Signpost: Sensors for Urban Monitoring

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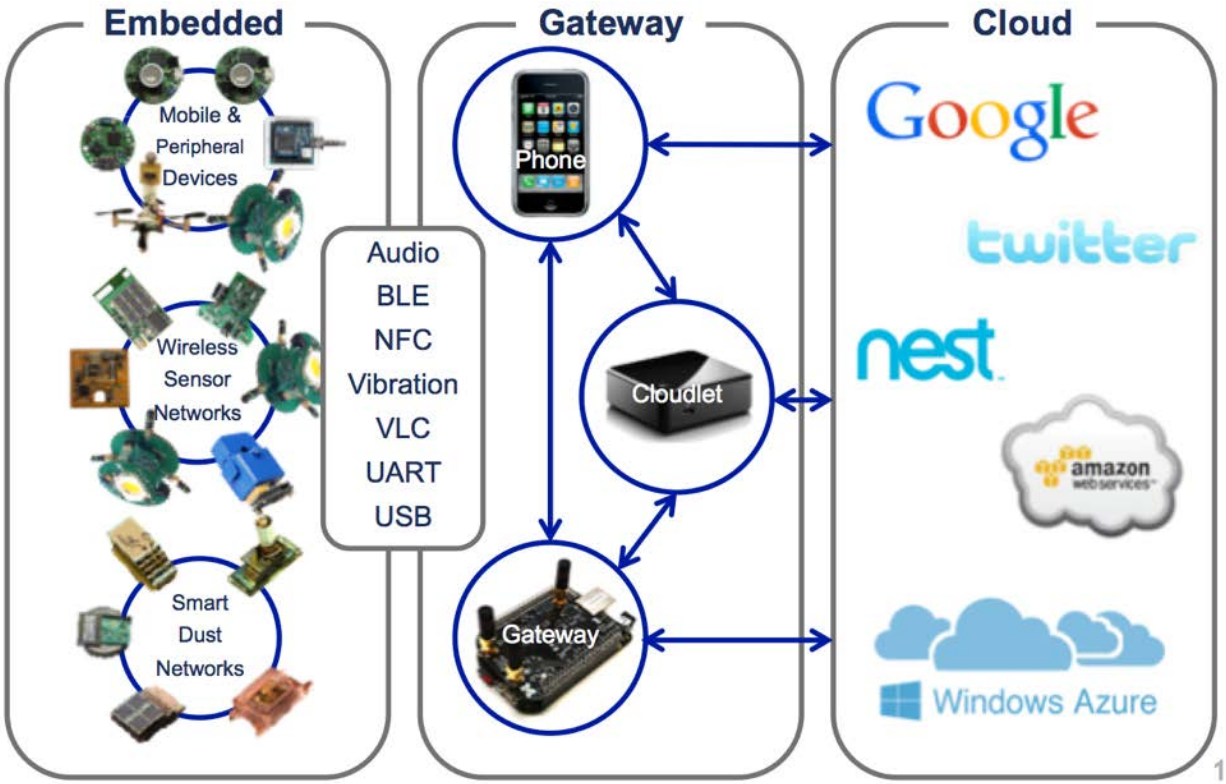
Neal Jackson, Pat Pannuto, Samuel Rohrer, and **Prabal Dutta**

A bit about my work…



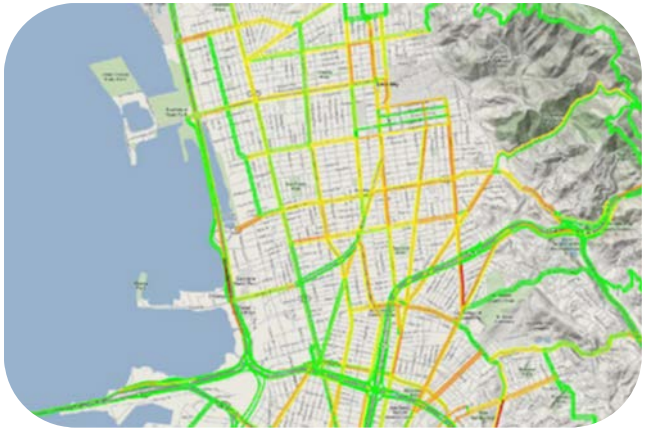
Wouldn’t it be interesting to...

