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Signpost Modules: Adaptive architecture providing safety, isolation, upgradability, and novel sensing paradigms

TerraSwarm
http://terraswarm.org/

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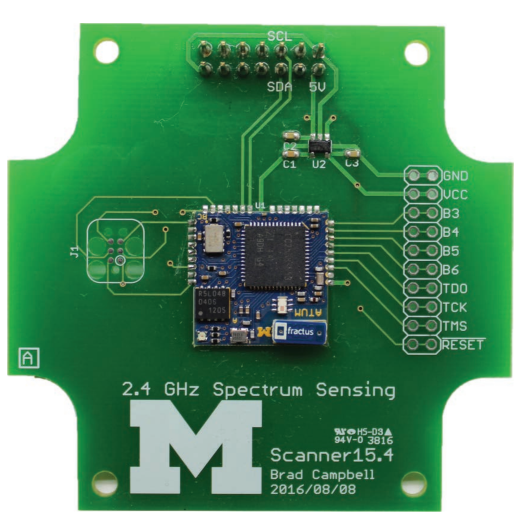
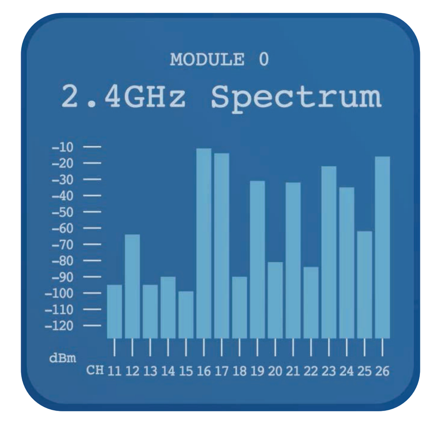
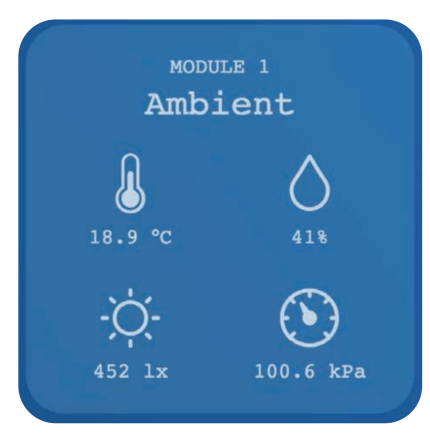
Modular Design makes the signpost a plug-'n-play testbed for urban sensing, facilitating integration of a diverse array of sensing modalities. Researchers, citizen scientists, city planners, or any other interested parties can add to the platform, without compromising other modules. Implementing the controller and power management as modules allows for future system improvements with minimal impact on infrastructure. The signpost backplane provides connection and isolation, leaving management to the modular controller module.

RF Spectrum



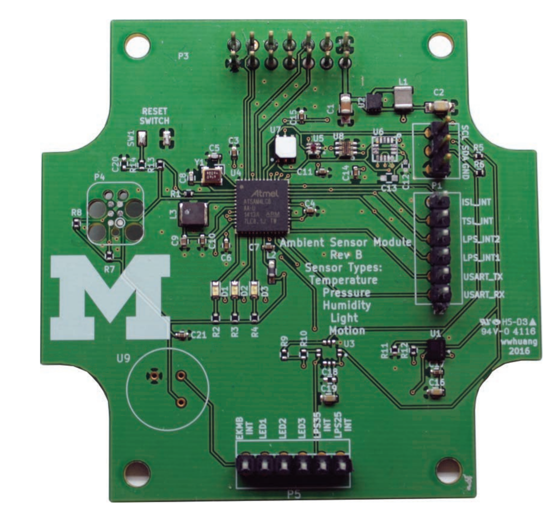
- Measure energy in each 802.15.4 spectral band
- City-wide spectrum usage data critical for whitespace applications and regulations





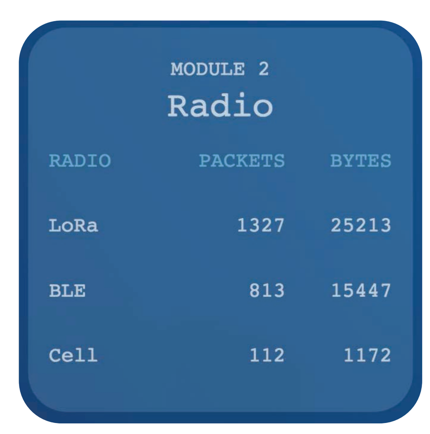
Ambient Environmental

- Classical environmental measures
  - Temperature, pressure, humidity, ambient light
- Allows sensitive sensors to compensate for local environmental factors



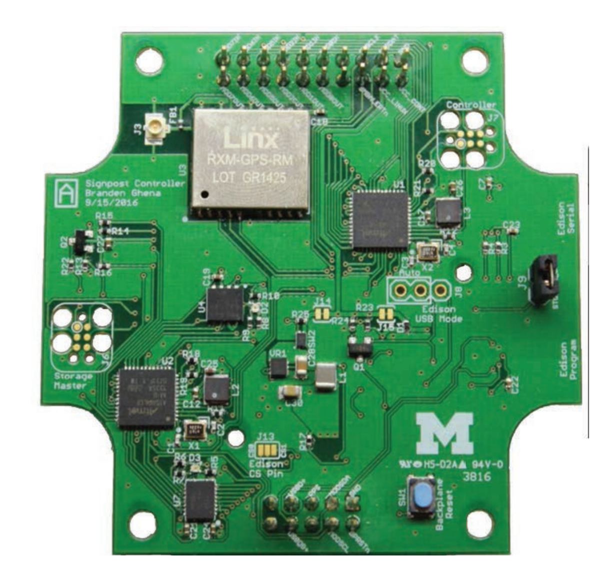
Radio

- Communicate signpost data
- **Bluetooth** – Local data to support immediate user engagement
- **LoRa** – Low energy, low data-rate, long-range
- **Cellular** – Higher energy, high bandwidth, long-range

