

Exercise Sensor Networks

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

$$5 \text{ samples/second} \times 0,005 \text{ seconds (for single measurement)} \times 8\text{mA} = 0,2\text{mAs}$$

Energy for transmission (sending and receiving)

$$\begin{aligned} & (200 \text{ bytes} \times 8 \text{ bit}) / (9600 \text{ bits/s}) \times (8\text{mA (basic consumption)} + 10 \text{ mA (for sending)}) + \\ & (200 \text{ bytes} \times 8 \text{ bit}) / (9600 \text{ bits/s}) \times (8\text{mA (basic consumption)} + 6\text{mA (for receiving)}) = \\ & 2/12\text{s} \times 18 + 2/12 \times 14\text{mA} = 5 + 1/3 \text{ mAs} \end{aligned}$$

Energy consumption while idle

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

$$\text{Idle time for rest of second } (1 - 0,025 - 0,333) = 0,641. \text{ Idle energy: } 0,641\text{s} \times 0,05 \text{ mA} = 0,03208 \text{ mAs}$$

Energy per second

$$0,2\text{mAs} + 5,33 \text{ mAs} + 0,03208 \text{ mAs} = \text{ca. } 5,56208 \text{ mAs}$$

$$\text{Battery provides } 1800\text{mAh} = 1800 \times 60 \times 60 \text{ mAs} / 5,56208 = \text{ca. } 1.165.031\text{s} / (60 \times 60 \times 24) = 13,48 \text{ days}$$

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Exercise 1.1 (2): Solution

This time the channel is monitored all the time:

Energy for computation and processing: $5 \text{ samples} \times 0,005\text{s} \times (8+6)\text{mA} = 0,35\text{mAs}$
 (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

$$(200 \text{ bytes} \times 8 \text{ bit}) / (9600 \text{ bits/s}) \times [(8\text{mA (basic consumption)} + 10 \text{ mA (for sending)})] = 2/12 \times 18 = 3 \text{ mAs}$$

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: $0,808\text{s} \times (8+6)\text{mA} = 11,31 \text{ mAs}$

Energy per second

$$0,35\text{mAs} + 3 \text{ mAs} + 11,31 \text{ mAs} = \text{ca. } 14,66 \text{ mAs}$$

Battery provides $1800\text{mAh} = 1800 \times 60 \times 60 \text{ mAs} / 14,676 = \text{ca. } 442,019 \text{ seconds} / (60 \times 60 \times 24) = \text{ca. } 5 \text{ days}$

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Exercise 1.1 (3): Solution

- = shorten / + = prolong

- Other influences:
- Battery does not provide 1.5V all the time
 - Energy supply heavily 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 is unequal to the lifetime of an average node
 - If important nodes fail, the network can be split into partitions which can communicate no more.
 - Packet collisions / channel noise will cause errors that require retransmission

Exercise 1.2: The length of an oscillation is denoted with λ . It is known from communication engineering that a sender's optimal efficiency is achieved if λ 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 868 MHz frequency band?

Solution:

868 MHz means 868×10^6 oscillations/second.

So one oscillation takes $1/868 \times 10^6$ seconds. Within this period the radio signal will travel

$$1/868 \times 10^6 \text{ s} \times 300\,000\,000 \text{ m/s} = 0,0864 \text{ m}$$

If the antenna is most efficient at a length $1/4$ of the oscillation, it should be about 8,6 cm long.