Lecture on Sensor Networks

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Communication in sensor networks

Classic medium access control (MAC) protocols for sensor nodes?

Paper: Aloha with Preamble Sampling for Sporadic Traffic in Ad Hoc Wireless Sensor Networks (A. El-Hoiydi)

In contrast to regular Aloha the so-called idle-listening should be avoided by making the node oversleep periods of silence. What follows is a best-case estimation of Aloha's potential for sensor networks.

The so-called genie (a central node) wakes up nodes in time, just before the channel is no more idle (or prior to the arrival of a message).

With this in mind the lower limit for the energy consumption in the best possible case can be estimated. The task of how to replace the central node by a good algorithm is still open.

All nodes including the current one create no message

$$b = 1 - 1\, e^{-g(N+1)}$$

The complementary event, an incoming message

The node itself creates a message → b_1

$$Pow^{RA} = b_1 P_{TX} + (b - b_1) P_{RX}$$

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Energy efficiency of Genie Aided Aloha

Example

$P_{\text{base consumption}}$ = 8 mA
P_{TX} = 20 mA
P_{RX} = 6 mA

A frame length is 10ms, i. e.
100 frames/second with 10
nodes wanting to send once per second.

$$b_1 = 1 - \frac{(1g)^0}{0!} e^{-1g}$$

$$b = 1 - 1 e^{-g(N+1)}$$

$$Pow^{GA} = b_1 P_{TX} + (b - b_1) P_{RX}$$

g=0,01 => b_1 = ~(1-0,99) = 0,01
gx10=0,1 => b = ~(1-0,90) = 0,095

P^{RA} = 0,01x(20+8) + (0,095-0,01)x(6+8) = 1,47 mA

Battery with 2000 mAh will last for 2000x60x60/1,47 = ~1361 hours

The theoretical upper limit for the lifetime is about 57 days.

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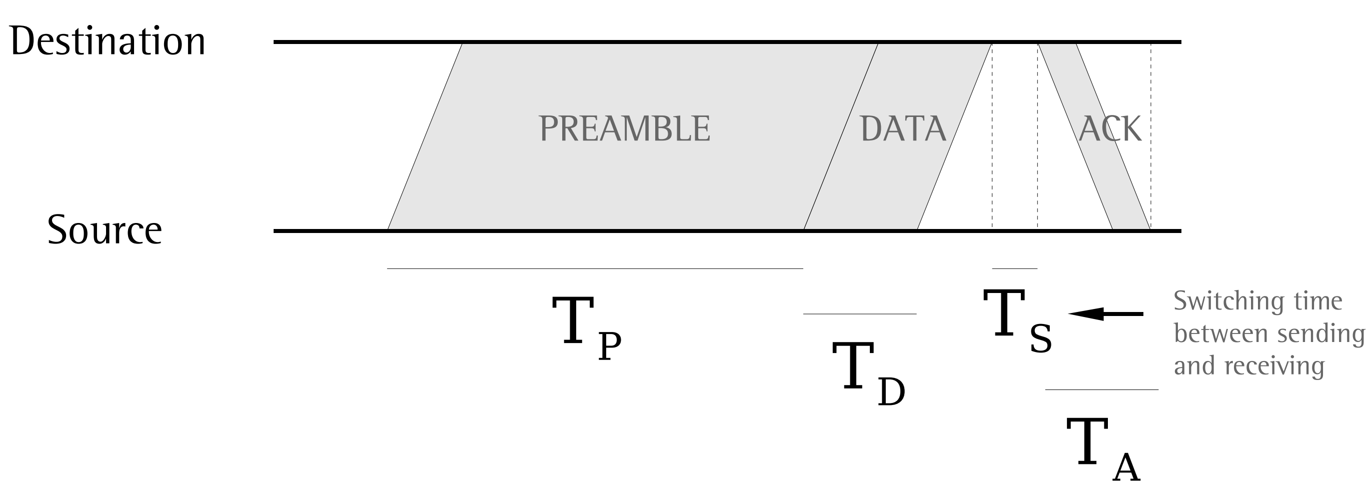
Energy efficient MAC protocols: Aloha with Preamble Sampling

Idea: Here nodes sleep in general. Controlled by their internal clock they wake up after every sleeping period (frame time) and monitor the channel for a certain amount of time. When there's no activity, they switch back to sleeping mode immediately.

A node wants to send: Before it can send its message to all participants, all of them have to be awake. To achieve this the sender creates an uninterrupted signal, the Preamble, which must last at least one sleeping period. Meanwhile the nodes wake up one by one, notice the activity on the channel and hence don't return to sleeping mode. After a full frame length the sender „picked up" all nodes and can now send its message.