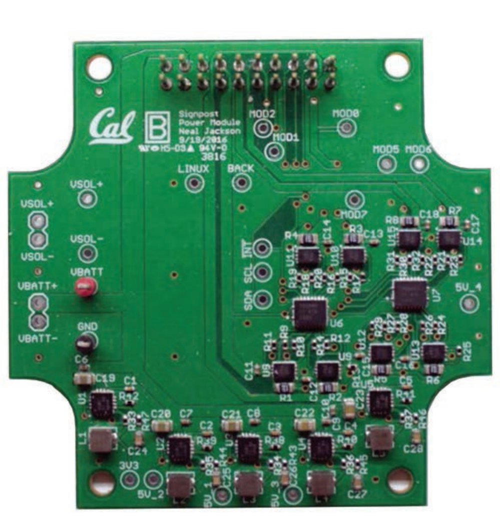


Controller

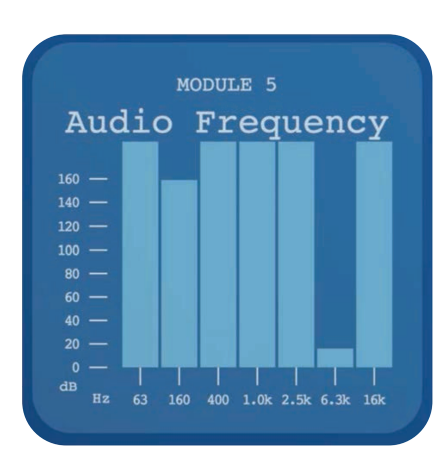
- Monitor & protect operations
- Control power, I²C, and USB isolation of each module
- Long-term storage of large volume data
- Duty-cycled Linux for balancing power, computation
- GPS for location, timestamp
  - Sync pulse to each module



Power

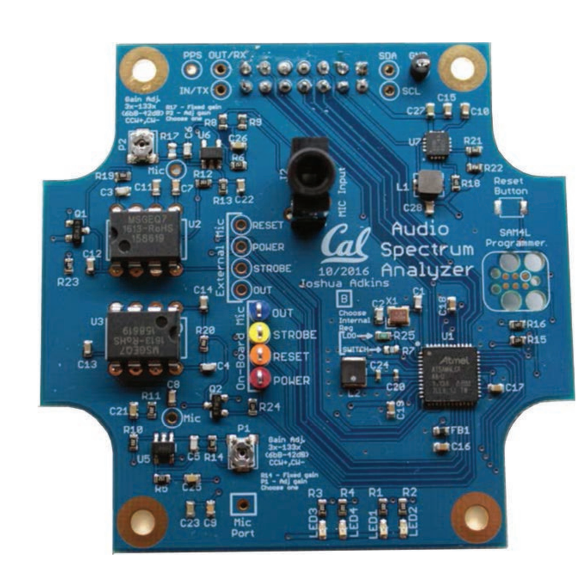


- Monitor energy input, battery charge state
- Regulation and monitoring of power for each module
- Enables controller to enforce arbitration rules upon modules



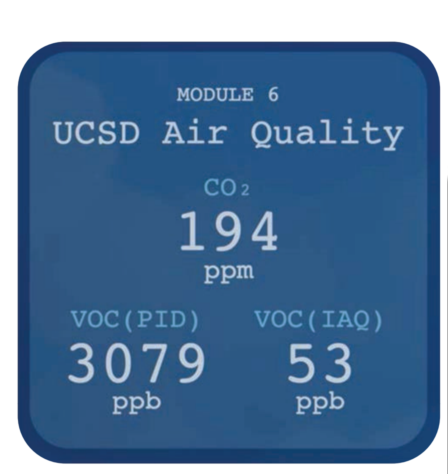
Audio

- Sample energy across the audio spectrum
- Background noise levels important to citizen health
- Raw audio never captured, protecting privacy



UCSD Air Quality

- Third-party sensing module integrated with signpost
- Measures environmental health data
  - Urban air quality can vary block-to-block, demands high fidelity sensing



Microwave Radar

- Motion tracking around the signpost
- Pedestrian counting without identifying individuals, preserving privacy
- 10 GHz radar balances energy and fidelity

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Platform Design: How to safely provide a common interface and resources to untrusted modules

