AALTO UNIVERSITY

FIRST SEMESTER, 2020/2021

DISTRIBUTED INTELLIGENT AUTOMATION SYSTEMS

ELEC 8102

(Time Allowed: THREE hours)

NOTE: Fill your name and student ID on every page of this form.
You may attempt all questions.
Threshold to pass the course is 50% marks and more.
Put the answers in the same form, in the boxes below the questions, you
may use additional sheets if needed.

SURNAME:

FORENAME(S):

ID:

For office use only

MARKS:		
1	Out of 20	
2	Out of 10	
3	Out of 10	
4	Out of 05	
5	Out of 15	
6	Out of 10	
TOTAL: (Out of 70)		

Name_____   Student ID: _____

Question 1) State-based design of automation control logic.   20 marks (10/10)

Consider the finite-state machine in Figure 1. It is controlling the automatic elevator in a two-story building. State S1 is the initial state. The state machine operates with the following Boolean variables:
- Up, Dn – commands to move the lift up and down accordingly;
- Close, Open – commands to close and open doors of the cabin.
- Bt1, Bt2 – lift calling buttons at the floor 1 and 2 accordingly;
- CabBt1, CabBt2 – buttons in the cabin for selecting the desired destination floor;
- DoorsClosed – sensor signal indicating that the doors of the lift are closed
- AtFlr1, AtFlr2 – Sensor signals indicating that the lift cabin has reached the Floor 1, and Floor 2, respectively.
- RESTART – button at the central control room to handle faults.
- ALARM – sound and light warning at the central control room.

Let us assume that the cabin is fully automatic: it opens its doors once it arrives at the desired floor and closes the doors automatically after 60 seconds, so you don't need to implement the door control.

Complete the following two tasks a) and b).
 a) **Add the following features to this state machine:**
1. If the lift remains motionless on the first floor for more than 2 minutes, it should automatically return to the second floor.
2. If moving from a floor to floor takes more than 2 minutes, the ALARM should be raised. State machine should transition to the alarm state and the corresponding output variable should be set to TRUE.
3. Once ALARM is raised, the elevator should be stopped and not react to any further commands from buttons until the RESTART button is pressed and held for 5 seconds.
4. Once the lift exits the alarm state, it should continue moving to the same direction. The ALARM variable should be reset to FALSE.
You can modify the state machine directly on Figure 1 and explain in the box below.
For starting timer in a state, use the following notation:
➔T1.IN(10s) means: start timer T1 for 10 seconds when the state is entered.

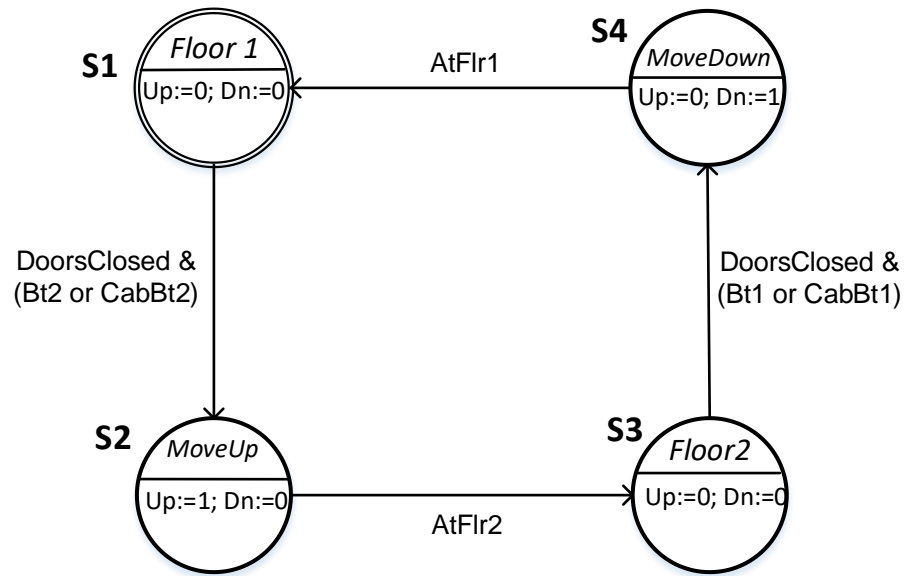**CONTINUED**

Name_____   Student ID: _____

S1   *Floor 1*   AtFlr1   **S4** *MoveDown*

Up:=0; Dn:=0   Up:=0; Dn:=1

DoorsClosed &
(Bt2 or CabBt2)

DoorsClosed &
(Bt1 or CabBt1)

S2 *MoveUp*   **S3** *Floor2*

Up:=1; Dn:=0   AtFlr2   Up:=0; Dn:=0

Figure 1.