An acknowledgment of the receiver (for the sender) is expected in order not to waste another full sleeping cycle in case of an error.



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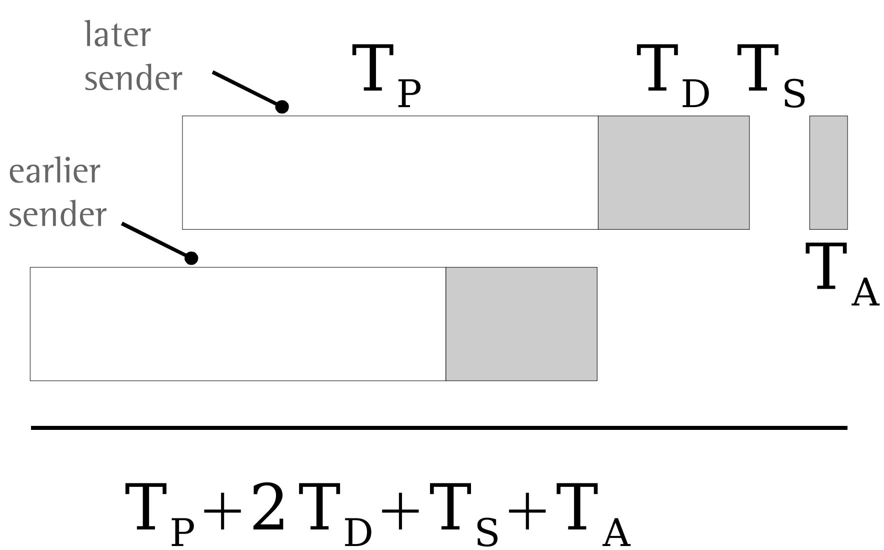
Energy efficient MAC protocols: Aloha with Preamble Sampling

Energy efficiency of Aloha with Preamble Sampling

A peculiarity about the duration of required silence, that a node needs to transmit a message error-free:

A sending cycle basically lasts for the Preamble's length T_P, the message's length T_D, the switching time T_S and the time for the ACK T_A. On a first glance one could think, that a node needs two of these cycles to transmit a message without any collisions (Aloha-typcial 2-slot problem). But in fact, the given time $T_P+2T_D+T_S+T_A$ is sufficient. To understand this, notice that a collision during the Preamble causes no problems (at least for the second sender).

The depicted collision is still allowed, so that the later sender can transmit its message, because a collision during the preamble causes no problem. Notice also the missing ACK of the receiver of the first message.



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Energy efficient MAC protocols: Aloha with Preamble Sampling

Energy efficiency of Aloha with Preamble Sampling

The given values for T_P,T_D,T_S and T_A are fractions of a frame length, hence e.g. T_P=1 makes sense to wake up all nodes.

$$P_S^{PAS}=e^{-gN(T_P+2T_D+T_S+T_A)}$$

W' for a free critical phase

$$b^{PAS}=1-e^{-g(N+1)(T_P+T_D+T_S+T_A)}$$

W' for incoming message

$$b_1^{PAS}=1-e^{-g(T_P+T_D+T_S+T_A)}$$

W' for message creation by a sender

$$Pow^{PAS}=b_1^{PAS}P_{TX}+(b^{PAS}-b_1^{PAS})P_{RX}$$

Average energy consumption

Remark: The energy consumption for the short wake-up is not yet contained.

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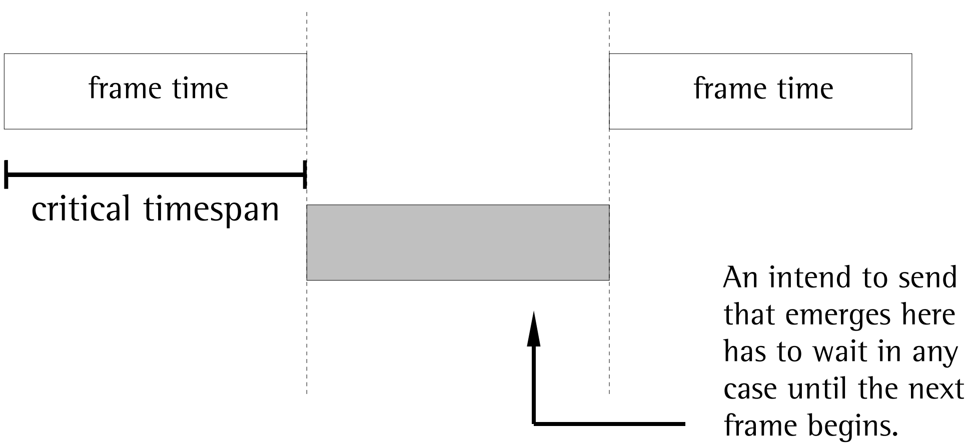
Classic medium access control (MAC) protocols for sensor nodes?

