Edge-Enabled Real-Time Data Processing and Transmission in Power-Efficient Weather Stations using IBIS

William Fowler[1]
Kate Keahey (advisor)[2], Alicia Esquivel Morel (advisor)[3]
Tufts University[1] , The University of Chicago | Argonne National Laboratory[2],
University of Missouri - Columbia[3]

Rationale

Why is weather sensing important?
- Addressing climate change requires more meteorological data.

Why does weather sensing need HPC?
- Managing large weather datasets is a challenge in weather forecasting[1].
- Access to high-quality datasets can improve forecasting capabilities.

Problem Statement

- Can we make automated weather stations more power efficient?
- Can we connect remote weather sensors to an IBIS device over LoRa?

Background

OpenIoTwx weather station[4]

Automatic Weather Stations:
Provide a lot-cost solution to acquiring meteorological data from remote locations.

- Previous low-cost weather stations rely on WiFi network.
- Growing need for weather stations to be enhanced with data-intensive peripherals, like cameras.

Proposed Solution - An improved Automatic Weather Station

- LOng-RAnge (LoRa) radio protocol used to transmit sensor data.
- Raspberry Pi used to aggregate data from multiple weather stations.
- Telegraf transfers data from the MQTT broker to InfluxDB which timestamps and stores the data.
- Chameleon Cloud-based[2] data visualization using Grafana.
- IBIS[3] - observational instrument for data collection at a large scale

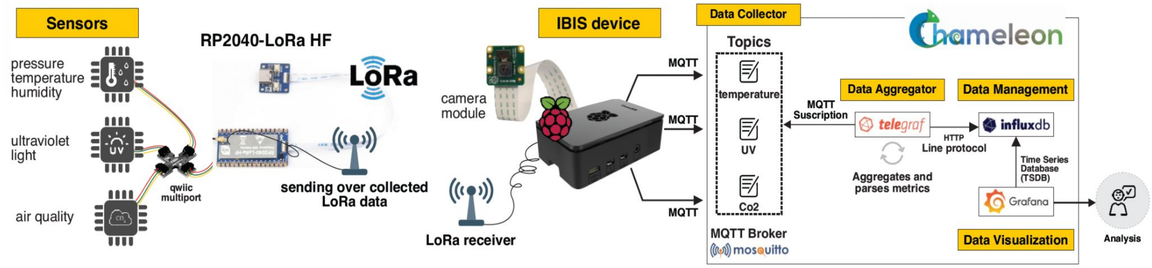

Figure 1. Schematic of the architecture of our weather station. It is integrated with IBIS, an observational instrument for data collection on a large scale.

Data Collection and Experimental Results

- Demo deployment collects data from one weather station with actual sensors and another station with simulated sensor data, which both transmit their data to the Raspberry Pi to be uploaded to the cloud data visualization service.
- The power monitoring experiment equips both the Raspberry Pi and RP2040 microcontroller with the weather sensors and monitors the power usage as they are collecting and transmitting data.

Demo Deployment

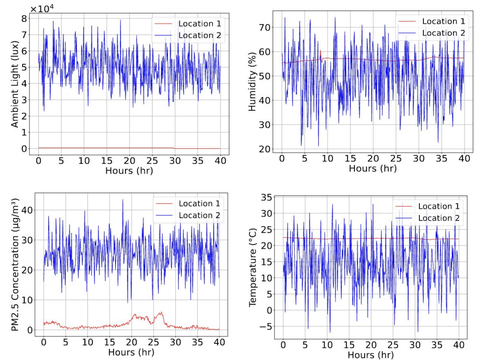

Fig. 2: Ambient light, humidity, PM 2.5, and temperature collected from sensors over a 40 hour period. Station 1 (red) are collected from sensors. Station 2 (blue) are simulated.

Power Monitoring

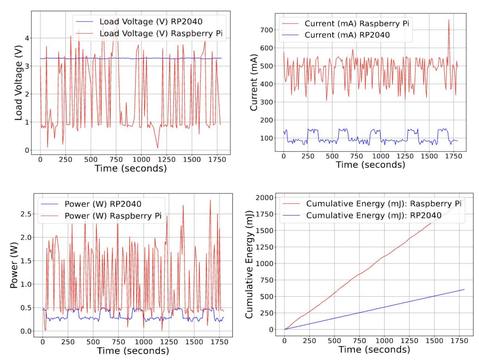

Fig. 3: Load voltage, current, power, and cumulative power over time for the RP2040 microcontroller (blue) and Raspberry Pi (red) when reading and transmitting sensor data.

Enhanced weather predictions

- Integration of camera and weather sensors can improve upon weather forecasting from image data from Chu et al.[5]
- Address challenges of managing large weather datasets by concentrating data from various locations in one place.

Conclusion and Future Work

- Added additional sensing capabilities and power-efficient transmission to improve upon existing automatic weather stations.
- Demo deployment tests data collection
- Our implementation addresses weather data needs and can be used in future weather forecasting applications.

[1] Himanshi Jain and Raksha Jain. 2017. Big data in weather forecasting: Applications and challenges. In 2017 International Conference on BigData Analytics and Computational Intelligence (ICBDAC). 138–142. https://doi.org/10.1109/ICBDACI.2017.8070824
[2] K. Keahey, J.Anderson, Z.Zhen, P. Riteau, P. Ruth, D.Stanzione, M.Cevik, J.Colleran, H. Gunawi, C. Hammock, J. Mambretti, A. Barnes, F. Halbach, A. Rocha, and J. Stubbs. 2020. Lessons learned from the Chameleon testbed. USENIX Conference on Usenix Annual Technical Conference (USENIX ATC'20).
[3] K. Keahey Z. Murry T. Sitzmann J. Zhou A. Esquivel Morel, M. Powersand P. Calyam. 2024. IBIS — An Infrastructure Management Framework for Adaptable, Multi-Sensor Data Collection in Scientific Research. ISCHigh Performance 2024 International Workshops (2024). https://doi.org/10.13140/RG.2.2.11758.22082 Preprint available on ResearchGate.
[4] Keith Maull. 2023. OpenIotwx. https://ncar.github.io/openiotwx/.
[5] Wei-Ta Chu, Xiang-You Zheng, and Ding-Shiuan Ding. 2017. Camera as weather sensor. J. Vis. Comun. Image Represent. 46, C (Jul 2017), 233–249. https://doi.org/10.1016/j.jvcir.2017.04.002

U.S. National Science Foundation WHERE DISCOVERIES BEGIN
NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Argonne NATIONAL LABORATORY
THE UNIVERSITY OF CHICAGO
Tufts UNIVERSITY
College of Engineering University of Missouri
Chameleon
IBIS Sensing Supercomputer