- Measure RF spectrum with high resolution
- Monitor pedestrian flow through cities
- Detect emergency situations

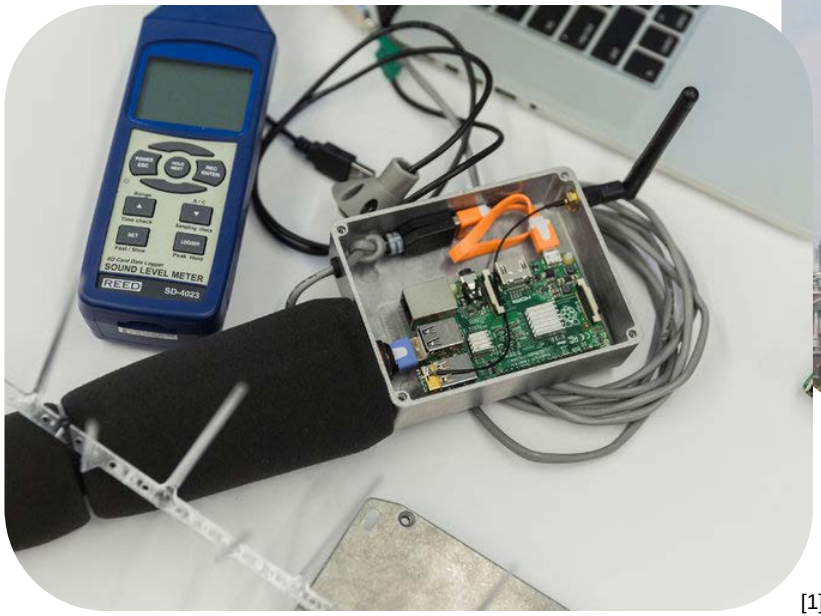
Cities could use data to understand dynamics

Real-time applications could use the data to improve process efficiency

Individuals could use data to understand their environment and change their behavior



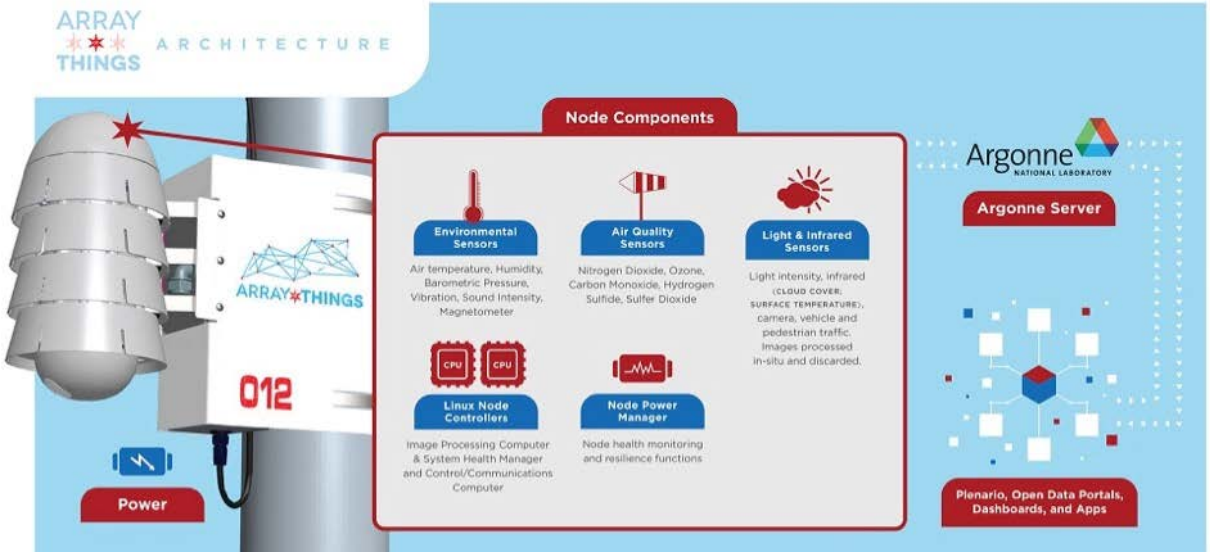
SONYC: distributed audio sensing



[1]

[1] Mydlarz et al. The design and calibration of low cost urban acoustic sensing devices.

Array of Things: environmental sensing



[2]

[2]

