Homework: Part I

John is the Head of the R&D section of a small industry, looking for innovation to improve profits. To this aim, he decides to equip the machines distributed in the industrial plant with sensor communicating measured data via wireless.
He heard about the IEEE 802.15.4/Zigbee technology and he would like to use this technology. To properly design the network, John calls you.

You had a first meeting during which he provided you the map of the industrial plant and the sizes of machines. He also tells you that he has some constraints about the number of devices to be deployed and their positions on machines. The figure below shows the number of devices and positions per machine. The node on the top (yellow square) is the coordinator: one coordinator per machine should be deployed and these coordinators will act as gateways sending data received from devices on the machine to a central unit through Wi-Fi. John clarifies you that the APs Wi-Fi are all using channel number 6 (i.e., only one of the Wi-Fi channels is occupied, that is channel number 6). Coordinators are also connected to the power grid, and no batteries are needed for them. All other nodes should be battery charged.

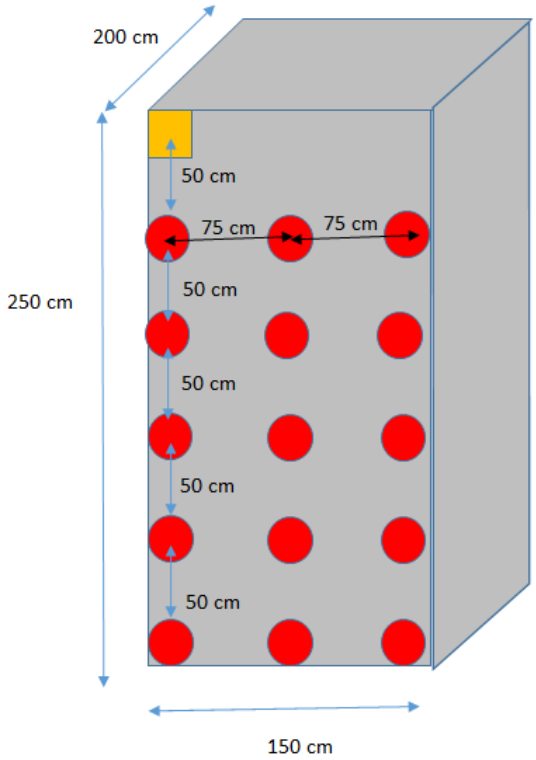


Figure 1.1: Machine with devices

After the meeting, you did some point-to-point measurements in the plant in order to characterize the radio channel, and from the results you derive a propagation coefficient, β, equal to 4.

