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Report IoT MAC layer

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Introduction

With the rise of the Internet of Things (IoT), there has been an urging need to review the communication protocols to make each IoT device communicate with each other. Indeed, IoT devices need to be energy-efficient, low-cost, and the network need to be scalable in order to support a huge traffic load from the different connected devices. While being able to offer traditional services, such as quality of service or a fair channel access, the network should also be able to be self-capable in various aspects such as organisation, configuration and recovering.

This report will focus on the MAC layer, and present several protocols that are used or proposed for IoT networking. Most of the research were made thanks to [1].

1 Contention based

Contention based protocol is a communications protocol for operating wireless telecommunication equipment that allows many users to use the same radio channel without pre-coordination. It is very easy to implement, however it lacks scalability mostly because of collisions between concurrent communications.

1.1 CSMA/CA

Carrier Sense Multiple Access (CSMA) is the most prominent contention based protocol. CSMA/CA is more particularly an extension with collision avoidance enabled. The avoidance principle is quite simple, where each transmitting device will wait for a random interval before transmitting if they find the transmission medium busy. The random interval allow to reduce the incidence of collision.

However, this protocol is suited for small networks, and is energy-consuming because of idle listening and the packets' overhead.

2 Contention free

In opposition to contention based protocols, contention free protocols are protocols that aim at removing collision related issues by using solutions such as defining slots of communication to avoid concurrent transmission. All the contention free protocols have a fixed number of resources, and the culprit of the protocols is to efficiently share those ressources among the different devices.

2.1 TDMA

Time Division Multiple Access (TDMA) is a protocol based on the adaptation of the available communication slots in function of the actual traffic intensity. The communicating devices will look for an empty slot and then send their information. Even if enhancement such as the dynamic management of the slots have been proposed, the channel utilisation and the need for frequent information exchange for synchronisation make the protocol energy-inefficient.

2.2 CDMA

Code Division Multiple Access (CDMA) protocol's particularity is that it applies a device-specific modulation code to the signal, so that the targeted device can restore the original signal while the other device will receive an attenuated signal.

Although fine for powerful and powered devices, CDMA is not suited for IoT devices. It is quite complex to use, and needs additional resources to process the communicated signal, thus increasing the overall system cost.

2.3 FDMA

Frequency Division Multiple Access (FDMA) is a contention free MAC protocol based on frequency modulation to enable communication between several devices. Because it requires additional circuitry to communicate and switch between different radio channels, and it is linear in construct, it is not suited in an IoT context.

3 Hybrid protocols

We see that most of the already available protocols where not suited enough to satisfy IoT communication. In order to overcome each protocol's weaknesses, combinations of protocols have been proposed to fulfil IoT communication's needs.

3.1 HyMAC

HyMAC protocol is a combination of CSMA, TDMA and FDMA, where each node is assigned with a frequency as well as a time slot, after sending a bandwidth request using the CSMA protocol. The main idea of this protocol is to switch between each protocol to use just the useful part of each protocol.

However, this method does not tackle the energy related and cost related issues, which makes HyMAC not suited for IoT communication. Among the TDMA and FDMA protocols used in pair with CSMA, TDMA seems to be the most promising solution, with less cost involved in its implementation than the FDMA's.

One variant of this protocol consists in dividing time in different frames, each frame containing 4 different sections:

- notification period (NP): base station announces the start of COP
- contention only period (COP): nodes that want to communicate use CSMA to send transmission requests
- announcement period (AP): base station attributes slots to successful nodes and announces them
- transmission only period (TOP): each node communicate during their slot

Although being slightly energy consuming and time consuming due to the contention period, this method is a good trade-off between the performance of CSMA and TDMA.

3.2 DPCF-M

Distributed Point Coordination Function-M (DPCF-M) is a hybrid of CSMA/CA and Point Coordinate Function (PCF). This protocol is design for cases where there are two kind of nodes: local nodes and Internet connected nodes (gateway nodes). The nodes will use CSMA/CA to communicate between them, or use a gateway node to communicate with an external server. In the second case, a device will send a Request For Gateway (RFG) to the gateway node, which will enter a beacon mode. During the beacon mode the gateway node will allow other nodes to communicate during defined slots, so that they can sleep during the rest of the time.

This method is more energy-efficient than simple CSMA/CA, but induce more cost due to the hardware for the gateway node. There is still also the collision problems of the CSMA/CA protocol.

3.3 M2M Communications Using Cellular Networks

This protocol comes from the observation that the overhead used in LTE-A is prohibitive since the data sent from IoT devices is not as important as with usual mobile devices (phones). A modification proposed is integrating the payload directly in the MAC's PDU. The receiver will be modified so that it can recognise the custom packet. By doing this, the efficiency is enhanced and we avoid unnecessary control.

To address the collision problem, each device can detect the overload by counting the number of time where they did not received an answer from the base station, and send that information to the base station. The base station can then adapt the number of available slots, by the mean of time, frequency or both of them.

3.4 Cognitive Radio-Based M2M Communications

This protocol combines the packet reservation multiple access (PRMA) protocol with a cognitive radio physical layer that uses television white spaces (frequencies allocated to a broadcasting service but not used locally) for communication. As seen before, IoT devices will send a reservation, which will be approved (or not) by a base station. The base station will then allocate them slots during which they can communicate. The allocation information will be sent during a downlink phase, prior to the uplink phase during which the IoT devices will emit their messages.

We can also imagine a polling method, where the base station will announce all the available slot, and each device will decide which unused resource to use. Although it removes the need to scan for unused resources, this method is not scalable to large networks, since it is based on a token passing method to decide which device can use a resource.

Conclusion

In conclusion, we saw that several MAC protocols were proposed to address the IoT communication's needs. Most of them are adaptation of existing protocols, and only partially fulfil the needs by sacrificing energy consumption or collision issues.

Those protocols also consider the IoT network to be somehow close to carrier network, with gateway/base station/special nodes that are able to communicate with Internet, who will act as the master in the communications.

That is why I am inclined to say that IoT did not find its soul protocol yet.

References

[1] A. Rajandekar and B. Sikdar. “A Survey of MAC Layer Issues and Protocols for Machine-to-Machine Communications”. In: *IEEE Internet of Things Journal* 2.2 (Apr. 2015), pp. 175–186. ISSN: 2327-4662. DOI: 10.1109/JIOT.2015.2394438.