1 – Exercise (7 points)

A personal area network (PAN) is composed of 4 motes and a PAN Coordinator. The PAN works in beacon-enabled mode. Mote 1 and Mote 2 have statistical (non-deterministic) traffic towards the PAN coordinator characterized by the following probability distribution: $P(r_{1,2}=75[bit/s])=0.5$, $P(r_{1,2}=225\ [bit/s])=0.1$, $P(r_{1,2}=0\ [bit/s])=0.4$. Mote 3 and Mote 4 have deterministic traffic towards the PAN coordinator with a required rate, $r_{3,4}$ of 450 [bit/s]. Assuming that: (i) the active part of the *Beacon Interval* (BI) is composed of *Collision Free Part* only; (ii) the motes and the PAN coordinator use b=225 [bit] packets for their transmissions which fit exactly one slot in the CFP, (iii) the nominal rate is 250 [kb/s], find the **duration of the single slot**, the **duration of *Beacon Interval* (BI)**, the **duration of the CFP,** the **duration of the inactive part**, a **consistent slot assignment** for all the uplink transmissions and corresponding the **duty cycle.**

Assuming that the energy consumption parameters are the following ones, find the average energy consumption in a beacon interval of the PAN coordinator; energy for receiving a packet E_{rx} =4[uJ], energy for transmitting a packet E_{tx} =7[uJ], energy for being idle in a slot E_{idle} = 3[uJ], energy for sleeping in a slot E_{sleep} = 3[nJ].

Solution

T_s=b/R=225[bit]/250[kb/s]=900us
BI=b/75[bit/s]=225[bit]/75[bit/s]=3s
Mote 1 and 2 need 3 slots in the CFP
Mote 3 and 4 need 6 slots in the CFP
T_{CFP}=18 x Ts =16.2ms
T_{ACTIVE}=17.1ms
$T_{INACTIVE}$=BI-T_{ACTIVE}=2982,9ms
Duty cycle = T_{ACTIV}E/BI=$5.7\text{x}10^{-3}$

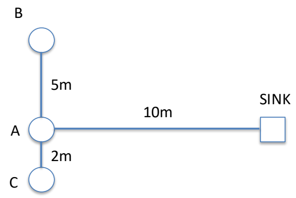
The energy consumed by the PAN coordinator is:
$E_{PANC}=E_{TX}+12E_{RX}+2[0.5\ (E_{RX}+2E_{IDLE}) + 0.1\ 3\ E_{RX} + 0.4\ 3\ E_{IDLE}] + 3314.3\ E_{SLEEP}$=74 [uJ] 84

2 – Exercise (4 points)

A ZigBee tree network is characterized by the following parameters: number of ZigBee routers per level, R_m=2, number of end devices per level, D_m=1, tree depth, L_m=3. How many addresses are needed to address all the devices in the network? Sketch the network structure properly assigning the addresses to end devices, ZigBee routers and ZigBee coordinator.

Solution
See slides

3 – Exercise (5 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 in a round robin fashion starting from node A (node A, then B, then C, then A, etc.) (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 (all the three nodes played the role of clusterhead) and the network lifetime (time to the first "death") with the following parameters: energy for collecting one sample, E_s= 1[uJ], 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=150[uJ] for all the three nodes.

Solution
A clusterhead
$E_A^A=E_S+2E_C+E_P+E_C+E_{TX}(10m)=35$ [uJ]
$E_B^A=E_S+E_C+ E_{TX}(5m)=10$ [uJ]
$E_C^A=E_S+E_C+ E_{TX}(2m)=7.48$ [uJ]

B clusterhead
$E_B^B=E_S+2E_C+E_P+E_C+E_{TX}(11.m)=38$ [uJ]
$E_A^B=E_S+E_C+ E_{TX}(5m)=10$ [uJ]
$E_C^B=E_S+E_C+ E_{TX}(7m)=12.88$ [uJ]

C clusterhead
$E_C^C=E_S+2E_C+E_P+E_C+E_{TX}(10.1.m)=35.48$ [uJ]
$E_A^C=E_S+E_C+ E_{TX}(2m)=7.48$ [uJ]
$E_B^C=E_S+E_C+ E_{TX}(7m)=12.88$ [uJ]

Energy consumed in one round
$E_A= E_A^A+ E_A^B + E_A^C=52.48$ uJ
$E_B= E_B^A+ E_B^B + E_B^C=60.88$ uJ
$E_C= E_C^A+ E_C^B + E_C^C=52.96$ uJ

The bottleneck is node B. Lifetime is: 150 [uJ]/60.88[uJ] = 2.26 rounds

3 – Questions (9 points)

CON [1212]
GET /humidity
(Token 2323)

1.A COAP client issues the request message at the right. Briefly explain the meaning of all the lines in the message and write a consistent and complete response from the COAP server assuming that the server includes the requested resource in the response message **(CLEARLY EXPRESS THE MESSAGE ID AND THE TOKEN ID IN THE RESPONSE MESSAGE)**

2. A sensor node performs channel access according to the CSMA/CA scheme of the IEEE 802.15.4 standard. Assuming that the probability of finding the channel busy is p=0.3 at each backoff period, find the probability that the sensor node does actually access the channel at the first attempt

3. A Dynamic Frame ALOHA system is used to arbitrate 3 tags. What is the average throughput after the first frame of length r_1=3?

Solution

1.SEE SLIDES

2. (1-p)^2=0,49

3. 4/3