OpenIoTwx: A Low-Cost, Modular Platform for Real-Time Environmental Monitoring

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INTRODUCTION

Motivation

- Ground-level measurements complement satellite and model data by capturing real-time local conditions, especially in areas affected by extreme heat [1].
- However, many commercial weather stations are costly, difficult to customize, and require technical expertise.
- OpenIoTwx is a low-cost, modular IoT platform designed to simplify environmental monitoring.

Objectives

This project aimed to:

- Develop a browser-based flashing and configuration wizard.
- Integrate RS485 wind speed and direction sensors.
- Design a modular 3D-printed globe thermometer.
- Estimate MRT using globe temperature, air temperature, and wind speed.
- Maintain compatibility with the existing OpenIoTwx cloud infrastructure.

OVERVIEW AND APPLICATIONS

OpenIoTwx platform

- Low-cost, modular platform for real-time environmental monitoring.
- ESP32 Atom Lite and RP2040 devices collect data from connected sensors.
- Measurements are transmitted to a gateway, published through MQTT, and processed by cloud services.
- Sensors can be added or replaced without redesigning the station.

Applications

- Weather and microclimate monitoring
- Outdoor heat-exposure assessment
- Air-quality monitoring
- Agricultural and ecological sensing
- Research and education

Design principles

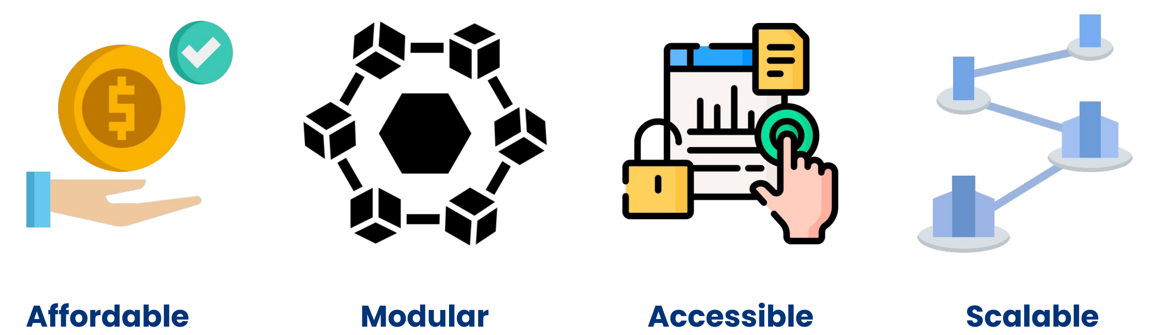

Figure 1. The OpenIoTwx principles of design

SYSTEM ARCHITECTURE AND WORKFLOW

Architecture

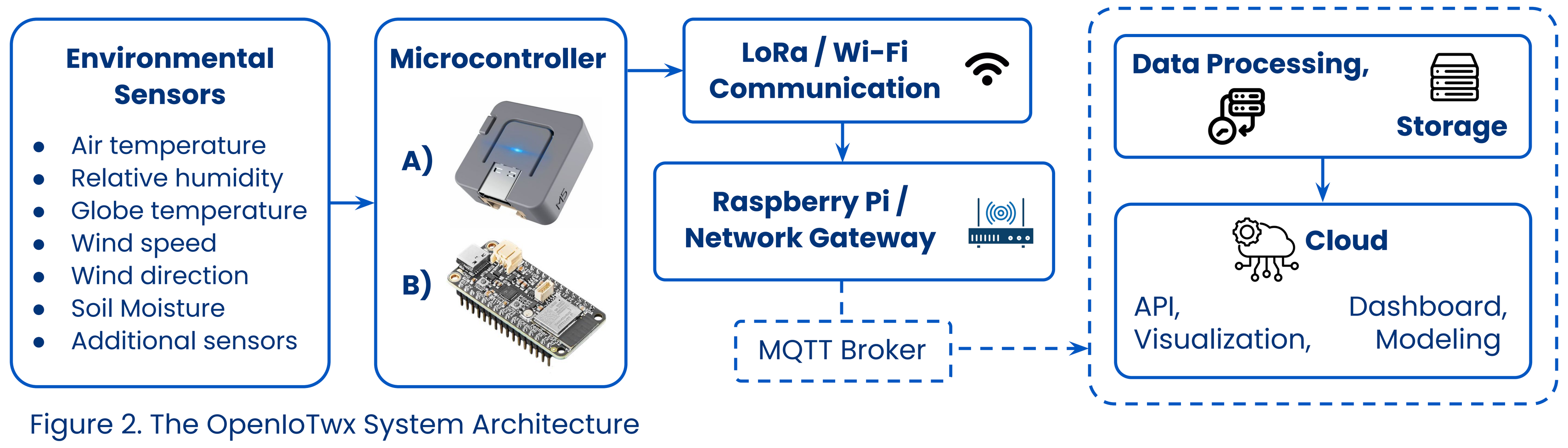

Figure 2. The OpenIoTwx System Architecture

