# Sound Level Monitoring System

## Report Highlights

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# Overview

## Introduction

## Architecture

- Technology
- Architecture diagram

## Implementation

- Acquisition
- Communication
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- Forecasting

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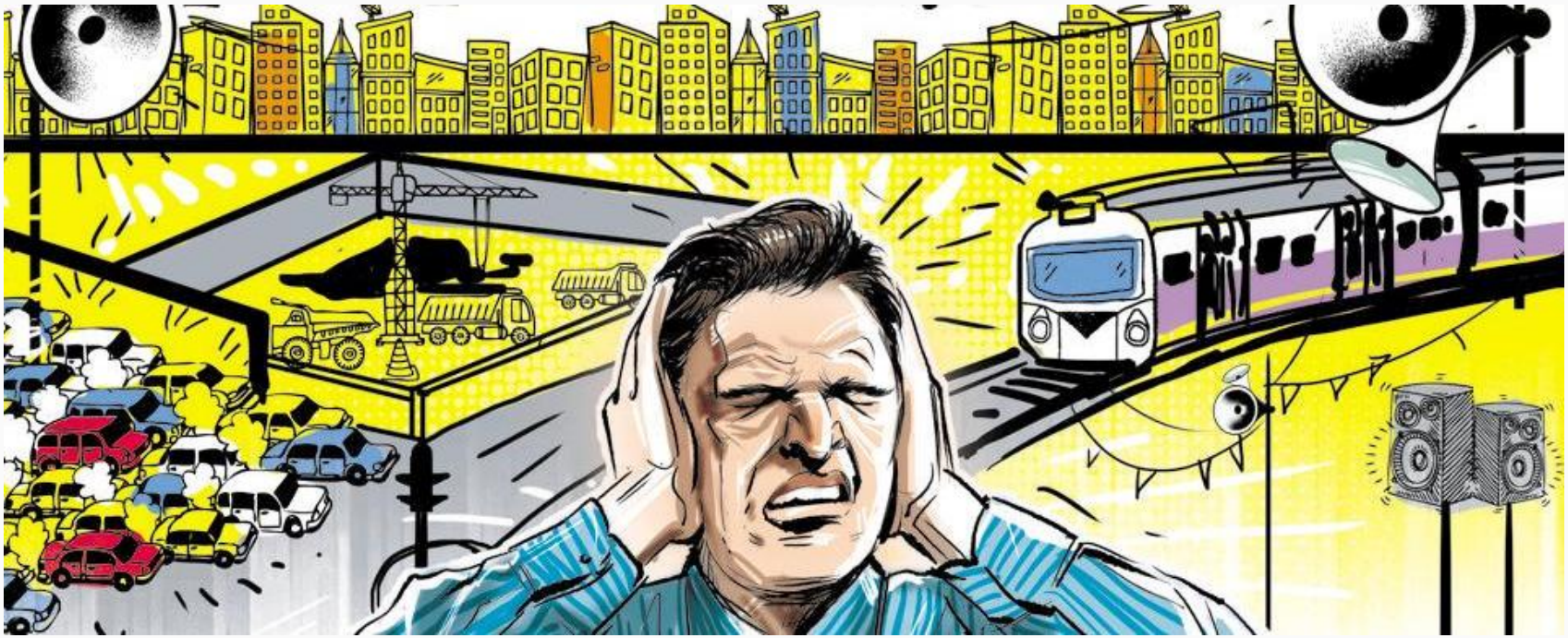
# Introduction

# Introduction [1/2]

Urban areas' **noise pollution** affects the quality of life of millions of people worldwide.
High noise levels are potentially **harmful** in regards of stress, sleep disturbances and cognitive function.



# Introduction [2/2]

The project goal is to **monitor indoor sound level** in order to detect and alert when the noise is too high by exploiting IoT technology.

In particular:

- **Acquire** and **process** periodically sound level values;
- **Store** the data in a time series database;
- **Forecast** future noise values;
- **Visualize** the data in a dashboard.

