Air Pollution Monitoring Station via Wi-Fi HaLow

UQ- METR4911

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Introduction

This project develops a low-cost, solar-powered air pollution monitoring station that uses Wi-Fi HaLow for long-range, low-power data transmission. The system measures the air quality in real time and stores results in a cloud database. This technology supports cleaner cities and informed environmental action.

Why Track air Quality?

- Air pollution is associated with **~7 million premature deaths** per year; most people breathe air above recommended guidelines.
- Health impacts include asthma, cardiovascular disease, and cancer; environmental impacts range from crop loss to ecosystem damage.
- Local monitoring reveals temporal and spatial hotspots, informs community advisories, and supports evidence-based policy.
- In SEQ, some pollutants have declined, yet **$PM_{2.5}$** and **ozone** remain concerns—sustained monitoring is needed.
- Continuous air quality data is essential for protecting public health and guiding sustainable policy

Figure 1: Simulated view of Brisbane under heavy air pollution, demonstrating the importance of real-time monitoring.

What is Wi-Fi HaLow?

- **Sub-1 GHz** IEEE 802.11ah variant: ~1 km range and improved penetration through walls/foliage.
- **Low power** operation enables multi-year battery life depending on duty cycle and payload.
- **Security**: WPA3 support and familiar Wi-Fi tooling; integrates without proprietary hubs.
- **Throughput**: Higher than LoRa/NB-IoT at similar ranges for telemetry workloads.
- Ideal for environmental sensing, agriculture, and smart-city deployments due to its long-range, low-power communication making it ideal for solar IoT stations.

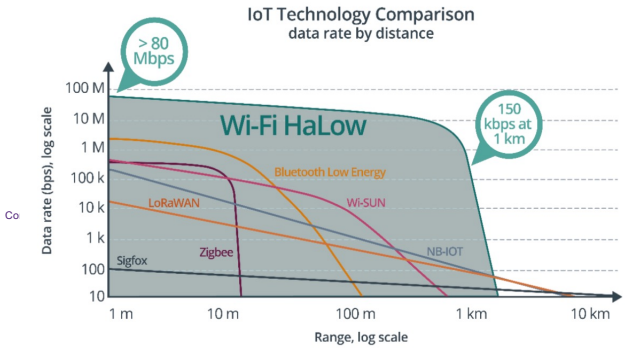

Figure 2: Comparison of IoT Communication Technologies Showing Data Rate Versus Range for Wi-Fi HaLow and Alternatives:

Objectives

- Develop a robust solar-powered station with intelligent battery management.
- Stream environmental data using Wi-Fi HaLow for long-range connectivity.
- Deliver a user-friendly interface for visualising real-time air quality.

Results & testing

- Stable transmissions up to ~1 km line-of-sight during early trials.
- Consistent eCO_2,AQI, TVOC, Humidity, Pressure and temperature logs in lab + outdoor settings.
- Solar-battery supply maintained multi-day operation at target duty cycle.

Acknowledgements
Thank you to Dr Matthew D'Souza for his wisdom and supervision.

References:
Chat GPT

System Design

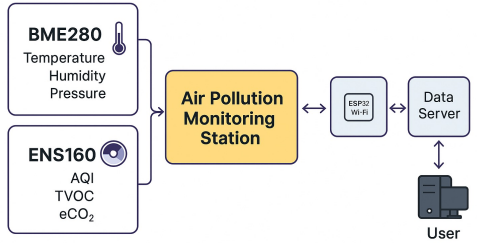

Figure 3: System flow diagram showing how the BME280 and ENS160 sensors transmit environmental data via the ESP32 Wi-Fi HaLow–enabled Air Pollution Monitoring Station to the Base Station, Data Server, and User Dashboard.

- **Comprehensive Air Monitoring:** Dual sensors track AQI, TVOC, eCO_2, temperature, humidity, and air pressure in real time.
- **Smart Connectivity:** Data is processed by a microcontroller and sent via **Wi-Fi HaLow** to a base station, then securely uploaded to the cloud.
- **Solar-Powered Reliability:** A 6000 mAh battery and 2.5 W solar panel provide continuous power, with built-in monitoring of charging time and battery voltage.

Figure 4: AI Rendered photo of final product

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