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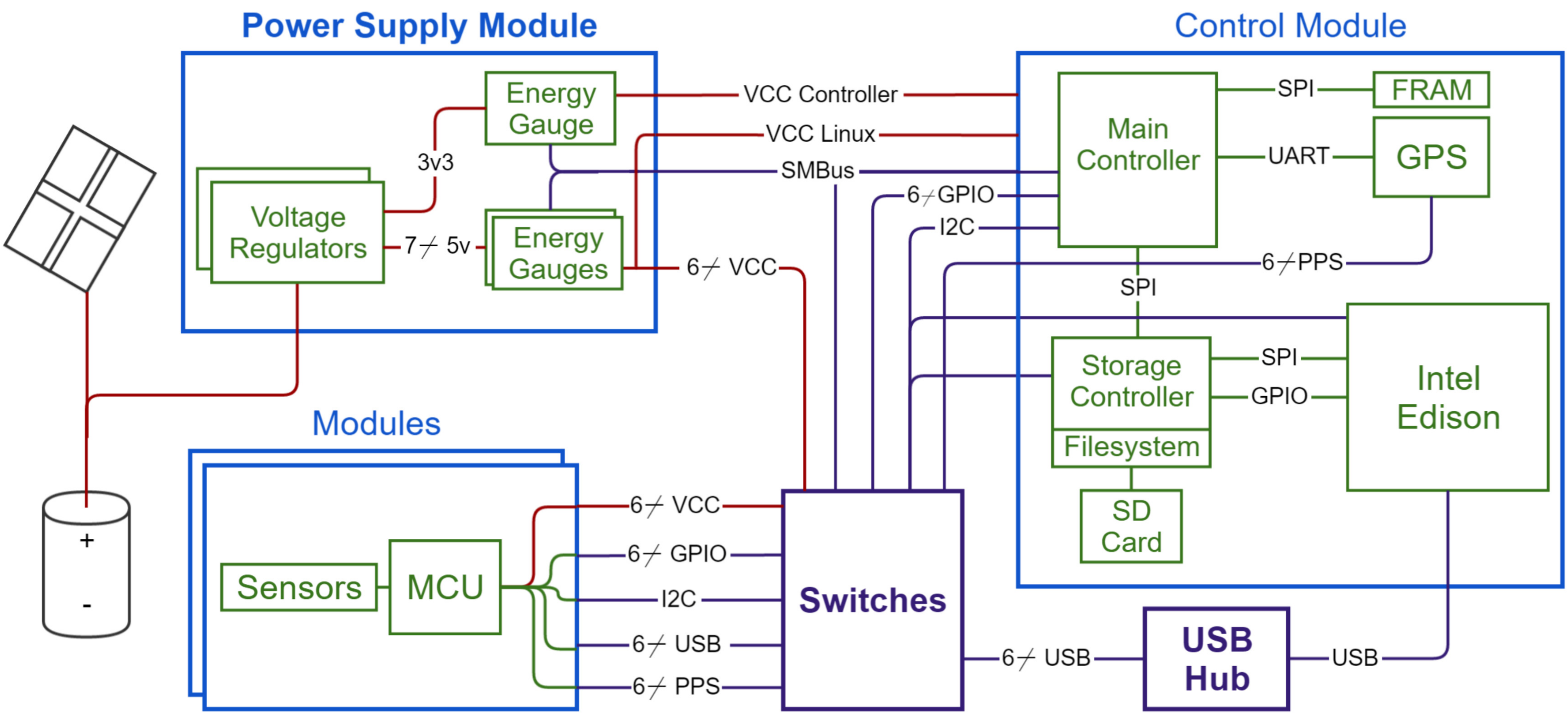
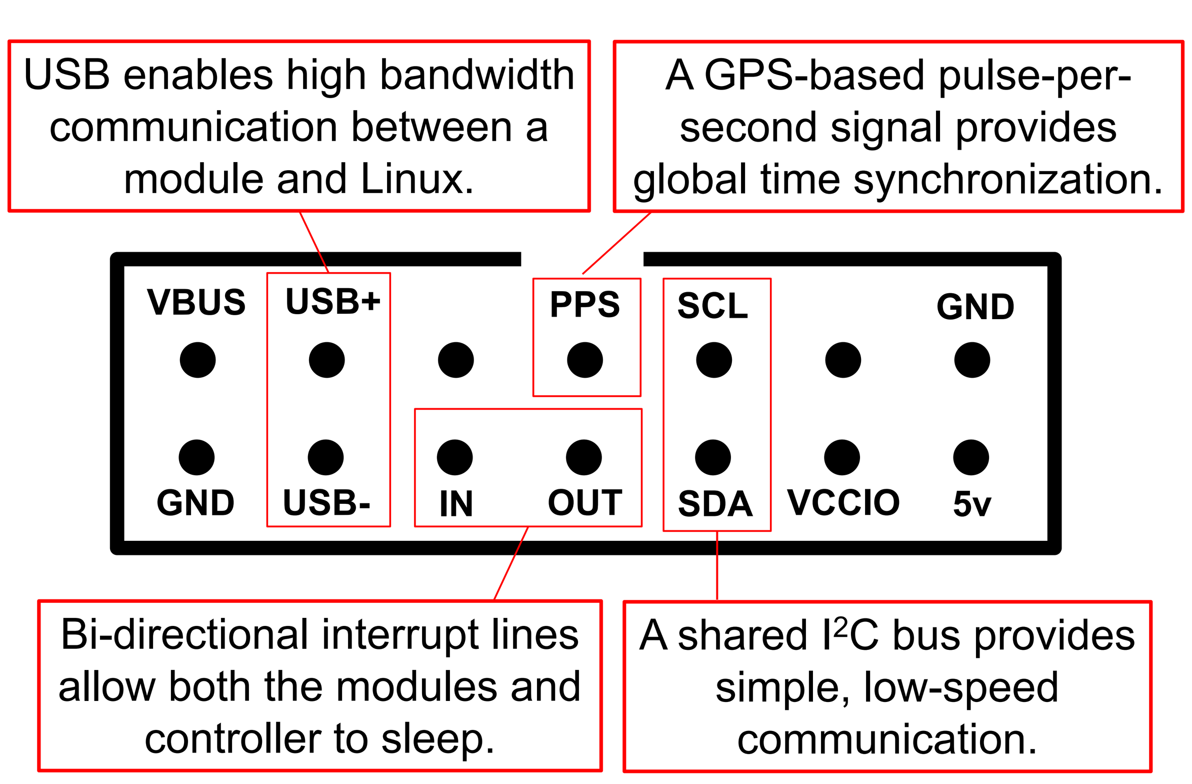
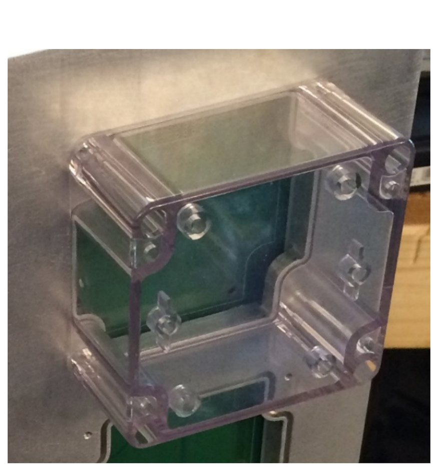
The signpost-based platform provides power, networking, storage, compute, and isolation to sensor modules through a standardized interface.