Name_____   Student ID: _____

b) Implement the modified state machine in Boolean logic and ladder diagrams.

First, present the Boolean equations implementing the state machine and after that the ladder diagram based on the Boolean equations.

<u>Notation and declarations:</u>

Timers are declared as follows	For Boolean operations, please use the
`T1: TON;`	following notation:
	A+B is A or B;
T1.IN(10s) means start timer T1 preset to 10	A B is A and B;
seconds at the arrival to the state (rising edge).	$\bar{A}$ is the negation of A.

Put the Boolean equations in this box. See the reminder below.

The state transition function is the logical sum of conditions on all incoming arcs to the state including the virtual loopback arc condition.

Name_____   Student ID: _____

Draw the ladder diagram in this box using the ladder guidelines. Extend the provided grid, if needed.

Name_____   Student ID: _____

Question 2 Happened before ordering of events and Lamport clocks   10 marks (2/2/3/3)

The strict partial order relation "happened before" (as defined in the lectures) is denoted by the arrow sign, e.g. $a \rightarrow b$. The word "strict" means that $a \rightarrow a$ is false for any event a.

a) For n processes ($n>1$), is it possible to use Lamport clocks to determine the happened-before relation of two events?
    Are there any limitations or additional conditions to be fulfilled to make it possible?
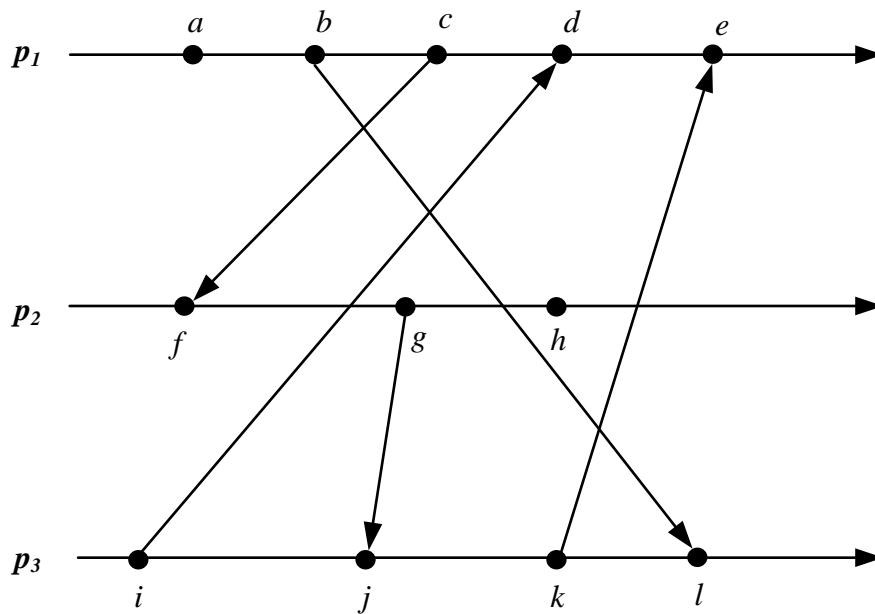

Figure 2.

b) Assign vector clocks to the events in the process diagram in Figure 2.

c) Find at least one event that has 5 happened-before events.

d) List all events that happened-before event "l".

CONTINUED

Name_____   Student ID: _____

Question 3: Clock synchronization.   **10 marks (3/4/3)**

a) A client attempts to synchronize with time server. It sends simultaneously 4 request messages and records the round-trip times and timestamps returned by the server in the table below.

