



checkBin

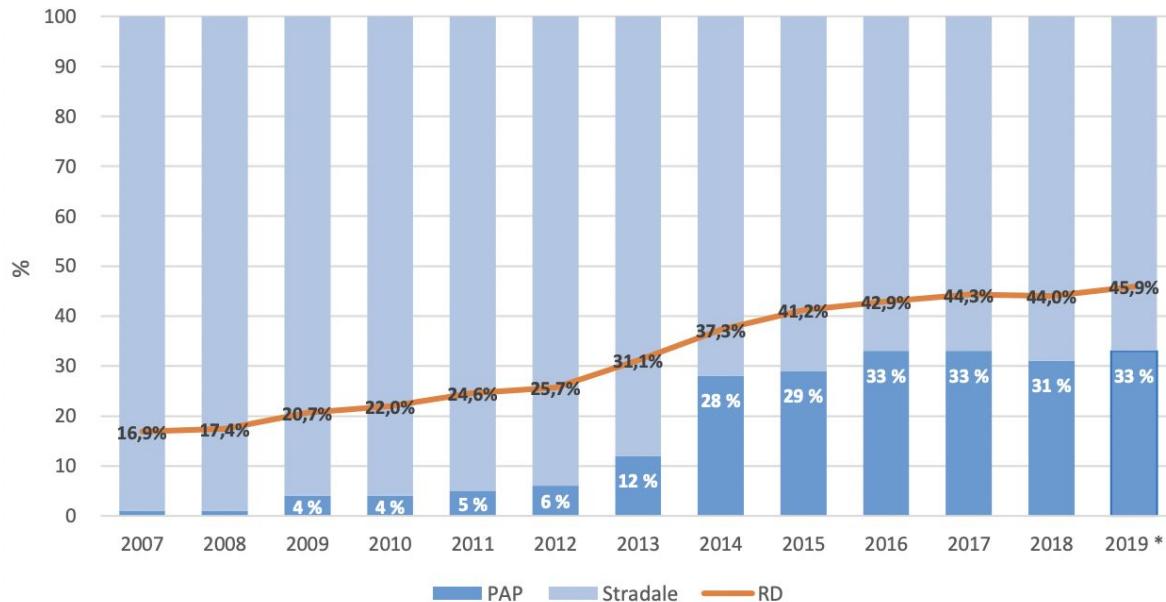
# The Problem



Photos: Corriere della Sera, Repubblica

# Existing approaches

Use of the Waste Management services in Rome



**PAP:** door to door collection

**Stradale:** on street bins collection

**RD:** percentage of recycled waste

# Our Solution

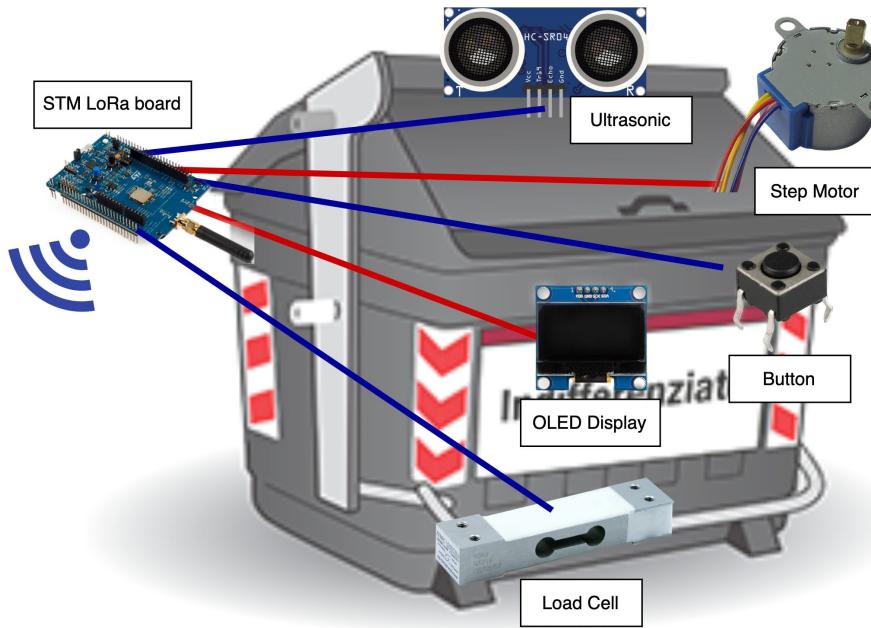


Introduction of smart bins to monitor their fill level and create a collective intelligence of the whole city status

