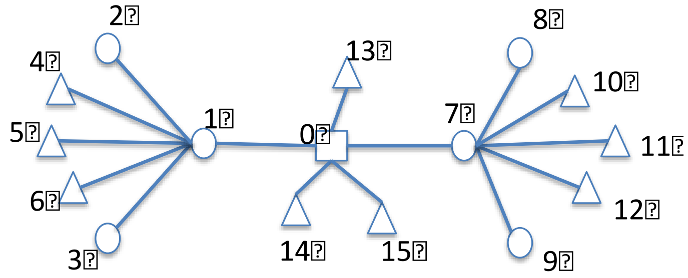
Internet of Things, ***September 8, 2015*** ***Available time: 2h***

Exercise 1 (4 points)

A multi-hop ZigBee personal area network (PAN) is characterized by the following topological parameters: number of ZigBee routers per tree level r=2, number of ZigBee end devices per tree level d=3, number of tree levels L=2 (The PAN coordinator plus two more levels). Plot a graph representing the network and assign network addresses to all the network devices according to the ZigBee address assignment rules.

Solution



Legend
Square: ZigBee coordinator
Circles: zigBee routers
Triangles: ZigBee end devices

Exercise 2 (6 points)

A Personal Area Network composed of 50 motes and a PAN Coordinator is operated according to the IEEE 802.15.4 beacon enabled mode with the following parameters:

- Active part composed of CFP only (no CAP) with slots of 128 [byte] packets;
- Nominal data rate is 250 [kbit/s];
- 20 motes of Type 1 generate uplink traffic whose rate follows this with the following distribution: P(r=25[bit/s])=0.4 P(r=50[bit/s])=0.6
- 30 motes of Type 2 generate uplink traffic whose rate follows the distribution: P(r=50[bit/s])=0.2 P(r=1[kbit/s])=0.8

Define a consistent Beacon Interval structure including the number of slots in the CFP, the Beacon Interval duration, and the duty cycle. Define a consistent slot assignment in the CFP for all the devices in the network. Write the average energy consumption for motes of Type 1 and 2 in case all the motes are in radio range (let E_{rx}=40[mJ] be the energy per slot for receiving/overhearing transmissions, and E_{idle}=20[mJ] and E_{sleep}=10[uJ] the energy per slot for being idle and sleeping, respectively).

Solution

The minimum rate required by all the motes is 25 [bit/s]. The beacon interval can be dimensioned such that one slot in the CFP per beacon interval corresponds to 25 [bit/s].

Thus, BI = 128 [byte] / 25 [bit/s] = 40.96 [s].

Mote of type 1 and 2 in the worst case require a bitrate of 50 [b/s] and 1[kb/s], respectively, which corresponds to 2 slots and 40 slots in the CFP

The total number of slots in the CFP is thus: 2 x 20 (Motes of Type 1) + 40 x 30 (Motes of Type 2)= 1240 slots.

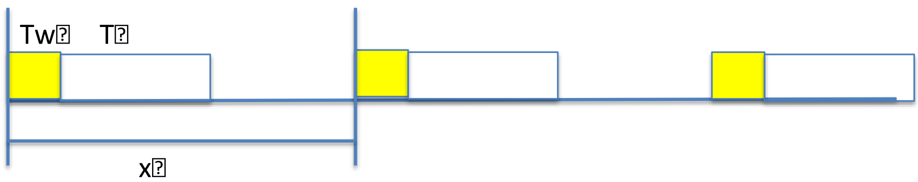
The slot duration can be calculated as: Ts=128 [byte] /250 [kb/s] = 4.096 [ms]
The duration of the CFP is Tcfp=1240 x Ts = 5.079 [s]
The duration of the inactive part is: Tinactive = BI – Tcfp – Ts= 35 [s]
The duty cycle is d=Tactive / BI = 0.12
Since the energy for receiving is the same as the energy for transmitting and all the motes are in radio range, Motes of Type 2 and 3 have the same average energy consumption, that is:
E=20(0.4 2 Etx + 0.6 (Etx + Eidle))+30(0.2 (2Erx+38Eidle) + 0.8 40Erx) + Erx + Esleep Nsleep,
Where Nsleep is the number of equivalent slot in inactive part of the BI (about 8500).

