Exam July 27, 2016

July 7, 2016

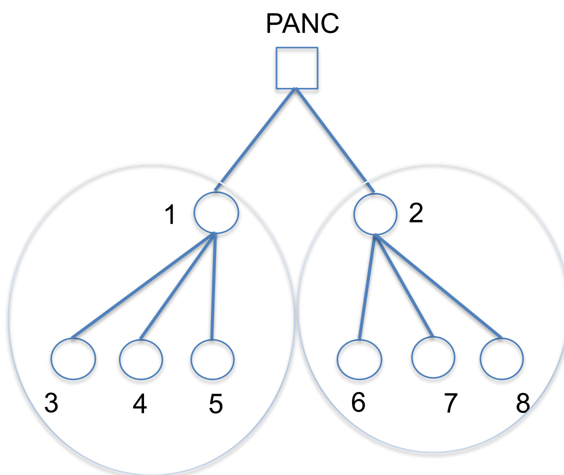

Figure 1: Reference topology for Ex. 1.

Exercise–1 (*July 27, 2016*)

The Personal Area Network in the figure is operated according to the IEEE 802.15.4 beacon enabled mode with the following parameters: (i) active part composed of CFP only (no CAP) with slots of 128 [byte] packets; (ii) nominal data rate is 250 [kbit/s]. The 8 motes in the figure are characterized by the following uplink traffic requirements:

- motes 1, 3, 5 and 7 generate uplink traffic whose rate has the following distribution: P(r=25[bit/s])=0.4 P(r=50[bit/s])=0.6
- motes 2, 4, 6 and 8 generate uplink traffic whose rate has the following distribution: P(r=50[bit/s])=0.2 P(r=1[kbit/s])=0.8

Motes 1 and 2, besides sending up to the PANC their own traffic, have to relay in each BI the traffic generated by their siblings nodes.

Define a consistent Beacon Interval structure including the number of slots in the CFP, the Beacon Interval duration, and the duty cycle. Define a consistent slot assignment in the CFP for all the devices in the network.

Solution of Exercise–1

The lowest required rate is 25 [bit/s]. Thus, the BI can be set as: $BI = \frac{128[byte]}{25[bit/s]} = 40.96[s]$.

Motes 1, 3, 5 and 7 require 2 slots in the BI for their own traffic. Motes 2, 4, 6 and 8 require 40 slots in the BI for their own traffic. Moreover, Mote

1 and Mote 2 also require extra slots for receiving and delivering traffic from their sibling nodes. Namely, Mote 1 requires extra 88 slots and Mote 2 requires extra 164 slots. To sum up, we have:

$$N_3 = N_5 = N_7 = 40$$

$$N_4 = N_6 = N_8 = 2$$

$$N_1 = 90$$

$$N_2 = 204$$

which leads to: $N_{CFP} = 40 \times 3 + 2 \times 3 + 90 + 204 = 422$.

The slot duration is $T_s = \frac{128[byte]}{250[kbit/s]}$=4.096[ms].

The duration of the active and inactive parts and the duty cycle are, respectively:

$$T_{active} = (N_{CFP} + 1) \times T_s = 1.72[s]$$

$$T_{inactive} = BI - T_{active} = 39.231[s]$$

$$\eta = T_{active}/BI = 4.2\%$$

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Exercise–2 (*July 27, 2016*)

A sensor node generates a stream of 5 packets at a fixed rate of one packet every x [s]. The packets must be delivered to a sink node for further processing. The nominal data rate is R=250[kb/s] and the packets are of L=1000[bit]. The operating power level for TX circuitry is P_{tx} =10[mW]; the power emitted to the antenna is P_o=100[mW]; the power consumed while in idle and sleep states are P_{idle}=60[mW] and P_{sleep}=10[mW], respectively; In case the sensor goes to sleep, it needs a wake-up time of T_w=500 [μs]. Write the energy consumption when x=10[ms] for transmitting the 5 packets in the 2 cases where (1) the sensor node goes to sleep after each transmission and wakes up when the following packet is ready (2) the sensor node is always active (assume that in both cases the sensor node is asleep at the very beginning of the operations). Is there any value of x for which case (2) is more energy-efficient than case (1)?