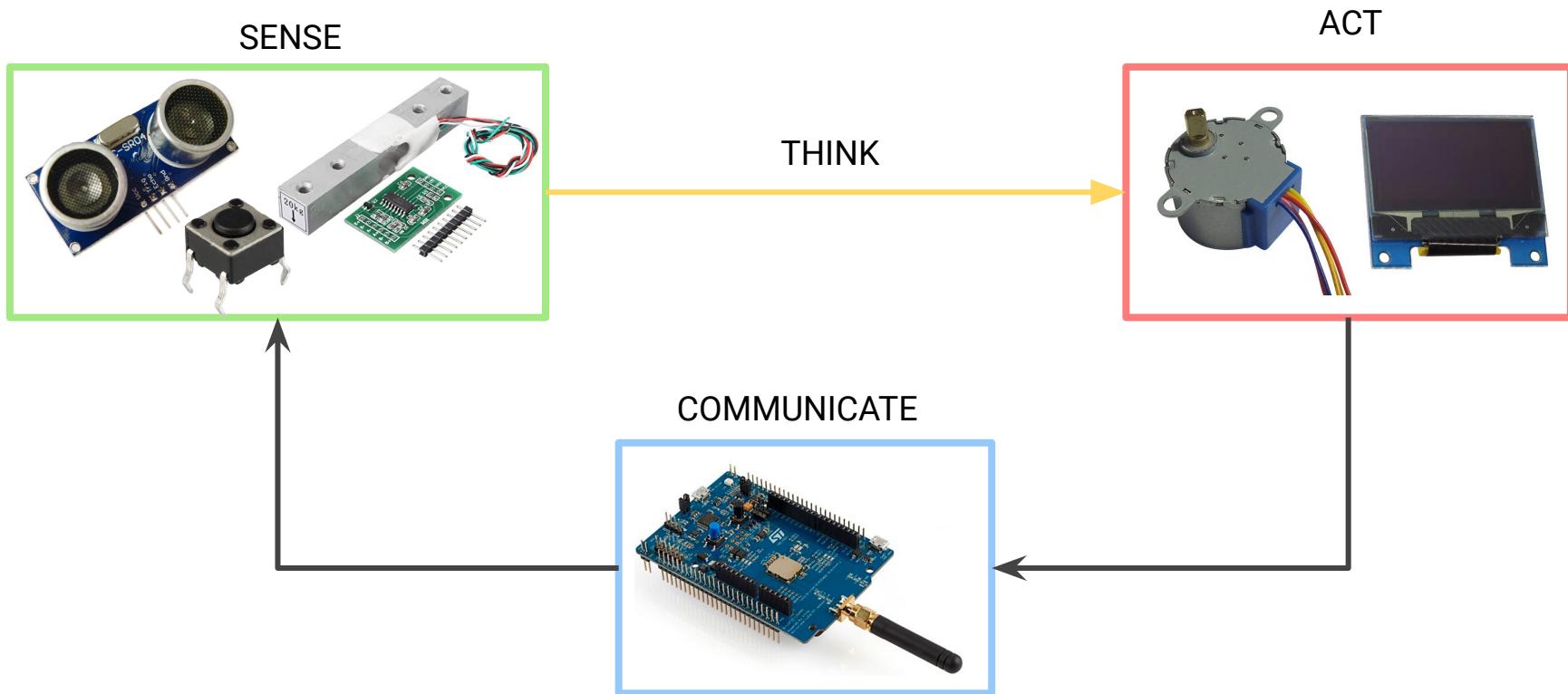
---

# Hardware

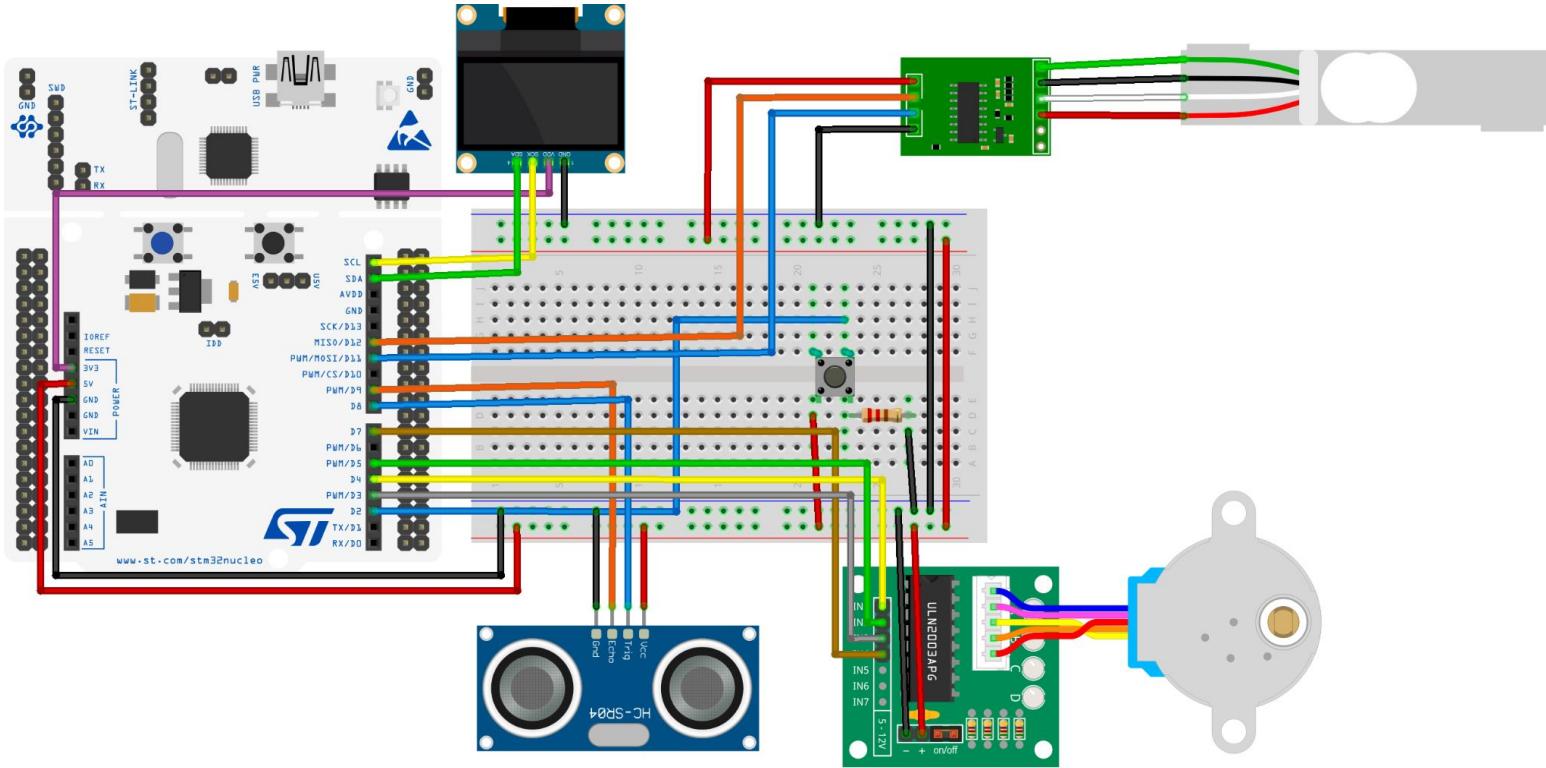
# Main hardware components



# Hardware components



# Wiring diagram



# Prototype

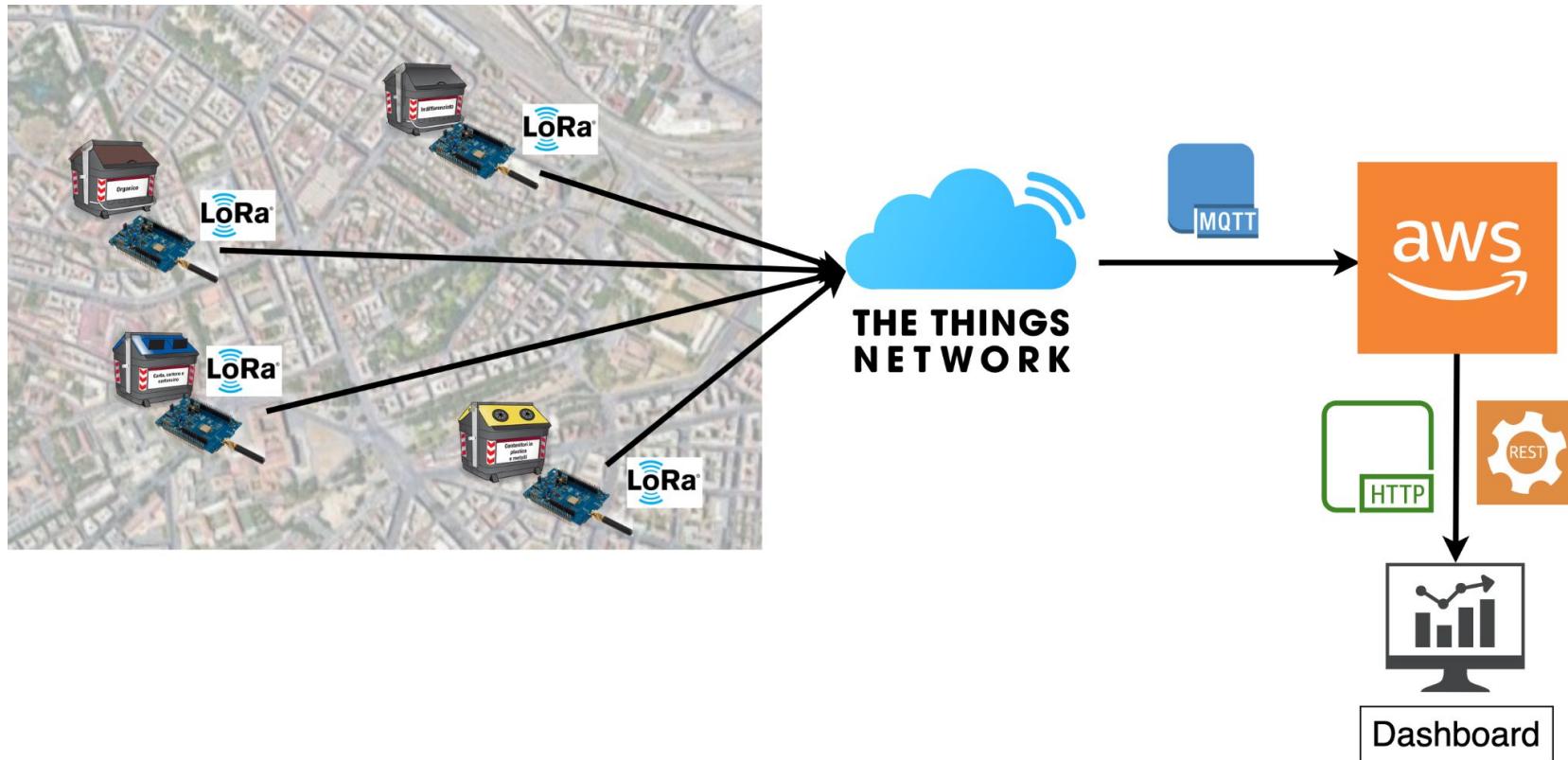


# Prototype

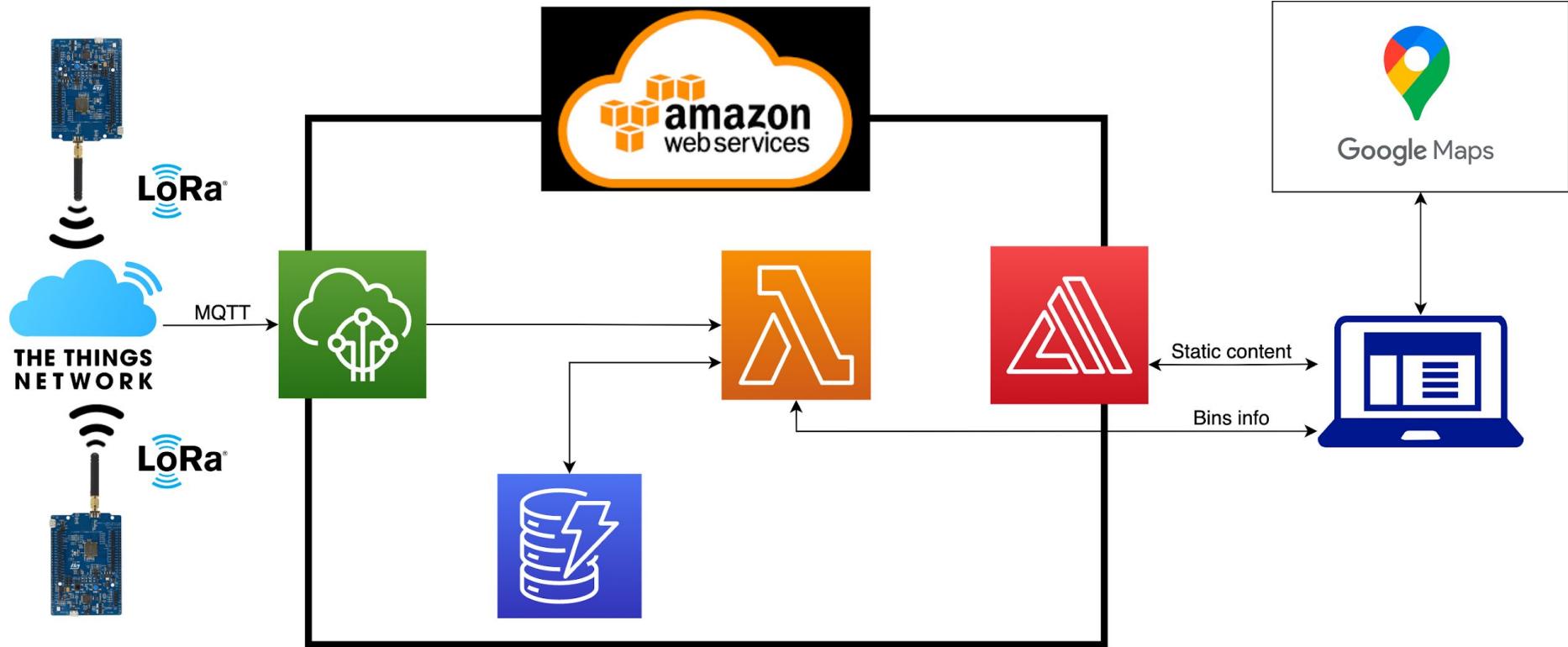


