HW & SW Codesign Academy

Workshop #1 : Accenture

Team 1

Introduction and Outline

Goal 1

Design and develop a **distributed solution** to reduce lines downtime due to temperatures exceeding predefined thresholds.

Goal 2

Identify and develop an **adaptive solution** to monitor plant historical data, to forecast the optimal temperature thresholds according to site location and to adapt the plant configuration.

Goal 1: overview

Task:

Design and develop a **distributed solution** to reduce lines downtime due to temperatures exceeding predefined thresholds.

(1)

We have a plant with many machines, each one endowed with a temperature sensor to alert when that line is in a critical condition.

Materials:

Arduino MKR WiFi 1010

Arduino Nano RP2040

Th1: Line 1 temperature threshold

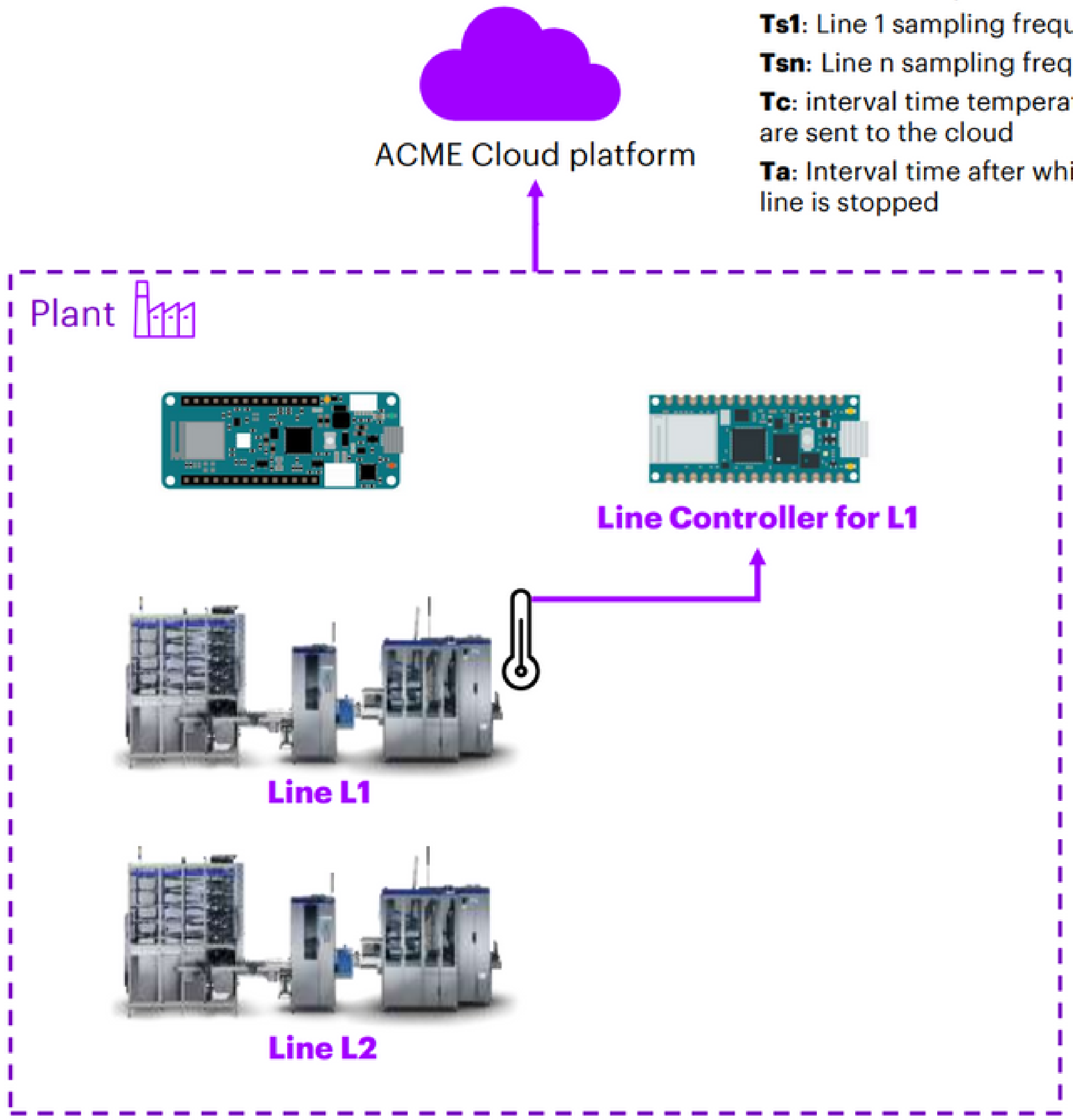
Thn: Line n temperature threshold

Ts1: Line 1 sampling frequency

Tsn: Line n sampling frequency

Tc: interval time temperature data are sent to the cloud

Ta: Interval time after which the line is stopped



Goal 1: physical communication

Communication with Arduino's : UDP vs UART

UART

Pros
Simple and straightforward to implement.
Low power consumption compared to WiFi.
No network setup or infrastructure required.
Cons
Range is limited by the wire length.
Not suitable for long-distance communication.
Scaling up requires additional wiring and can get messy.

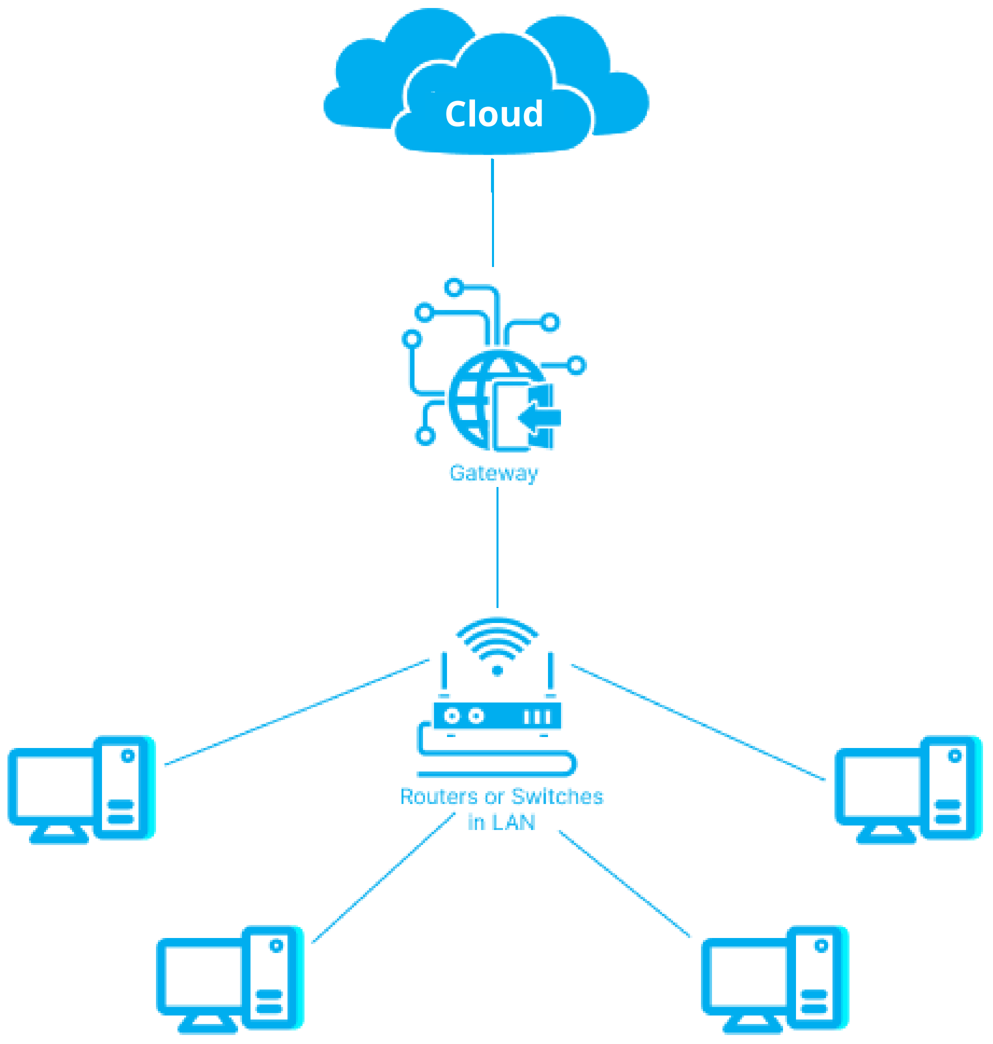
UDP (WiFi)

