Hand in procedure. This assignment must be made in teams of 2 students. Hand in the template, with your Uppaal models in the appendix, as well as your Uppaal models themselves. Deadline is January 9.

Problem statement. In this assignment, we consider the effect of different schedules on the latency in the WirelessHART protocol. We assume the same set up as in the SDF assignment, i.e., with 4 sensors and 3 actuators and 1 Gateway, and the same network topology.

As before, all nodes communicate by the TDMA protocol. This means that time is divided in fixed length frames, and each frame is subdivided into slots. We assume that one slot takes one time unit, and we use $sfs$ize to denote the number of slots in a frame. Each node within the network gets allotted a slot within this frame, where this node can send its data. Recall that communication is bidirectional.

In this exercise, we start by considering single data paths, rather than the global network. (See slide 15 of the TDMA explanation.)

1. Nodes are perfectly synchronized, i.e. no clock drift occur
2. A node can send only one data item per slot. So, to multiple data items (e.g. data from different nodes), multiple slots are needed.
3. Each 20 time units (Report Interval), all sensor nodes generate that needs to be sent to the Gateway, and the Gateway has obtained new data to be sent to each node.
4. The computation time at the gateway is neglect able, i.e. takes 0 time.

Tasks.

1. (a) Model in Uppaal a data path $p_1$ from sensor2 to actuator2 that is given by $p_1 = \text{sensor2 sensor4 sensor3 gateway actuator2}$. Assume that the slots are assigned as follows: actuator2 sends at slot 1, gateway at slot 2, sensor3 at slot 3, sensor4 at slot 4, sensor2 at slot 5.
(b) Use Uppaal to determine the time end-to-end delay it takes for a message from \texttt{sensor2} to arrive at actuator 2.

2. Same questions, but now for the situation where the slots are allocated as follows: actuator2 sends at slot 5, gateway at slot 2, sensor3 at slot 3, sensor4 at slot 4, sensor2 at slot 1.

3. Rather than considering a fixed slot allocation, use Uppaal to find out the best TDMA slot allocation, i.e. where the end-to-end delay is minimal.

4. Now assume a second data path: 
   \[ p_2 = \texttt{sensor1 actuator2 gateway sensor3 sensor4 actuator3}. \]
   Assume the same slot allocation as in item 1. In addition, sensor1 sends at slot 6 and actuator3 at slot 7. Finally, we first execute \( p_1 \) and \( p_2 \).
   
   (a) Model the new situation in Uppaal.
   
   (b) Use Uppaal to determine the time end-to-end delay it takes for a message from \texttt{sensor1} to arrive at actuator 3.

   (c) Use Uppaal to find the best TDMA slot allocation.

5. Finally, try to find an optimal schedule (i.e. an optimal routing strategy and TDMA slot assignment) so that data from \texttt{sensor2} arrives at \texttt{sensor2} and data from \texttt{sensor1} arrives at \texttt{actuator3}.