# Network and Cloud

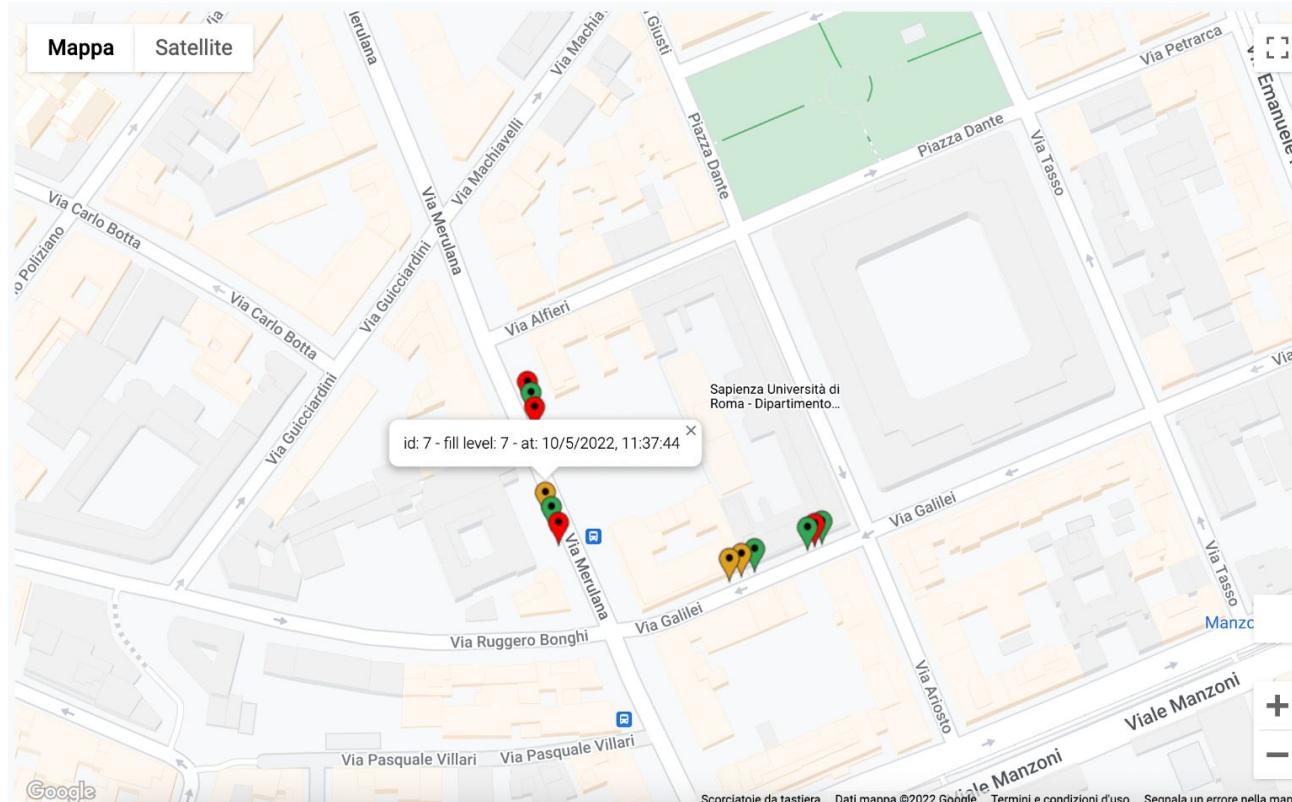
# Network diagram



# Cloud diagram



# Web Dashboard



## checkBin

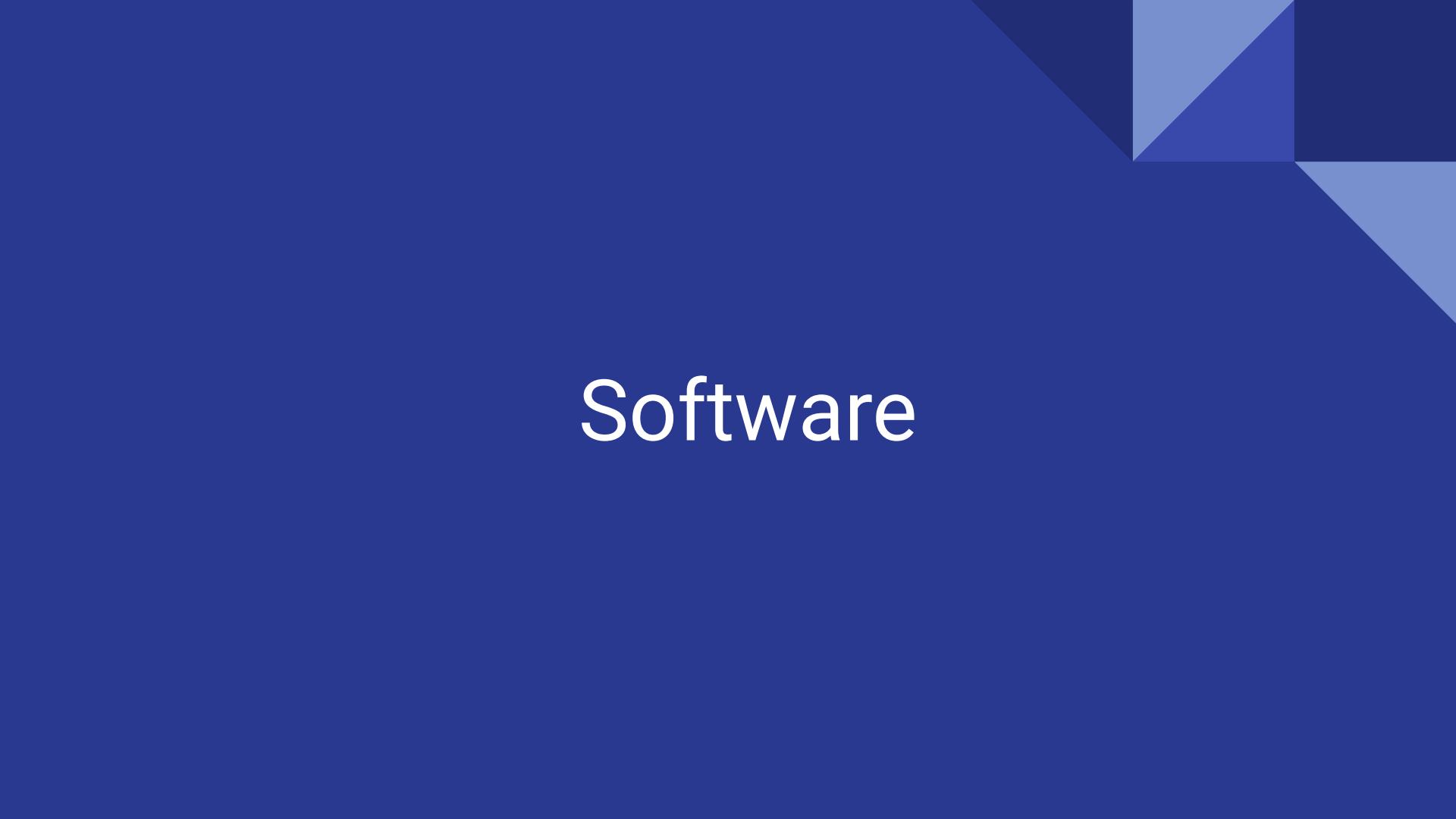
### Legend

- Fill level between 8 and 10
- Fill level between 5 and 7
- Fill level between 0 and 4

To add a new bin, fill the form with the coordinates and click on "Add Bin". After a while will appear the new bin's ID

GitHub Repository: [checkBin](#)

The background of the slide features a dark blue gradient. Overlaid on this are several light blue triangles of varying sizes and orientations, creating a sense of depth and movement.