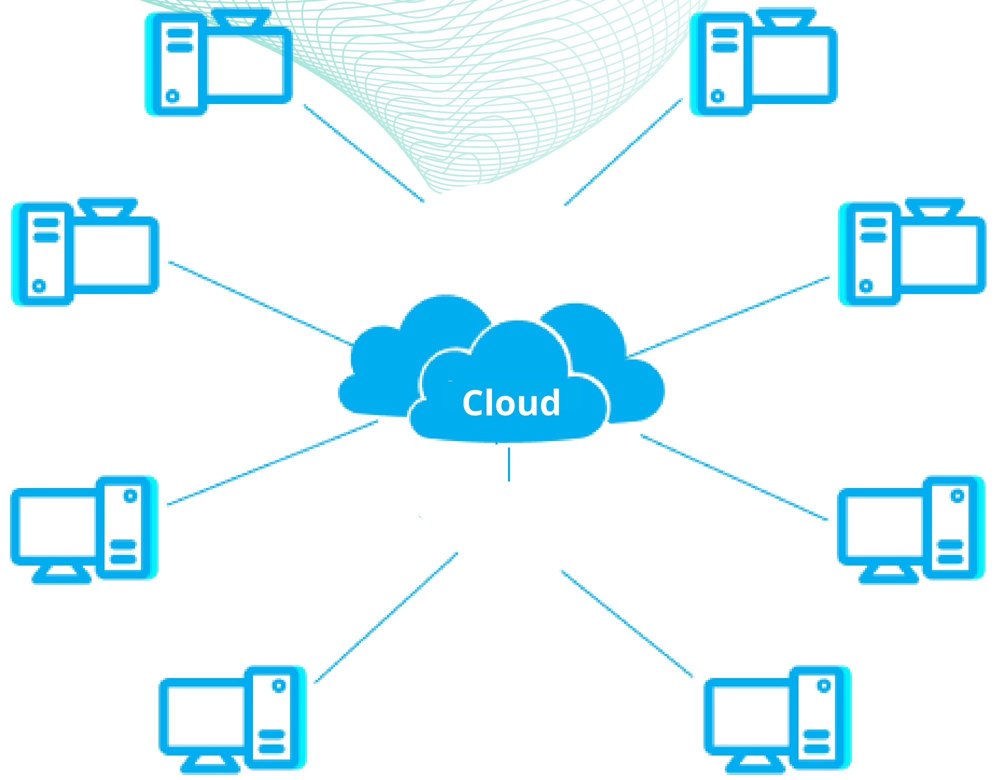
Pros
Can communicate over longer distances without additional wiring.
Allows for networked communication and Internet connectivity.
More flexible and scalable, especially for larger setups.
Broadcasting is possible, simplifying communication with multiple devices.
Cons
More complex setup and potential security concerns.
Higher power consumption compared to wired methods.