[2] https://arrayofthings.github.io/

These systems have some drawbacks

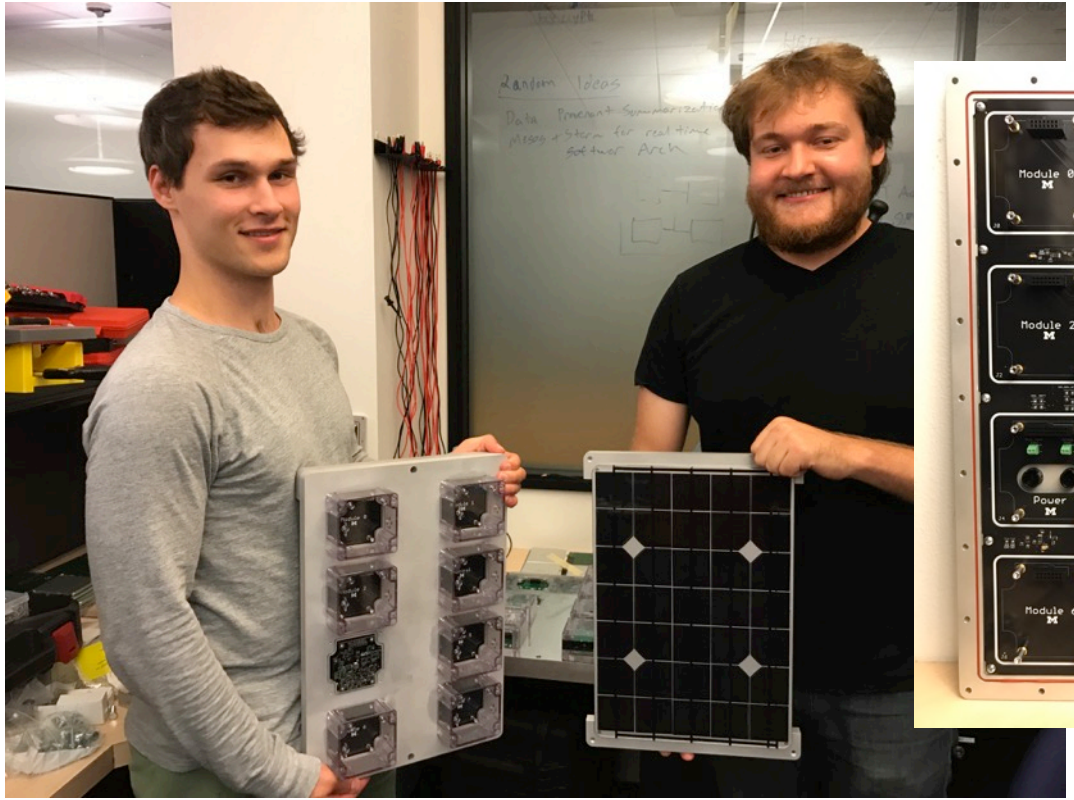
Limits potential deployment scenarios

- Bucket-truck installation
  - Expensive! Not conducive to experimentation!
- Mains-powered
  - Expensive! Restricts placement options!
- Monolithic, not modular
  - Makes extensibility and experimentation difficult

[2]

[2] https://arrayofthings.github.io/

Signpost platform: infrastructure-“free” infrastructure (backplanes, modules, sensors, and mechanicals)



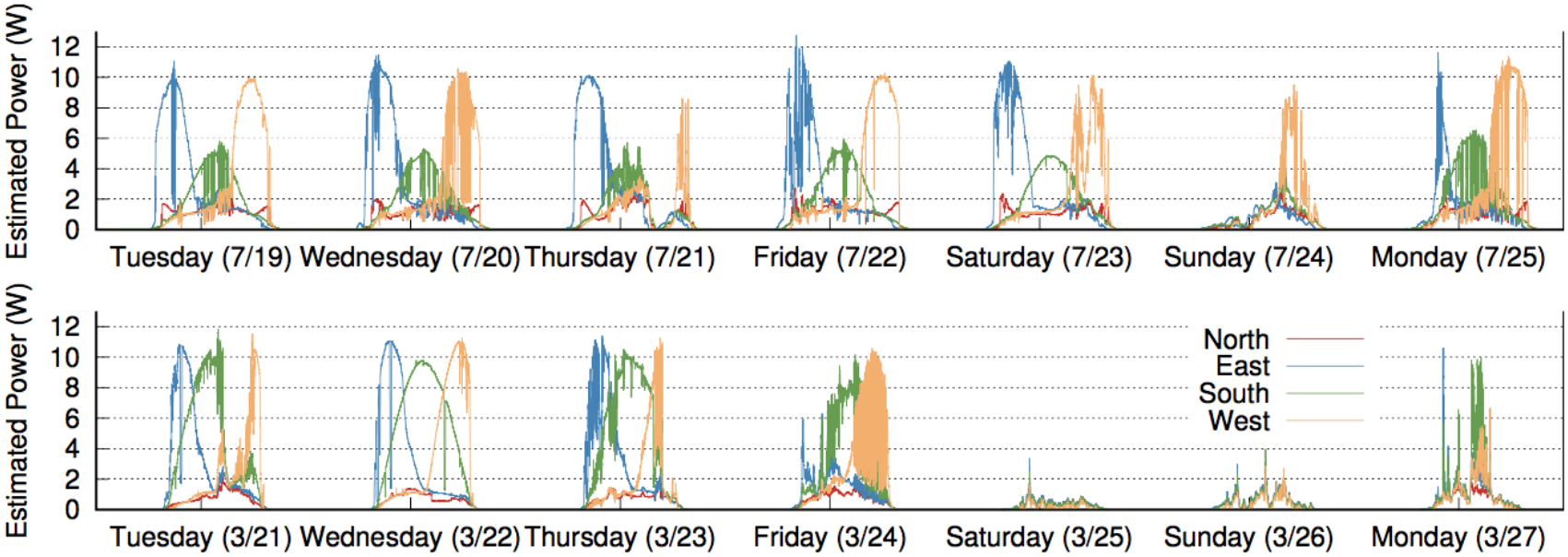
Signpost platform: infrastructure-“free” infrastructure