# Architecture

# Technology

## Hardware:

- **ESP32**: power-efficient MCU;
- **MAX4466**: adjustable microphone amplifier module.

## Software:

- **Arduino** IDE and **Wiring** language;
- **HTTP** and **MQTT**: communication protocol;
- **Flask**: Python web application framework;
- **InfluxDB**: time series data database;
- **Prophet**: time series data forecaster;
- **Grafana**: time series data visualization and analysis platform.

# Architecture

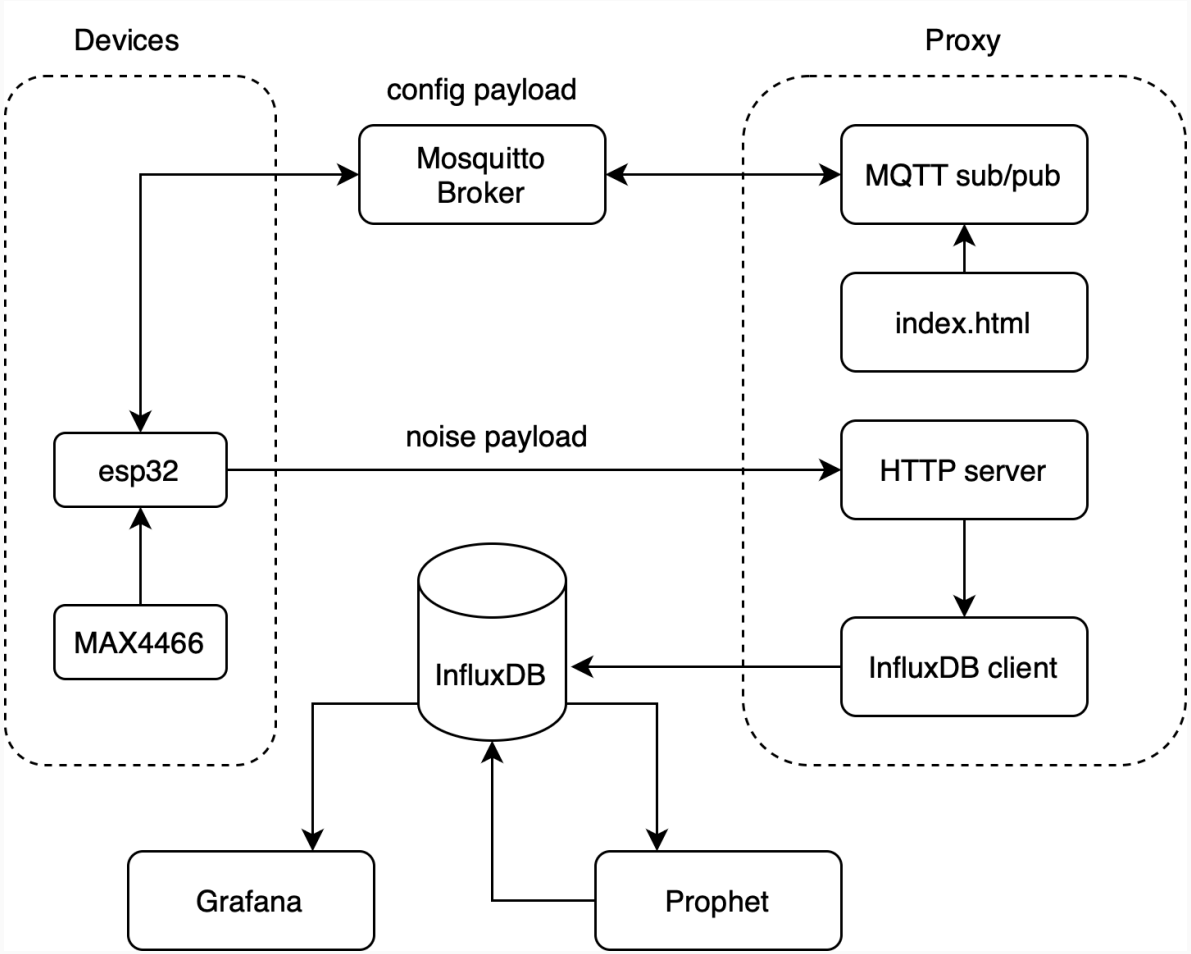



**Figure 1:** Project Architecture

# Implementation

# Acquisition

## Sound level values:

- **Window Sampling**: analog reading over 50ms window;
- Computing **Peak-to-Peak voltage**:

$$PeakToPeak = signalMax - signalMin \tag{1}$$

- Computing **Voltage in RMS**:

$$RMS = \frac{PeakToPeak \cdot 3.3}{4095} \cdot 0.707 \tag{2}$$

- Computing **SPL**:

$$SPL = 20 \cdot \log_{10}\left(\frac{RMS}{0.00631}\right) - Gain + Sensitivity + 94 \tag{3}$$

Where MAX4466 Gain is kept at 25dB and Sensitivity is -44dB.

# Communication [1/3]

## Payload:

- Composition of **Sound level**, **RSSI** and **Alarm status** characters ';' separated.

## HTTP Communication:

- **HTTP 1.1** persistent connection;
- The average **Round-trip time** is ∼40ms (same network), and ∼410ms if considering (cloud) storage.

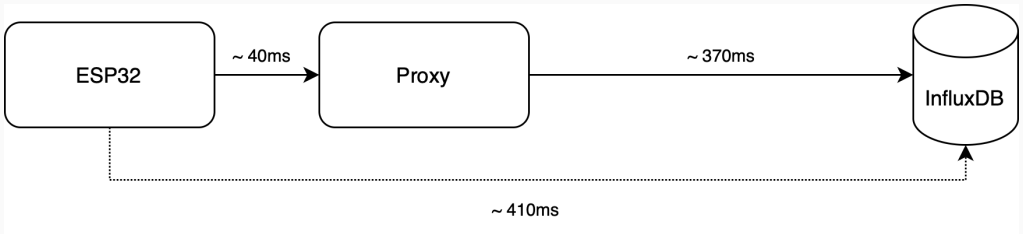



**Figure 2:** Payload round-trip time representation.

# Communication [2/3]

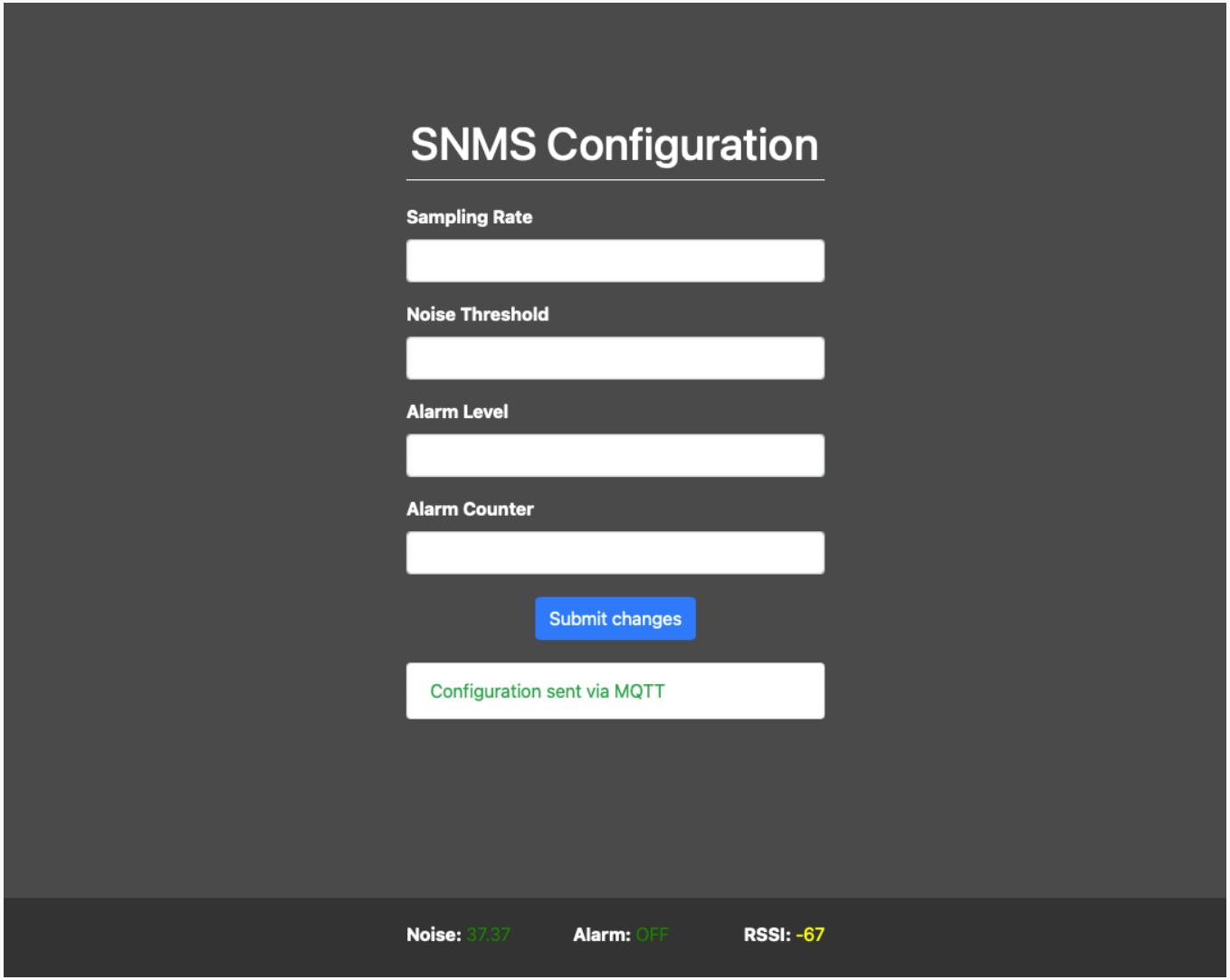



**Figure 3:** Configuration web page.

# Communication [3/3]

## Configuration Parameters:

- **samplingRate**, **noiseThreshold**, **alarmLevel** and **alarmCounter** are saved server-side in json format;
- When awaken, the ESP32 asks (and receives after) the Proxy for the latest configuration via **MQTT** (QoS 1);
- **Proxy** responsabilities:
  - Retrieve and send current configuration via MQTT;
  - Get, check and update new configuration via web page.

# Storage

## Two Buckets:

- **Samples** Bucket:
  - Stores **sensor values** received by the Proxy;
  - **Fields**: *`rssi`*, *`noise`* and *`alarm`*;
  - **Data retention**: 12 hours.
- **Aggregation** Bucket:
  - Collection of tasks compute and store (average) aggregations of sample bucket values;
  - **Aggregation Window**: 10 seconds;
  - **Data retention**: 7 days.

# Dashboard [1/2]

## Grafana dashboard:

- Periodically queries the InfluxDB database;
- For each of *`rssi`*, *`noise`* and *`alarm`* values, shows:
  - History graph;
  - Current status;
  - Forecasted values (just for noise values).

# Dashboard [2/2]


**Figure 4:** Sound level monitoring system dashboard.

# Forecasting [1/2]

## Prophet model:

- Allows to forecast time series data trends;
- Trained on the **sliding window** of the last 6 hours of data;
- Forecasts 10 seconds in the future.

## Evaluation:

- Trained on 1 hour of train dataset;
- Tested on 30 minutes of test dataset;
- Predictions every 10 seconds;
- **MSE**: 40.