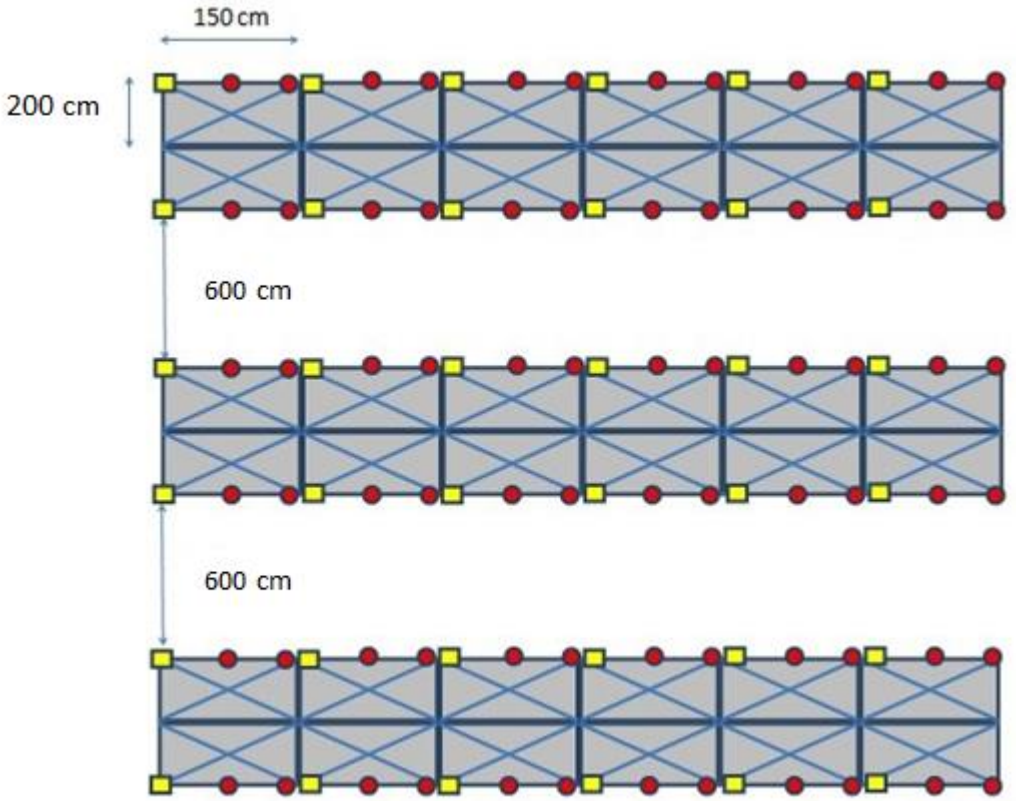


Figure 1.2: Map of the devices in the industrial plant

You can deploy Zigbee routers or Zigbee end devices, but they can only use the Beacon-enabled mode and NO GTSs can be used.

Assuming that:

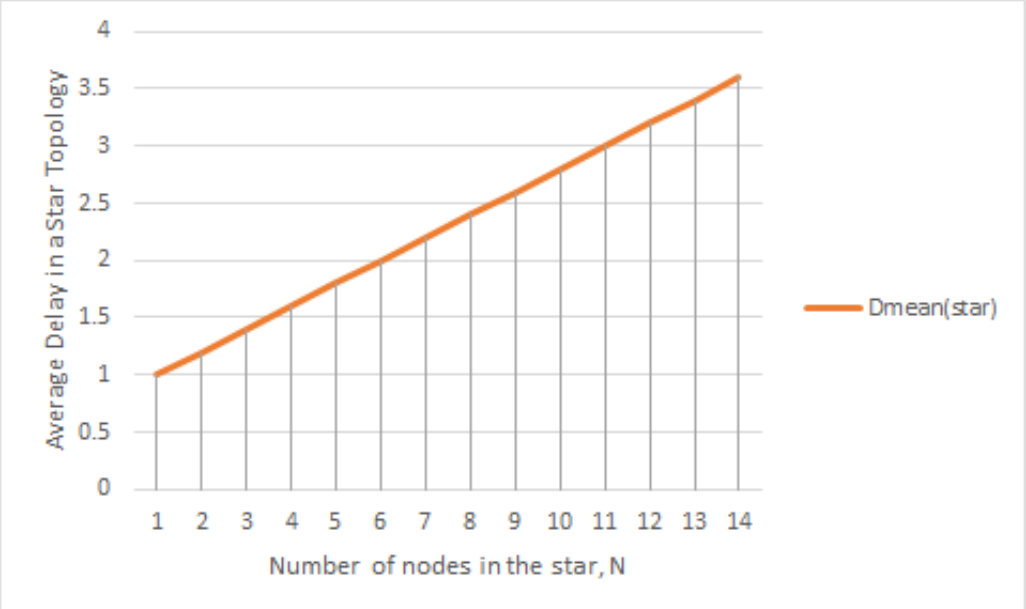
1. Devices transmit with a power of 0 dBm and they have a receiver sensitivity equal to the sensing threshold equal to -95 dBm.
2. Devices have to transmit data of 10 bytes (payload), through packets of 20 bytes in total.
3. Routers may perform data aggregation, without loss of information, but this aggregation (compression) has a cost in terms of energy consumption equal to 2 μJ per packet compressed.