Interface. Sensor modules are added to the platform through a standard electrical and mechanical interface. The interface is designed to provide the necessary features we envision for modules.



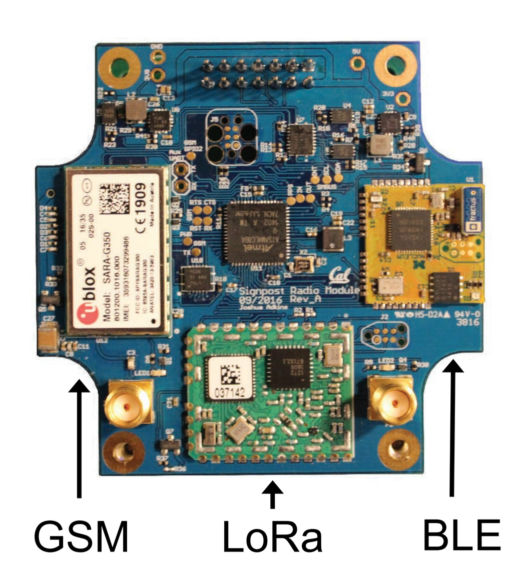


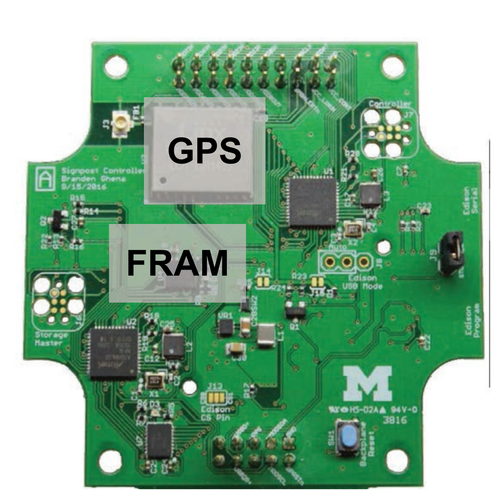
An off-the-shelf case seals modules to the waterproof sensing platform.

The case can be easily modified to accommodate different sensors.

Shared Resources. Providing power, networking, storage, location, and higher-performance computation **lowers the bar** to building and deploying a module.

A radio module provides cellular (GSM), long range 915mHz (LoRa), and Bluetooth Low Energy (BLE) networking.

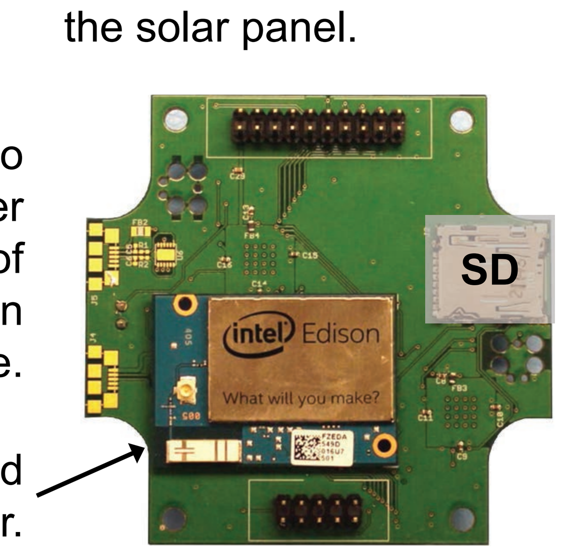




The controller provides non-volatile storage on an SD card and FRAM. It uses a GPS module to provide location and time data. The controller also manages and arbitrates power provided by the solar panel.

Modules will be able to access the general, higher performance computation of the Intel Edison through an in development RPC interface.

Intel Edison embedded Linux computer.

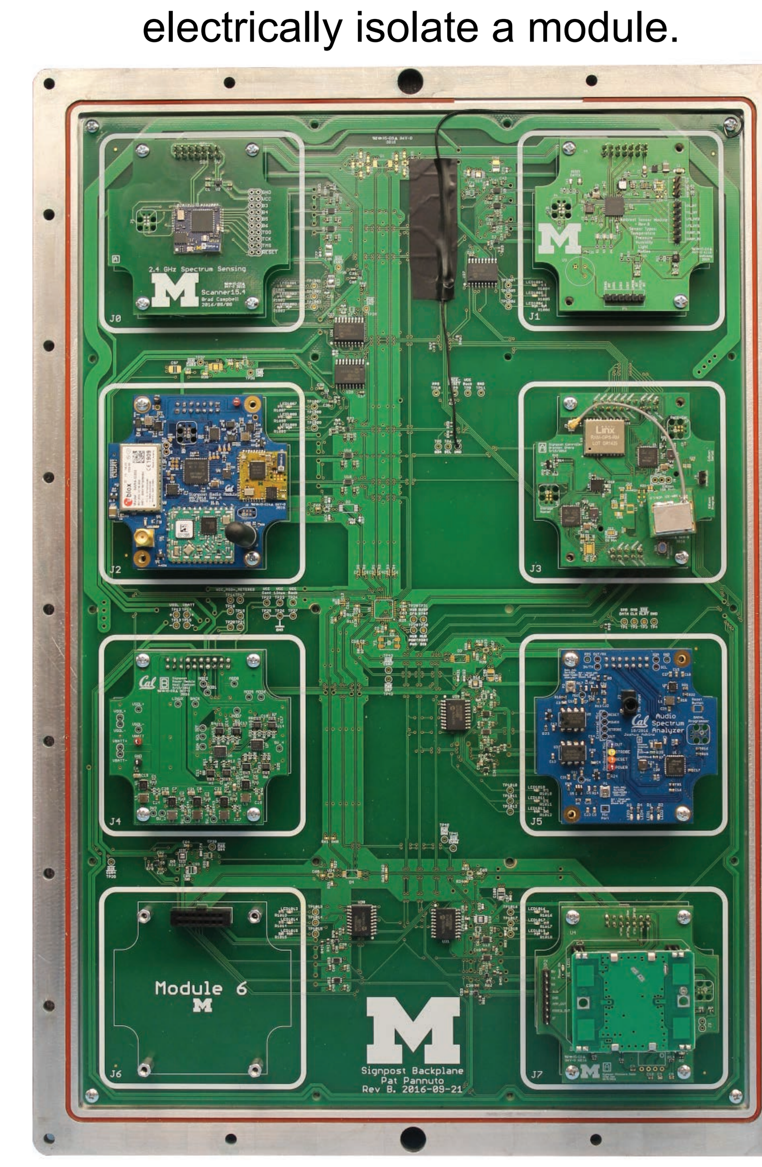


These components are the most technically difficult parts of designing a sensor system. The signpost platform does them for you.