	Round-trip (ms)	Time (hr:min:sec.msec)
1	14	08:17:36.526
2	20	08:17:36.525
3	15	08:17:36.524
4	22	08:17:36.523

Which of these times should it use to set its clock? To what time should it set it? Estimate the accuracy of the setting with respect to the server's clock. Provide the full calculation.

b) A computer clock is reading 14:46:32.0 (hr:min:sec) when it is discovered to be 3 seconds fast. Would you try to set it back to the right time at that point? Why? And, if yes, how?

c) If clocks C1...C4 are externally synchronized with bound 2D, does it mean that they are internally synchronized with bound 4D? Why?

Name_____   Student ID: _____

Question 4 and 5: Engineering with IEC 61499 Function Blocks

INFORMATION for Question 4 and 5

Consider a chemical tank plant as illustrated in Figure 3 below. The plant has the following sensors and actuators:
- MaxLevel, HighLevel, LowLevel, MinLevel, corresponding to four level sensors in descending order from the highest to the lowest level. Outputs high if they get submerged in the liquid, otherwise it outputs low.
- Three temperature sensors MaxTemp, MidTemp, and MinTemp in descending order from highest to lowest temperature level.
- A chemical gas sensor GasSensor (with binary outputs) outside of the tank. It outputs high if it detects the presence of the gas, otherwise it outputs low.
- One heater Heat (binary output).
- Two liquid inlets FastInlet and SlowInlet, and one outlet. The outlet is connected to the next processing station to supply liquid from this tank.
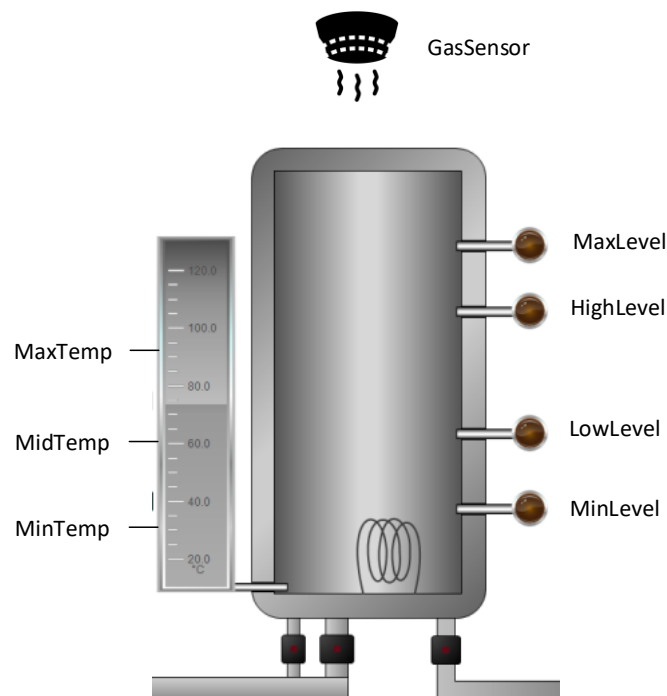

Figure 1. Illustration of the Plant.

The production should satisfy the following requirements below:

1. The temperature of the liquid must be kept between MaxTemp and MidTemp level (it should alternate and reach those two levels).
2. The liquid in the tank should be transferred to the next processing station when the liquid's temperature is above MidTemp.

3. The liquid level should be maintained in between MaxLevel and MinLevel (it should alternate and reach those two levels).
4. When the liquid level is between MaxLevel and LowLevel, the rate of change of liquid level (whether the level is increasing or decreasing) should be higher than when the liquid level is not between MaxLevel and LowLevel.
5. The liquid emits a dangerous gas which can be detected by the GasSensor. If the tank is somehow leaking such gas at any point in time, all liquid should be taken out from the tank and no more heating process should occur. Upon no detection of the gas by GasSensor, the plant should operate back normally.

