LoRa at Columbia University

Introduction

LoRa (from “long range”) is a low-power wide-area network technology that operates in the unlicensed sub-GHz frequency band. LoRa enables battery-powered Internet of Things (IoT) devices with a long lifespan, e.g., up to a year when powered by AAA batteries. LoRa devices can communicate over a long range, in ideal conditions up to 6 miles. Both commercial (private) and community (public) LoRa networks exist. The most well known community network is The Things Network (TTN) where the network infrastructure consisting of LoRa gateways is operated by volunteers.

We are setting up a LoRa network on the Columbia University campus. We hope to make LoRa available across the entire Morningside Heights campus and adjacent blocks and neighborhoods. Our longer-term goal is to make the LoRa technology freely available to the Columbia community, e.g., students and faculty exploring IoT-related projects. We wish to enable novel educational and research projects in the fields of environmental monitoring, building automation, smart cities, and transportation. Like the Makerspace and the COSMOS testbed, the LoRa infrastructure will provide our student community with access to cutting-edge technology for hands-on experimentation.

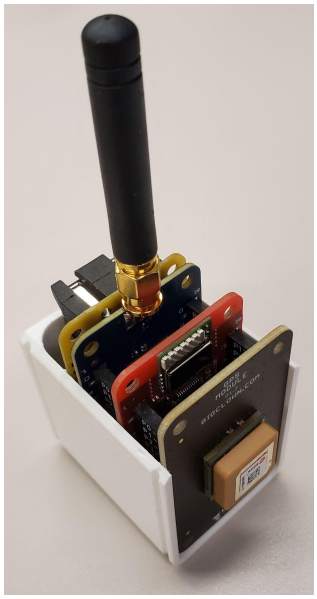
Current State

(as of December 2021)

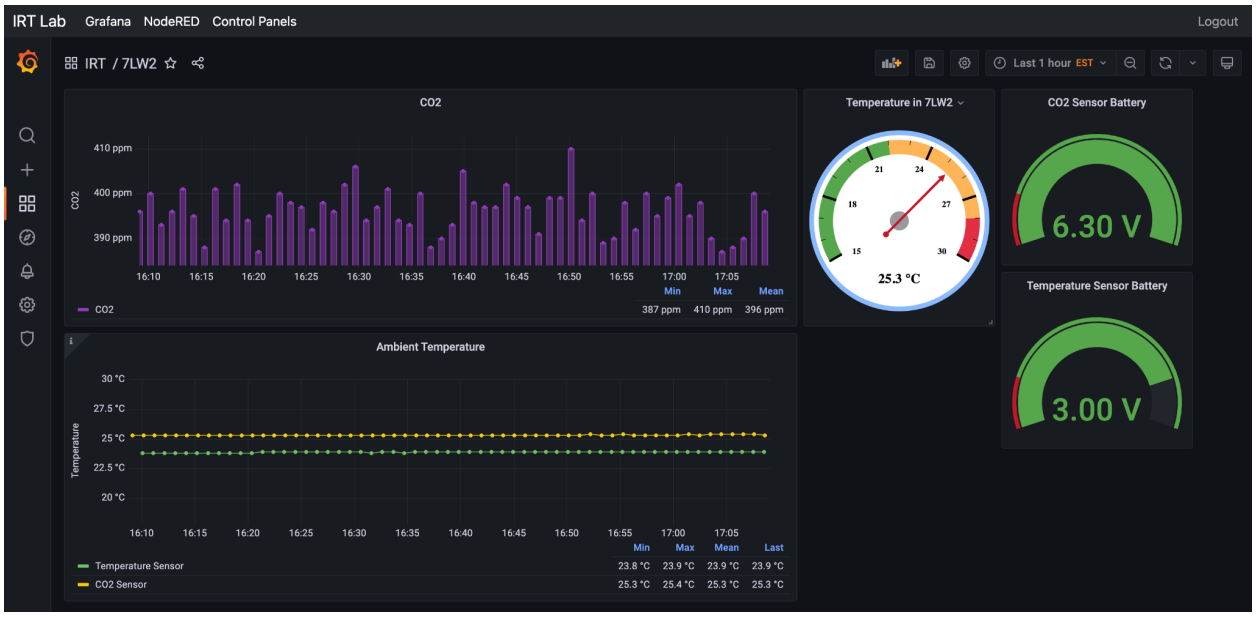
We have an operational indoor LoRa gateway installed in the Shapiro Center (CEPSR). The gateway covers the CEPSR building and upper parts of the campus only. The gateway is connected (federated) with the The Things Network and is open and available for any LoRa device to use.