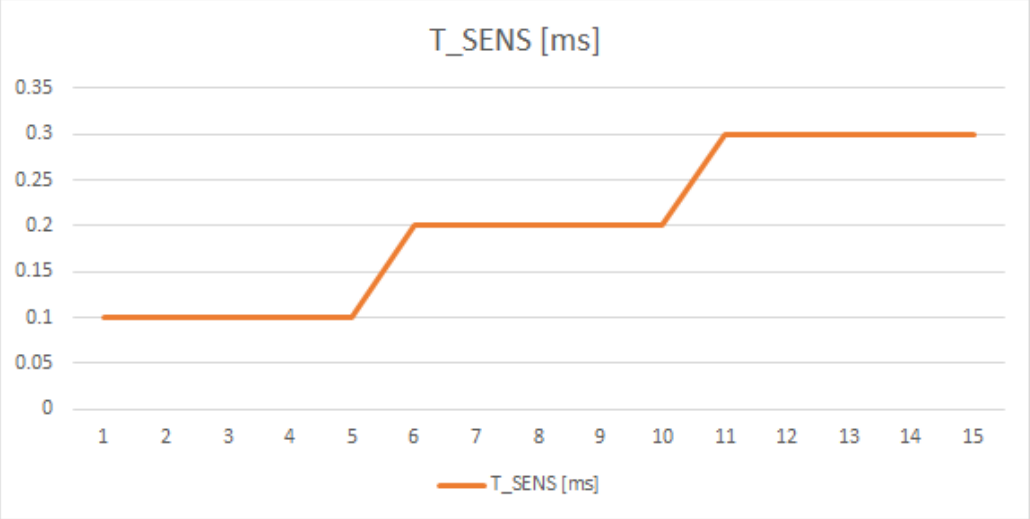
John asks you to provide him:

1. A proper assignment of the 802.15.4 channels to the different PANs (802.15.4 adjacent channels may be used in case of need), such that the C/I (when no intra-PAN interference is present) is larger or equal to 1.3 dB.
2. Given that the application requires a minimum packet success rate of 60% and each coordinator gather data every 65 ms at maximum, which topology could be implemented? Where to locate routers / where to locate end devices (if any)? Draw the topology.
3. Given the topology defined at point 2, provide him an estimation of the total network

throughput and of the average delay, assuming the average delay for a star topology as a function of the number of nodes in the network is given in the figure below (assume no losses and no delays are present in the links between the coordinators and the central unit).

4. An estimation of the total cost for setting up the whole network.
5. An estimation of the cost per year for the batteries, assuming that:
   (a) The network must work for 10 hours per day.
   (b) Each device is equipped with 4 batteries with a cost of 0.20 euro each, and providing an initial energy (whole energy provided by the four batteries), E_initial, equal to 10000 J.
   (c) Power consumption: Ptx(at 0 dBm) = 20 mW; Psens = 10 mW; Prx = 10 mW and no power is consumed during backoff and idle.
   (d) The sensing duration varies depending on the number of nodes competing for the channel as shown in the figure below.





Homework: Part II

Consider the mesh topology shown in the figure below. Assume that nodes work in non Beacon-enabled mode and that Zigbee AODV routing is used. The Success Probability related to MAC, $P_{MAC}(N)$, is given in the table below. The Average Delay for a star topology case is given in the figure of part I.

Assume nodes are all synchronized, therefore at each step of the communication those nodes that have a packet to be transmitted will perform the CSMA/CA protocol at the same time and will compete for the channel. Assume also that no hidden terminal problem is present (all nodes may hear one each other) and that RREQ could be retransmitted such that each node is able to find the optimum path to reach the Coordinator.

Compute:

1. The average (by averaging among all the nodes) Packet Success Probability.
2. The average (by averaging among all the nodes) Packet Delay.
3. Assuming now that Many-to-One routing is used, which is the path followed by each node to reach the Coordinator?

N	P_{MAC}
1	1
2	0.95
3	0.9
4	0.85
5	0.8
6	0.75
7	0.7
8	0.65
9	0.6