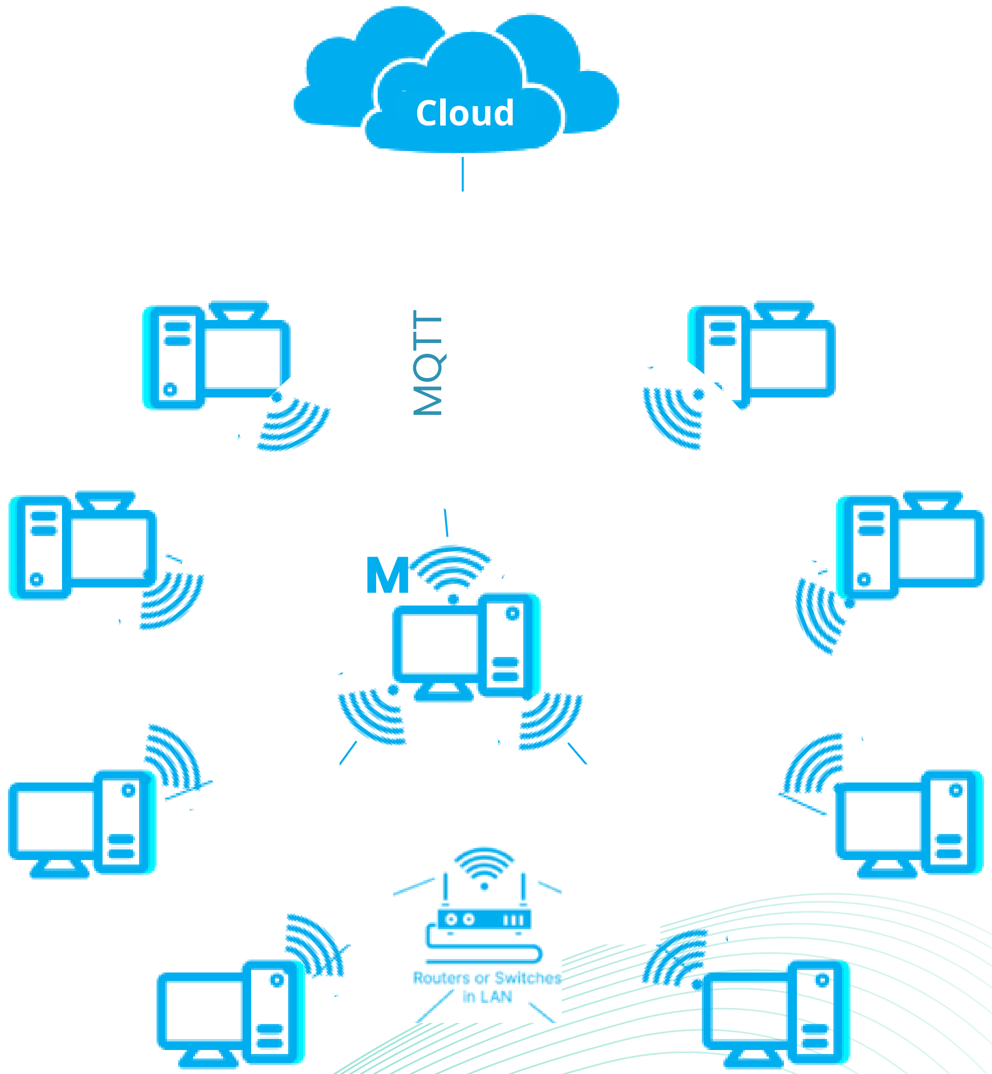
FACTORY TEMPCONTROL

Goal 1: plant network

Centralized vs decentralized: a third way, switching Master



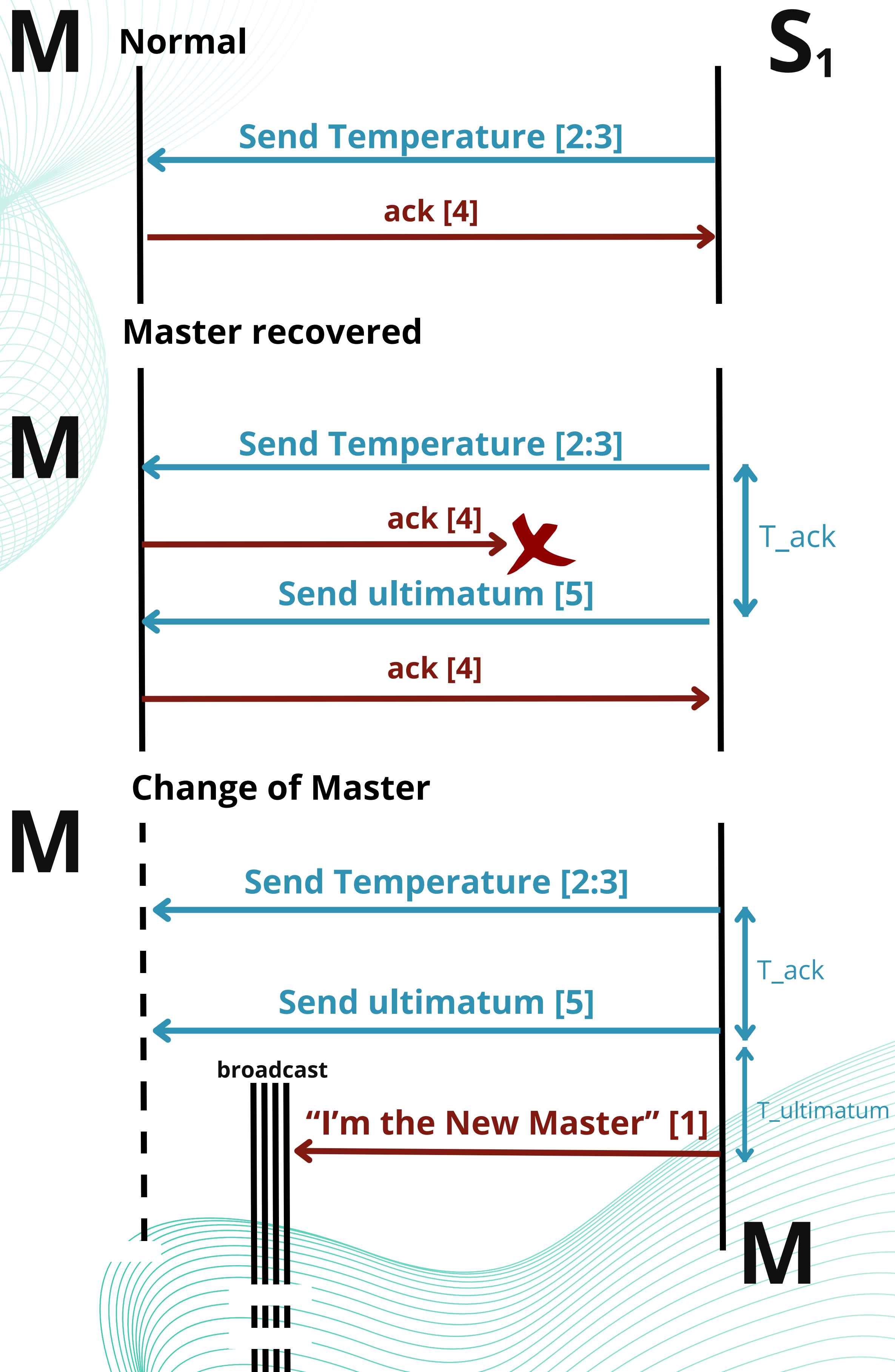




Goal 1: Switching master implementation

operation code		Direction M/S
0	"I'm alive "	everyone
1	"I'm the new Master"	M->broadcast
2	T<Threshold	S->M
3	T>Threshold	S->M
4	Temperature correctly received (ACK)	M->S

operation code		Direction M/S
5	Ultimatum Message	S->M
6	Go to Attention State	M->broadcast
7	"You Must stop"	M->S
8	Go back to Normal State	M->broadcast
-	-	-