- Easy (two bolt) installation

Signpost platform: infrastructure-“free” infrastructure

- **Easy (two bolt) installation**
- Solar energy harvesting

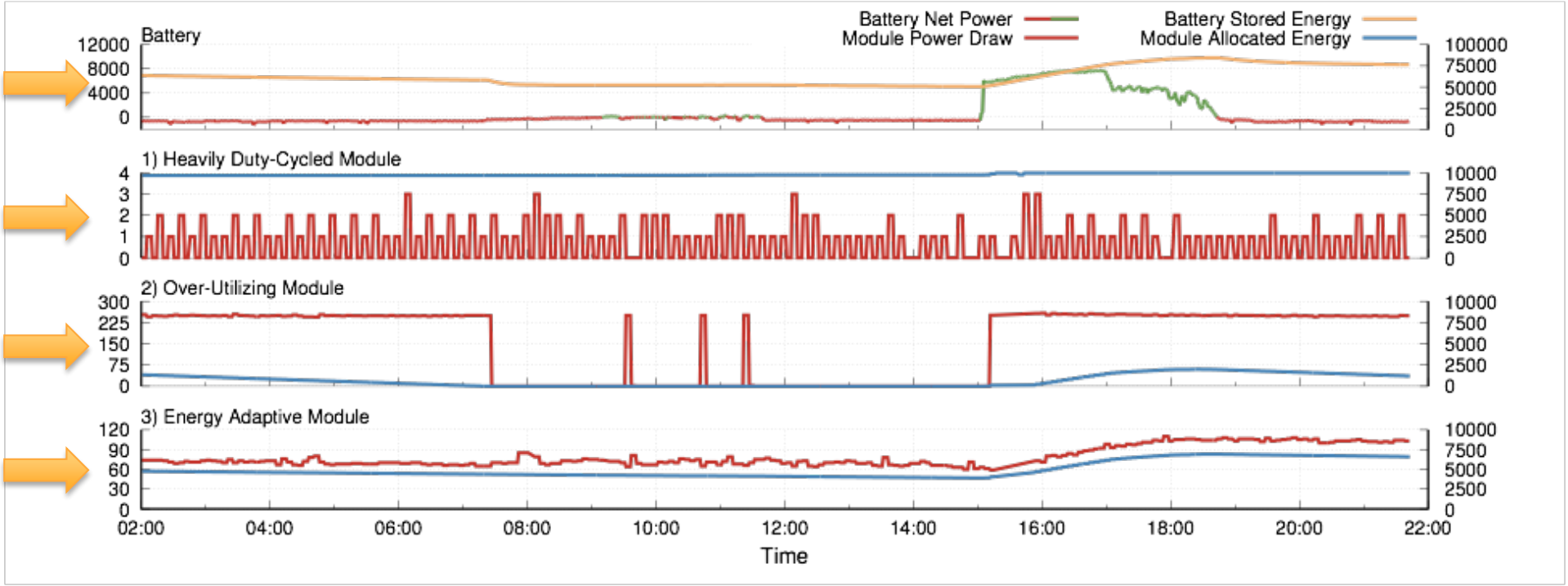
How much energy is available? $P_{avg} = 0.2 – 2W$



Exposing energy hints, controls to applications

Service	System Call	Description
Init	`i2c_address = module_init(**api_handles)`	Initialize module
Network	`response = network_post(url, request)`	HTTP POST data to URL
	`network_advertise(buf, len)`	Advertise data over BLE
	`network_send_bytes(destination, buf, len)`	Send via best available medium
Storage	`record = storage_write(buf, len)`	Store data
Energy	`energy_info = energy_query( )`	Request module energy use
	`energy_set_warning(threshold, callback)`	Receive energy usage warning
	`energy_set_duty_cycle(duty_cycle)`	Request duty cycling of module
Processing	`processing_call_rpc(path, buf, len, callback)`	Run code on Linux compute
Messaging	`messaging_subscribe(callback)`	Receive message from a module
	`messaging_send(module_id, buf, len)`	Send message to another module
Time	`time_info = get_time( )`	Request current time and date
	`time_info = get_time_of_next_pps( )`	Request time at next PPS edge
Location	`location_info = get_location( )`	Request location

Energy adaptivity in practice



Signpost platform: infrastructure-“free” infrastructure

- **Easy (two bolt) installation**
- **Solar energy harvesting**
- Modular and extensible *platforms*

