Exam September 2, 2016

September 1, 2016

Exercise–1 (*September 2, 2016*)

A Personal Area Network is operated according to the IEEE 802.15.4 standard and is composed of 20 sensor nodes and a PAN Coordinator (only Collision Free Part, nominal data rate, R= 250[kbit/s], packet length, L=128[byte]). 15 sensor nodes (out of 20) require an equivalent rate of r [bit/s], whereas the remaining 5 sensor node require twice that rate (2r [bit/s]). Assuming that the network administrator sets a duty cycle of 1%, find the maximum allowed value for r, and the corresponding Beacon Interval duration (assume to assign one slot in the CFP to each mote requiring a rate of r).

Solution of Exercise–1

The duty cycle is $\eta = \frac{N_{active}}{N_{total}} = 0.01$, where N_{active} and N_{total} are the number of slots in the active part and in the overall BI, respectively. If we assume that one slot is assigned to each sensor node requiring a rate of r, then we can write: $N_{active} = 15 \times 1 + 5 \times 2 + 1 =$ 26 (note that we have added here "1" corresponding to the beacon slot). We can then derive $N_{total} = N_{active}/\eta = 2600$.

The value of rate r is: $r = \frac{L}{N_{total}\frac{L}{R}} = 96.1[bit/s]$.

The duration of the BI is: BI $=\frac{L}{R}N_{total}$=10.64[s].

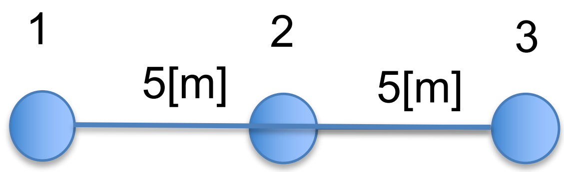

Figure 1: Reference topology for Ex. 2.

Exercise–2 (*September 2, 2016*)

Sensor node 1 and sensor node 2 are equipped with cameras and collect images with size I=12.8[kbyte]. The two sensors have to deliver the images to sensor 3 by using packets whose length is L=128[byte]. Assuming that: the energy required to operate the TX/RX circuitry is E_c=6 [uJ/packet], the energy required to support sufficient transmission output power $E_{tx}(d) = kd^2$ [nJ/packet], being k=120 [nJ/packet/m^2], find the total energy consumption (energy consumed by sensor 1, sensor 2 and sensor 3) to deliver one single image each in the following two cases:

- sensor 1 and sensor 2 send directly the images to the sink.
- sensor 1 sends the image to sensor 2, sensor 2 sends to sensor 3 its own image and a compressed version of sensor 1s image (compression ratio 0.1, that is, the compressed image has size .1 x I). In this case the energy required by sensor 2 to compress the image is E_p= 0.1 [μJ] for each packet of the original uncompressed image.

Solution of Exercise–2

The uncompressed image requires $N = I/L = 100$ packets to be delivered; the compressed image requires $0.1N/L = 10$ packets to be delivered.

In Case 1, the energy consumed by the three sensor nodes is:

$$E_1 = 100[E_c + E_{tx}(10[m])]$$

$$E_2 = 100[E_c + E_{tx}(5[m])]$$

$$E_3 = 200E_c$$

The total energy is, therefore, $E^1_{tot} = 400E_c + 100E_{tx}(10[m]) + 100E_{tx}(5[m]) = 800[\mu J] + 1200[\mu J] + 300[\mu J] = 2.3[mJ]$

In Case 2, the energy consumed by the three sensor nodes is:

$$E_1 = 100[E_c + E_{tx}(5[m])]$$

$$E_2 = 110[E_c + E_{tx}(5[m])] + 100E_p$$

$$E_3 = 110E_c$$

The total energy is, therefore, $E^1_{tot} = 320E_c + 210E_{tx}(5[m]) + 100E_p = 640[\mu J] + 630[\mu J] + 10[\mu J] = 1.28[mJ]$

Exercise–3 (*September 2, 2016*)

A wireless link is characterized by a packet error rate in the two directions (left-right, right-left) of 1% and 0.5% respectively. Assuming that the packet used for delivering information from left to right have size L=128[byte], the acknowledgements in the opposite direction have size A=8[byte], and the nominal rate in both directions is R=100[kbit/s], find the average transmission time to successfully send a packet and get the corresponding acknowledgement (negligible propagation delay).

Solution of Exercise–3

The probability to successfully send a packet and receive the corresponding ACK is: P=(1-0.01)(1-0.005)= 0.985. The average number of transmissions required to send a packet successfully is given by the ETX=1/P=1.015.

The time required to complete a successful transmission is:

$$RTT = L/R + A/R = 10.24[ms] + 0.64[ms] = 10.88[ms].$$

The expected transmission time is: ETT = $ETX \times RTT$ = 11.04[ms].

Exercise–4 (*September 2, 2016*)

A RFID system based on Dynamic Frame ALOHA is composed of 4 tags. Assuming that the initial frame size is r=2, find the overall collision resolution efficiency, .η

The efficiency is defined as $\eta = \frac{n}{L_n}$, being n the initial population size and L_n the total number of slots to arbitrate all the tags. In our case, $n = 4$ and L_n can be found be applying the recursive formula:

$$L_n = r + \sum_{i=0}^{n-1} L_{n-i} P(S = i).$$

In our case it is:

$$L_4 = 2 + \sum_{i=0}^{3} L_{4-i} P(S = i).$$

It can be noted that, P(S=2)=P(S=3)=P(S=4)=0, thus the formula reduces to:

$$L_4 = 2 + L_4 P(S = 0) + L_3 P(S = 1),$$

where P(S=0)=P(S=1)=0.5.

Recursively, we can write:

$$L_3 = 3 + \sum_{i=0}^{2} L_{3-i} P(S = i).$$

We have: P(S=3)= 2/9, P(S=2)=0, P(S=0)=1/9, and P(S=1)=2/3, which leads to:

$$L_3 = 3 + 1/9 L_3 + 2/3 L_2$$

Again, L_2 can be found as:

$$L_2 = 2 + \sum_{i=0}^{1} L_{2-i} P(S = i),$$

where P(S=0)=1/2 and P(S=1)=0, which leads to:

$$L_2 = 2 + 1/2 L_2.$$

Solving in L_2 we get L_2=4; substituting the value of L_2 in the expression of L_3 we get:

$$L_3 = 3 + 1/9 L_3 + 8/3,$$

which leads to $L_3 = 6.375$. Finally, substituting the value of L_3 in the expression of L_4 we get:

$$L_4 = 2 + 1/2L_4 + 0.5 \times 6.375,$$

which leads to $L_4 = 16.75$. The efficiency is $\eta = \frac{4}{16.75} = 0.23$

Solution of Exercise–4

Exercise–5 (*September 2, 2016*)

Briefly describe the channel access mechanism of SMAC

Solution of Exercise–5

See slides. CSMA with virtual carrier sensing.

Exercise–6 (*September 2, 2016*)

Sensor nodes 1, 2 and 3 run the SPARE MAC protocol, they are all in range and they have one slot each in the Data Sub-Frame. Sensor 1 and 3 have traffic towards sensor 2 characterized by a Poisson point process with intensity 1= 2[packet/frame] 3= 1[packet/frame], respectively. Find out the probability that the transmissions of sensor 1 and sensor 3 do collide at sensor 2.

Solution of Exercise–6

The collision probability is the probability that bot sensor 1 and sensor 3 have at least one packet ready for transmission towards sensor 2, that is, P=$(1 - e^{-\lambda_1})(1 - e^{\lambda_2}) = 0.546$