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])=0.6, $P(r_{1,2}$=225 [bit/s])=0.2, $P(r_{1,2}$=0 [bit/s])=0.2. Motes 3 and 4 have deterministic traffic towards the PAN coordinator with a required rate, $r_{3,4}$ of 225 [bit/s]. The PAN coordinator has to deliver downlink traffic towards the four nodes according to the following pattern: traffic towards Mote 1 and Mote 2 $P(r_{1,2}^{PANC}$=75[bit/s])=0.5, $P(r_{1,2}^{PANC}$ =225 [bit/s])=0.1, $P(r_{1,2}^{PANC}$ =0 [bit/s])=0.4; traffic towards Mote 3 and 4 deterministic with required rate $r_{3,4}^{PANC}$ 75 [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=128 [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 transmissions (**UPLINK AND DOWNLINK**), and corresponding the **duty cycle.**

Assuming that the energy consumption parameters are the following ones, find the average energy consumption in a beacon interval for 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].

The BI duration can be found by setting BI=b/r_{min}, being r_{min}=75[b/s], which leads to BI=1.706[s].

Uplink traffic (from motes to PANC) worst case:
Mote 1: 3 slots
Mote 2: 3 slots
Mote 3: 3 slots
Mote 4: 3 slots

Downlink traffic (from PANC to motes) worst case:
To Mote 1: 3 slots
To Mote 2: 3 slots
To Mote 3: 1 slots
To Mote 3: 1 slots

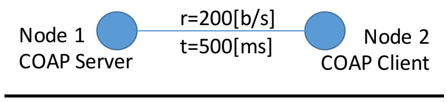
The total number of slots required in the CFP is therefore: N_{cfp}= 21

The duration of the slot is: T_s=b/R=512[us].
The duration of the CFP is $T_{cfp}=N_{cfp}\ T_s$ = 10.76[ms]
The duration of the inactive part is: BI-T_{cfp}=1.69[s]
The duty cycle is $\eta=T_{cfp}/BI=0.0063$

The average energy consumption of the PANC is:

$$E= E_{tx}+2[0.2\ (3\ E_{idle}) + 0.2\ (3\ E_{rx}) + 0.6\ (E_{rx} + 2E_{idle})] + 2 \times 3\ E_{rx} + 2\ [0.4\ 3\ E_{idle} + 0.5\ (E_{tx} + 2E_{idle}) +0.1(3\ E_{tx})\ ] + 2\ E_{tx} + 3300\ E_{sleep}$$

2 – Exercise (6 points)



Node 1 in the figure mounts a temperature sensor to collect temperature samples at an extremely high pace; node 1 runs a COAP server and the resource associated to temperature samples is */temp;* Node 2 runs a COAP client and is interested in reading 20 consecutive temperature samples collected by node 1. The figure reports the nominal bit rate of the link between node 1 and node 2, r=200[bit/s] and the one-way propagation delay t=500[ms]. Assuming that COAP request messages have size L_{req}=8 [byte], COAP response messages have size L_{resp}=10 [byte], the energy consumed for transmitting/receiving a message (both request/response) $E_{rx/tx}$=8[uJ], find the total time for the COAP client to obtain the 20 temperature samples and the energy consumed by the COAP server in the two cases where COAP uses/doesn't use the Observation mode (assume that the size of request/response messages is the same in the two operation modes, assume perfect transmission).

Solution

T_{req} = Lreq/200[b/s] =320[ms]
T_{resp} = Lresp/200[b/s] = 400[ms]

No Observation mode

T= 20 (T_{req} + T_{resp} +2t)=34.4 [s]
Eserver = 20 (Etx + Erx)= 320[uJ]

Observation mode

T= T_{req} + t + 20 T_{resp} + t = 9.32 [ms]
Eserver = Etx + 20Erx = 168[uJ]

3 – Exercise (4 points)

A RFID system based on Dynamic Frame ALOHA is composed of 2 tags. Assuming that the initial frame size is r=4, find the overall collision resolution efficiency, η (assume that after the first frame, the frame size is correctly set to the current backlog size).

Solution

Let's apply the recursive formula:

$$L_2 = 4 + \sum_{i=0}^{1} L_{2-i} P(S = i)$$

where:
P(S=0) = 4 x $(1/4)^2$ = ¼
P(S=1) = 0

L_2 = 4 + ¼ L_2
L_2 = 16/3

The efficiency is η = 0.375

4 – Questions (9 points)

1. Briefly describe COAP message error detection and retransmission mode.

2. A wireless link is characterized by a Bit Error Rate (BER), p=0.001. Assuming that transmissions on the link use packets of length L=128[byte] which are acknowledged with ACK with size L=8[byte], find an estimate for the Expected Transmission Count (ETX) of the link.
3. A sensor node runs the IEEE 802.15.4 Carrier Sensing Multiple Access (CSMA); what is the average backoff time after the third failed attempt to access the channel? (the node has tried to access the channel for 3 times and the channel was busy)

Solution

1. **See slides**
2. **The packet success probability is $P_s = (1\text{-}p)^{8(L+Lack)}$; the ETX = $1/P_s$ = 2.97**
3. **After the third failed attempt, the sensor draws the radom backoff time in the window [0, 2^4-1]. On average, it will have to wait 7.5 backoff periods**