Exercise 3 (6 points)

A sensor node generates a stream of 3 packets at a fixed rate of one packet every x [s]. The packets must be delivered to a sink node for further processing. The nominal data rate is R=250[kb/s] and the packets are of L=1000[bit]. The operating power level for TX circuitry is P_{tx} =100[mW]; the power emitted to the antenna is P_o=100[mW]; the power consumed while in idle and sleep states are P_{idle}=60[mW] and P_{sleep}=10[mW], respectively; In case the sensor goes to sleep, it needs a wake-up time of T_w=500 [us]. Write the energy consumption for transmitting the 3 packets in the 2 cases where (1) the sensor node goes to sleep after each transmission and wakes up when the following packet is ready (2) the sensor node is always active (assume that in both cases the sensor node is asleep at the very beginning of the operations).
Is there any value of r for which case (2) is more energy-efficient than case (1)?

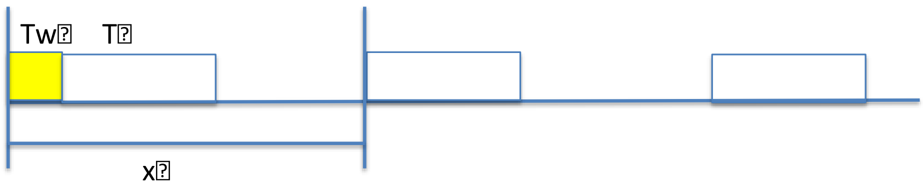
Solution

Case 1: mote switches on and off



E1= 3[TwPtx+(Ptx+Po)T+Psleep(x-T-Tw)]

Case 2: mote stays active after first transmission



E2=PtxTw+(Ptx+Po)T+Pidle x – Pidle Tw – Pidle T + 2[(Ptx+Po)T+Pidle (x-T)]

We have to check for which values of x E2 is lower than E1. By solving the inequality in x, we get:
x < 4.76 [ms]

Questions (10 points)

1. A SPARE MAC network is characterized by the following parameters: number of slots in the signaling sub frame N=10, number of slots in the data sub frame M=10, slot duration T=500[us], slot length L=128[byte]. Each node in the network is assigned 1 slot in the SSF and 2 slots in the DSF. What is the nominal (overall) data rate? What is the data rate of the data channels?

   The nominal data rate is L/T=2.048[Mb/s]. The data rate of the data channels is r=2L/21T=195[kb/s]
2. Briefly describe the Observation operation mode of COAP.

   See slides
3. Tell which one(s) of the following statement is (are) true and which one(s) is (are) false. BRIEFLY MOTIVATE THE ANSWER. UNMOTIVATED RESPONSES WILL NOT BE CONSIDERED
   a. The communication provided by COAP is only best-effort FALSE
   b. In SMAC the channel access is contention-based TRUE
   c. RPL is a reactive routing protocol FALSE
   d. The backoff procedure of IEEE 802.15.4 is used after collided transmissions FALSE
4. An RFID system is composed of 3 tags and uses a Dynamic Frame ALOHA access protocol. Assume that the initial frame size is r=4 and that after the first frame no tags have been resolved. What is the backlog predicted by Schoute's estimate? Find out the probability that the resolved tags after the second frame is equal to *i*, with *i*=0, 1, 2, 3 if the second frame length is set to Schoute's estimate.

   After the first frame no tags have been resolved, thus all the 3 tags have chosen the very same slot for transmitting. According to Schoute's estimate, the backlog is equal to the number of collided slots multipled by 2.39, all rounded up to the closest integer. In our case, only one collided slot is observed, so Schoute's estimate predicts a backlog of 2 tags. The second frame is then set to r=2 slots. Then, the requested probability values are: P(S=2)=0, P(S=3)=0, P(S=1)=1-P(S=0), P(S=0)=2(1/2)3