Deployment workflow

1. The user selects the microcontroller and connected sensors.
2. Station, network, and sensor parameters are entered through the web wizard.
3. The microcontroller is connected by USB.
4. Compatible firmware is flashed directly through the browser.
5. Configuration information is written to the device.
6. The station collects and transmits environmental observations.
7. Measurements are processed, stored, and made available to downstream applications.

KEY TECHNICAL CONTRIBUTIONS

Web-based device setup

- Select the microcontroller and firmware
- Configure station, network, and sensors
- Flash the device directly through USB
- Reduce the need for programming experience

Wind sensor integration

- Measures wind speed and direction
- Validates and converts sensor responses
- Adds wind data to the transmitted payload
- Supports future third-party sensors

SCAN HERE

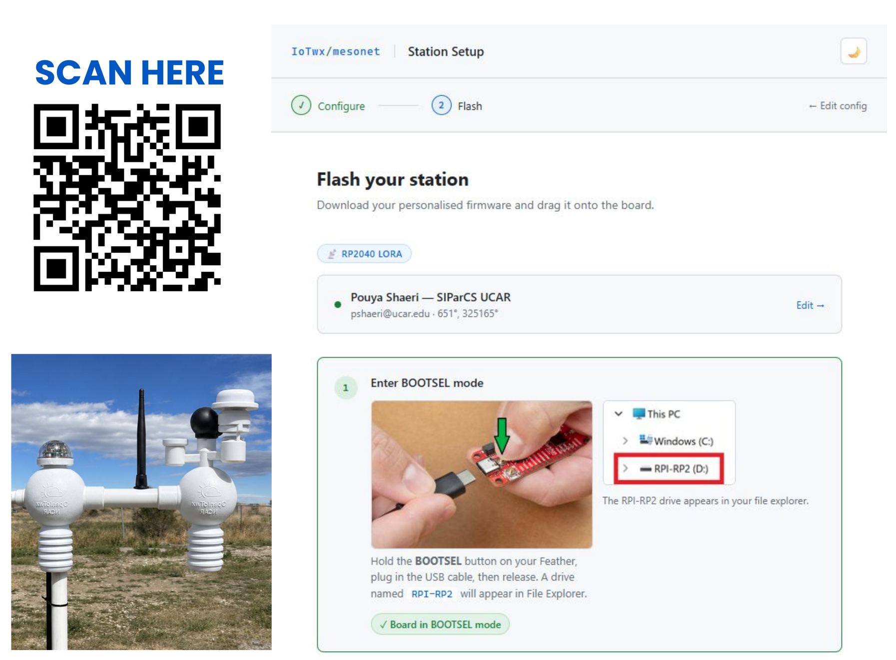

Figure 3. The web wizard interface, Wind and Globe sensors

Globe Thermometer and MRT

A 3D-printed globe thermometer was designed to measure globe temperature and estimate MRT using air temperature and wind speed [2].

$$T_{\mathrm{MRT}} = \left[(T_g + 273.15)^4 + \frac{1.1 \times 10^8 v_a^{0.6}}{\varepsilon_g D^{0.4}} (T_g - T_a) \right]^{1/4} - 273.15$$

SYSTEM DEMONSTRATION

- Environmental measurements were successfully collected and transmitted through the IoT pipeline.
- The data payload included air temperature, globe temperature, wind speed, wind direction, and calculated MRT.
- Measurements were stored and displayed through the OpenIoTwx cloud services.