# Forecasting [2/2]

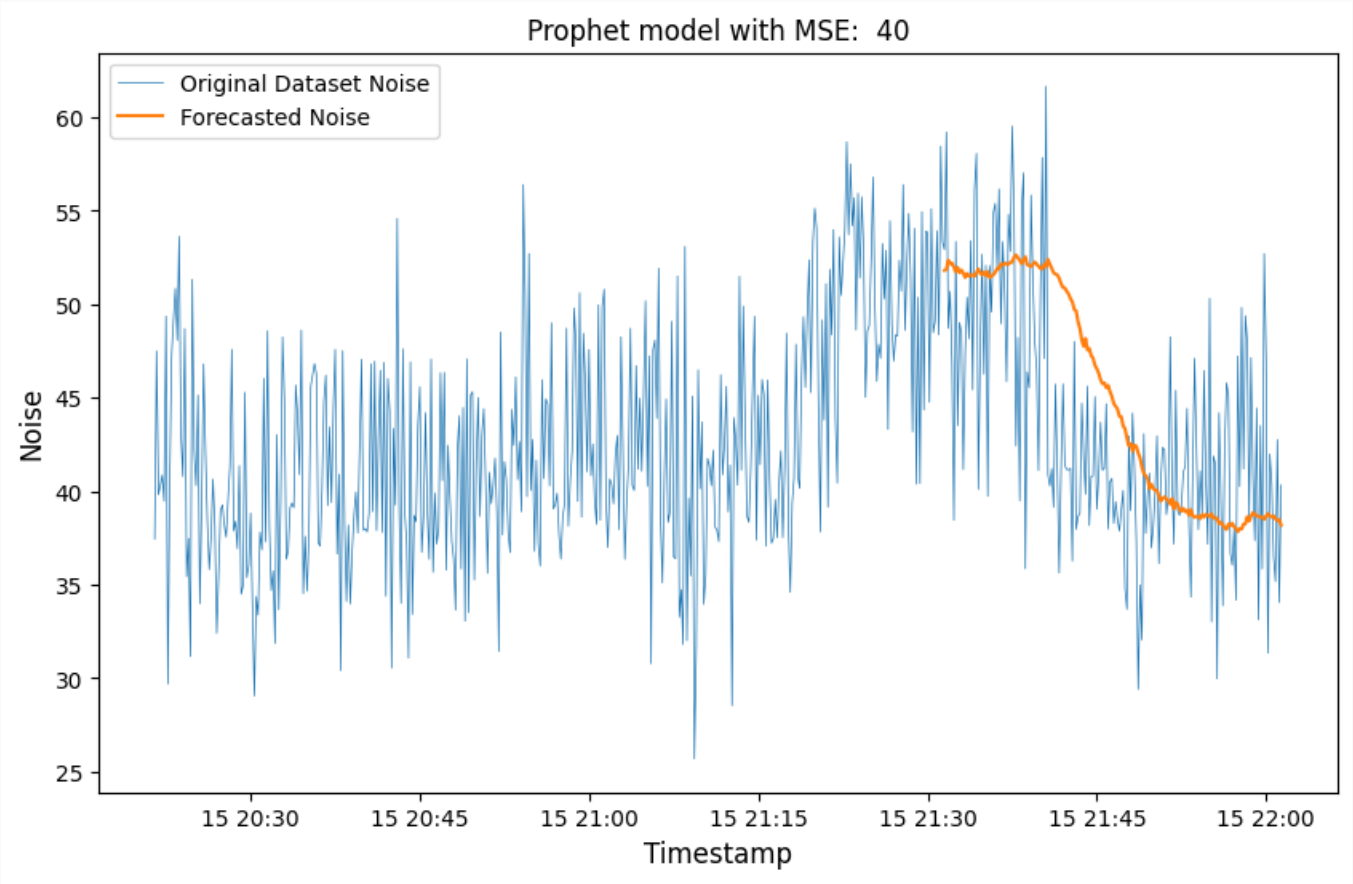



**Figure 5:** Forecasting sound values validation.

# Conclusion

## Results

- The system is overall **reliable** for the given task;
- Grafana dashboard allows a **clear understanding** of the overall environment sound level situation;
- The forecaster allows to predict quite accurately the trend direction.

## Future works

- **Hardware adjustments** in order to reduce fluctuations;
- Improvement in **security** aspect;
- Extending the system to a **cluster of devices**: one for each room.

Questions?