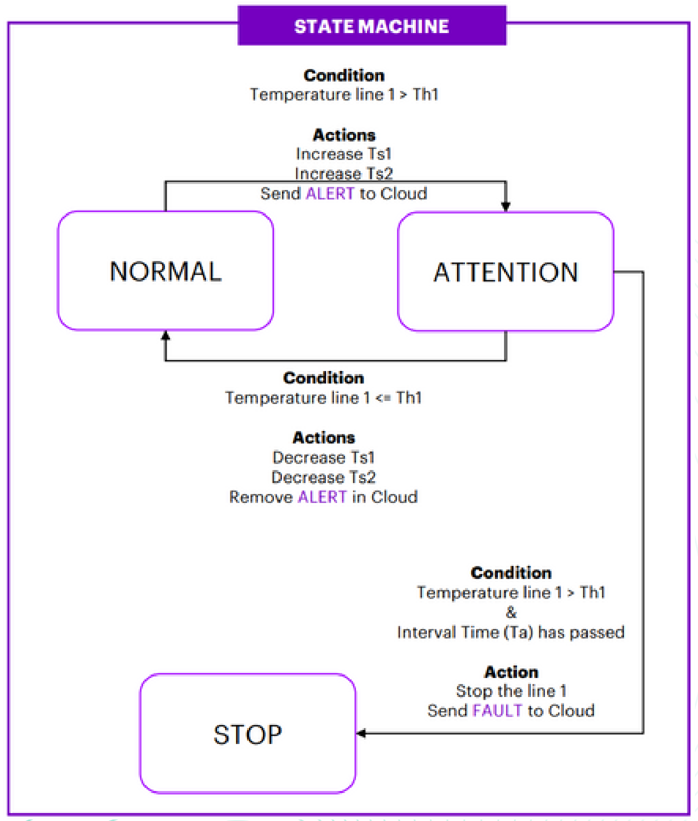


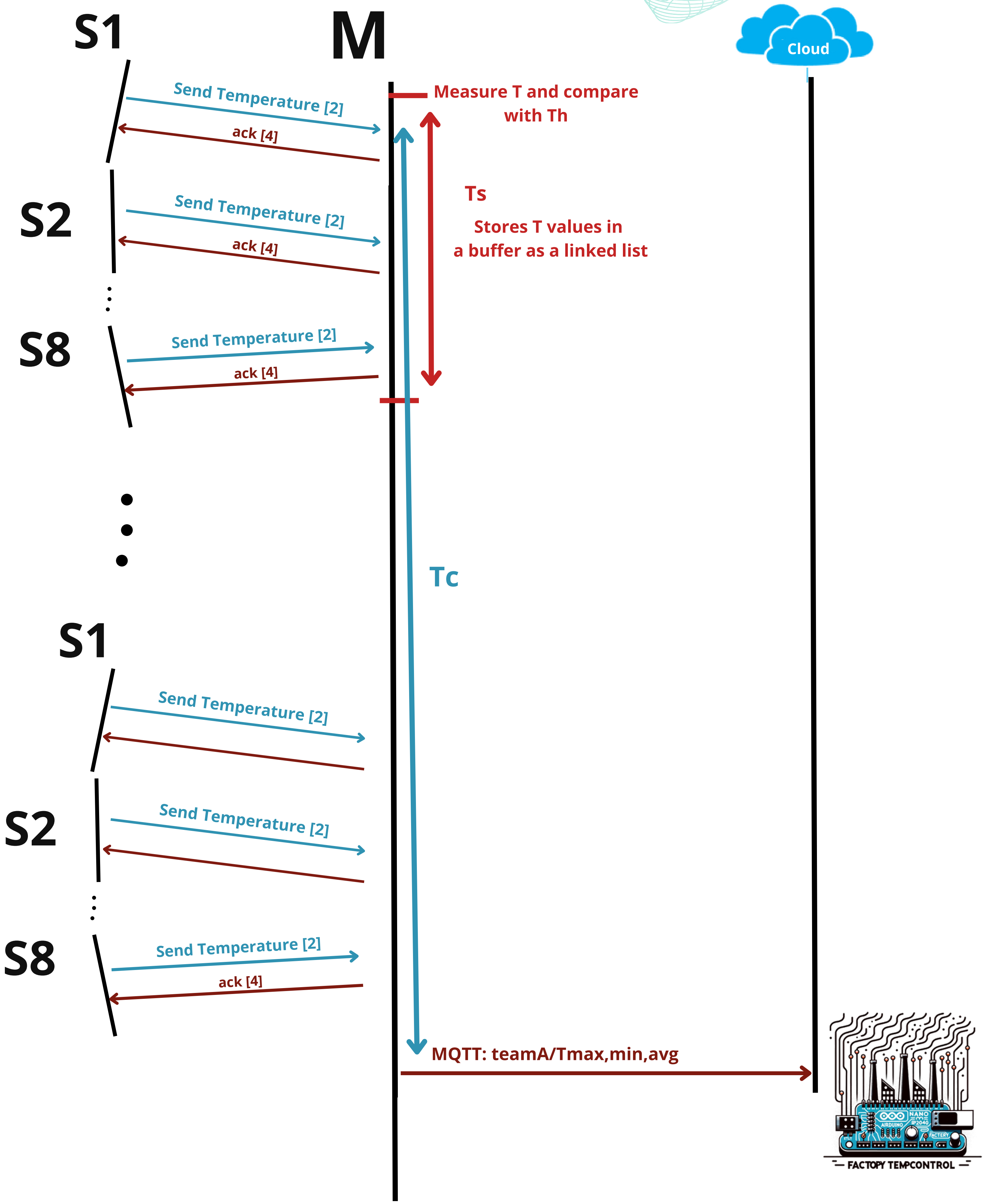
Goal 1: Master to Cloud implementation

MQTT communication: Normal mode

operation code		Direction M/S
0	"I'm alive "	everyone
1	"I'm the new Master"	M->broadcast
2	T<Threshold	S->M
3	T>Threshold	S->M
4	Temperature correctly received (ACK)	M->S

operation code		Direction M/S
5	Ultimatum Message	S->M
6	Go to Attention State	M->broadcast
7	"You Must stop"	M->S
8	Go back to Normal State	M->broadcast
-	-	-



