Lecture on Sensor Networks

Communication in sensor networks

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

Aloha with Preamble Sampling for Sporadic Traffic in Ad Hoc Wireless Sensor Networks by 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 can be estimated. The task of how to replace the central node by a good algorithm is still open.

All nodes create no message

$$b = 1 - 1\, e^{-gN}$$

The complementary event, an incoming message

The node itself creates a message

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

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Energy efficiency of Genie Aided Aloha

$$b_1 = 1 - e^{-1g}$$

$$b = 1 - 1\,e^{-gN}$$

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

Example

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

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

g = 0.01 => b_1 = ~(1-0.99) = 0.01
g x 10 = 0.1 => b = ~(1-0.90) = 0.095

P^{RA} = 0.01x(20+8) + (0.095-0.01) x (6+8) = 1.47mA

Battery with 2,000mAh will last for 2,000 x 60 x 60/1.47 = ~1,361 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 is no activity, they switch back to sleeping mode immediately.

A node wants to send

- All participants have to be awake before a node can send its message to them.
- The sender creates an uninterrupted signal, the Preamble, which must at least last one sleeping period.
- The nodes wake up one by one, notice the activity on the channel and hence do not return to sleeping mode.
- After a full frame length the sender „picked up“ all nodes and can now send the message.
- The sender expects an acknowledgment from the receiver. In case of an error the waste of another full sleeping cycle is avoided.

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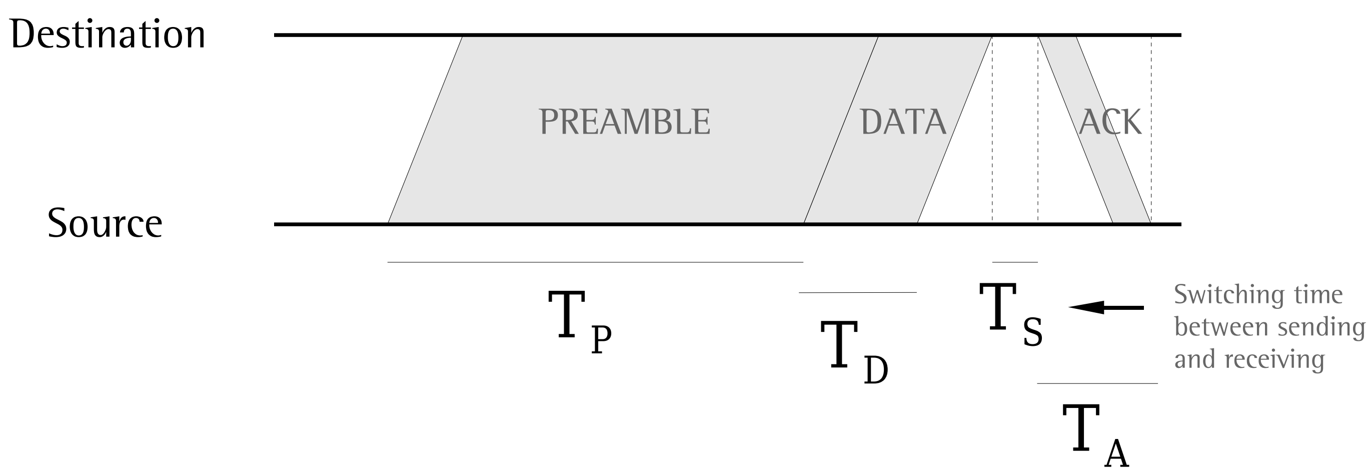
Genie Aided Aloha
Aloha w. Preamble Sampling
Slotted Aloha
CSMA-Variants
Bit pattern Protocols
Binary Countdown

Energy efficient MAC protocols: Aloha with Preamble Sampling



- T_P: Length of Preamble
- T_D: Length of Message
- T_S: Switching time
- T_A: Time for ACK

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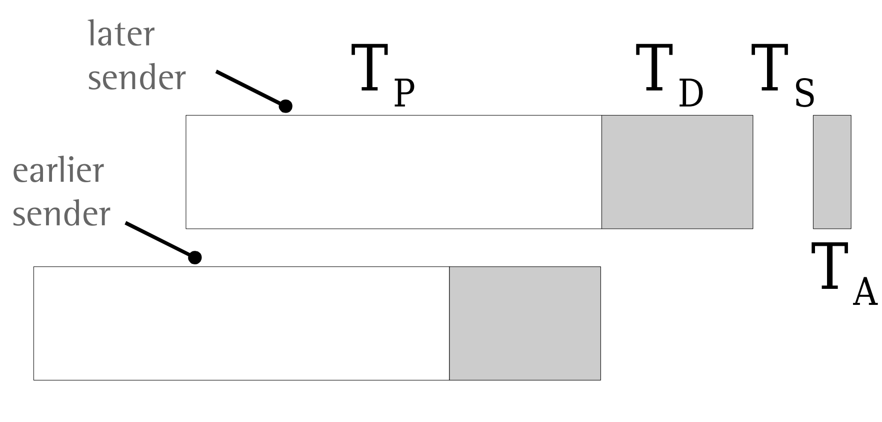
Energy efficient MAC protocols: Aloha with Preamble Sampling

Energy efficiency of Aloha with Preamble Sampling

A sending cycle lasts for T_P, T_D, T_S and 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 the given time $T_P+2T_D+T_S+T_A$ is sufficient.