Isolation. Integrated mechanisms for physical isolation, electrical isolation, and fair distribution of resources ensure reliability and security.

An internal o-ring attempts to isolate water damage to a single sensor module if a leak occurs.

The platform backplane allows the controller to completely electrically isolate a module.



This prevents faulty, malicious, or greedy modules from negatively impacting the entire signpost platform.

It also allows a module to share private information (such as a key) on the shared bus.

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An Energy-Harvesting City-Scale Sensing Network

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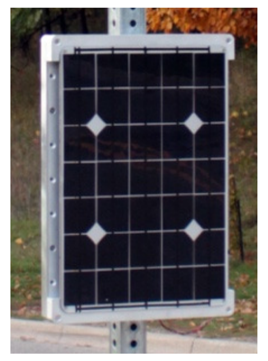
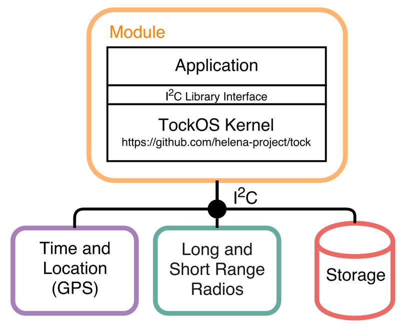
October 26, 2016

A city-wide sensing platform that is deployable, scalable, and driven by applications.

Each signpost system is a self-contained unit capable of powering itself, communicating wirelessly, and supporting several sensor modules. The system bolts onto existing signposts located in a city to provide distributed sensing points with minimal installation complexity. By supporting plug-in sensor modules, the system is upgradable as applications and sensing needs change.

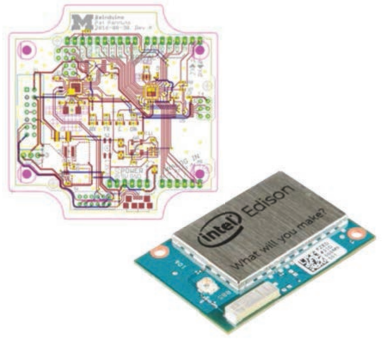
Energy-harvesting removes the need for battery replacement or expensive AC mains wiring.





Onboard storage, communication, and energy management, plus software libraries for modules simplifies adding sensor modules to the system.

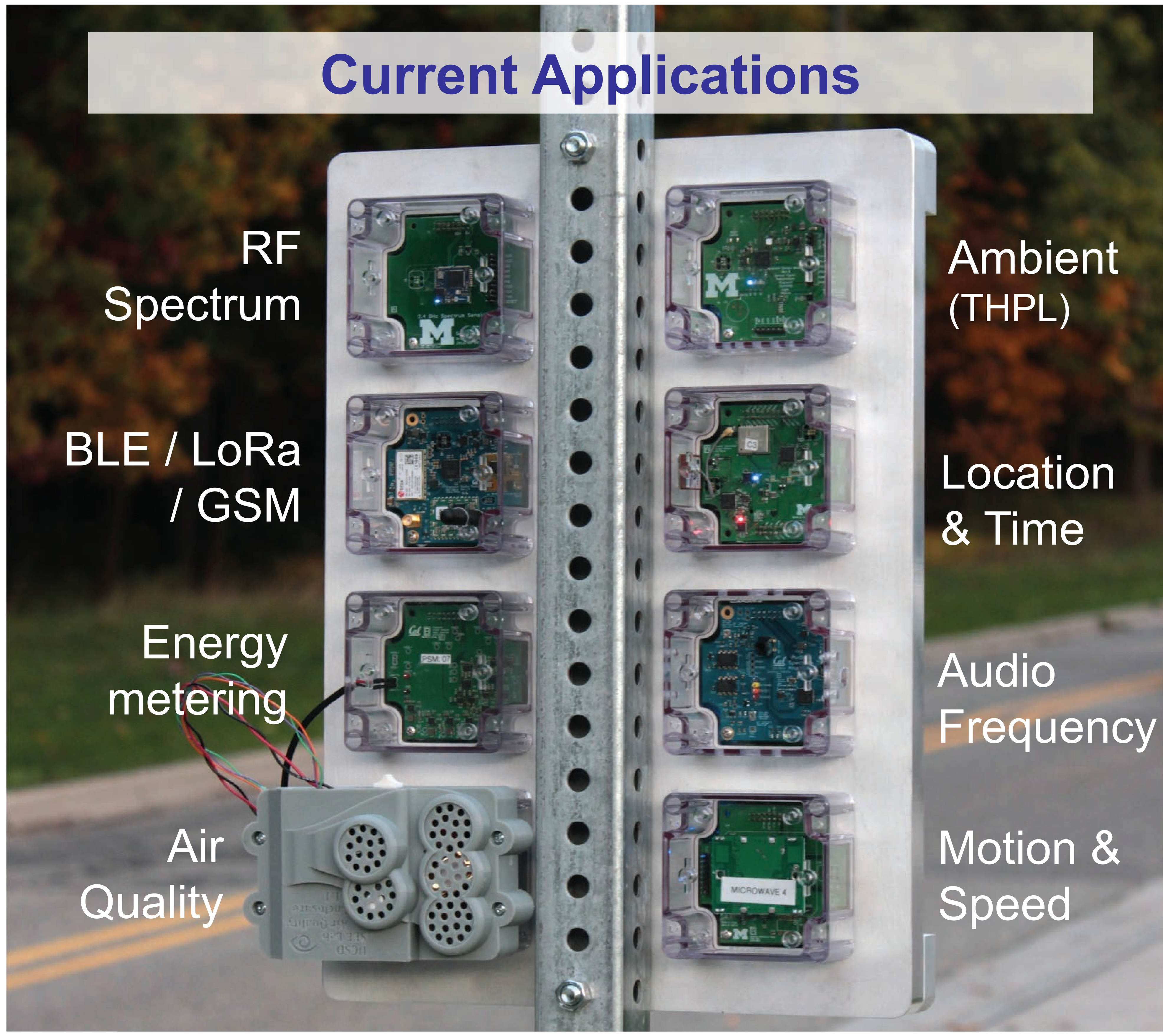
Arduino compatible modules, an onboard Linux computer as a resource, and a cloud infrastructure simplify application development.