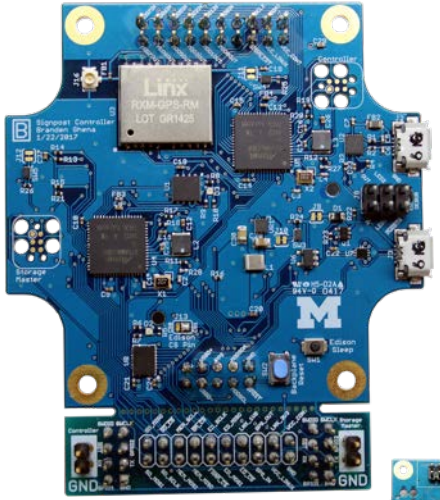
Deployment	Services Needed						
	Power	Comms	Proc	Storage	Time	Sync	Location
Caraoke [3]	■	■			■		
Bouillet et al. [4]	■	■					
Aircloud [5]	■	■					
Girod et al. [6]	■	■	■			■	■
Ledeczi et al. [7]	■	■	■			■	■
SenseFlow [8]	■	■					
Argos [9]	■	■			■		
SONYC [1]	■	■	■	■			
Kyun Queue [10]	■	■		■	■		
Micronet [11]	■	■		■			

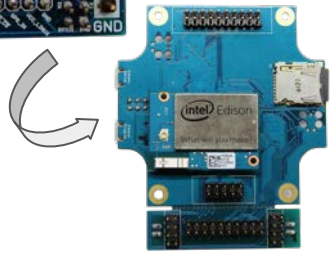
* See last side for references

Core Modules Provide Services to Sensor Modules

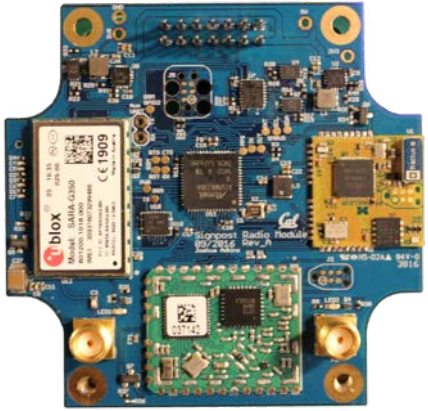
Power Module

Processing Module





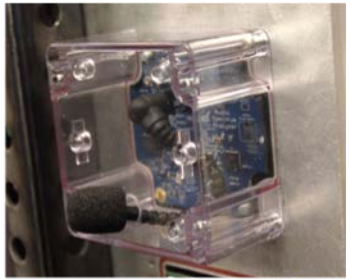
Communications Module



Platform Provides Isolation

- Guarantees module access to the other services
- Mechanical isolation in the case design
- Electrical isolation in backplane (interconnect)
- Control module manages resource isolation
  - Energy
  - Networking
  - Storage
  - Compute

Mechanical Isolation

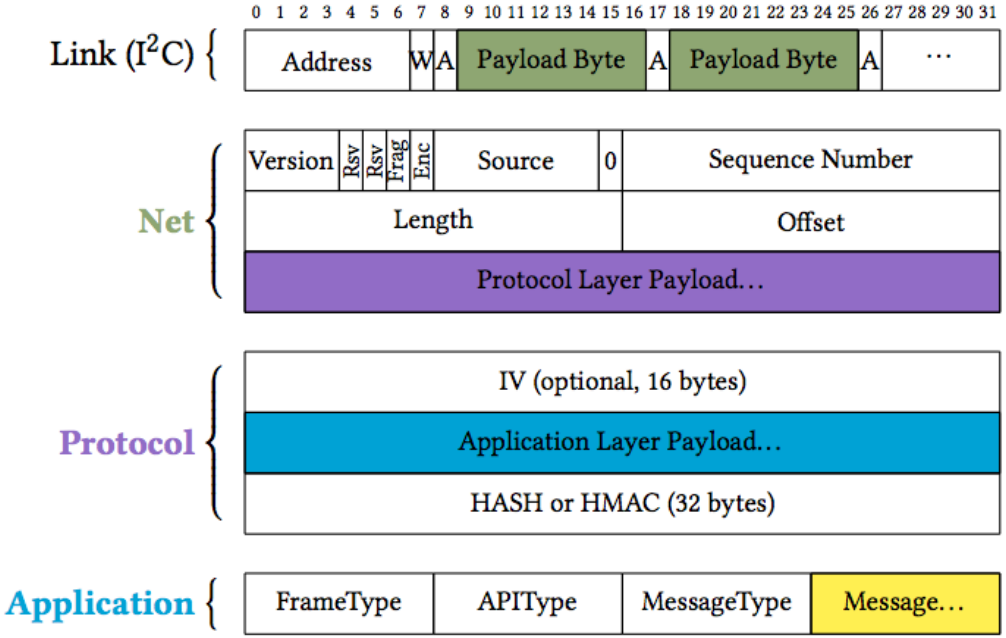


Electrical Isolation

Resource Isolation

Platform provides software services

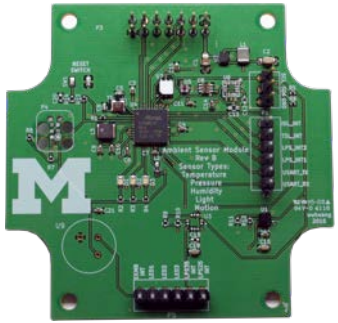
Encryption to prevent eavesdropping on bus



