Internet of Things, ***Aug 27, 2020*** **Total Available time: 2.00 hours**

1 – Exercise (7 points)

A IEEE 802.15.4 network is composed of a PAN Coordinator and two motes. Each slot can carry packets of 128 [byte]. The nominal rate is R=125 [kb/s] and the active part is composed of the beacon slot and the CFP only. The motes and the PAN coordinator have the following traffic pattern:

- Mote 1 requires a data rate r_1 in each BI according to the following probability distribution: $P(r_1=0) = 0.3$, $P(r_1=8[bit/s]) = 0.6$, $P(r_1=24[bit/s]) = 0.1$;
- Mote 2 requires a data rate r_2 in each BI according to the following probability distribution: $P(r_2=16[bit/s]) = 0.3$, $P(r_2=8[bit/s]) = 0.7$;
- The PAN coordinator requires a data rate r_{pan} towards each one of the two motes in each BI according to the following probability distribution: $P(r_{pan}=0[bit/s]) = 0.3$, $P(r_{pan}=4[bit/s]) = 0.7$;

Find (i) the slot duration, (ii) the duration of the BI, the number of slots required by mote 1, (iii) the number of slots required by mote 2, (iv) the number of slots required by the PAN coordinator, duration of the Beacon Interval, (iii) Write the expression of the average energy consumption in one Beacon Interval of Mote 1 assuming that it is out of range of all the other mote (use E_tx, E_rx, E_idle, E_sleep to represent the energy for transmitting, receiving, being idle and sleeping in one slot)

Ts=8.192ms

BI=128[byte]/4[bit/s]=256 s

N_1=6, N_2=4, N_{panc}=2 (1 slot for each mote)

$E_1=E_{rx}+0.1\ 6\ E_{tx} + 0.6\ (2E_{tx}+4E_{idle}) + 0.3\ 6\ E_{idle} + 4\ E_{idle} + E_{idle} + 0.3\ E_{idle} + 0.7\ E_{rx} + N_{sleep}\ E_{sleep}$

A IEEE 802.15.4 network is composed of a PAN Coordinator and two motes. 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 motes and the PAN coordinator have the following traffic pattern:

- Mote 1 requires a data rate r_1 in each BI according to the following probability distribution: $P(r_1=0)=0.3$, $P(r_1=2[bit/s]) = 0.6$, $P(r_1=24[bit/s])=0.1$;
- Mote 2 requires a data rate r_2 in each BI according to the following probability distribution: $P(r_2=16[bit/s])=0.3$, $P(r_2=8[bit/s]) = 0.7$;
- The PAN coordinator requires a data rate r_{pan} towards each one of the two motes in each BI according to the following probability distribution: $P(r_{pan}=0[bit/s])=0.3$, $P(r_{pan}=4[bit/s]) = 0.7$;

Find (i) the slot duration, (ii) the duration of the BI, the number of slots required by mote 1, (iii) the number of slots required by mote 2, (iv) the number of slots required by the PAN coordinator, duration of the Beacon Interval, (iii) Write the expression of the average energy consumption in one Beacon Interval of Mote 1 assuming that it is out of range of all the other mote (use E_tx, E_rx, E_idle, E_sleep to represent the energy for transmitting, receiving, being idle and sleeping in one slot)

Ts=4.096ms

BI=128[byte]/4[bit/s]=256 s

N1=6, N2=4, Npanc=2 (1 slot for each mote)

$E_1=E_{rx}+0.1\ 6\ E_{tx} + 0.6\ (2E_{tx}+4E_{idle}) + 0.3\ 6\ E_{idle} + 4\ E_{idle} + E_{idle} + 0.3\ E_{idle} + 0.7\ E_{rx} + N_{sleep}\ E_{sleep}$

2 – Exercise (4 points)

Find the average efficiency of Dynamic Frame ALOHA collision resolution protocol with an initial population of n=3 tags and an initial frame size r=1. Assume that the size of the frames after the first one is "optimally" set to the current backlog.