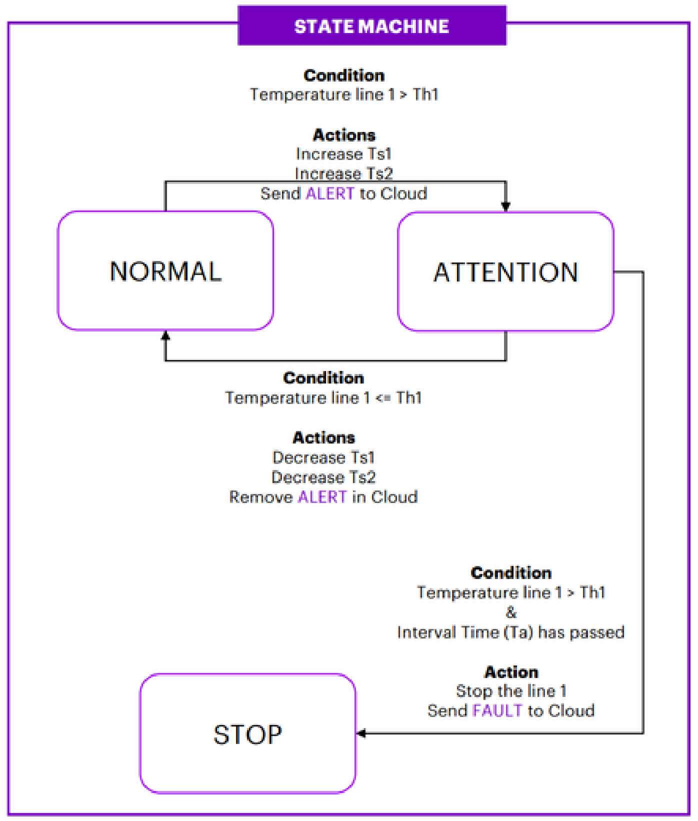


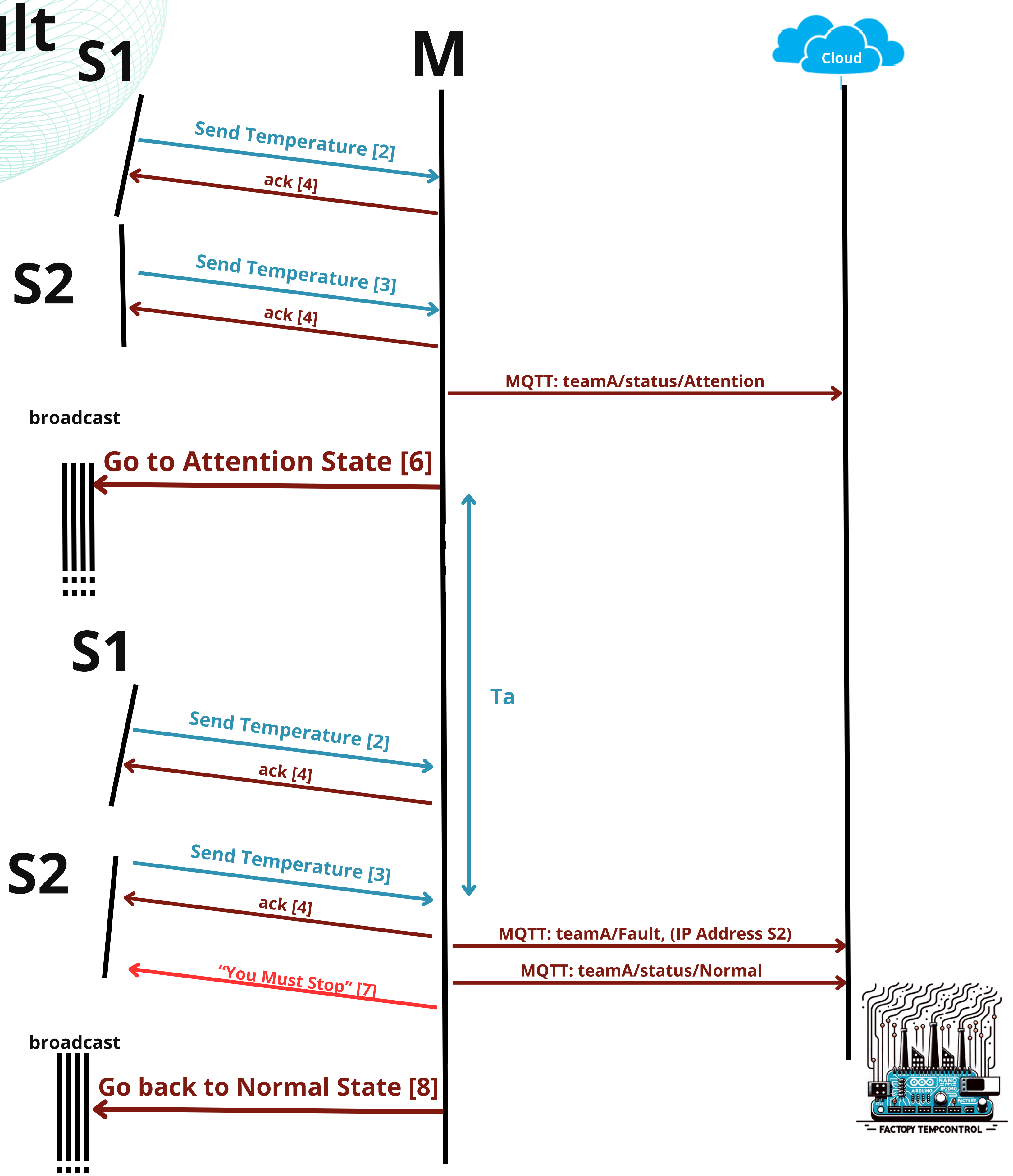
Goal 1: Master to Cloud implementation

MQTT communication: Send Alert, Fault

operation code		Direction M/S
0	“I’m alive “	everyone
1	“I’m the new Master”	M->broadcast
2	T<Threshold	S->M
3	T>Threshold	S->M
4	Temperature correctly received (ACK)	M->S

operation code		Direction M/S
5	Ultimatum Message	S->M
6	Go to Attention State	M->broadcast
7	“You Must stop”	M->S
8	Go back to Normal State	M->broadcast
-	-	-



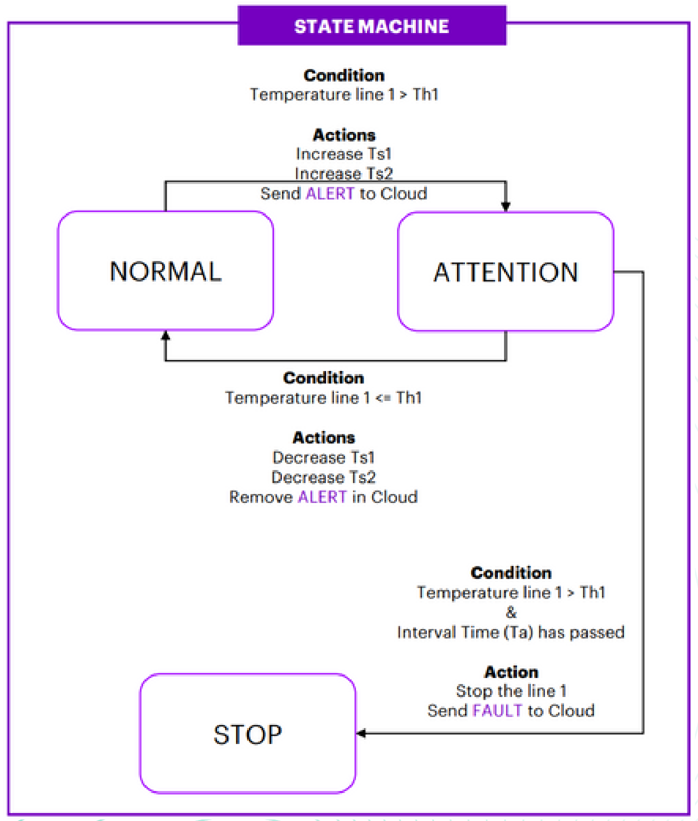


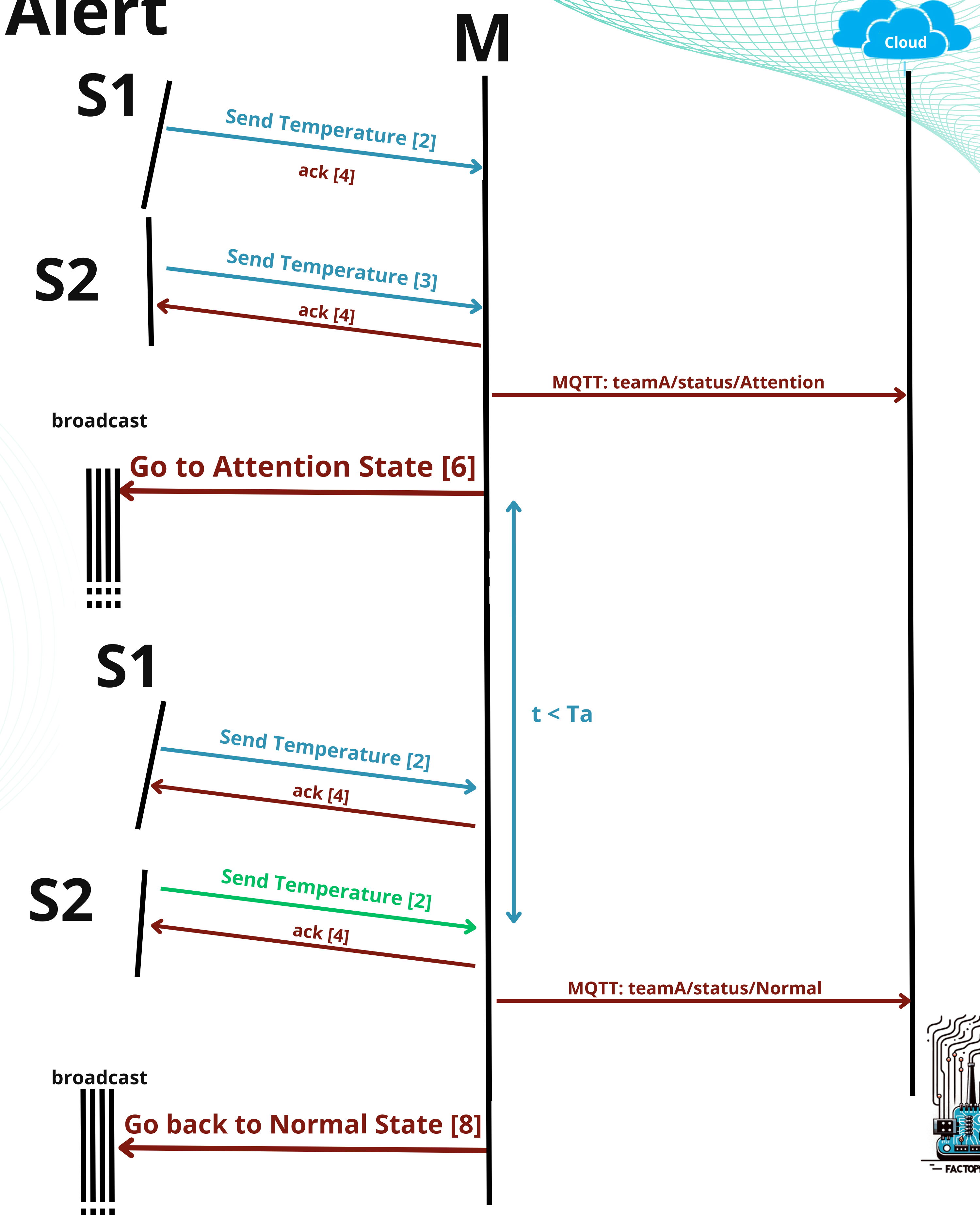
Goal 1: Master to Cloud implementation

MQTT communication: Send/Remove Alert

operation code		Direction M/S
0	“I’m alive “	everyone
1	“I’m the new Master”	M->broadcast
2	T<Threshold	S->M
3	T>Threshold	S->M
4	Temperature correctly received (ACK)	M->S

operation code		Direction M/S
5	Ultimatum Message	S->M
6	Go to Attention State	M->broadcast
7	“You Must stop”	M->S
8	Go back to Normal State	M->broadcast
-	-	-