Some important points that **must be taken into account**:
*   Use the state-based approach.
*   The initial condition: Some liquid is present in the tank. The liquid level is at the MinLevel and the temperature is below MinTemp.
*   Some of the plant's physical characteristics:
    o   There is heat dissipation that if the heater is off, the liquid's temperature will drop. The heater's heating capability is higher than the heat dissipation.
    o   Heater, inlets, and outlet have mechanical components, such that these actuators must not be alternatingly turned on and off very quickly to avoid mechanical wear.
    o   Note that, with regards to their flow rates, slow inlet < outlet < fast inlet. In other words, the flow rate of the FastInlet is higher than the SlowInlet. The flow rate of the Outlet is higher than the SlowInlet, but lower than the FastInlet. The sum of the flow rate of both FastInlet and SlowInlet is higher than the Outlet's flow rate.

Name_____   Student ID: _____

Question 4:   **5 marks**

Based on the specifications, **develop** a control application as a network of IEC 61499 basic function blocks with inputs and outputs based on the plant's specifications above.

- A template of the application composed of two controller function blocks is provided in Figure 4. The template is incomplete, so you need to **connect** the input and output interfaces of the function blocks to the plant connectors ("FROM THE PLANT" and "TO THE PLANT"). **SnsEvt** corresponds to the event coming from the plant, which is generated in association to any changes of the value of any sensors, while **ControlEvt** refers to the event going to the plant. **E_MERGE** refers to a function block that merges two events. **PLCInit** generates the event which triggers the initialization of the function blocks.

- Note that both controller function blocks may or may not have missing input or output interface(s). If you think there are missing interfaces, then insert such interfaces on the controller function blocks and also connect all interfaces to their respective plant connectors. You may put your modifications directly on the provided drawings, or you may draw the function blocks on the answer text box.
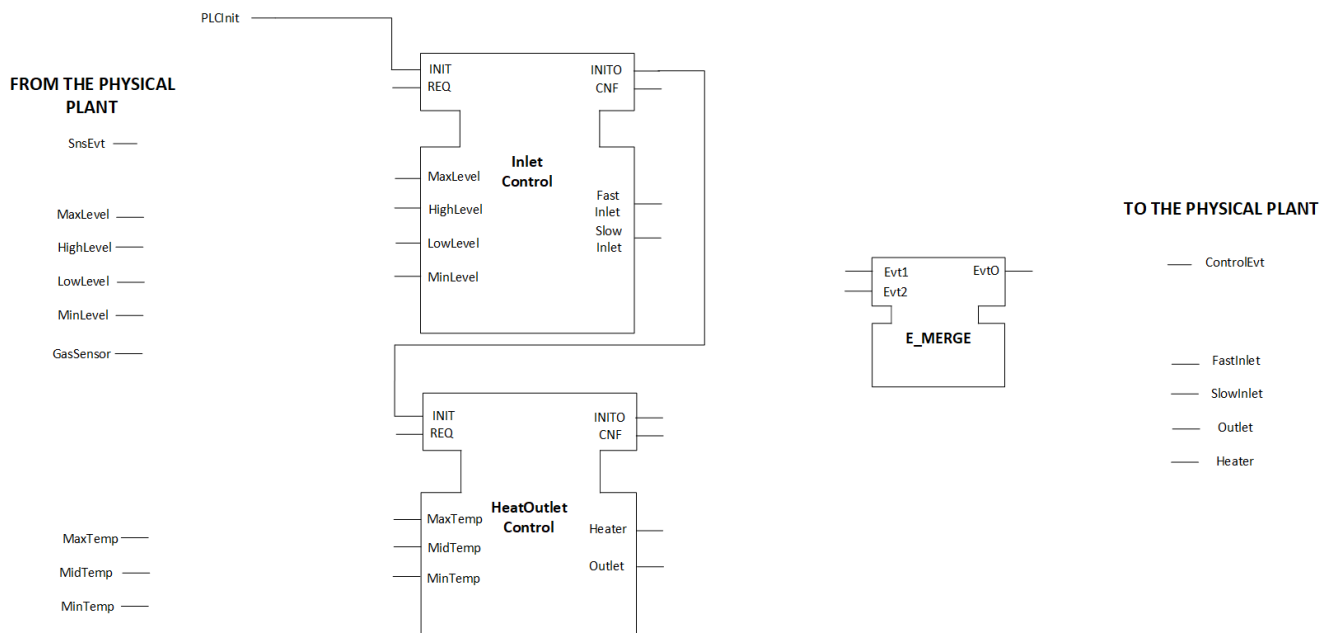
Figure 2. Controller Function Blocks.