Diverse and growing set of sensor modules

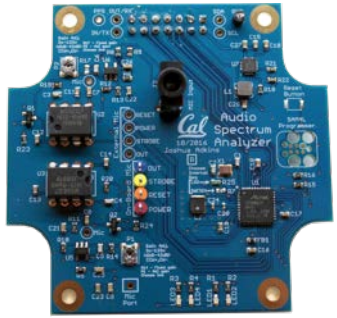
15-2700 MHZ
RF Spectrum

Environmental
Data



Speed and
Motion

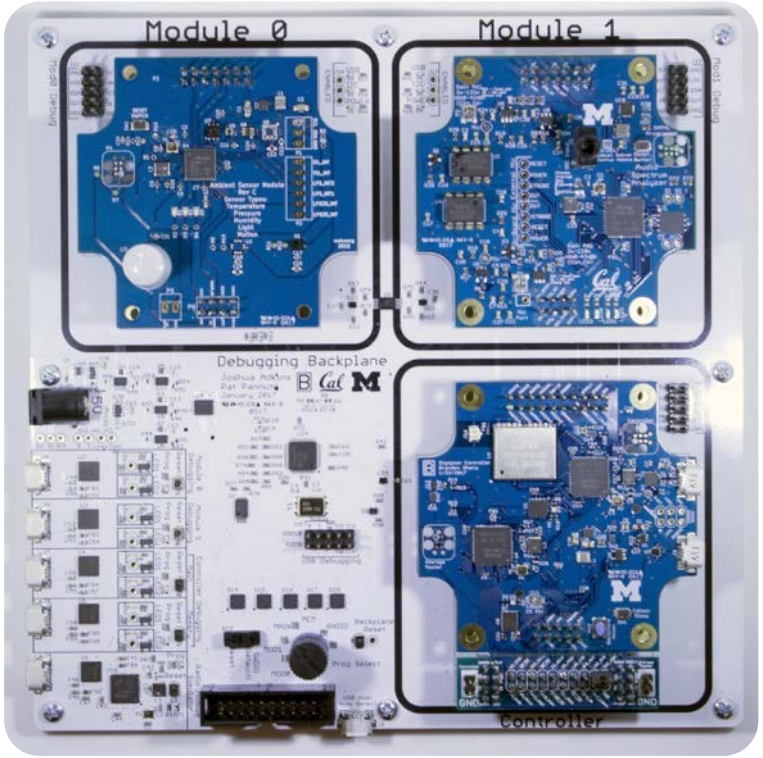
Audio
Spectrum



Signpost platform: infrastructure-“free” infrastructure

- **Easy (two bolt) installation**
- **Solar energy harvesting**
- **Modular and extensible *platforms***
- ***And many other challenges…***

Signpost Development Kits



Emulates a running Signpost

- Platform for module development, bring-up
- Test applications with different energy profiles
- Exposes more debugging output

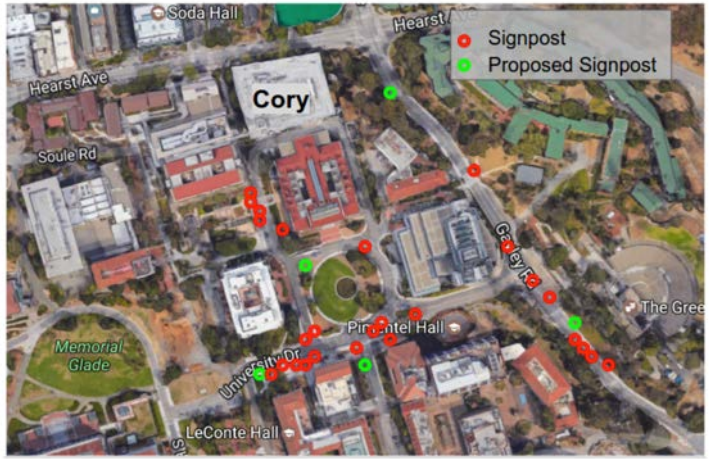
Future

Deployment on Berkeley campus

- Starting with 5
- Grow to 25 by October

Collaboration to build applications

- SeaGlass IMSI Catcher Detection [12]
- ChemiSense air quality monitoring
- Dynamic wireless channel selection through RF spectrum sensing



[12] Ney et al. SeaGlass: Enabling City-Wide IMSI-Catcher Detection. 2017.