Solution of Exercise–2

The packet transmission time, T, is: $T = \frac{L}{R} = 4[ms]$

Case 1 - node goes to sleep after transmission.

$$E_1 = 5(P_{tx}T_w+(P_{tx}+P_o)T)+5P_{sleep}(x-T-T_w) = 5(5\mu J+440[\mu J])+275[\mu J] = 2.5[mJ]$$

Case 2 - node always active

$$E_2 = T_wP_{tx}+5(P_{tx}+P_o)T+P_{idle}(5x-5T-T_w) = 5\mu J+5\times440[\mu J]+1770[\mu J] = 3.975[mJ]$$

By solving the inequality $E_2(x) < E_1(x)$, we get $x < 3.98[ms]$, which is impossible given that the packet transmission time is $T = 4[ms]$.

Exercise–3 (*July 27, 2016*)

An RFID system is composed of 4 tags and uses a Dynamic Frame ALOHA access protocol. Assume that the initial frame size is r=4 and the tags choose the following slots for transmitting: tag 1 slot 1, tag 2, tag 3 and tag 4 slot 3. What is the backlog predicted by Schoutes estimate? Find out the probability that the resolved tags during the second frame is equal to i, with i=0, 1, 2, 3. 4 if the second frame length is set to Schoutes estimate.

Solution of Exercise–3

After the first frame one tag has been resolved (tag 1) and the other four tags have collided in one slot. Schoute's estimate observes c=1 collided slots, and thus the current backlog is estimated to be equal to round(2.39c) = 2. If the second frame length is set according to Schoute's estimate, we have the following probabilities for the number of tags resolved during the second frame, S_2:

$$P(S_2 = 0) = 2(\frac{1}{2})^3 = \frac{1}{4}$$

$$P(S_2 = 1) = 2\binom{3}{2}(\frac{1}{2})^3 = \frac{3}{4}$$

$$P(S_2 = 2) = 0$$

Exercise–4 (*July 27, 2016*)

A COAP client issues a CONFIRMABLE message. Assuming that the packet error rate is p=0.2 and the MAX-RETRANSMIT parameter is 2, find the probability that the CONFIRMABLE message in the end goes through.

Solution of Exercise–4

The CONFIRMABLE message goes through within two attempts if it goes through at the first attempt (probability 1-p) or if it goes through at the second attempt (probability p(1-p)). The overall probability is: $P = (1 - p)(1 + p) = (1 - p^2) = 0.96$

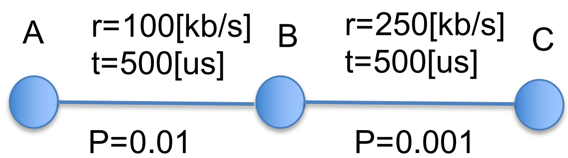

Figure 2: Reference topology for Ex. 5.

Exercise–5 (*July 27, 2016*)

Find out the Expected Transmission Time (ETT) for the two wireless links in the figure assuming packet size l=128[byte]. Each link is labeled with the corresponding packet error probability, p, the nominal data rate, r, and the propagation delay, t. Assume negligible size for the acknowledgements and a repetition time-out equal to the round trip time for the link.

Solution of Exercise–5

The total time for transmitting a packet through link i and receive the corresponding ACK is: $T_i = \frac{l}{r_i} + 2t$. Thus we have, T_1=11.24[ms] and T_2=5.096[ms].

The ETX for the two links is: $ETX_{AB} = \frac{1}{1-0.01} = 1.01$ and $ETX_{AB} = \frac{1}{1-0.001} = 1.001$.

The ETT for the two links is then: $ETT_{AB} = ETX_{AB}T_1$ and $ETT_{BC} = ETX_{BC}T_2$

Exercise–6 (*July 27, 2016*)

A PAN based on SPARE MAC is characterized by the following parameters: number of slots in the signaling sub frame, N=10, number of slots in the data sub frame, M=5, nominal rate, R=100[kb/s], slot size, l=127[byte]. Find the slot duration, T_s and the rate of the channel defined as one slot per frame, r.

Solution of Exercise–6

The slot duration is: $T_s = \frac{l}{R} = 10.16[ms]$.

The frame duration is $T_f = T_s \times (N + M + 1) = 162.56$[ms], and the channel rate is $r = \frac{L}{T_f}$=6.25[kb/s].