Goal 1: Results

normal state

```
02:53:07.638 -> Connected to WiFi
02:53:08.833 ->
02:53:08.833 -> Connected to broker!
02:53:08.833 -> MQTT connected!
02:53:08.833 -> Node started. IP address: 192.168.1.15
02:53:09.253 -> I'm not master... threshold set to: 38
02:53:18.975 -> Temp sent to master...
02:53:20.201 -> Received ack
02:53:24.787 -> Received NORMAL message. Returning to normal phase.
02:53:29.047 -> Temp sent to master...
02:53:39.092 -> Temp sent to master...
02:53:39.157 -> Sent ultimatum Message...
02:53:49.230 -> Temp sent to master...
02:53:49.294 -> No UltimatumACK received. I'm the master now.
02:53:49.681 -> Subscribed to teamA/threshold
02:53:59.686 -> Temperature Readings (threshold = 38):
02:53:59.686 -> Node: 192.168.1.15 - Temperature: 30
02:53:59.686 -> Max Temperature: 30
02:53:59.686 -> Min Temperature: 30
02:53:59.686 -> Average Temperature: 30.00
02:53:59.686 -> Received threshold value is the same as the old one.
02:54:59.705 -> Temperature Readings (threshold = 38):
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 29
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 29
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 30
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 29
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 30
02:54:59.705 -> Node: 192.168.1.15 - Temperature: 29
02:54:59.705 -> Max Temperature: 30
02:54:59.705 -> Min Temperature: 29
02:54:59.705 -> Average Temperature: 29.33
```

attention to stop state

```
02:55:51.679 -> Connected to WiFi
02:55:52.875 ->
02:55:52.875 -> Connected to broker!
02:55:52.906 -> MQTT connected!
02:55:52.906 -> Node started. IP address: 192.168.1.14
02:55:53.293 -> I'm not master... threshold set to: 38
02:55:59.942 -> I'm not master... threshold set to: 40
02:56:03.008 -> Temp sent to master...
02:56:03.945 -> ATTENTION PHASE started. Adjusted sampling period.
02:56:13.049 -> Temp sent to master...
02:56:13.114 -> Sent ultimatum Message...
02:56:13.468 -> Received ack
02:56:13.501 -> Received ack
02:56:18.150 -> Temp sent to master...
02:56:18.697 -> Received ack
02:56:23.217 -> Temp sent to master...
02:56:23.638 -> Received ack
02:56:24.898 -> Received STOP message. This node will now be killed.
02:56:24.898 -> Killed....
02:56:28.221 -> Killed....
```

Slave

```
teamA/max : msg.payload : number
38
10/18/2023, 12:06:09 PM   node: debug 2
teamA/min : msg.payload : number
28
10/18/2023, 12:06:09 PM   node: debug 2
teamA/avg : msg.payload : number
31.83
10/18/2023, 12:06:51 PM   node: debug 2
teamA/status : msg.payload : string[9]
"ATTENTION"
10/18/2023, 12:07:01 PM   node: debug 2
teamA/status : msg.payload : string[6]
"NORMAL"
10/18/2023, 12:07:14 PM   node: debug 2
teamA/max : msg.payload : number
39
10/18/2023, 12:07:14 PM   node: debug 2
teamA/min : msg.payload : number
30
10/18/2023, 12:07:14 PM   node: debug 2
teamA/avg : msg.payload : number
34
10/18/2023, 12:07:26 PM   node: debug 2
teamA/status : msg.payload : string[9]
"ATTENTION"
10/18/2023, 12:07:49 PM   node: debug 2
teamA/fault : msg.payload : string[12]
"192.168.1.10"
10/18/2023, 12:07:49 PM   node: debug 2
teamA/status : msg.payload : string[6]
"NORMAL"
```

Cloud

Goal 1: Results

Master

```
02:57:18.935 -> Connected to WiFi
02:57:19.191 ->
02:57:19.191 -> Connected to broker!
02:57:19.224 -> MQTT connected!
02:57:19.224 -> Node started. IP address: 192.168.1.14
02:57:30.161 -> I'm the master
02:57:30.258 -> Subscribed to teamA/threshold
02:57:30.258 -> Received threshold value is the same as the old one.
02:57:31.550 -> ACK SENT
02:57:41.076 -> ACK SENT
02:57:51.211 -> ACK SENT
02:58:01.356 -> ACK SENT
02:58:09.334 -> 192.168.1.14 node has a value above the threshold.
02:58:11.498 -> ACK SENT
02:58:16.408 -> ACK SENT
02:58:19.345 -> Temperature Readings (threshold = 40):
02:58:19.345 -> Node: 192.168.1.14 - Temperature: 41
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Node: 192.168.1.14 - Temperature: 41
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Node: 192.168.1.14 - Temperature: 40
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Node: 192.168.1.14 - Temperature: 40
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Node: 192.168.1.14 - Temperature: 40
02:58:19.345 -> Node: 192.168.1.15 - Temperature: 30
02:58:19.345 -> Max Temperature: 41
02:58:19.345 -> Min Temperature: 30
02:58:19.345 -> Average Temperature: 34.73
02:58:21.608 -> ACK SENT
02:58:26.549 -> ACK SENT
02:58:29.358 -> 192.168.1.14 node that was over threshold. Killed.
02:58:29.358 -> 192.168.1.14 node that was over threshold. Solved situation.
02:58:29.358 -> Killed....
02:58:39.401 -> Killed....
```

