Internet Of Things

Prof. Alessandro Redondi

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1. **Exercise (8 pts)**: A personal area network (PAN) is composed of 4 motes and a PAN Coordinator. The PAN works in beaconenabled 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 $P(r_{1,2} = 75[bit/s]) = 0.5, P(r_{1,2} = 225[bit/s]) = 0.1, P(r_{1,2} = 0[bit/s]) = 0.4$; traffic towards Mote 3 and 4 deterministic with required rate $r_{3,4}$ of 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 $E_{rx} = 4[\mu J]$, energy for transmitting a packet $E_{tx} = 7[\mu J]$, energy for being idle in a slot $E_{idle} = 3[\mu J]$, energy for sleeping in a slot $E_{sleep} = 3[nJ]$.

2. **Exercise (5 pts)**: One sensor node (A) acts as publisher in a system operated by MQTT. A smartphone (B) is subscribed to the topic where A is publishing. Assuming that

   - A publishes at time $t = 0$ with QOS = 1. A stop-and-wait protocol with timeout of 5 ms is used
   - The link from A to the broker is characterised by a capacity $R = 100$kbps and a propagation delay τ=1ms
   - PUBLISH and PUBACK messages have size L = 40 bytes
   - The link from the broker to B is characterised by a capacity $R = 1$Mbps and a propagation delay τ=1ms

   Find the time of arrival of the message published by A at B in two cases:

   - The PUBLISH message and the PUBACK message are received correctly by the broker and A
   - The first PUBLISH message is lost
   - The first PUBLISH message is lost and the QoS was 0.

3. **Exercise (4 pts)**: A Personal area network is composed of 10 motes and a PAN coordinator. The Beacon Interval is 12 s and each mote is assigned one slot in the CFP. Assuming that:

- 5 motes are characterized by a Poisson distributed traffic with $\lambda = 0.1$ packets/s
- 3 motes are characterized by a Poisson distributed traffic with $\lambda = 0.5$ packets/s
- 2 motes are characterized by deterministic traffic and transmit one packet per slot in the CFP
- The overall TX/RX energy per slot is $E_{\text{tx/rx}} = 50\mu$J
- The energy for being idle in one slot is $E_{\text{idle}} = 20\mu J$

Compute the average energy consumed by the PAN coordinator in one Beacon Interval.

4. **Questions (9 pts)**
   (a) Describe MQTT QoS levels. Assuming that a perfect communication link exists between a publisher and the broker, what is the best QoS we can set and why?
   (b) Describe the main differences between parametric (trilateration) and non-parametric (fingerprinting) localization systems.
   (c) A ZigBee network is characterized by the following parameters: $L_m = 3$ (three layers), $R_m = 1$ (number of zigbee routers), $D_m = 3$ (number of end devices). Tell how many addresses are needed to support all the devices in the network and plot a consistent address assignment scheme.