Key Research Themes

1. Private by design: do not collect what must be kept private. Filtering done at the hardware level, no camera, no identifying data collected.
2. Energy-proportional computing: Sensing and communication must scale to current harvesting conditions.
3. Distributed applications: Balance signpost-local resources, communication bandwidth, and cloud resources.

Current Applications



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TerraSwarm
http://terraswarm.org/

The Swarm Gateway Architecture

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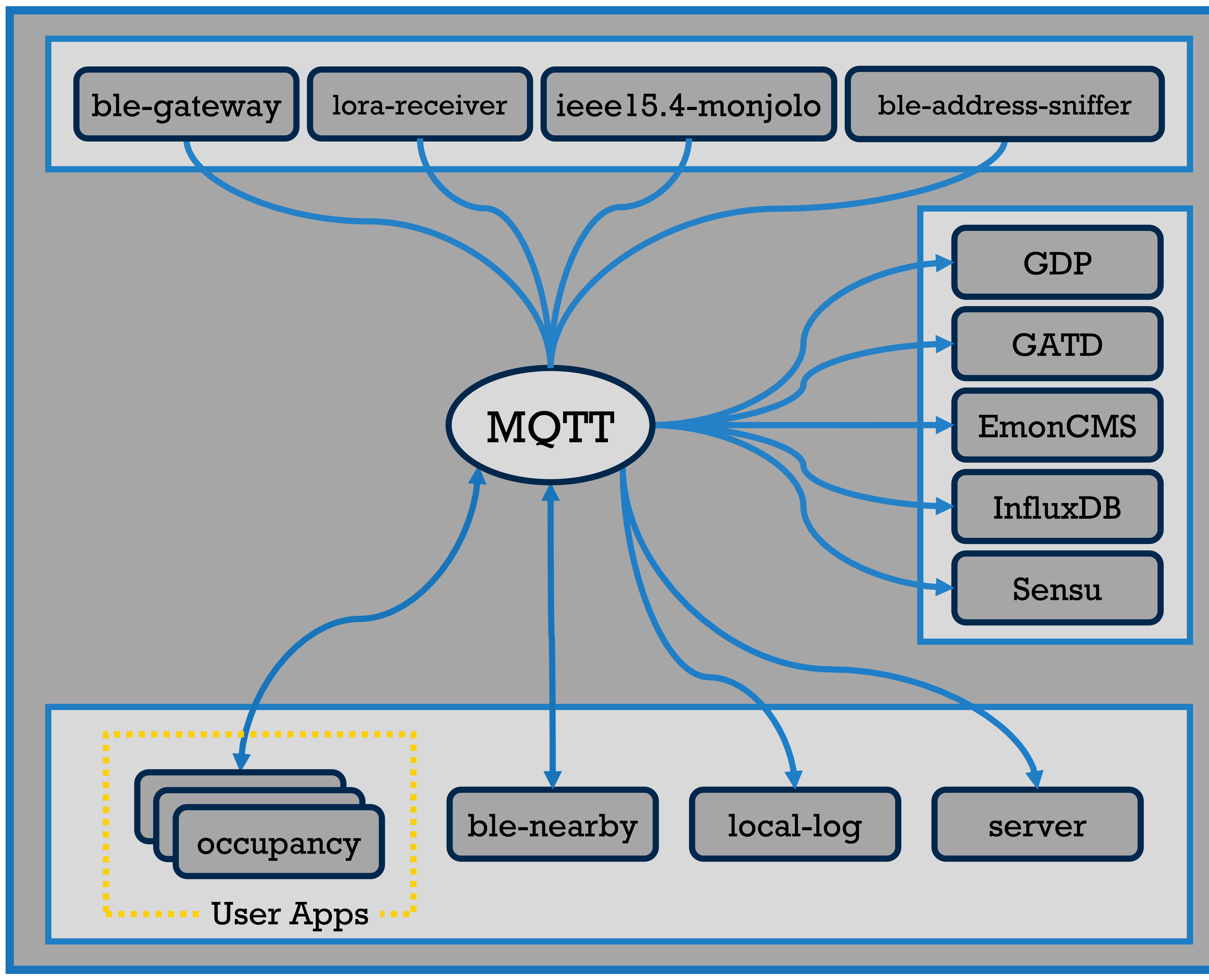
University of Michigan

