Internet of Things, ***July 24, 2019*** **Total Available time: 1.30 hours**

1 – Exercise (7 points)

A IEEE 802.15.4 network is composed of a PAN Coordinator and five motes. Each mote is assigned 3 slots in the Collision Free Part, and each slot can carry packets of 128 [byte]. The nominal rate is R=250 [kb/s] and the active part is composed of the beacon slot and the CFP only. The network is operated with a duty cycle η=10%. The motes have the following traffic pattern: mote 1 and mote 2 generate packets according to a Poisson process with parameter λ_1=0.5 [packets/s], mote 3 and mote 4 generate packets according to a Poisson process with parameter λ_2 = 2 [packet/s], mote 5 generates packets deterministically at a rate r=10[packets/s]. The PAN coordinator has one slot in the CFP to deliver downlink traffic with the following traffic pattern: the probability that the downlink slot is used to send data to mote 1 is 0.3, the probability that the downlink slot is used to send data to mote 2 is 0.2, the probability that the downlink slot is used to send data to mote 3 is 0.5.
Find: the duration of the Beacon Interval, the duration of a slot, the equivalent rate defined as "one slot per Beacon Interval", the average energy consumed by mote 1 and the PAN coordinator assuming E_{rx} = 1[uJ], E_{tx},=3 [uJ], E_{idle} = 0.5 [uJ] and E_{sleep} = 1[nJ] to be respectively the energy for receiving, transmitting (circuitry + emitted power) , being idle and sleeping in a slot (assume that the three motes are out of range one-another).

SOLUTION
N_{cfp}= 3x 5 +1 = 16, N_{active} =17, Ts=128[byte]/ 250[kb/s] = 4.046 ms
T_{active}= N_{active} x Ts = 69,63 ms
BI=Tactive/η=696.3ms
The probabilities that mote 1 and 2 generate 0, 1, 2 or >= 3 packets per beacon interval are:
$P_1(N=0) = e^{-\lambda_1 BI}$, $P_1(N=1)= \lambda_i BI\, e^{-\lambda_1 BI}$, $P_1(N=2)= (\lambda_i BI)^2/2\, e^{-\lambda_1 BI}$, $P_1(N>=2)=1-P_1(N=0)-P_1(N=1) -P_1(N=2)$

The probabilities that mote 3 and 4 generate 0, 1, 2 or >= 3 packets per beacon interval are:
$P_2(N=0) = e^{-\lambda_2 BI}$, $P_2(N=1)= \lambda_2 BI\, e^{-\lambda_2 BI}$, $P_2(N=2)= (\lambda_2 BI)^2/2\, e^{-\lambda_2 BI}$, $P_2(N>=2)=1-P_2(N=0)-P_2(N=1) -P_2(N=2)$

Mote 5 always have a packet ready for transmission.

The average energy consumed by Mote 1 is:
$E_{panc} = E_{rx} + 12\, E_{idle} + P_1(N=0)\, 3\, E_{idle} + P_1(N=1)(2E_{idle}+E_{tx})+ P_1(N=2)(E_{idle}+2E_{tx})+ P_1(N>=3)3E_{rx} + 0.3E_{rx} + 0.7E_{idle} + N_{sleep}\, E_{sleep}$

The average energy consumed by the PANC is:
$E_{panc} = E_{tx} + 2[P_1(N=0)\, 3\, E_{idle} + P_1(N=1)(2E_{idle}+E_{rx})+ P_1(N=2)(E_{idle}+2E_{rx}) + P_1(N>=3)3E_{rx}] + 2[P_2(N=0)\, 3\, E_{idle} + P_2(N=1)(2E_{idle}+E_{rx})+ P_2(N=2)(E_{idle}+2E_{rx}) + P_2(N>=3)3E_{rx}] + 3E_{rx} + E_{tx} + N_{sleep}\, E_{sleep}$

2 – Exercise (4 points)

Two tags must be resolved through a binary tree tag resolution protocol. Find the average efficiency. **MOTIVATE THE ANSWER. UNMOTIVATED ANSWER WILL NOT BE CONSIDERED** 2/3.5

3 – Exercise (6 points)

A COAP client operating with the Observe mode is registered to the topic /temp on a COAP server with the registration mode that forces the server to send a non-stimulated message every 2 [minutes] starting at time t=0. Assuming that the probability to loose one message (data or ACK) is p=0.1, find the average energy consumed by the COAP client in a time period of 10 minutes in the two cases where the COAP server uses/does not use CONFIRMABLE messages to send the temperature samples to the COAP client. Energy for receiving a COAP message, E_{rx}=4[uJ], energy for transmitting a COAP message, E_{tx}= 10[uJ], energy for being idle E_{idle}=0[uJ].

4 – Questions (9 points)

1. Three RFID tags are arbitrated by Dynamic Frame ALOHA. Tell if the following statements are true or false. **MOTIVATE THE ANSWER. UNMOTIVATED ANSWER WILL NOT BE CONSIDERED**
   a. The higher the dimension of the first frame the higher the efficiency of the arbitration process. F
   b. The higher the dimension of the first frame, the higher the average throughput after the first frame T

2. A LoRaWAN is deployed in a noisy environment (high interference in the background). Discuss advantages and disadvantages in the SF assignment. See slides
3. What is the average throughput of a single frame Frame-ALOHA with N=3 tags and r=4 slots? 81/64