Internet of Things, ***June 5, 2019*** **Total Available time: 1.30 hours**

1 – Exercise (6 points)

A personal Area Network based on IEEE 802.15.4 beacon enabled mode (only CFP) is deployed to collect temperature samples out of 20 sensor nodes. 4 sensor nodes of type 1 are characterized by the following traffic requirements: P(r=16[bit/s]) = 0.3, P(r=160[bit/s])=0.5, P(r=8[bit/s])=0.2. The remaining 16 sensor nodes of type 2 have deterministic traffic with rate r= 80[bit/s]. Assuming that the nominal rate is R=250[kb/s], that the temperature samples are L=25[byte] long and fit exactly in one slot of the CFP, design the Beacon Interval structure (slot duration, BI duration, number of slots in the BI, duty cycle) under the requirement that all sensor nodes have the required channel rate towards the sink/PAN coordinator. Assuming that all the motes are not in direct reach one-another, what type of mote (type 1 or type 2) consumes more energy in a BI (motivate the answer)?

Solution

BI= 25[byte]/8[bit/s] = 25[s]

N_1=20 slots

N_2= 10 slot

$N_{cfp} = 4N_1+16N_2$=240

N_{active}= 241

T_s= 25[byte]/250[kb/s] = 800[us]

$T_{active}=T_s\ N_{active}$ = 192.8[ms]

Duty cycle= T_{active}/BI = 7 10^{-3}

$$E_1 = 0.3(2E_{tx} + 18E_{idle}) + 0.520E_{tx} + 0.2(E_{tx} + 19E_{idle}) + 220E_{idle} + E_{rx} + E_{sleep}$$

$$E_2 = 10E_{tx} + 230E_{idle} + E_{sleep} + E_{rx}$$

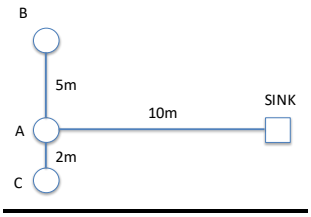
2 – Exercise (6 points)

A Dynamic Frame ALOHA system is used to arbitrate 3 tags. Find out the average throughput after two frames knowing that the first and the second frames have size r_1=2, r_2=2.

Solution

$$E[S] = \frac{1}{4}\frac{3}{4} + \frac{3}{4}\frac{1}{2}3 + \frac{3}{4}\frac{1}{2} = 27/16$$

3 – Exercise (6 points)



Nodes A, B and C in the figure periodically collect and send temperature samples to the remote sink. The transmission phase is managed through a dynamic clustering approach which works as follows: two nodes send their samples to the cluster head which then takes the average out of all the sample (two received + one obtained locally) and sends a single packet to the SINK.

The cluster head role is assigned repeating the following pattern A-B-B-C (when cluster head is C, B sends its message directly to C, and viceversa – not through A).

Find the **energy consumed by A, B and C** in one round and the network lifetime (time to the first "death") with the following parameters: energy required to operate the TX/RX circuitry E_c=6 [uJ/packet], energy required to support sufficient transmission output power $E_{tx}(d)= k\ d^2$ [nJ/packet], being k=120 [nJ/packet/m^2], energy for taking the average of 3 samples E_p= 4 [uJ], initial energy budget E_b=300[uJ] for all the three nodes.

Solution

A clusterhead

$E_A^A = 2E_c + E_p + E_c + E_{tx}(10m) \quad E_B^A = E_c + E_{tx}(5m) \quad E_C^A = E_c + E_{tx}(2m)$

B clusterhead

$E_A^B = E_c + E_{tx}(5m) \quad E_B^B = 2E_c + E_p + E_c + E_{tx}(\sqrt{(125)}) \quad E_C^B = E_c + E_{tx}(7m)$

C clusterhead

$E_A^C = E_c + E_{tx}(2m) \quad E_B^C = E_c + E_{tx}(7m) \quad E_C^B = 2E_c + E_p + E_c + E_{tx}(\sqrt{(104)})$

Energy consumed by the three motes in one round

$$E_A = E_A^A + 2E_A^B + E_A^C \quad E_B = E_B^A + 2E_B^B + E_B^C \quad E_C = E_C^A + 2E_C^B + E_C^C$$

Lifetime = 300[uJ] /E_B =3.16

3 – Questions (8 points)

1. A binary tree protocol is used to arbitrate 5 tags. The counter values of the four tags are the following: Tag 1: 1, Tag 2: 3, Tag 3: 3, Tag 4: 1, Tag 5: 2. Assuming that the reader issues a TRIGGER command, find the new counter values of the tags and tell if the following slot is collided or not.
   Tag 1:0, Tag 2:2 Tag 3:2 Tag 4:0, Tag5: 1, collision

2. Briefly explain the use of *message ID* and *Token number* in COAP messages
   See slides

3. Briefly explain the use of the retain flag in MQTT
   See slides