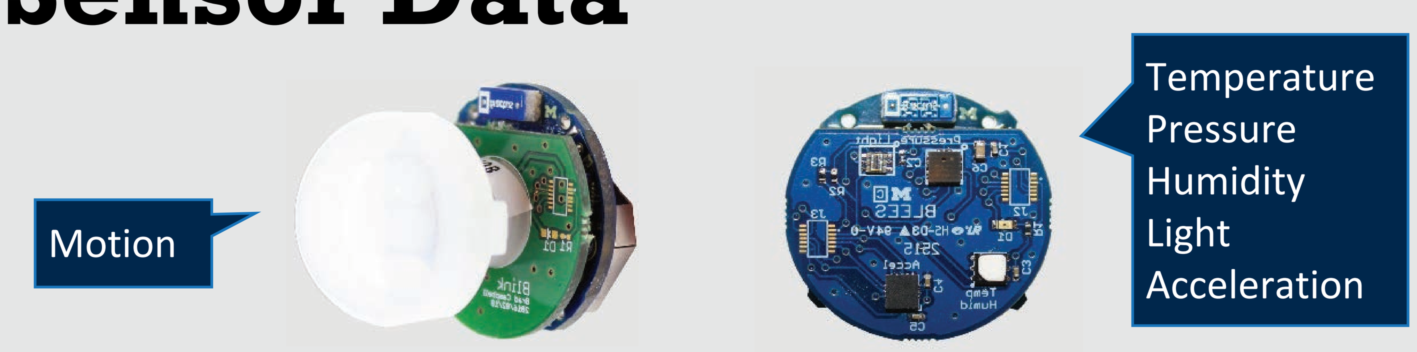
October 26, 2016

Design Goals

- Provide gateway functionality for a wide range of possible devices
- Make data streams available through a useable protocol and in an understandable format
- Support local application interactions with devices and data streams
- Relay data streams to various back-end systems for storage, monitoring, and visualization

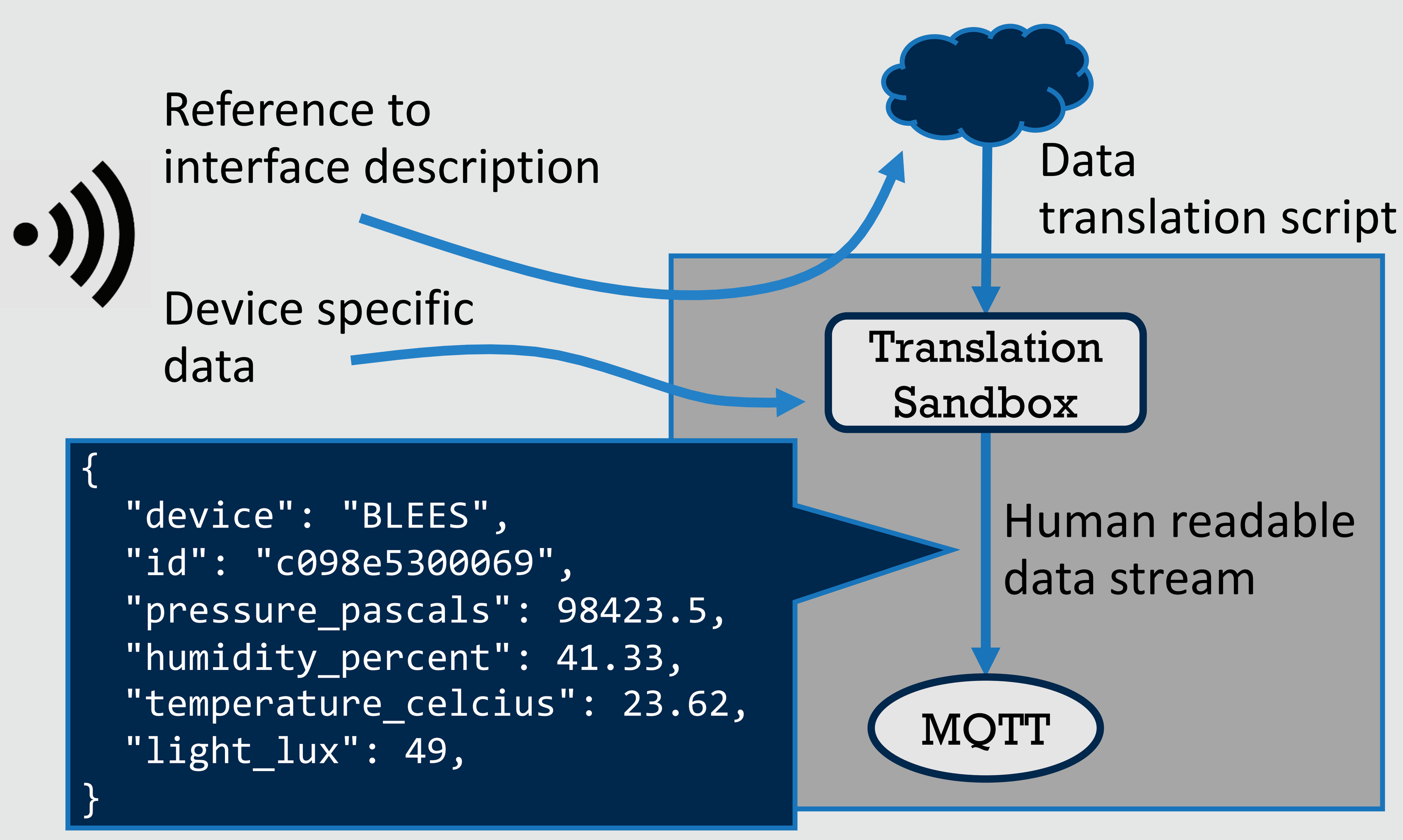


Sensor Data



Sensors transmit data in arbitrary binary formats. These need to be translated into a human-readable format.

Each device is responsible for transmitting an interface description that the gateway can use to translate its data.