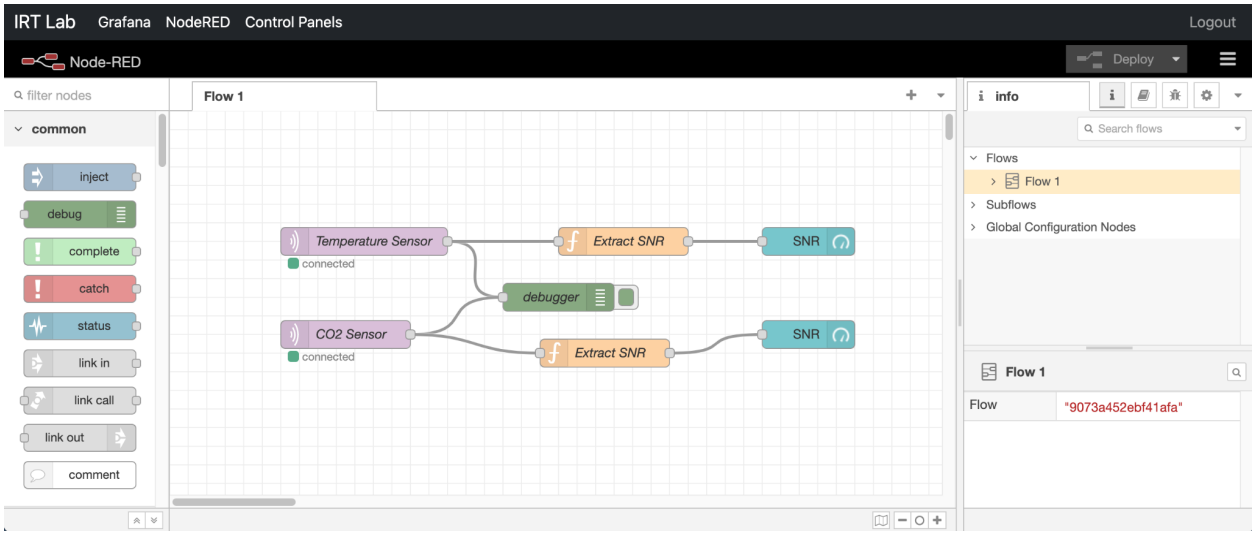
We have a variety of LoRa-capable IoT sensor devices based on the Hardwario TOWER kit, pictured below (and we will have more). The devices are battery (AAA) powered and use low-power components for a long lifespan. We currently have two of the devices connected to our LoRa network to measure the temperature and CO_2 levels in one of the labs in CEPSR.

Hardware Components



We have also installed and configured data storage and computational services for the sensor devices. The services are based on Grafana, MQTT, and NodeRED and can be used to quickly build dashboards and perform simple actions based on sensor measurements:





Next Steps

We are currently working to expand the LoRa network range, build and connect additional sensor devices, and to develop a scalable data storage and processing architecture for sensor data.

To expand the range of our LoRa network, we are planning to install a bigger outdoor LoRa gateway on the rooftop of Mudd. Mudd is one of the tallest buildings on campus and a gateway installed there will be able to cover the entire Morningside Heights campus, and probably much of the neighborhood.

We are specifically looking to provide usable LoRa coverage inside all buildings on the campus regardless of floor or location, and in Riverside and Morningside parks. The Mudd rooftop location has excellent line of sight in all directions and as such it is a good place for an outdoor LoRa gateway:

We are also looking to build and connect more IoT sensors measuring various kinds of phenomena. This effort will also include building sensors deployable on lawns, in classrooms, in gardens or parks, outdoor and indoor areas, and small enough to fit in a goat[1] or cow collar. This effort will mostly involve assembling existing hardware building blocks available from the maker community, with only lightweight electrical engineering work. Most of the work will involve writing firmware in C/C++ in an Arduino-like environment and interfacing with network services of the LoRa network.

We also have an ongoing research project investigating the possibility of using the GPS Real Time Kinematics (RTK) technology to provide positioning on campus with cm-level accuracy. If successful, we will consider integrating GPS RTK with LoRa sensors for highly accurate

[1] https://riversideparknyc.org/goatham/

localization of environmental sensors. The LoRa network may possibly double-serve to obtain sensor measurements from sensors and to disseminate GPS RTK corrections to the GPS receiver on the sensor.

Finally, as part of another ongoing research project, we are designing a novel data storage and processing service for sensor measurements collected by LoRa sensors. The service consists of geographically partitioned databases running on larger devices such as the Raspberry Pi. The service provides a single logical geographically dispersed database to the IoT application processing sensor data.

Student Project Opportunities

In Spring 2022, we welcome undergraduate and graduate students interested to work on all aspects of the above described project. We will be offering for-credit, unpaid semester-long research projects in the following broad areas:

1. LoRa network deployment, measurements, and evaluation:
    a. Help with installation and configuration of outdoor LoRa gateway
    b. Measure LoRa signal coverage across campus and the neighborhood
    c. Explore advanced LoRa features (broadcast, multicast, GPS-RTK integration)
2. Design and implementation of LoRa IoT sensors (with existing hardware kit) for
    a. Garden monitoring (soil, moisture, humidity, light)
    b. Animal tracking (GPS-RTK, accelerometer)
    c. Classroom monitoring (CO_2/temperature/humidity/occupancy)
    d. Air quality monitoring (PM2.5 or similar)
    e. Noise monitoring for Columbia neighborhood
    f. Pedestrian or railroad crossing warning and monitoring
3. IoT applications collecting, processing, and visualizing sensor measurements
    a. Design and implementation of dashboards and widgets to present sensor data
    b. Low-code/no-code programming for the LoRa network and devices

Appendix

Panoramic view from the potential outdoor LoRa gateway site (larger photo):