Notice that a collision during the Preamble causes no problems (for the second sender).

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



$$T_P+2T_D+T_S+T_A$$

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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.

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

P' for a free critical phase

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

P' for incoming message

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

P' for message created by a sender

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

Average energy consumption

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

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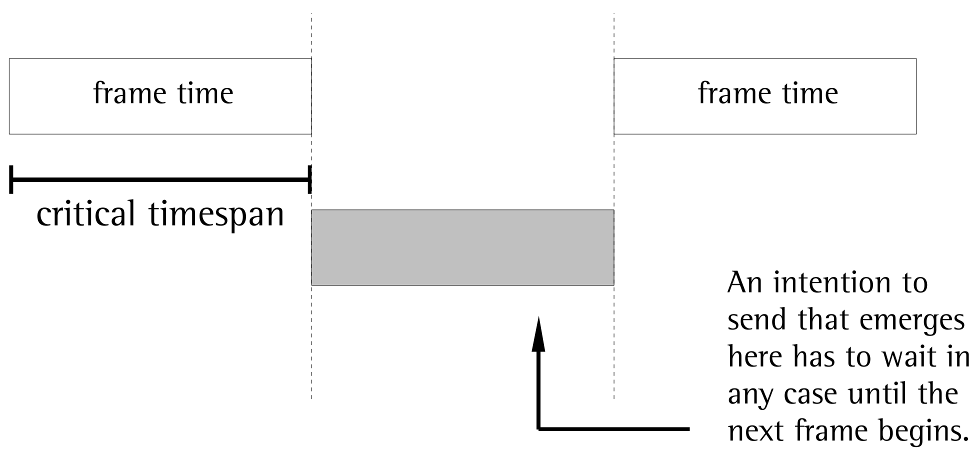
Classic medium access control (MAC) protocols for sensor nodes?

Slotted ALOHA: Time is divided into fixed intervals. Each interval lasts for exactly 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 is not the sent frame itself, but the preceding frame length. It is decided at that point, whether one or more senders want to occupy the upcoming frame. If a sender wins the frame no other sender will be added.

Advantage: The critical phase becomes 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 is 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 is no consideration of other participants. The so-called carrier detection tackles this problem.

A station waits until the channel is idle before it starts to send. 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. A station does not necessarily have to wait until the end of the frame. Instead, a node (given good conditions) can start to send at any time.

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 is no advantage compared to slotted ALOHA.

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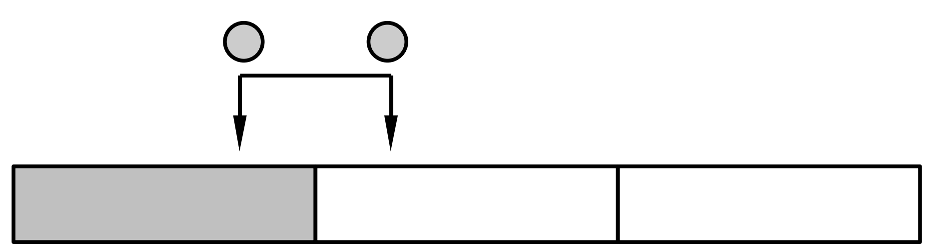
Classic medium access control (MAC) protocols for sensor nodes?

Protocols with carrier detection: Non-Persistent CSMA

Different from 1-Persistent CSMA, the channel is not continuously monitored for the end of the current transmission. If the channel is not idle the station waits 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 (practically to zero), a collision is therefore highly unlikely. 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 unlikely, but would be desirable. In any case, the average delay increases.



