Internet of Things, Exam– July 1, 2015

Family Name	
Given Name	
Student ID	

Total Available time: 2 hours

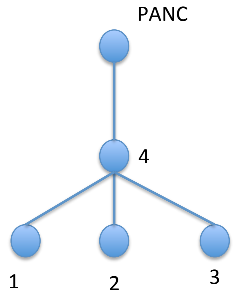
1 – Exercise (7 points)

The two-hop personal area network (PAN) in the figure 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(required rate=75[bit/s])=0.5, : P(required rate=225 [bit/s])=0.1, P(required rate=0 [bit/s])=0.4.
- Mote 3 and Mote 4 have deterministic traffic towards the PAN coordinator with a required rate of 450 [bit/s].

Assuming that:

- the active part of the Beacon Interval (BI) is composed of Collision Free Part only
- The collision free part is divided in two: the first part is dedicated to the transmissions from Motes 1, 2 and 3 towards Mote 4, the second part is used by Mote 4 to deliver its own traffic and the relayed one to the PANC.
- the motes use b=128 [bit] packets to communicate with the PANC which fit exactly one slot in the CFP
- 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 and the duration of the inactive part, a consistent slot assignment for the four motes, and the duty cycle.

Solution

The minimum rate required by all the four motes is 75 [bit/s]. The beacon interval can be dimensioned such that one slot in the CFP per beacon interval corresponds to 75 [bit/s].

Thus, BI = 128 [bit] / 75 [bit/s] = 1.7 [s].

Mote 1 and 2 in the worst case require a bitrate of 225 [kb/s] which corresponds to 3 slots in the CFP

Mote 3 requires a rate of 450 [bit/s] which corresponds to 6 slots in the CFP

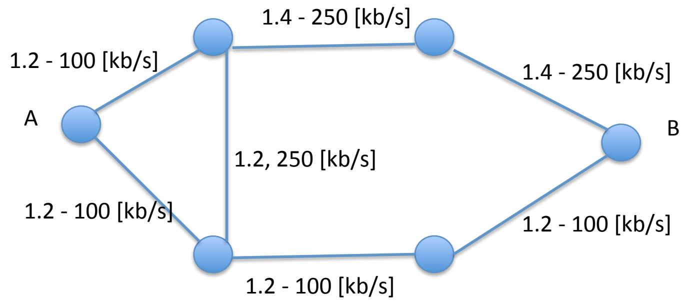
Mote 4 requires a rate of 450 [bit/s] which corresponds to 6 slots for its own traffic and then it must be able to relay also the traffic from the other 3 motes. In total, mote 4 requires 6+3+3+6=18 slots

The total number of slots in the CFP is thus: 3 (Mote 1) + 3 (Mote 2) + 6 (Mote 3) + 18 (Mote 4) = 30 slots.

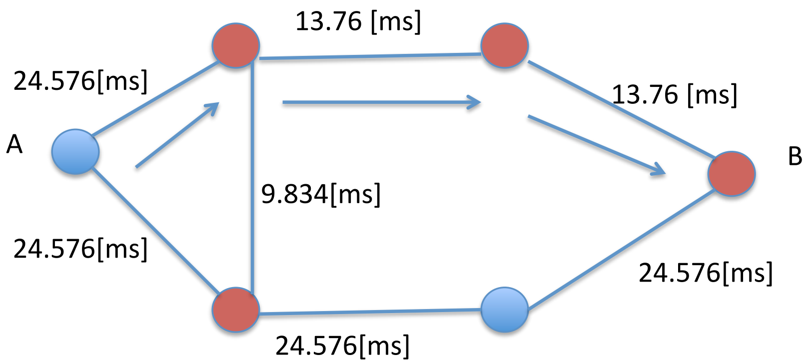
The slot duration can be calculated as: Ts=128 [bit] /250 [kb/s] = 512 [us]
The duration of the CFP is Tcfp=30 x Ts = 15.56 [ms]
The duration of the inactive part is: Tinactive = BI – Tcfp – Ts= 1.685 [s]
The duty cycle is d=Tactive / BI = 0.01

2 – Exercise (4 points)

The nodes in the figure exchange packets of L=128[byte] which are acknowledged with ACKs of the same size. The figure reports for each wireless link the corresponding link capacity C and *Expected Transmission Count* (*ETX*). Find the *Expected Transmission Time* (*ETT*) metric for all the wireless links (assume negligible propagation delay); find the shortest path from node A to node B using the *ETT* as routing metric.



