Internet of Things, Exam– July 28, 2015 **Total Available time: 2 hours**

1 – Exercise (6 points)

The Personal Area Network in the figure runs the SPARE MAC protocol where ovals represent reachability between nodes (numbers are mote IDs, letters indicate ovals IDs) with the following parameters:

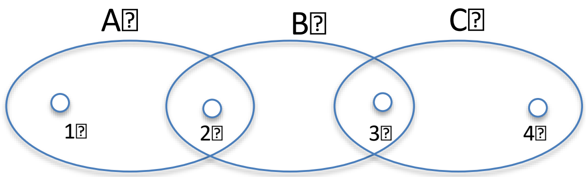
- frame specification: N=10, M=5,
- slot specification: duration Ts=8,192[ms], packet length L=128[byte]

The slot assignment in the frame is as follows:

- Mote 1: slot 1 in the signaling subframe, slot 1 in the data subframe
- Mote 2: slot 2 in the signaling subframe, slot 2 and 3 in the data subframe
- Mote 3: slot 3 in the signaling subframe, slot 4 in the data subframe
- Mote 4: slot 4 in the signaling subframe, slot 5 in the data subframe

Find:

1. the nominal data rate
2. the data rate corresponding to one BCH (one slot in the signaling subframe)
3. how many additional motes can be added to the network in the cases the additional motes are added (i) to oval A (NON overlapping region with oval B), and (ii) to the overlap region between ovals B and C;
4. a consistent slot assignment schedule for a new mote 5 entering the network in oval B (the region NON overlapping with ovals A and C)



Solution

The nominal data rate is R=L/Ts = 125 [kb/s]

One slot in the BCH carries 128[byte] every Tf [s] where Tf=(N+M+1)*Ts=131,1[ms], thus the equivalent rate is: r=L/Tf=7,812[kb/s]

Mote added to the overlap between A and B

The biggest two-hop cluster is A U B; three motes are in the two-hop cluster currently (1, 2 and 3) with N=10 available position, thus Nmax <= 7.

The biggest one-hop cluster is the one composed by 2, 1 and the new nodes. The number of slots already in use in such one-hop cluster are 2 (by mote 2) + 1 (by mote 1); since M=5 the remaining space is for 2 new motes, Nmax <=2.

Mote added to the overlap between B and C

The biggest two-hop cluster is B U C; three motes are in the two-hop cluster currently (1, 2 and 3) with N=10 available position, thus Nmax <= 7.

The biggest one-hop cluster is the one composed by 2, 3 (or equivalently 1) and the new nodes. The number of slots already in use in such one-hop cluster are 2 (by mote 2) + 1 (by mote 3 or 1); since M=5 the remaining space is for 2 new motes, Nmax <=2.

2 – Exercise (4 points)

In the same setting of Exercise 1, assume that Mote 1 and Mote 3 generate unicast traffic directed to Mote 2 according to Poisson point processes with parameters $\lambda 1=10$ [packets/s] and $\lambda 3=4$ [packets/s]. What is the average collision probability at Mote 2?

Solution

The frame duration is Tf=131,1[ms]. We can define the probability that mote 1 and mote 3 generate 0, 1 or 2 packets to be delivered to mote 2 in a Tf period of time as:

$$P(k_i = 0) = e^{-\lambda_i T_f}$$

$$P(k_i = 1) = \lambda_i T_f e^{-\lambda_i T_f}$$

$$P(k_i = 2) = \frac{(\lambda_i T_f)^2}{2} e^{-\lambda_i T_f}$$

Mote 2 has 2 slots in its reception schedule, thus mote 1 and mote 3 will collide if they both generate 2 or more than 2 packets in a Tf time frame; moreover, they will also collide if they generate exactly 1 packet in a Tf time frame and they decide to send this packet to mote 2 in the same reception slot. Assuming that mote 1 and 3 choose randomly which slot to use to send the packet to mote three, the cumulative collision probability will be:

$$P_{coll} = [1 - P(k_1 = 0) - P(K_1 = 1)][1 - P(k_3 = 0) - P(K_3 = 1)] + P(K_1 = 1)P(K_3 = 1)\frac{1}{2}$$

which leads to 0.091

3 – Exercise (6 points)

A personal Area Network based on IEEE 802.15.4 beacon enabled mode is deployed to collect temperature samples out of 1000 sensor nodes. Each sensor node collects one temperature sample every 5 minutes and has storage space to store one single sample (if a new sample is acquired and the previous one is still in the local memory, the previous sample is discarded and substituted by the new one).