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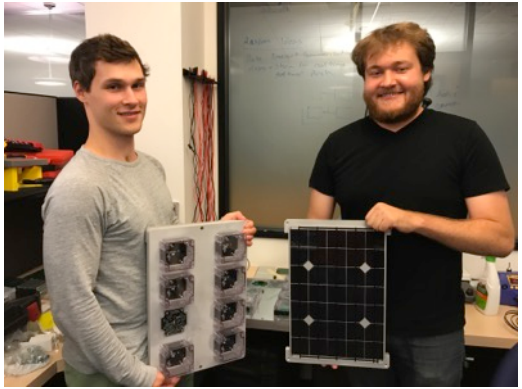

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References

[1] Mydlarz et al. The design and calibration of low cost urban acoustic sensing devices. 2015.
[2] arrayofthings.github.io. Retrieved on June 12, 2017.
[3] Abari et al. Caraoke: An E-Toll Transponder Network for Smart Cities. 2015.
[4] Bouillet et al. Fusing Traffic Sensor Data for Real-time Road Conditions. 2013.
[5] Cheng et al. AirCloud. A Cloud Based Air-Quality Monitoring System for Everyone. 2012.
[6] Girod et al. The Design and Implementation of a Self-calibrating Distributed Acoustic Sensing Platform. 2006.
[7] Ledeczi et al. Multiple Simultaneous Source Localization in Urban Terrain. 2005
[8] Li et al. An Experimental Study on People Tracking. 2015
[9] Rose et al. Mapping the Urban Wireless Landscape with Argos. 2010.
[10] Sen et al. Kyun Queue: A Sensor Network System to Monitor Road Traffic Queues. 2012
[11] Illston et al. Design and Deployment of Traffic Signal Stations within the Oklahoma City Micronet. 2009.
[12] Ney et al. SeaGlass: Enabling City-Wide IMSI-Catcher Detection. 2017.

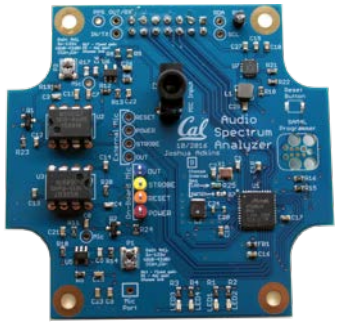
Can modules adapt to varying energy?

- Implemented a simple energy policy
- Incoming energy is split between module’s “virtual batteries”
- Module energy usage is subtracted from their “virtual battery”
- If a module uses too much energy it is cut off
- If a battery is full the energy is redistributed

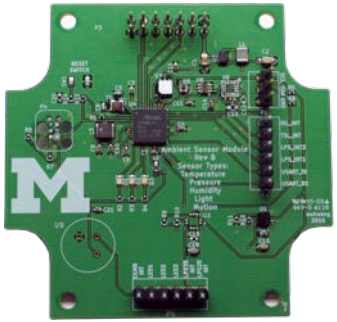
Three modules running

- Very low power duty-cycled module
- High power module
- Module adapting to a target lifetime

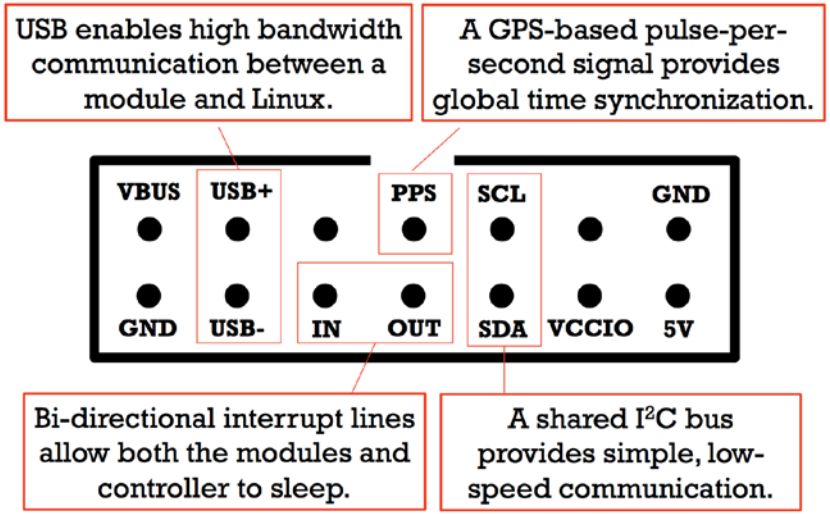
Modules plug into a standard interface



Audio spectrum module



Environmental sensing module



Signpost platform: infrastructure-“free” infrastructure

- Easy (two bolt) installation
- Solar energy harvesting
- Modular and extensible *platforms*