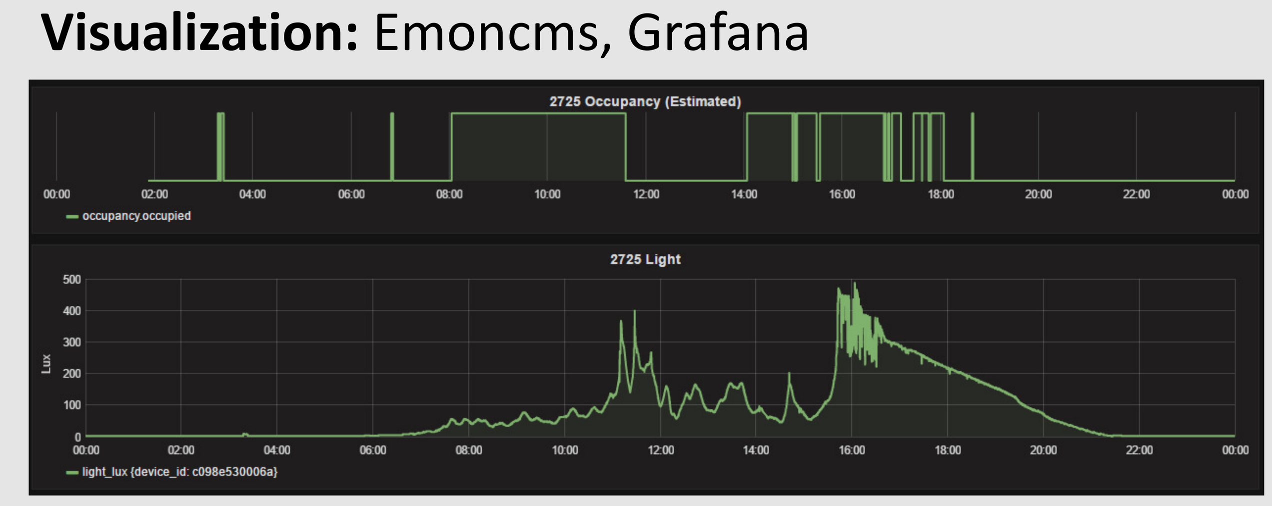
Cloud

Connecting to the cloud can provide additional capabilities such as long-term data storage, monitoring of gateways and devices, and visualization of sensor data. Services on the gateway pull data from the MQTT broker and translate to the format expected by the cloud service.

Storage: GDP, GATD, Emoncms, InfluxDB

Monitoring: Sensu

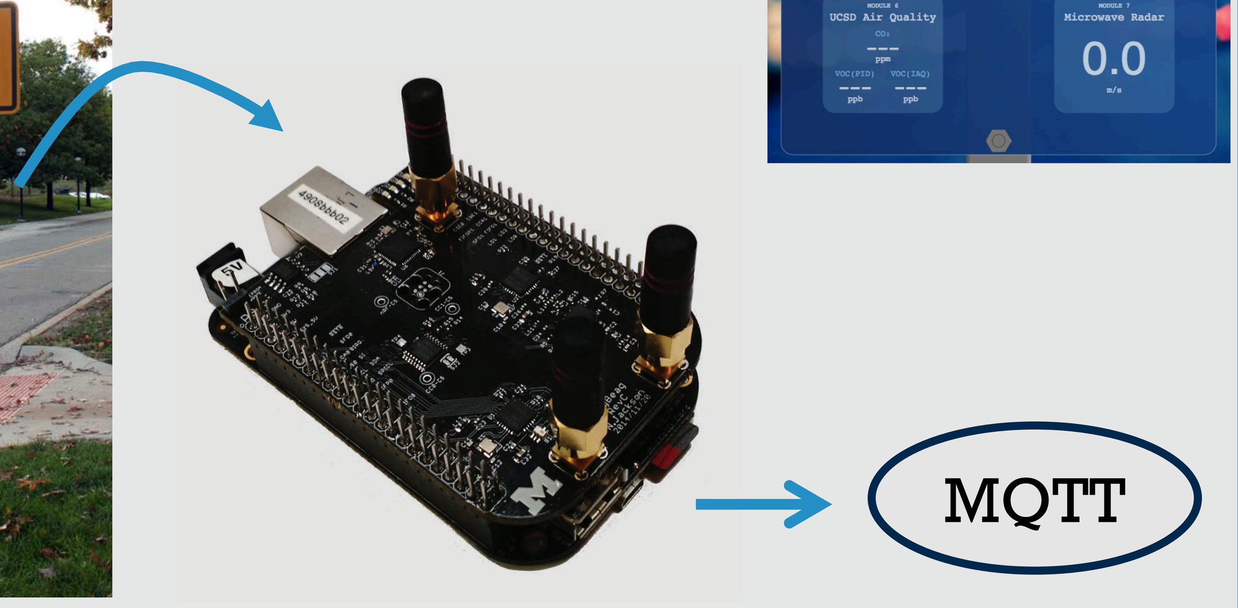
Visualization: Emoncms, Grafana



Signpost

Signpost transmits data over LoRa, a low-power wide area network. A swarm-gateway receives these messages, translates them into human-readable JSON, and makes them available via the MQTT broker.

Check out our demo at:
j2x.us/signp



Local Interactions

Enabling local interactions enables low-latency control, provides functionality despite possibly intermittent network connections, and creates a natural environment for running user applications that interact with the nearby physical world.

Data streams can be interacted with locally through MQTT, a publish-subscribe protocol. An MQTT message broker runs on each gateway to receive and distribute messages. Local services can pull from these streams and create new ones.

Example:

- list of devices seen in the last hour
- list of nearby devices, determined by RSSI

User applications can subscribe and publish to the MQTT broker and can interact directly with cloud services. Future work will focus on fair resource allocation for user applications.

Example user applications:

- determine occupancy of a room
- control lights in room based on occupancy
- send a twitter message when a device's power state changes

Gateways announce their presence locally over BLE, mDNS, and SSDP to enable discovery by users and other gateways. Users can connect over HTTP to view a list of devices and their recent data, remotely subscribe to data streams, or run local applications on the gateway.

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