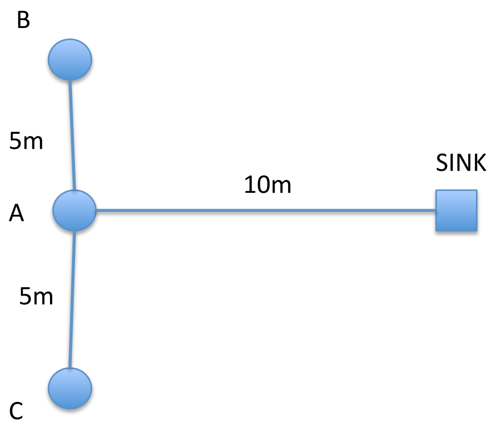
Solution
The Round Trip Time (RTT) for each link can be calculated as RTT=2LC where C is the capacity of the specific link. The ETT can then be calculated as ETT=ETX x RTT. The following figure reports the ETT values for all the links and the corresponding shortest path between A and B.



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 work as follows: two nodes send their samples to the clusterhead which then takes the average out of all the sample (two received + one obtained locally) and sends a single packet to the SINK.
The clusterhead role is assigned in a round robin fashion starting from node A (node A, then B, then C, then A, etc.) (when clusterhead is C, B sends its message directly to C, and viceversa – not through A).
Find the network lifetime (time to the first "death") with the following parameter set:

- energy required to operate the TX/RX circuitry Ec=6 [uJ/packet],
- energy required to support sufficient transmission output power Etx(d)= k d^2 [nJ/packet], being k=120 [nJ/packet/m^2], the
- energy for taking the average of 3 samples Ep= 4 [uJ]
- initial energy budget Eb=122[uJ] for all the three nodes



Solution

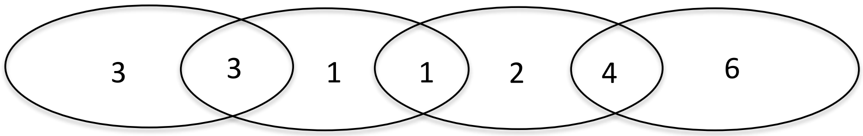
The energy consumed by the three nodes in one round is:

$$E_C = E_B = 2E_c + E_{tx}(5m) + E_{tx}(10m) + 2E_c + E_p + E_c + E_{tx}(10m) = 61[\mu J]$$
$$E_A = 2E_c + 2E_{tx}(5m) + 2E_c + E_p + E_c + E_{tx}(10m) = 52[\mu J]$$

Two round of data collection can be performed.

3 – Questions (10 points)

1. Given the network topology in the figure, what is the minimum number of slots in the signaling subframe and in the data subframe under SPARE MAC (numbers represents the numbers of motes within each area of the topology, ovals represent the coverage range: motes in the same oval can hear each other, motes in the intersection between two ovals can hear the motes in both the ovals)? EXPLAIN WHY.



   N=13, M=10

2. Briefly describe the header compression standardized in 6LowPAN.
   See slides
3. Describe the structure and the usage of the *Routing Table* and the *Routing Discovery Table* in ZigBee AODV routing.
   See slides
4. 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=0.05 at each backoff period, what is the probability that the sensor node does actually access the channel within the first two tries.

The probability to find the channel free in two consecutive backoff period is P=(1-p)2=0.9.
The required probability is therefore: P+(1-P)P=0.9+0.09=0.99

5. A Dynamic Frame ALOHA system is used to arbitrate 4 tags. What is the average throughput after the first two frames of the arbitration process knowing that the respective frame lengths are r_1=2, r_2=2?

After the first frame either 0 or 1 tag is resolved. The probability of the two events (0 or 1 tag resolved) is ½. If one tag is resolved after the first frame, 3 tags are left and the new frame length is 3 slots long. Either 1 or 0 tags can be resolved in this case with probability ¾ and ¼ respectively.
In summary, the average number of tags solved after 2 frames is:
E[S]= ½ ½ +1/2 ¼ +1/2 ¾ 2= 9/8