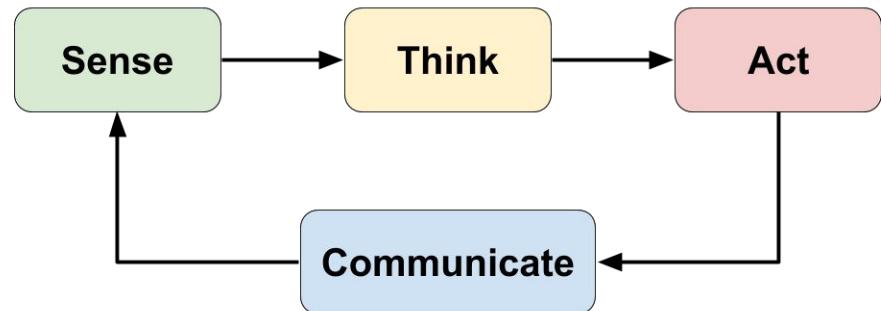
# Software

# Code on the Board

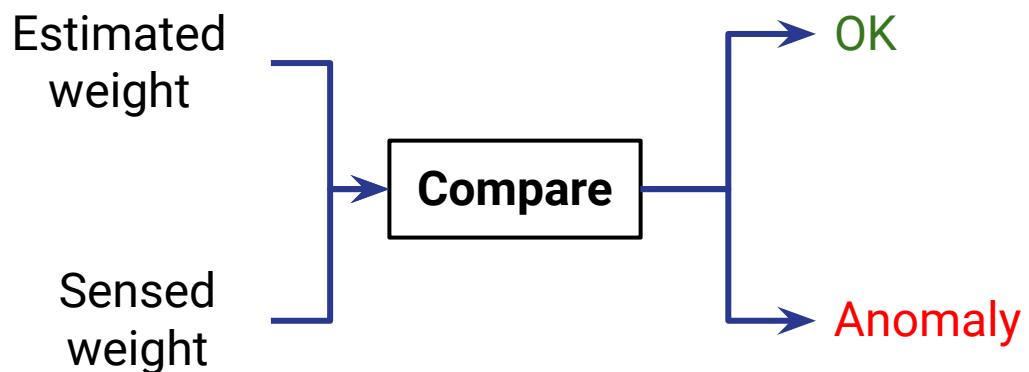
Functions necessary to:

- read values from the sensors
- act using the actuators
- send data using LoRa

Moreover we wrote all the logic that governs the system using the above functions.

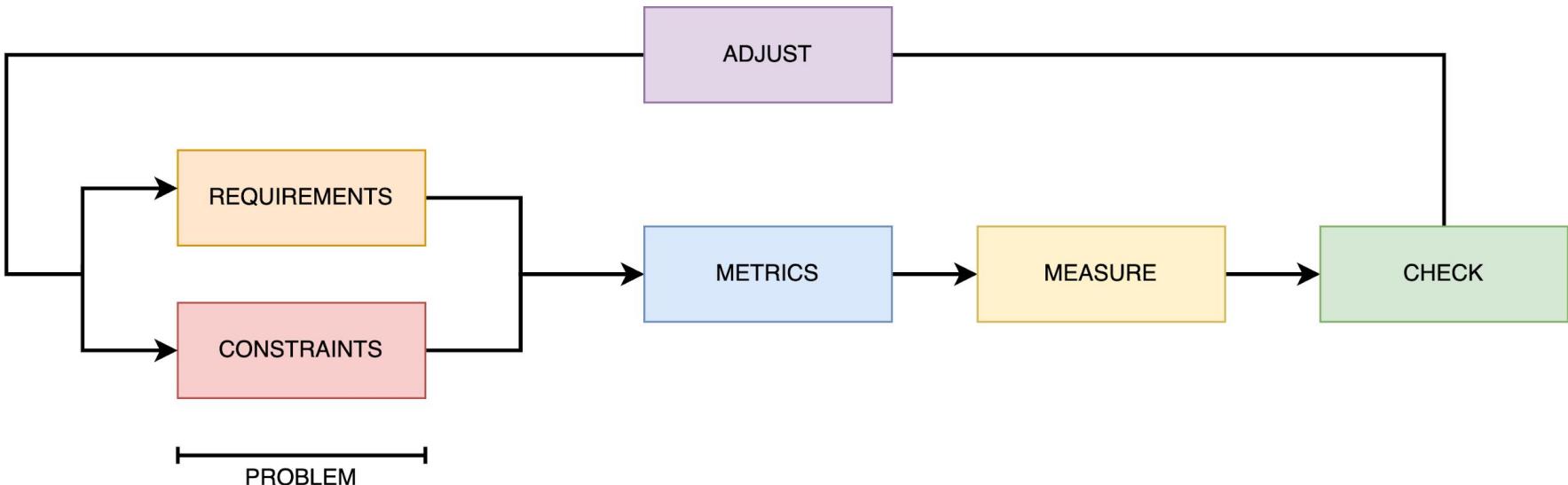


# Anomalies



# Evaluation

# Requirements



# Requirements and metrics

- The accuracy error of the fill level must be at most 10%;
- The update of the fill levels must be shown in the dashboard within 2 hours from the actual changes;
- The system must be energy independent for at least a year;

\* These requirements were set making reasonable assumptions on the observed real world.

# Requirements and metrics

- The capacity of the bin must not be reduced by more than 5% (both in weight and volume);
- The system must be compliant with the LoRa duty cycle restrictions;
- The ratio of wrong fill level measurements over total fill level measurements must be < 5%;
- The system must be able to scale up.

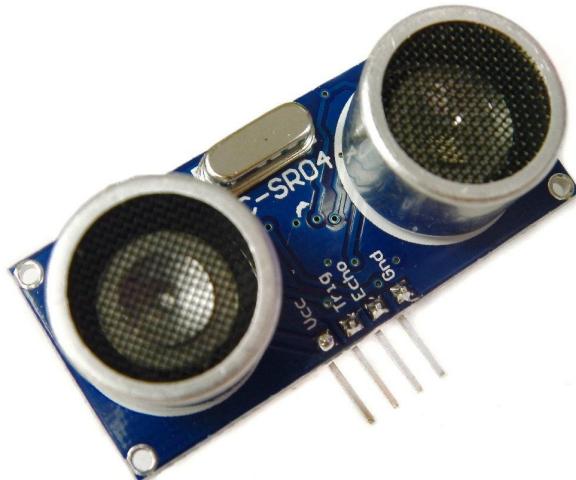
\* These requirements were set making reasonable assumptions on the observed real world.