Name_____   Student ID: _____

Name_____ Student ID: _____

Question 5: **15 marks**

Develop the **COMPLETE** Execution Control Chart / ECC of the controller IEC 61499 function blocks. Templates of the ECC of both controller function blocks are provided in Figures 5 and 6, along with several algorithms.

Note, that the templates are incomplete. They lack state transition conditions, names of the states and their algorithms, and the event output. Some state(s) may also be missing, so you may need to add those if you think this is the case. Then, explain and **describe** the states that you defined in the ECC!
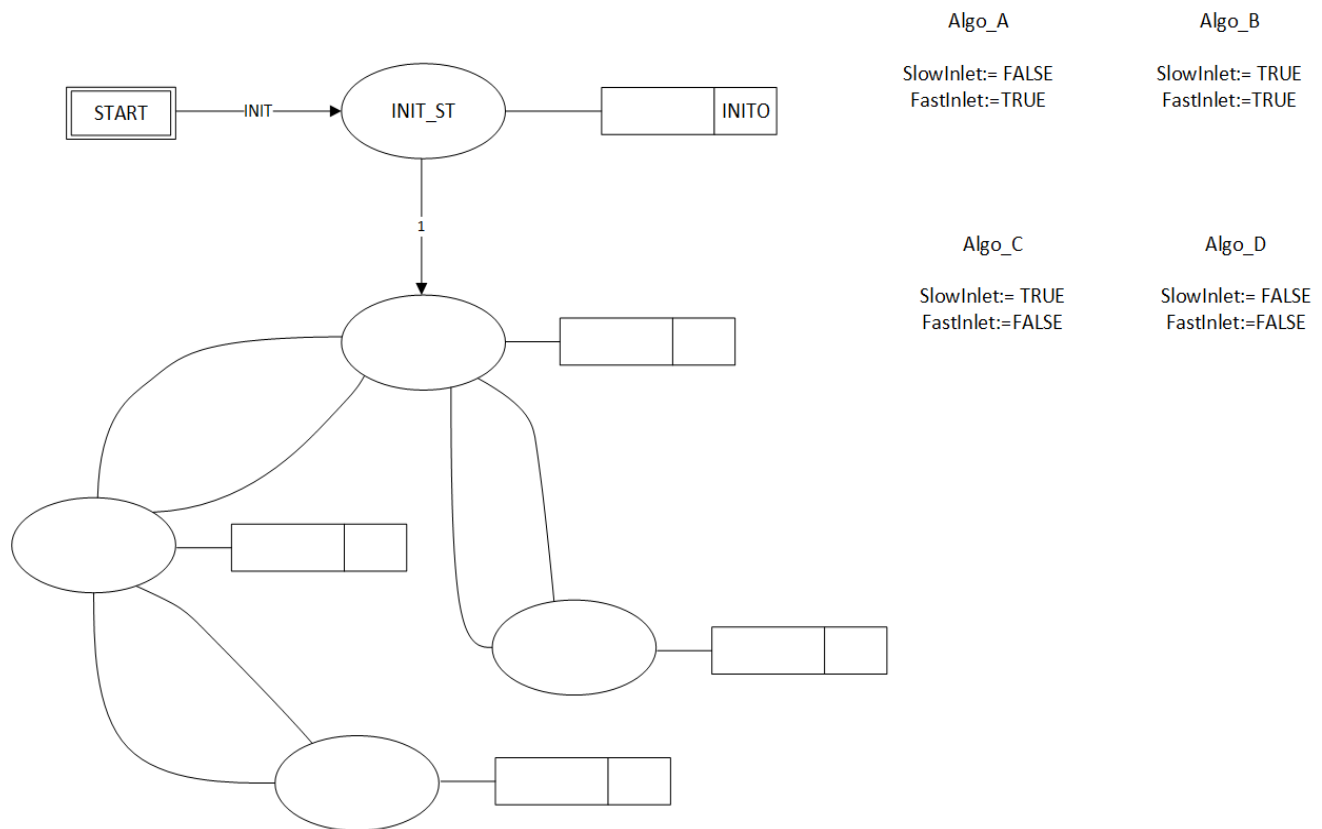

Algo_A

SlowInlet:= FALSE
FastInlet:=TRUE

Algo_B

SlowInlet:= TRUE
FastInlet:=TRUE

Algo_C

SlowInlet:= TRUE
FastInlet:=FALSE

Algo_D

SlowInlet:= FALSE
FastInlet:=FALSE

Figure 3. ECC of InletControl Function Block.

