Exercise Sensor Networks – (till may 2nd, 2005)

Lecture 1: Motivation

Exercise 1.1: Estimation of a node's lifetime

The following data about a sensor node is known:

Consumption in sleep-mode:	50 uA = 0,05mA [1u = 10^{-6}]
Consumption while CPU running (for doing calculations):	8mA
Additional consumption for sending (via radio):	10mA
Additional consumption for receiving (via radio):	6mA

The battery provides an amount of energy of 1800 mAh. The node is driven with the same voltage that is provided by the battery.

How long can a node be driven if every 200ms a measurement has to take place but sending is required only once per second? We assume that each attempt to send a packet requires to receive one packet as well and that a node knows exactly when a foreign packet will arrive. Each packet consists of 200 bytes of data. The wireless radio connection has a capacity of 9600 bits/s. A single measurement takes 5ms.

(1) How long can a node be driven?
(2) To what extend does the lifetime decrease if a node does not know when a packet of another node arrives and thus has to listen to the radio channel all the time?
(3) A couple of influences have not been taken into account in the above calculation. Find some of them and quote why they shorten or prolong a node's lifetime.

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Exercise 1.1 (1): Solution

Energy for computation and processing

5 samples/second x 0,005 seconds (for single measurement) x 8mA = 0,2mAs

Energy for transmission (sending and receiving)

(200 bytes x 8 bit)/(9600 bits/s) x (8mA (basic consumption) + 10 mA (for sending)) +
(200 bytes x 8 bit)/(9600 bits/s) x (8mA (basic consumption) + 6mA (for receiving)) =
2/12s x18 + 2/12x14mA = 5+1/3 mAs

Energy consumption while idle

active time: 0,025s computation and processing
0,333s transmission

Idle time for rest of second (1-0,025-0,333) = 0,641. Idle energy: 0,641s x 0,05 mA = 0,03208 mAs

Energy per second

0,2mAs + 5,33 mAs + 0,03208 mAs = ca. 5,56208 mAs

Battery provides 1800mAh = 1800x60x60 mAs / 5,56208 = ca. 1.165.031s / (60x60x24) = 13,48 days

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Exercise 1.1 (b): Solution

This time the channel is controlled all the time:

Energy for computation and processing: 5 samples/s x 0,005s x (8+6)mA = 0,35mAs
(here we assume that the node listens to the channel all the time – which is actually the case for most available hardware. An interrupt will trigger to process an incoming bit. Afterwards normal operation is resumed).

Energy for transmission (receive): Here receiving is not possible while sending

(200 bytes x 8 bit)/(9600 bits/s) x [(8mA (basic consumption) + 10 mA (for sending)) = 2/12 x18=3 mAs

Energy consumption while idle: (simply replace the sleep consumption by basic consumption + energy for sending)

active time: 0,025s computation and processing
0,167s transmission

Idle time for rest of second (1-0.025-0.167) = 0,808. Energy: 0.808s x (8+6)mA = 11.31 mAs

Energy per second

0,35mAs + 3 mAs + 11.31 mAs = ca. 14.66 mAs

Battery provides 1800mAh = 1800x60x60 mAs/14.676 = ca. 442,019 seconds / (60x60x24) = ca. 5 days

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Exercise 1.1 (c): Solution

- = shorten / + = prolong

Other influences:

- \- Battery does not provide 1.5V all the time
- \- Energy supply headily depends on temperature
- \- Routing and accumulation of data was not taken into account
- \+ Compression of redundant data was not taken into account
- \- The lifetime of the network in unequal to the lifetime of an average node If important nodes fail the network can be split into partition which can communicate no more.
- \- Packet collisions / channel noise will cause errors that require retransmission

Exercise 1.2: The length of an oscillation should be denoted with lambda. It is known from communication engineering that a sender's optimal efficiency is achieved if lambda is 1/4 of the oscillation's length. Note that the signal travels approx. at the speed of light (300000 km/s). How long should the antenna of the sensor node be if it sends within the 2.4 GHz frequency band?

Solution:

2.4 GHz means 2.4×10^9 oscillations/second.

So one oscillation takes $1/2.4 \times 10^9$ seconds. Within this period the radio signal will travel

$1/2.4 \times 10^9 \times 300000$ km = 12.5 cm

If the antenna is most efficient at a length of ¼ of the oscillation, it should be 3.125 cm.