$L_4=3+L_4P_0+L_3P_1+L_2P_2+L_1P_3$

$P_3=0$

$P_2=36/81$

$P_1=24/81$

$P_0=21/81$

$L_3=3+L_3P_0+L_2P_1+L_1P_2$
$P_2=0$
$P_0=1/9$
$P_1=2/3$

$L_2=2+L_2P_0$
$P_0=1/2$
Thus $L_2=4$

Substituting L_2 in L_3 we get
$L_3=3+L_3\,(1/9)+(2/3)\,4$
$L_3=[3+(8/3)](9/8)=51/8$

Substituting L_3 and L_2 in L_4 we finally get $L_4=9$

Find the average efficiency of Dynamic Frame ALOHA collision resolution protocol with an initial population of n=4 tags and an initial frame size r=1. Assume that the size of the frames after the first one is "optimally" set to the current backlog.

$L_3=1+L_3P_0+L_2P_1+L_1P_2$

$P_2=0$
$P_1=0$
$P_0=1$

$L_3=3+L_3P_0+L_2P_1+L_1P_2$
$P_2=0$
$P_0=1/9$
$P_1=2/3$

$L_2=2+L_2P_0$
$P_0=1/2$
Thus $L_2=4$

Substituting L_2 in L_3 we get
$L_3=3+L_3\,(1/9)+(2/3)\,4$
$L_3=[3+(8/3)](9/8)=51/8$

The total L3 is:
$L3=51/8+1=59/8$

3 – Exercise (6 points)

A MQTT client (Client 1) is subscribed to the topic /lumen. The MQTT broker is connected to 2 additional MQTT clients which publish messages on the topic /lumen according to the following traffic processes:

- Client 2 publishes one message on topic /lumen according to a Poisson process with parameter $\lambda=0.5$ message/second
- Client 3 publishes one message on topic /lumen according to a Poisson process with parameter $\lambda=1$ message/second

Find the average energy consumed by the MQTT Client 1 in a time period of 15 minutes in the two cases where the all the publish messages require QoS level 0 and 1. Clearly describe the message exchange session between the MQTT broker and Client 1 in the three cases.
Use the following parameters: energy for sending/receiving MQTT publish messages, E_{rx}=10[uJ], energy for sending/receiving MQTT signaling messages (various ACK messages), E_{tx}= 3 [uJ], energy for being idle E_{idle}=0[uJ].

QoS0

E_1=1350 Erx

QoS1

E_1=1350 (Erx+Etx)

A COAP client (Client 1) is interested in retrieving the resource /motex/temperature.txt available at a COAP server. The resource reflects temperature readings at the COAP server which get updated with frequency f=2[Hz]. Find the average energy consumed by the COAP client Client 1 in a time period of 15 minutes in the two cases where COAP Observe mode is not adopted, and COAP Observe mode is adopted with the option of receiving every new sample of temperature reading.

Observe
E_1=1800 Erx

No Observe
E_1 = 1800 (Erx+Etx)

3 – Questions (9 points)

1. Tell if the following statements are true or false. **MOTIVATE THE ANSWER. UNMOTIVATED ANSWER WILL NOT BE CONSIDERED**
   a. The CAN bus is based on random access procedures. **TRUE**
   b. The COAP supports only synchronous exchange between client and server. **FALSE**
   c. In the AODV protocol each mote has the full knowledge of the network topology. **FALSE**

A wireless link is characterized by the following parameters: a bit error rate in both directions, p = 0.001, packets size, L=100[byte], acknowledgment size= 10[byte]. Find the Expected Transmission Count (ETX) for the link.

$ETX= 1/[(1-p)^{8L} (1-p)^{8Lack}]=2.41$

A wireless link is characterized by the following parameters: a bit error rate in both directions, p = 0.001, packets size, L=50[byte], acknowledgment size= 10[byte]. Find the Expected Transmission Count (ETX) for the link.

$ETX= 1/[(1-p)^{8L} (1-p)^{8Lack}]=1.61$