Assuming that the nominal rate is R=250[kb/s], that the temperature samples fit exactly in packets of 50[byte], design the Beacon Interval structure (slot duration, BI duration, number of slots in the BI) which minimizes the duty cycle under the tight requirement that all the acquired samples get to the PAN coordinator (null sample loss).

Do the same if the sensor nodes can store locally two temperature samples.

Solution

To avoid sample loss, a temperature sample must be delivered to the PAN coordinator before a new sample is collected. Hence, each sensor node must be assigned a channel towards the PAN coordinator able to deliver at least one temperature sample every 5 minutes (or even faster). This means that we have an upper bound on the beacon interval duration, that is, BI <= 5[minutes]. If we assume that one temperature sample fits exactly one slot, we have Ts=50[byte]/250[kb/s]=1.6[ms]. We need 1000 slots at least in the BI, thus Tactive=1000 Ts = 1.6[s]. The corresponding duty cycle is minimum and is 1.6[s]/5[minutes]=0.005.

If each sensor node can store two samples locally, it means that it can wait 10 minutes before sending one temperature sample to the PANC. In short, the duration of the active part remains the same but the BI duration doubles, which leads to half the duty cycle calculated at the previous step.

Questions (10 points)

1. A localization system based on a wireless sensor network has two anchor nodes with coordinates (0,0), (10, 0) and (0, 10). A mobile node "estimates" the following distance values to the anchor nodes d_1=10m and d_2=5m d_3=15m; assuming to resort to gradient descent to localize the mobile node, write (i) the objective function which the gradient descent algorithm wants to minimize and (ii) equations which specify the update step of the gradient descent algorithm (assume to set a learning rate of 0.5).

The objective function of the gradient descent aims at minimizing the sum of the squares of the localization error, that is,

$$f(x,y) = \frac{1}{2}(\sqrt{x^2+y^2}-10)^2 + \frac{1}{2}(\sqrt{(x-10)^2+y^2}-5)^2 + \frac{1}{2}(\sqrt{x^2-(y-15)^2}-15)^2$$

The update step can be defined by taking the partial derivatives of the objective function wrt x and y, that is,

$$x := x - \alpha(1 - \frac{10}{\sqrt{x^2+y^2}})x - \alpha(1 - \frac{5}{\sqrt{(x-10)^2+y^2}})(x-10) - \alpha(1 - \frac{15}{\sqrt{x^2+(y-10)^2}})x$$

$$y := y - \alpha(1 - \frac{10}{\sqrt{x^2+y^2}})y - \alpha(1 - \frac{5}{\sqrt{(x-10)^2+y^2}})y - \alpha(1 - \frac{15}{\sqrt{x^2+(y-10)^2}})(y-10)$$

2. A COAP client sends the following message to a COAP server.

   CON [08bx10]
   GET /light
   Token [10x5]

   Specify the content of the response message (message ID, token ID and type of message) from the server assuming that: (i) the server responds immediately with a confirmable message, (ii) the server has the requested resource.

   The content of the response message can be:
   ACK [08bx10]
   2.05 Content
   Token [10x5]
   16°C

3. A RFID collision arbitration system is based on multi-frame dynamic frame ALOHA. Find out the efficiency of the collision arbitration process if the initial number o tags is N=3 and the initial frame size is r=2.
   The resolution time L3 is:
   $$L_3 = 2 + P(S=0)L_3 + P(S=1)L_2 + P(S=2)L_1$$
   with P(S=2)=0, P(S=0)=1/4 and P(S=1)=3/4
   Similarly, L2 is:
   $$L_2 = 2 + P(S=0)L_2 + P(S=1)L_1$$
   with P(S=0)=P(S=1)=1/2
   Resolving for L2 and substituting the value of L2 in the expression of L3, it turns out L3=11/3.
   The efficiency is therefore 9/23.
4. Briefly describe the process of *active scanning* in the context of IEEE 802.15.4 network formation.

   See slides