B-MAC uses a low power listening (LPL) mechanism to reduce energy consumption. LPL means that the listener wakes up and listens for data transmission. If there is no data transmitted, then the receiver goes back to sleep. This phenomenon is called a false positive.

When a node wants to send data, it sends an announcement long enough to cover the sleeping period of the receiver. Then the sender transmits the data to the target address. There is no fragmentation supported since B-MAC expects short messages.

To reduce power consumption, B-MAC uses a clear channel assessment (CCA) mechanism. The idea is to reduce energy consumption, a better separation between signal and noise on the channel is useful.

That means that B-MAC must analyze the noise on the channel. When a false positive occurs, a sample is placed in a queue to analyze the noise in the following transmission. Multiple samples can be stored because the noise caused by the environment can frequently change. B-MAC also has an optional feature to implement an acknowledgment mechanism.

Wise-Mac is another asynchronous protocol based on an N-sender/1-receiver structure [2]. It is an infrastructure protocol, and it assumes there is one central node with an unlimited power supply and a connection to a high-speed network. Because of the unlimited energy of the central node (or access point), it will manage the network.

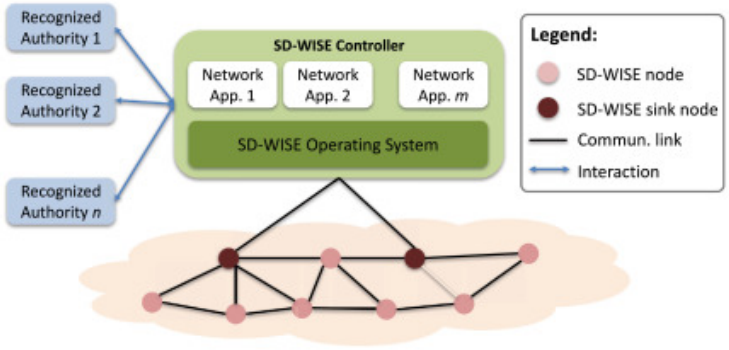

Figure 3: Example of Wise-MAC Network [1]

As in B-MAC, nodes have different sleeping periods. Those periods are stored in a table in the access point. So the central node can handle a message after another. To optimize the data rate, if a node has messages waiting, it will notify the access point in the header of its current message. Then the access point can awake it before the end of its sleeping period if it has nothing else to do.

Finally, X-MAC works like B-MAC but tries to improve it by changing its announcement [2]. When B-MAC uses a long announcement, X-MAC uses a short announcement repeated to be noticed by the receiver node.

2.3 Hybrid Protocols

A hybrid protocol is a protocol that can switch its protocol based on a chosen parameter. Z-MAC is a hybrid protocol that switches between CSMA and TDMA based on the network contention [3].

In CSMA each node checks if the channel is free or not. If it is free the node sends its message to the station, if it is not free the node returns to sleep for a defined time. The topology of the network is like in S-MAC protocol with cluster nodes.

In TDMA each node has a period of time when it can emit. This time period is fixed and detained by the station node. The topology is like in B-MAC protocol but without announcement since the emitting time of each node is determined.

3 Cross layer protocols

Unlike single layer protocols, which only take into account the state of the physical layer to determine when to sleep or not, cross layer protocols use other layers to determine when to sleep or not. For example, P-MAC also uses the network layer through pattern [5].

P-MAC is working like S-MAC or T-MAC but it tries to improve the power consumption by using a pattern. One of the most important sources of energy waste is the idle listening time or the time that a node is awake (so using power) waiting for a message that may or may not come. T-MAC has improved

S-MAC on this point by fixing a threshold where to go to sleep if no message was received. P-MAC tries to improve even more that point by analysing the traffic of the neighbor to determine if a node needs to wake up or not.

To do so, P-MAC uses patterns. A pattern is a string of bits that indicate if a node needs to wake up or not. This pattern replaces the schedule presented in S and T-MAC. Based on the traffic on the network, a node will receive a pattern that will determine his behavior for the next slots of time. Unlike in T-Time where a node wakes up at each slot of time, a pattern can indicate to a node that it can sleep for the next two slots of time and wake up for the third.

By limiting the idle time where a node consumes energy but does not work, P-MAC is able to save even more power than the previous version of the protocol like S-MAC or T-MAC.

There are other protocols that use the network layer such as CL-MAC but there also protocols that use other layers than the network one [4]. For example, XLP is a protocol that will use the network and the transport layer in addition to the physical one [6].

4 Conclusion

To conclude, there are a lot of different protocols for wireless sensor network. Some of them are more optimise in order of power consumption and bit rate which are really important in that kind of network. The choice between synchronous, asynchronous or hybrid must be done based on our problem. For example, the Wise-MAC protocol which requires a station with unlimited power can be really efficient but cannot be done in certain context. The choice of which protocol we are going to use for our solution is very important because a bad choice can bring a lot of problem such life time limited due to too important power consumption.

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