Master election

```
03:05:18.977 -> Temp sent to master...
03:05:19.364 -> Received ack
03:05:29.046 -> Temp sent to master...
03:05:29.498 -> Received ack
03:05:39.122 -> Temp sent to master...
03:05:39.638 -> Received ack
03:05:49.187 -> Temp sent to master...
03:05:49.767 -> Received ack
03:05:59.218 -> Temp sent to master...
03:05:59.605 -> Received ack
03:06:09.286 -> Temp sent to master...
03:06:09.738 -> Received ack
03:06:10.350 -> ATTENTION PHASE started. Adjusted sampling period.
03:06:19.353 -> Temp sent to master...
03:06:19.867 -> Received ack
03:06:24.414 -> Temp sent to master...
03:06:24.769 -> Received ack
03:06:29.477 -> Temp sent to master...
03:06:30.026 -> Received ack
03:06:30.640 -> Received NORMAL message. Returning to normal phase.
03:06:34.541 -> Temp sent to master...
03:06:44.607 -> Temp sent to master...
03:06:44.672 -> Sent ultimatum Message...
03:06:54.739 -> Temp sent to master...
03:06:54.804 -> No UltimatumACK received. I'm the master now.
03:06:54.804 -> MQTT disconnected. Attempting to reconnect...
03:06:54.804 -> WiFiClient disconnected. Attempting to reconnect...
03:06:54.933 -> Broker reconnected!
03:06:54.933 -> MQTT reconnected!
03:06:54.933 -> Subscribed to teamA/threshold
03:07:04.934 -> Temperature Readings (threshold = 40):
03:07:04.934 -> Node: 192.168.1.15 - Temperature: 30
03:07:04.934 -> Max Temperature: 30
03:07:04.934 -> Min Temperature: 30
03:07:04.934 -> Average Temperature: 30.00
03:07:04.934 -> Received threshold value is the same as the old one.
03:08:04.948 -> Temperature Readings (threshold = 40):
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 30
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 29
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 30
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 30
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 30
03:08:04.948 -> Node: 192.168.1.15 - Temperature: 30
03:08:04.948 -> Max Temperature: 30
03:08:04.948 -> Min Temperature: 29
03:08:04.948 -> Average Temperature: 29.83
```

Goal 2:

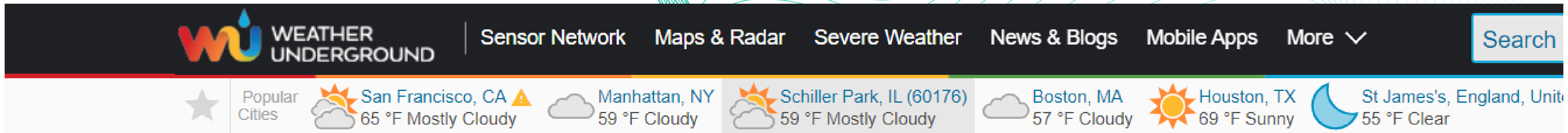
Task:

Identify and develop an **adaptive solution** to monitor plant historical data, to forecast the optimal temperature thresholds according to site location and to adapt the plant configuration.

Steps:

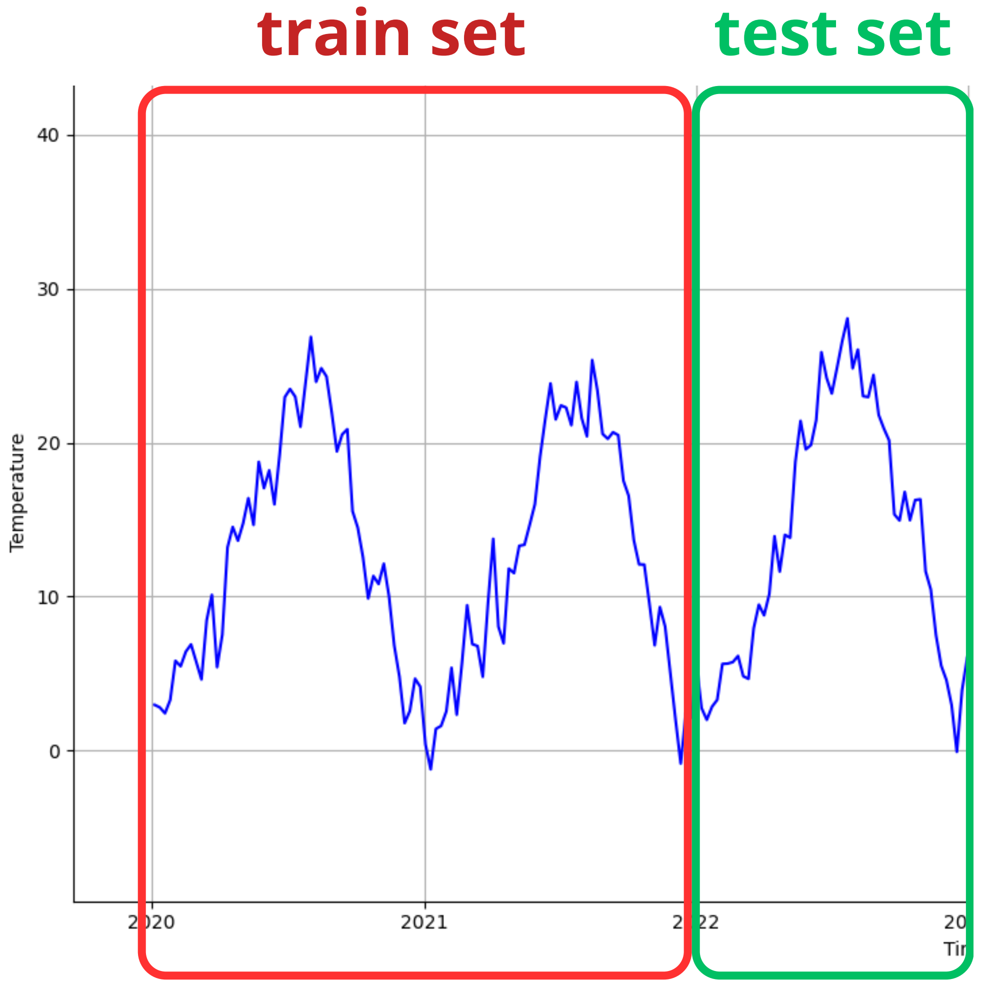
- Acquiring a dataset
- Develop or choose a Timeseries Forecasting model
- Generate a dataset of predicted future temperatures
- Inference distribution and system update

