Medium Access Control (MAC) in WSN

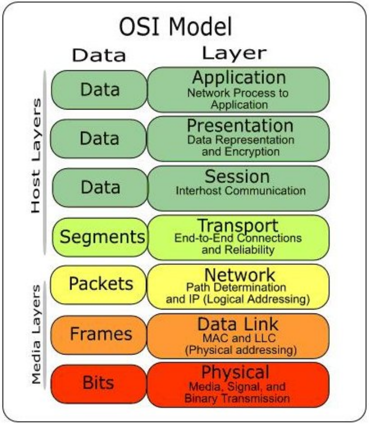
Jørgen Enger Fjellin
jorgenef@ifi.uio.no

November 1, 2011

Introduction

"A prominent example of today's non-optimized WSN deployment experiences is that the start-up alone costs the network a third of its battery power."

MAC is a part of the second lowest layer in the OSI-model.



Main motivation

The main motivation is to get the energy-consumption in a Wireless Sensor Network down by optimizing the MAC.

Why the MAC?

- The MAC controls the radio in a Wireless Sensor Node
- The radio is what consumes the most power
- The smarter we use our radio, the longer the node survives

A node will consume more or less power dependent of what mode the node is in.

Radio (sleep)	900 nA
Radio (idle)	1.5 mA
Radio (transmit)	22 mA
Radio (receive)	14 mA
Microcontroller (active)	8 mA
Microcontroller (idle)	2 mA

The trained eye will discover that some modes consumes more power than others.

When do we use the radio?

- Receiving
- Transmitting
- Packet collision
- Overhearing
- Overhead
- Idle listening
- What can we do??
- Make sure we don't do the things we have listet above more than we need to.

So, what can we do?

If you boil it down to the general idea there is really only two main approaches for regulating access to a shared wireless medium. There is the **reservation**-based protocols, and there is the **contention**-based ones.

Reservation-based

Contention-based

Reservation-based protocols, pros and cons

Pros

- Ensuring fairness
- Collision-free

Cons

- Depends on knowledge of network topology
- And sufficient synchronisation in the network
- Which can generate large overhead
- Not very supportive of mobile nodes that comes and goes

Contention-based protocols, pros and cons

Pros

- Not dependent on topology knowledge
- Nor on synchronisation
- Thus handles mobile nodes quite well

Cons

- Not as efficient as the reservation-based
- Does not guarantee fairness
- In extreme cases a node might never be heard

Ways to cope with this

Different WSN will have different applications, challenges, traffic, e.g. they have very different attributes. This means that different protocols will be better suited to some WSNs than others. The authors have gone through various protocols, which we can put in the following categories:

- Scheduled protocols
- Protocols with common active periods
- Preamble sampling protocols
- Hybrid protocols

We will now take a closer look on these categories.

Scheduled protocols

The basic idea is to set up a schedule for sending and recieving between nodes in the network in order to avoid/minimize collisions, overhearing and idle listening.

The scheduling protocols are good protocols for WSNs that has periodic and high-load traffic.

We can schedule both time slots and frequency slots (channels), some protocols even utilizes both.

- **TDMA** - *Time Division Multiple Access*
- **FDMA** - *Frequency Division Multiple Access*

One of the main challenges with the scheduled protocols is how to set up and maintain a specific schedule in the WSN.

There are currently three main methods used in order to deal with it.

- Scheduling of communication links
- Scheduling of senders
- Scheduling of recievers

Scheduling of communication links

- Dedicated slot between specific sender and receiver
- No collisions or overhead
- Most energy efficient solution when the schedule is running
- Can generate a lot of overhead when:
    - Traffic conditions vary
    - The clockwork throughout the network is imprecise
    - Network dynamics (nodes coming and going)

Scheduling of senders

- Specified slot for the sender, all other nodes must listen
- Minimizes idle listening, since nodes know when to listen
- Eliminates collisions
- Overheads are reduced (as receiving side is transparent to the schedule)
- Overhearing still a problem
  - (This can be minimized by applying some header filtering in the node)

Scheduling of recievers

- Each node gets it's listening slot
- Overhearing is eliminated
- Idle listeing is minimized
- Overheads are reduced (as sending side is transparent to the schedule)
- Collisions can occure
- Hence needs a good contention resolution method

Challenges

The use of scheduled protocols can be quite allright, but it can also lead to some challenges / problems.

1. Complexity in Infrastructure-less Networks

Networks without a central access point one hop away from nodes generally results in elevated complexity and high cost of maintaining tigh syncronization and distributing good slots.

2. Scalability

As the network grows the complexity grows and it becomes harder to find collision-free slots.

3. Broadcast Communication

Unless the protocol is sender scheduled, the same packet have to be transmitted several times in order to reach the nodes that needs it. Not very energy efficient!

4. Reduced Flexibility

When something in the network changes (topology, traffic or flow) the schedule must be re-calculated and retransmitted.

5. Memory Footprint

Network topology information must be stored, and maintaining memory status consumes energy that scales with memory size.

Protocols with common active periods

Here nodes define common active/sleep periodes.

Sleep periods conserve energy and prolongs WSN lifespan.

Common active/sleep periods require some amount of synchronization.

Suitable for applications in which traffic is periodic and applications where keep-alive packets are are periodically exchanged.

An example, SMAC (Sensor MAC)

SMAC splits the active periods into two sub periods. One for exchanging sync-packets, and the other for exchanging datapackets.

Border nodes

A node may recieve more than one synchronization packet. This node will start to follow all the sleep-schedules it has recieved, and is called a border node.

When N nodes follow the same schedule, they are called a virtual cluster. A network most likely contains several virtual clusters.

Challenges

The use of common active/sleep periods of a fixed size can also lead to some problems.

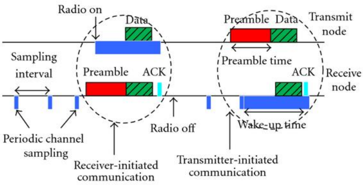
1. **Rigidity**

Determining the optimal length of the active periods.

2. **Sleep delay**

Since packets are only sendt during the active periods, there will allways be a delay equal to the length of the sleep period in addition to the normal delay.

Preamble sampling protocols



By reducing synchronization overhead, preamble-sampling protocols realize larger energy savings; however, this comes at the cost of a longer preamble.

Challenges

The use of a longer preamble causes two major problems:

1. Costly collisions

The preamble sampling technique shifts the cost of coping with idle listening from the receiver to the transmitter, which makes it more costly to transmit.

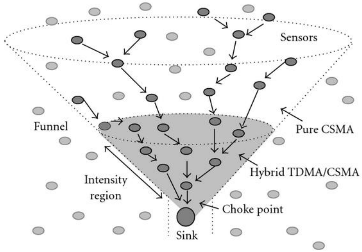
2. Limited Duty Cycle

Lowering the duty cycle in order to save energy means making the preamble longer making it even more expensive energy-wise to transmit. Thus you cannot extend the duty cycle indefinately in order to save energy.

Hybrid protocols

To optimize the MAC for WSN, different approaches is needed for different networks and applications. A combination of protocols can sometimes be a good solution.

Funneling MAC



Hardware factors

Hardware too can be of importance.

- Single Chip vs. Wakeup Radio
- Packet-Based vs. Bit-Based Radio
- Frequency-Agile MAC Protocols
- Memory Size and Usage
- Transmit Power Control

To sum up

There are many things to consider when choosing / designing a MAC for a WSN.

For now, most sensornodes run on batteries, hence the motivation to save energy by optimizing the MAC.

This might change in the future, as it is expected that nodes will be relying on power harvesting.