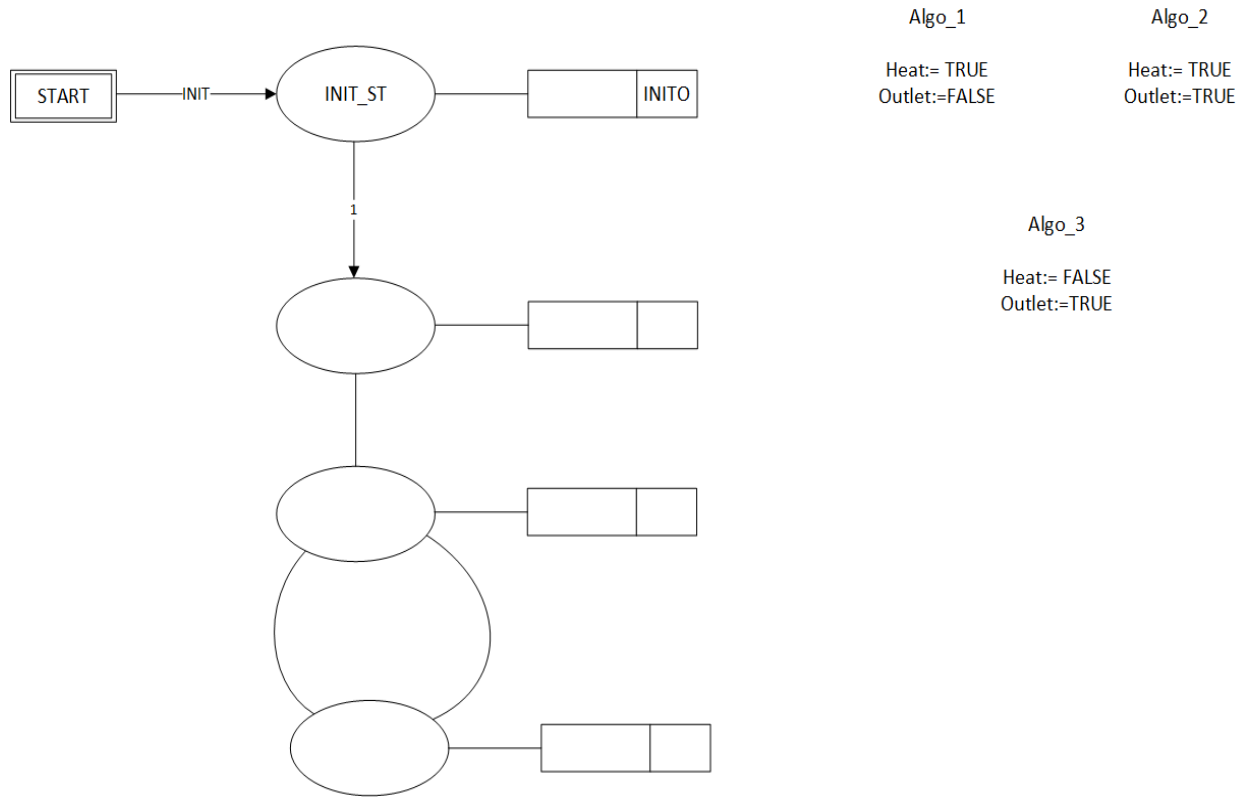Name_____   Student ID: _____

Figure 4. ECC of HeatOutletControl Function Block.