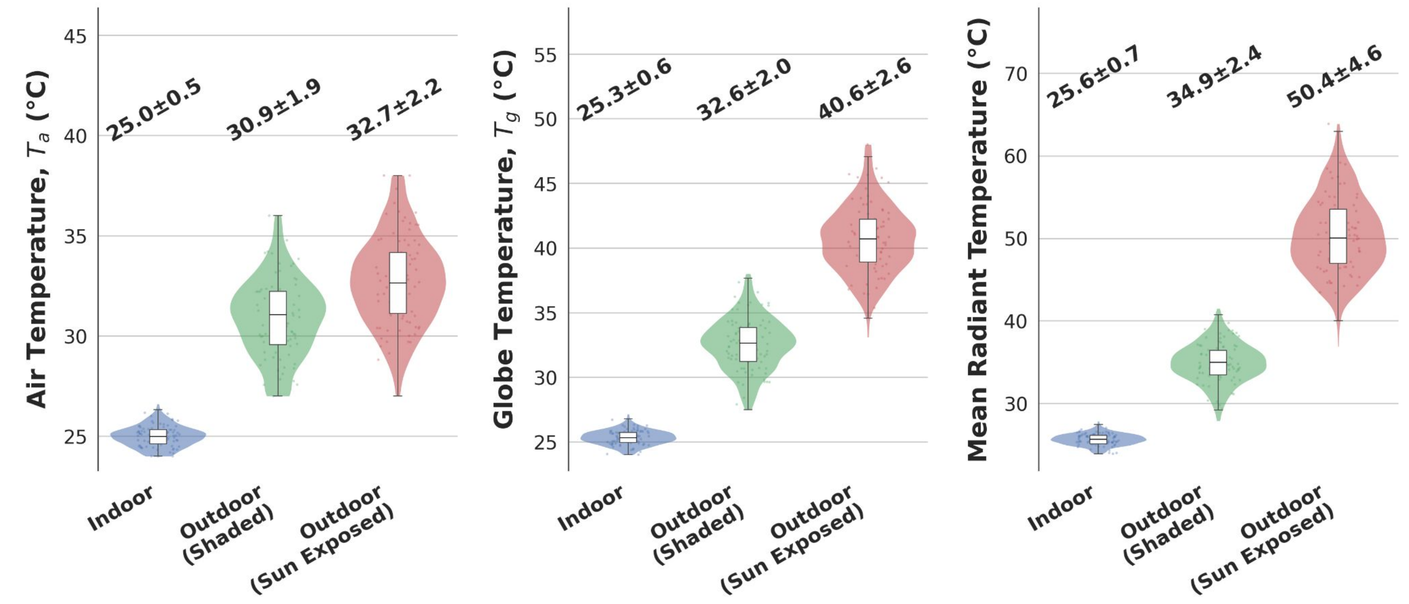

Figure 4. Air, globe, and mean radiant temperature (mean ± SD) under indoor, shaded, and sun-exposed conditions, showing increasing divergence from air temperature with radiant exposure.

CONCLUSION

This project developed a browser-based wizard for flashing and configuring OpenIoTwx [3] devices, integrated RS485 wind sensing and third-party sensors, and added a 3D-printed globe thermometer for MRT estimation. These improvements make the platform more accessible for research, education, community monitoring, and heat-exposure studies.

FUTURE WORKS

- Deploy OpenIoTwx stations in Arizona communities affected by extreme heat and heat stress.
- Web app flashing tool integration into CIRRUS mesonet data management system
- Integration with GDEX and expand the codebase to support additional environmental sensors.
- Calibrate and validate the globe thermometer and wind sensor against reference instruments and Improve weather resistance and long-term outdoor reliability.

REFERENCES

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[3] NSF National Center for Atmospheric Research, “OpenIoTwx”. https://ncar.github.io/openiotwx/

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