# Fill level accuracy

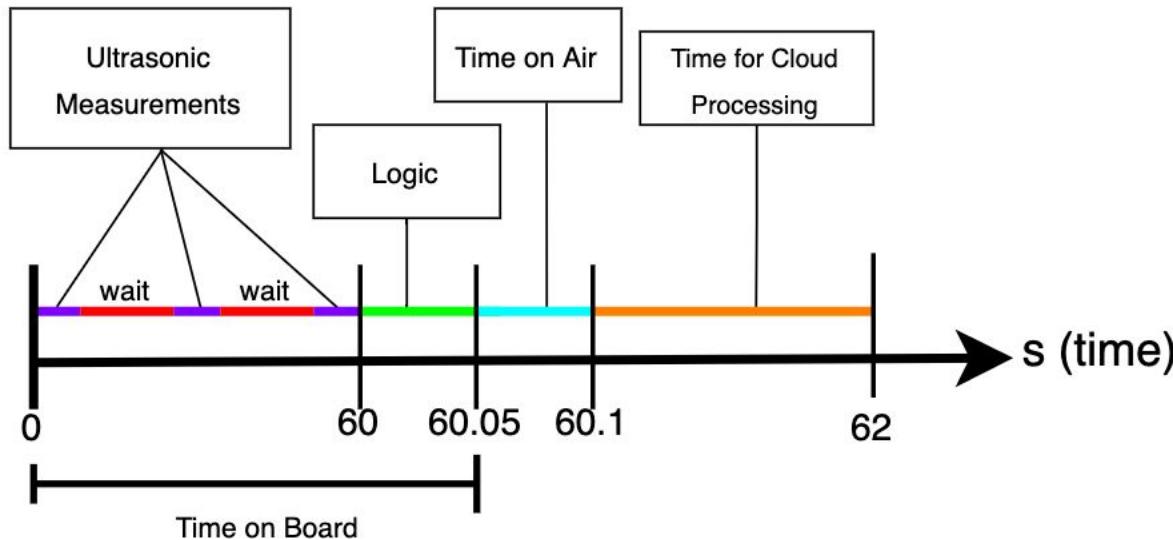
Fill level → value between 0 and 9

Fill level step represents a range of  
size  $\text{bin\_height}/10$

Error percentage of the fill level:  
max 10% of the total height



# Latency on the web dashboard update



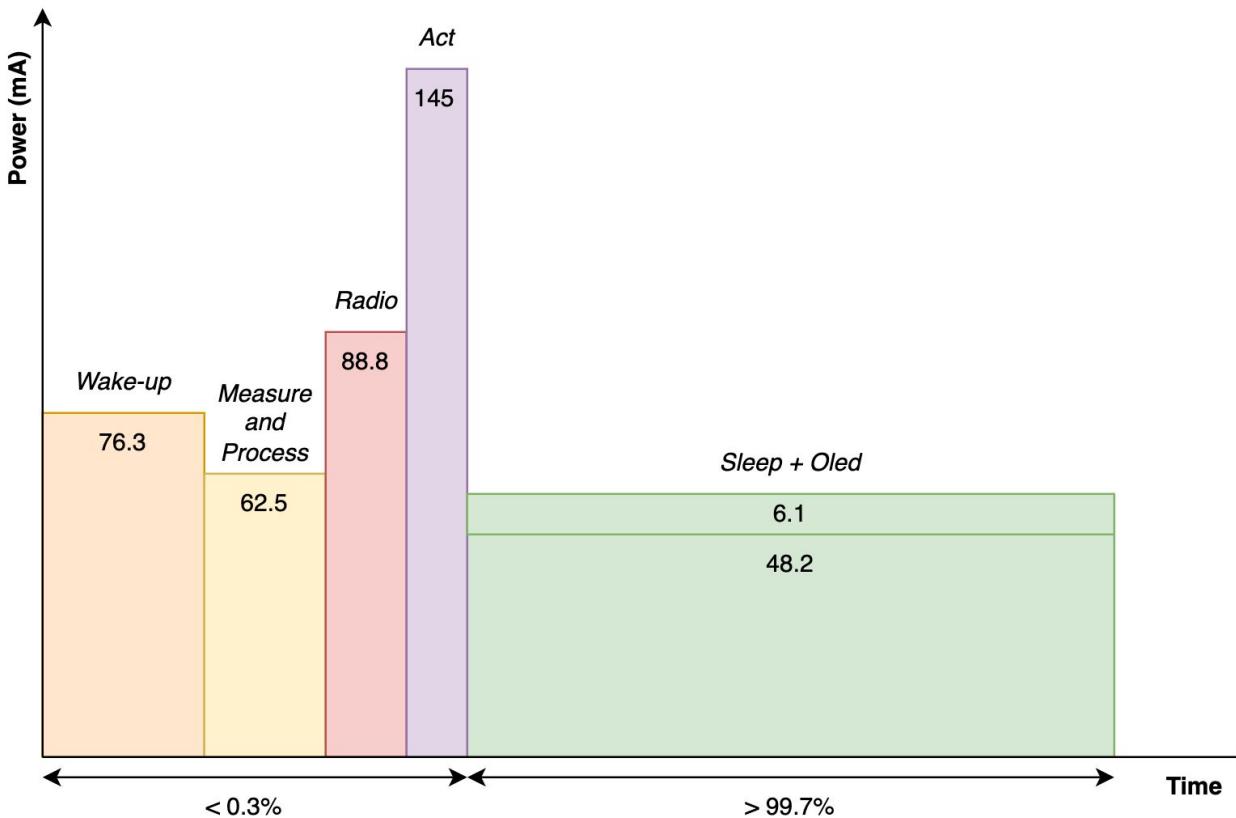
\*the image is NOT in scale

$$\begin{aligned}\text{Latency} &= T_{\text{Board}} + T_{\text{Air}} + T_{\text{Cloud}} = T_{\text{Ultrasonic}} + T_{\text{Logic}} + T_{\text{Air}} + T_{\text{Cloud}} \\ &= 60 + 0.05 + 0.05 + 2 = 62.1 \text{ s} \approx 62 \text{ s}\end{aligned}$$