Slotted ALOHA: The time is divided into fixed intervals. Each interval lasts exactly for one frame time. It is only allowed to send at the beginning of a frame. Still, little mutual considerateness is implemented here. But the participants have to be synchronized.



Remark: The critical phase isn't the sent frame itself, but the frame length before. Because here is decided, whether one or more senders want to occupy the upcoming frame. If a sender won the frame, it is uncritical, because then by definition of the process no other sender will be added.

Advantage: The critical phase gets shorter.

Disadvantage: If two intentions to send emerge, the collision in the next frame is certain. Notice the still weak packet throughput. Furthermore, the next frame will even be waited for when nobody is sending, i.e. there's almost always a delay.

How does the packet throughput for slotted Aloha improve?

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Classic medium access control (MAC) protocols for sensor nodes?

Protocols with carrier detection: 1-Persistent CSMA (Carrier Sense Multiple Access)

The biggest problem of the Aloha-variants is that there's no consideration of other participants. The so-called carrier detection tackles this problem.

Before a station starts to send it waits until the channel is idle. Only then the packet will be issued. If a collision occurs the random timer based error correction applies and the station finally sends the packet once again – again only if the channel is idle. If two stations intended to send at the same time, the one with the shorter waiting period after the collision will send its packet first.

This procedure is called 1-Persistent CSMA, because the probability of sending when the channel is idle is 1.0.

Advantage: More flexible than slotted Aloha, because not in every case the end of the frame will be waited for. Instead a node (given good conditions) can start to send anytime.

Disadvantage: If two stations intend to send during a transmission, it is certain that there will be a collision at the beginning of the next frame. In this case there's no advantage compared to slotted ALOHA.

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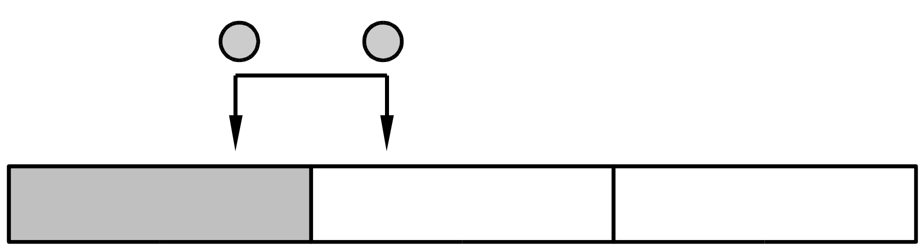
Classic medium access control (MAC) protocols for sensor nodes?

Protocols with carrier detection: Non-Persistent CSMA

Difference to 1-Persistent CSMA: The channel isn't continuously monitored for the end of the current transmission. If the channel wasn't idle the station will wait for a random amount of time. After this time, the station checks again whether the channel is idle.

Advantage: The probability of two stations starting to send at the same time drops drastically (quasi to zero), a collision is therefore highly improbable. Hence the case of a repeated transmission on grounds of a collision (like with 1-Persistent CSMA) is in a way always anticipated.

Disadvantage: Although e.g. two stations intend to send, no transmission begins after the end of the current one, because both of them wait for a random amount of time. The end of one period falling exactly together with the beginning of the next available frame is highly improbable, but would be desirable. In any case, the average delay increases.