Goal 2: Dataset acquisition

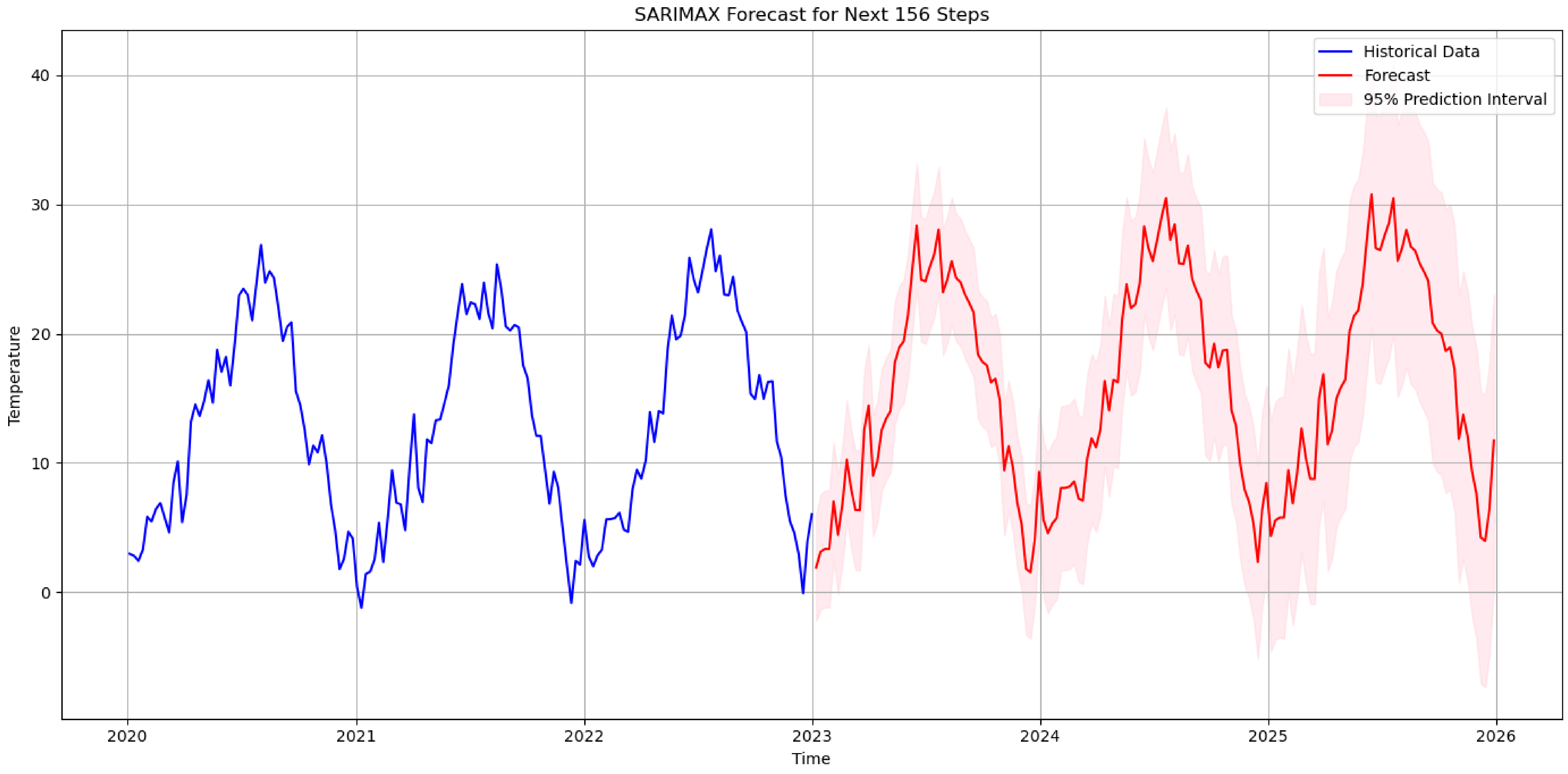


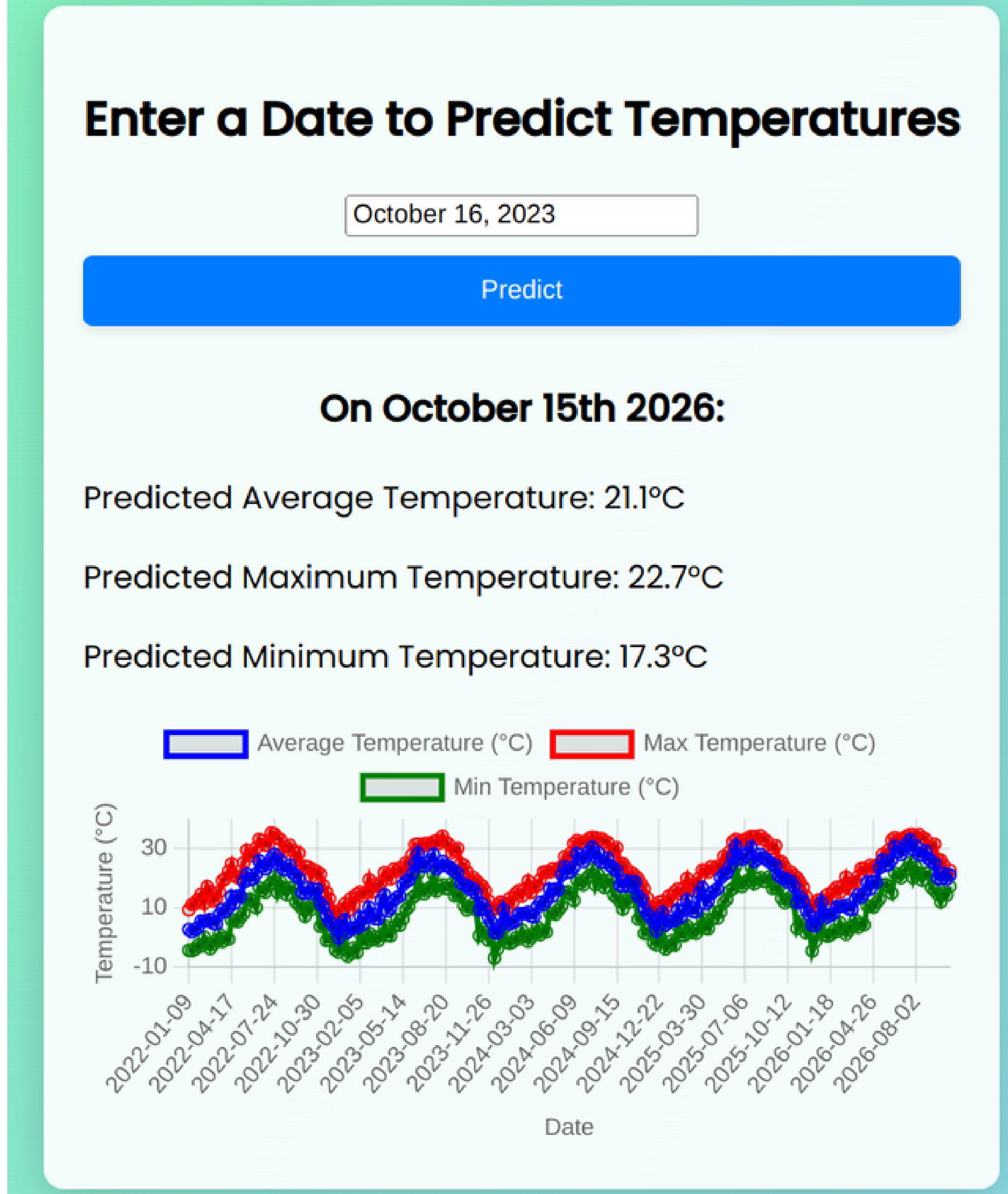
Time	Temperature (°F)		
Feb	Max	Avg	Min
1	54	42.2	30
2	64	47.3	34
3	54	45.6	37
4	54	42.9	36
5	59	43.2	34
6	41	36.5	32
7	63	48.2	32
8	61	44.0	30
9	57	43.8	32
10	54	44.2	37
11	55	44.2	32
12	46	40.8	36
13	48	39.2	28
14	43	38.6	34
15	52	38.9	30

- Acquired temperature history of Turin from Weather Underground website.
- Conversion of the dataset.txt in a .csv file
- Partition in training set and test set



Goal 2: Predict future temperatures





- Developed a Python script that forecasts future temperature values thanks to SARIMA algorithm and the starting dataset.
- Developed an application, based on the script, which visualizes the maximum, minimum and average values predicted until the specified date

Goal 2: System update

```
Connected to WiFi

Connected to broker!
MQTT connected!
Node started. IP address: 192.168.1.6
I'm the master
Subscribed to teamA/threshold
OLD THRESHOLD -> 40 .... NEW THRESHOLD -> 38
```

```
10/18/2023, 1:02:02 PM   node: debug 2
teamA/threshold : msg.payload : number
38
```

- We've implemented a script that takes a new value of treshold based on forecasted data taken from our model and update it
- When a new master is elected, it takes the new value for the treshold as first thing

- If the MQTT broker is down, the treshold value will be the last updated value associated to the threshold