Name_____   Student ID: _____

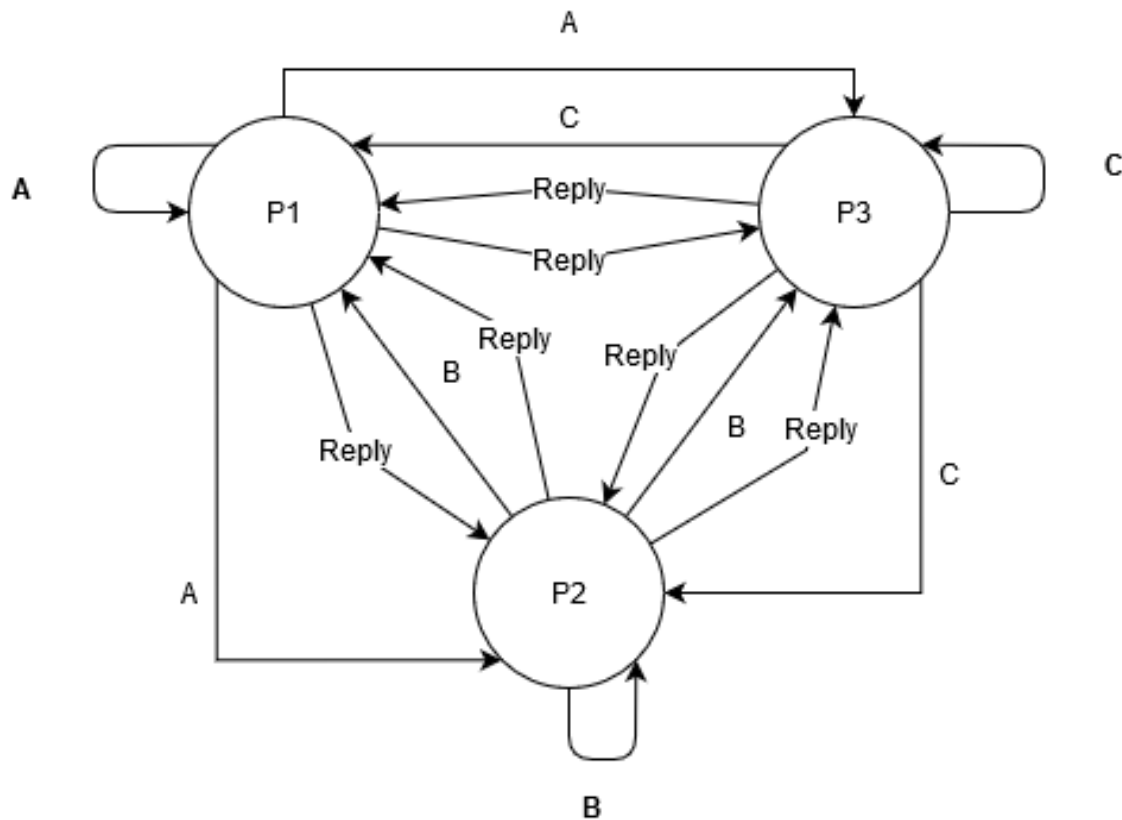Name_____   Student ID: _____

Question 6 : Mutual exclusion.   **10 marks (5/5)**

Given the multicast synchronization system in Figure 7. Imagine a situation in which processes P1, P2 and P3 are requesting simultaneously to access the Critical Section (CS).

Figure 7. Multi-thread system

a) Assume that this system is being simulated in a computer, so all processes are executed by a single device in separate threads. Assign arbitrary values to the logical clock timestamps of the request messages A, B and C, so the CS access is granted to Pn.

		Timestamp		
		A	B	C
CS granted to	P1			
	P2			
	P3			

b) The same situation was tested in a different testbed. Now, each process runs in a separated device with internal clock synchronization (bound D=5ms). The new implementation is interconnected through an asymmetrical wireless network. The average communication delay values are 5 ms for download, while for upload from P2 and P3 takes 18 ms and 15 ms for P1. No logical clocks are implemented in this test, instead, the real-time clock timestamp is used to evaluate mutual exclusion in multicast synchronization. Assume time stamps A, B and C are 06/12/2020 10:00:00.000 + A (B, C respectively) (in ms) from your previous answer in question a). For instance, if your answer was A = 5 for P1, then the timestamp is 06/12/2020 10:00:00.005.

Could there be a situation where the algorithm based on the real-time timestamps could break the ME3 property? If yes, present an example of such a scenario with timestamps of the messages involved.