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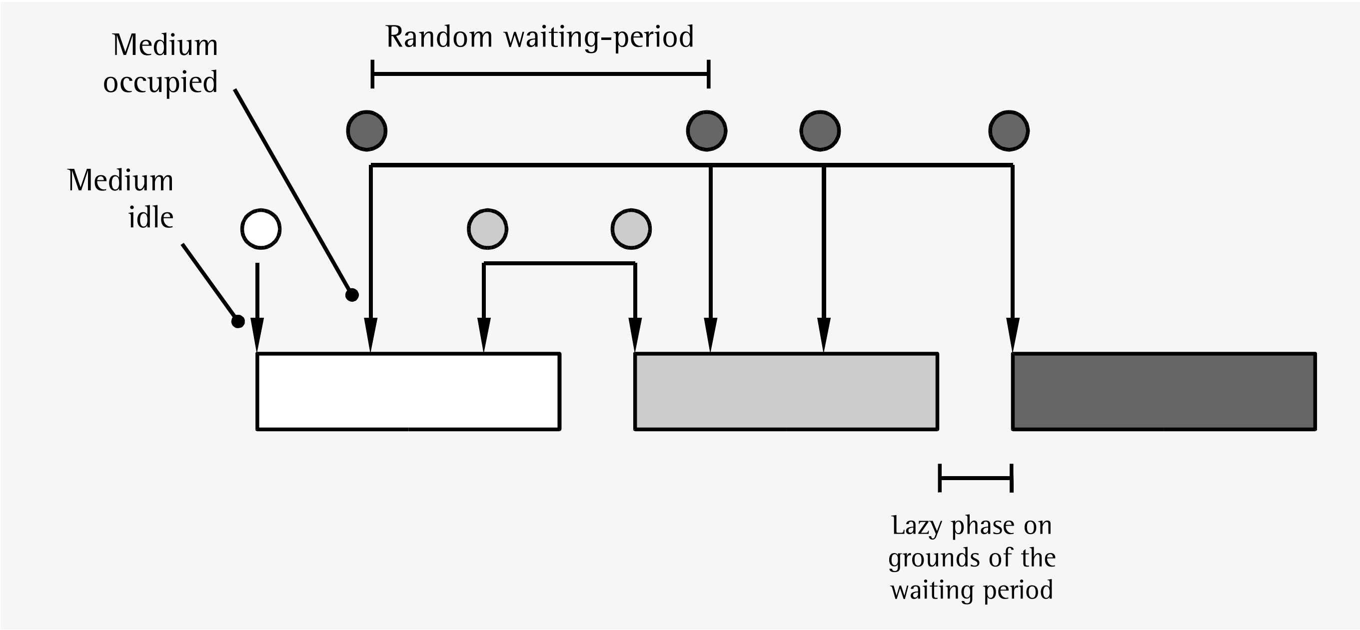
Protocols with carrier detection: Non-Persistent CSMA

○ Nodes with intention to send



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Protocols with carrier detection: CSMA/CD (CD=collision detection)

A disturbed transmission can be detected by the sender early (= collision detection), especially in the case of cable based communication. Then it makes sense for both of the stations to interrupt the transmission to save valuable bandwidth that would otherwise be used for a packet that couldn't be saved anyway.

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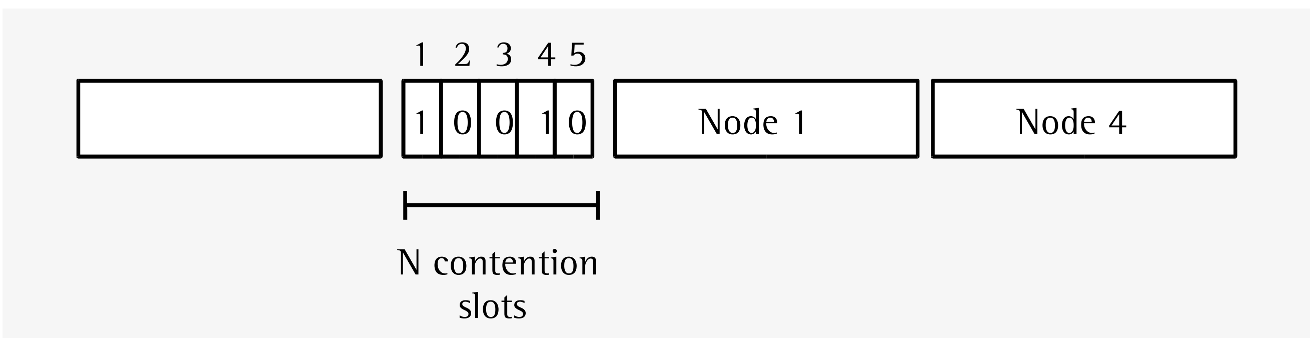
Collision-free protocols: Bit Pattern Protocol

Stations agree upon a short frame in front of the transmission. Every station has a narrow time window in which (on intention to send) a 1 (a signal) can be set. Afterwards, transmissions start in the so-arranged order.



Advantage: Collisions are completely avoided

Disadvantage: The N contention slots must always be waited for, even if only one stations exists / intends to send. If N is very large, A part of the bandwidth is lost. A good synchronization is necessary..

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Collision-free protocols: Binary Countdown

Procedure: Each station gets a (continuous) number that is e.g. (here) represented by 4 bits. Hence the number of time slots is reduced to 4. The following stations be awake:

Station	ID
4	0010
5	0101
9	1001

In the time slot of the first bit stations 5 and 9 send a signal because their 2^0 bit is set. Station 4 is quiet on grounds of the unset bit, but knows at the same time that it is out of the running because its bit pattern doesn't match the already sent pattern any more.

In the timeslot of bit 2^1 nobody sends, so both stations 5 and 9 have another chance. But in the slot of bit 2^2 station 5 wins with a sent signal because the previous bit mattern already doesn't match the one for station 9.

Advantage: Short bit pattern

Disadvantage: Now as before one bit pattern per frame length, uneven distribution of the right to send.

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