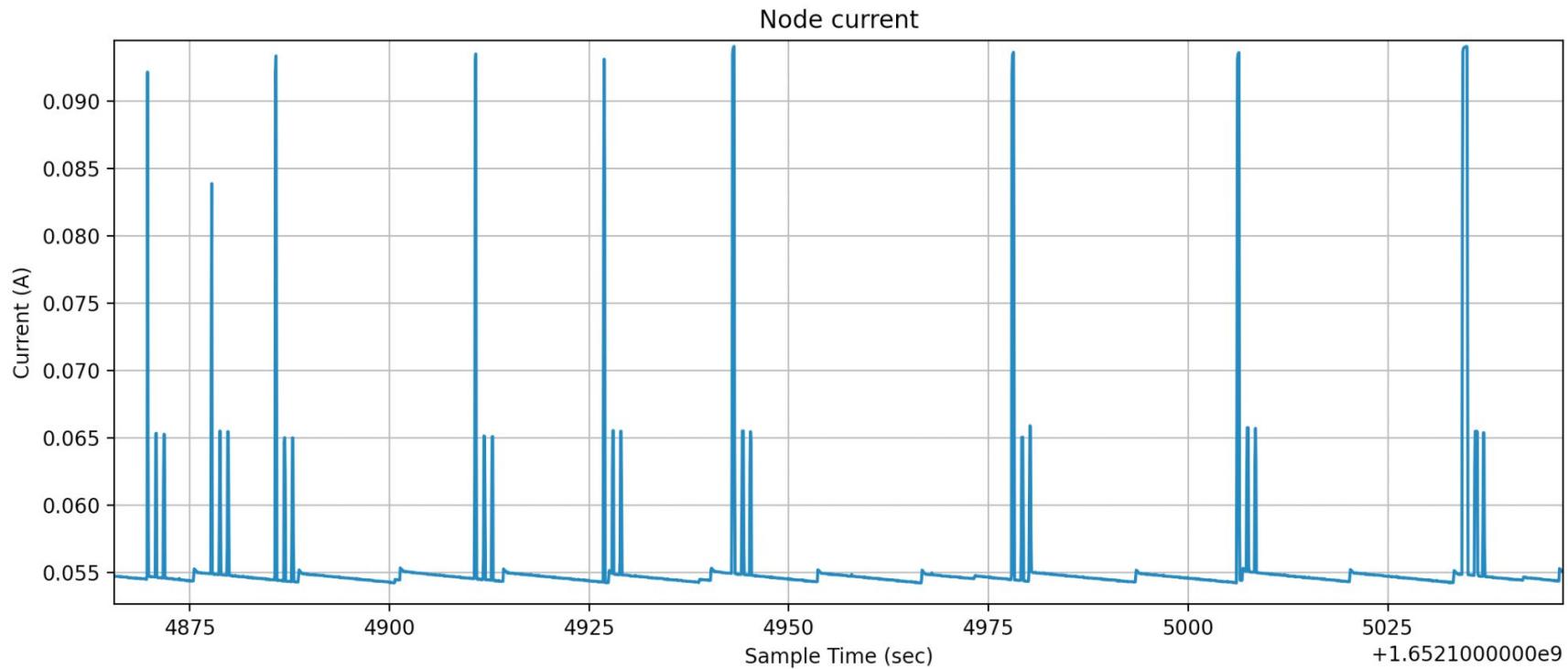
# Energy consumption/1



# Energy consumption/2

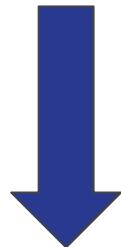


# Energy consumption/3



# Battery

500A battery reduces bin capacity  
by at least 8% in standard bins



Must implement charging method



# Charging methods

5W solar panel



1400 - 3400 mAh per day



# Accuracy of the system

Fill level from ultrasonic sensor	Total measurements	Detected anomalies	Undetected anomalies
0	2	0	0
1	3	0	0
2	5	0	0
3	4	0	0
4	7	0	0
5	6	1	0
6	3	0	0
7	3	1	0
8	4	0	1
9	3	0	0
-----	-----	-----	-----
Total	40	2	1



# Scalability

## Experiment system\_simulation #315591

User mazzitel

Submitted 2022-05-10 14:33:39

Started 2022-05-10 14:33:40

Duration 10 minutes (17%) of 1 hour

Nodes 12

State Running

● Stop ⬇️ Download

🔗 Actions on selected nodes ▾

Nodes	UID	Firmware	Monitoring	Deployment	Actions	⋮
st-Irwan1-14.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-15.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-16.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-17.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-18.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-19.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-20.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-21.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-22.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-23.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-24.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>
st-Irwan1-25.saclay.iot-lab.info				Success	<span style="color: green;">▶</span> <span style="color: green;">⌚</span> <span style="color: green;">⟳</span> <span style="color: green;">☰</span> <span style="color: green;">🔗</span> <span style="color: green;">✖</span>	<span style="color: grey;">□</span>