The Signpost Platform: Infrastructure-free Infrastructure

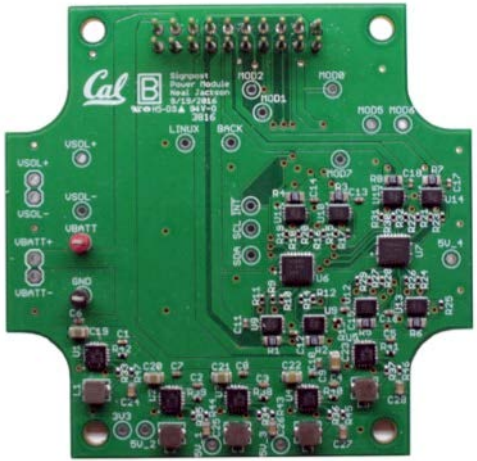
- **Easy (two bolt) installation**
- **Solar energy harvesting**
- **Modular and extensible**

Provides the infrastructure to enable city-scale sensing

- Distributed programming model (uses Tock)
- Big/Little arch allows performance & efficiency
- Isolation enables sharing of the platform

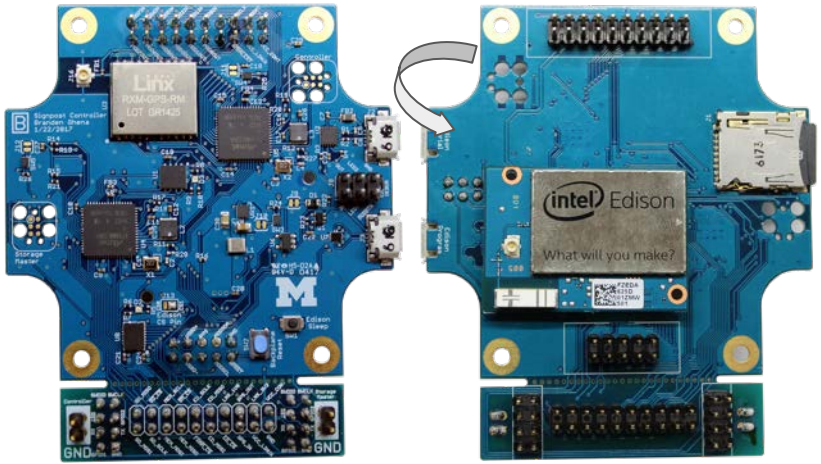
Power module provides and monitors power

- Regulates power from the battery
- Monitors energy usage by each module
- Charges battery from the solar panel



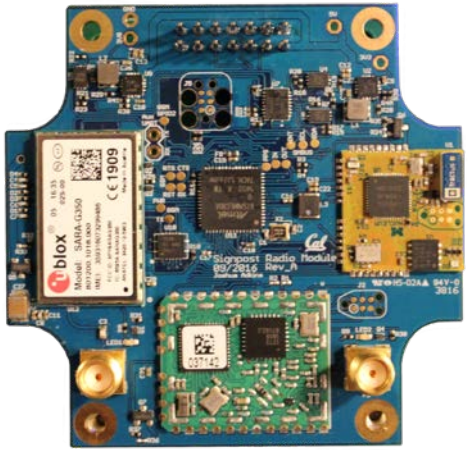
Control Module Manages the Platform

- Time, Location, Synchronization
  - Provided by GPS
- Bulk storage on SD Card
- Energy usage statistics
- Higher performance compute
  - Runs on Intel Edison
  - Accessible through RPC Interface



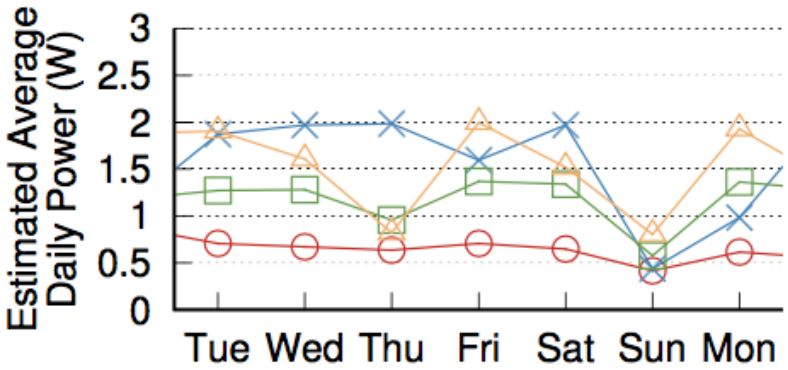
Radio Module Provides Networking

- Cellular
  - Fast/higher reliability
- LoRa
  - Long Range 915 Mhz band (100-1000kbps)
- Bluetooth Low Energy
  - Signpost-to-phone communication



How much energy is available?

- The directions are comparable
  - A vertical solar panel is not too detrimental



- Enough energy to run many city-scale applications
- Not enough energy to run all applications on a Linux Computer