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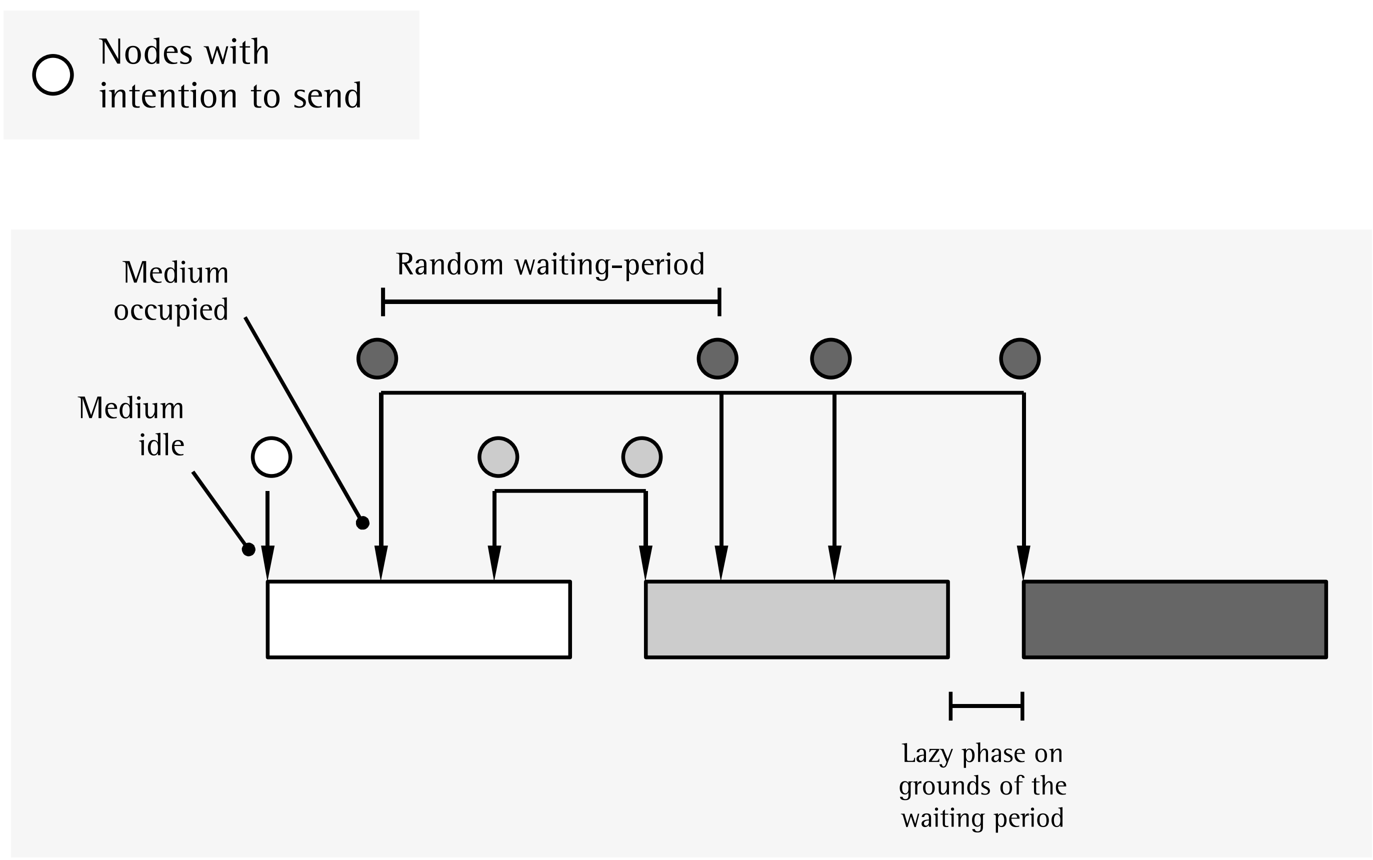
Protocols with carrier detection: Non-Persistent CSMA



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

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

A disturbed transmission can be detected early by the sender (= 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 cannot be saved anyways.

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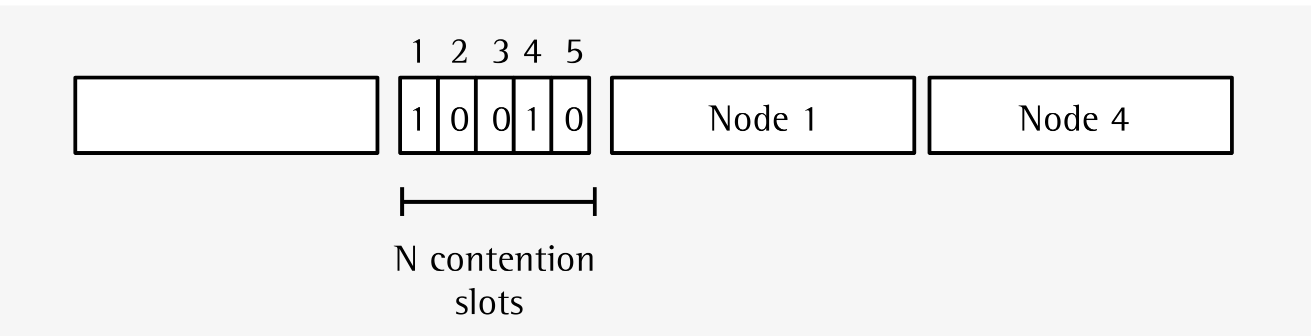
Classic medium access control (MAC) protocols for sensor nodes?

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

Collision-free protocols: Binary Countdown

Procedure: Each station gets a (continuous) number which 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
2	0010
5	0101
9	1001

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

In the time slot 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 set bit. Time slot 2^3 is no more necessary since station and 2 are out of the race already. However, since no one can tell that for sure, this slot has to pase also.

Advantage: Short bit pattern

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