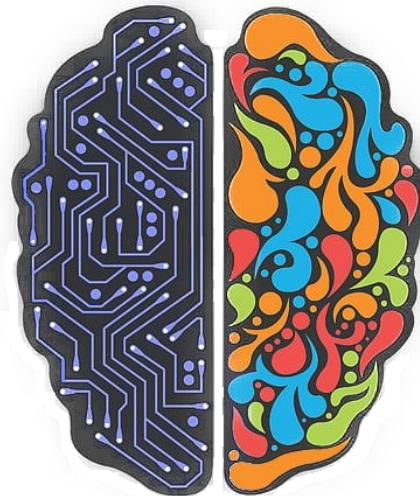
# Simulation

Time	Entity ID	Type	Data preview	Verbose stream
↑ 14:39:51	test-device	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF11BW125 SNR: 11.2 RSSI: -77	<input checked="" type="checkbox"/>
↑ 14:39:45	eui-70b3d57ed0050665	Forward uplink data message	MAC payload: 34 <> FPort: 2 Data rate: SF8BW125 SNR: 10.5 RSSI: -75	<input type="checkbox"/>
↑ 14:39:41	eui-70b3d57ed005066f	Forward uplink data message	MAC payload: 30 <> FPort: 2 Data rate: SF8BW125 SNR: 11.2 RSSI: -88	<input type="checkbox"/>
↑ 14:39:40	eui-70b3d57ed0050664	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF8BW125 SNR: 11.25 RSSI: -79	<input type="checkbox"/>
↑ 14:39:29	test-node-2	Forward uplink data message	MAC payload: 38 <> FPort: 2 Data rate: SF9BW125 SNR: 12.5 RSSI: -77	<input type="checkbox"/>
↑ 14:39:29	eui-70b3d57ed0050660	Forward uplink data message	MAC payload: 34 <> FPort: 2 Data rate: SF8BW125 SNR: 11.25 RSSI: -81	<input type="checkbox"/>
↑ 14:39:28	eui-70b3d57ed0050662	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF8BW125 SNR: 8.2 RSSI: -77	<input type="checkbox"/>
↑ 14:39:23	eui-70b3d57ed005065c	Forward uplink data message	MAC payload: 30 <> FPort: 2 Data rate: SF10BW125 SNR: 9.8 RSSI: -89	<input type="checkbox"/>
↑ 14:39:22	eui-70b3d57ed005065e	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF10BW125 SNR: 11 RSSI: -82	<input type="checkbox"/>
↑ 14:39:19	eui-70b3d57ed0050665	Forward uplink data message	MAC payload: 33 <> FPort: 2 Data rate: SF8BW125 SNR: 9 RSSI: -71	<input type="checkbox"/>
↑ 14:39:16	eui-70b3d57ed005065f	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF8BW125 SNR: 10.75 RSSI: -91	<input type="checkbox"/>
↑ 14:39:14	eui-70b3d57ed0050664	Forward uplink data message	MAC payload: 34 <> FPort: 2 Data rate: SF8BW125 SNR: 8.25 RSSI: -78	<input type="checkbox"/>
↑ 14:39:13	eui-70b3d57ed0050661	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF9BW125 SNR: 13.5 RSSI: -87	<input type="checkbox"/>
↑ 14:39:10	eui-70b3d57ed005065d	Forward uplink data message	MAC payload: 39 <> FPort: 2 Data rate: SF9BW125 SNR: 9.5 RSSI: -87	<input type="checkbox"/>

```
1652186383.366101;st-lrwan1-20;AFTER--  
1652186384.912023;st-lrwan1-24;Message Sent  
1652186384.912297;st-lrwan1-24;SEND: 9  
1652186384.912419;st-lrwan1-24;Sent: 9  
1652186384.912509;st-lrwan1-24;AFTER--  
1652186384.971985;st-lrwan1-25;BEFORE  
1652186384.972234;st-lrwan1-25;RANDOM NUMBER: 1  
1652186386.432435;st-lrwan1-19;Message Sent  
1652186386.433761;st-lrwan1-19;SEND: 0  
1652186386.435270;st-lrwan1-19;Sent: 0  
1652186386.435312;st-lrwan1-19;AFTER--  
1652186390.162332;st-lrwan1-25;Message Sent  
1652186390.163737;st-lrwan1-25;SEND: 4  
1652186390.164674;st-lrwan1-25;Sent: 4  
1652186390.164995;st-lrwan1-25;AFTER--  
1652186390.658987;st-lrwan1-14;BEFORE  
1652186390.661526;st-lrwan1-14;RANDOM NUMBER: 9  
1652186393.34021;st-lrwan1-22;Fail to send: no ACK received  
1652186393.340272;st-lrwan1-22;SEND: 9  
1652186393.341022;st-lrwan1-22;Sent: 9  
1652186393.342377;st-lrwan1-22;AFTER--
```

# Future plans

# Machine learning



Interval between  
measurements

Specific weight for  
each waste type

# e-ink Display

0.005mA in standby

8mA during update phase

e-ink :0.16mAh per day

vs

oled: 54mAh per day



# Charging methods

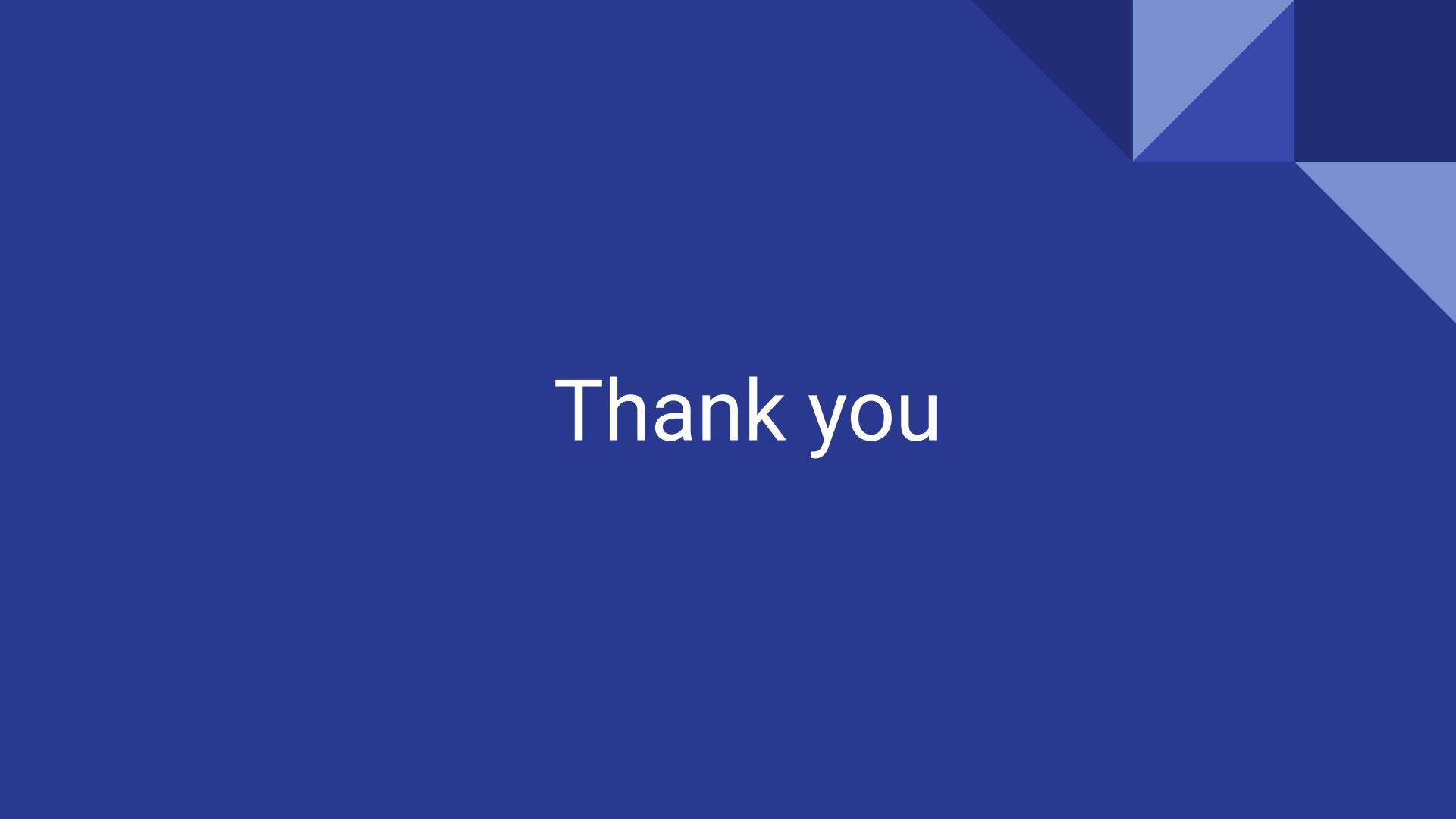
Mechanical energy



Sunlight



Electric power

The background features a large, solid dark blue rectangle. In the top right corner, there is an abstract geometric pattern composed of several triangles. These triangles are primarily different shades of blue, creating a sense of depth and movement. The pattern includes a large dark blue triangle pointing down and to the left, a medium-sized light blue triangle above it, and a smaller dark blue triangle to its right. Below this main cluster, there are more triangles of varying sizes and orientations, some pointing upwards and others downwards, all set against the dark blue background.

Thank you