KyRON

Kentucky Sensor Network

Data collection, curation, and processing

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What do we want to address?

- **Connectivity**: Enhance our ability to generate and collect data from distributed devices and sensors.
- **Data management:** Provide automated and semi-automated methods for curation, aggregation, augmentation, and subscription
- **Computation:** Provide data processing services throughout the network in addition to data transport.
- Potential focus areas might include environmental monitoring, smart cities, agriculture, and biomedical surveillance.

Connectivity

- Not connected, data downloaded offline in batches

- Cellular
  - Good coverage, but high unit/service costs
  - High-power consumption

- WiFi
  - Very common, but with limited range
  - High-power consumption

- Bluetooth
  - Short-range, few available sensors

Amazon Sidewalk

- A secure community network that uses Amazon Sidewalk Gateways, such as compatible Amazon Echo and Ring devices, to provide cloud connectivity for IoT endpoint devices.

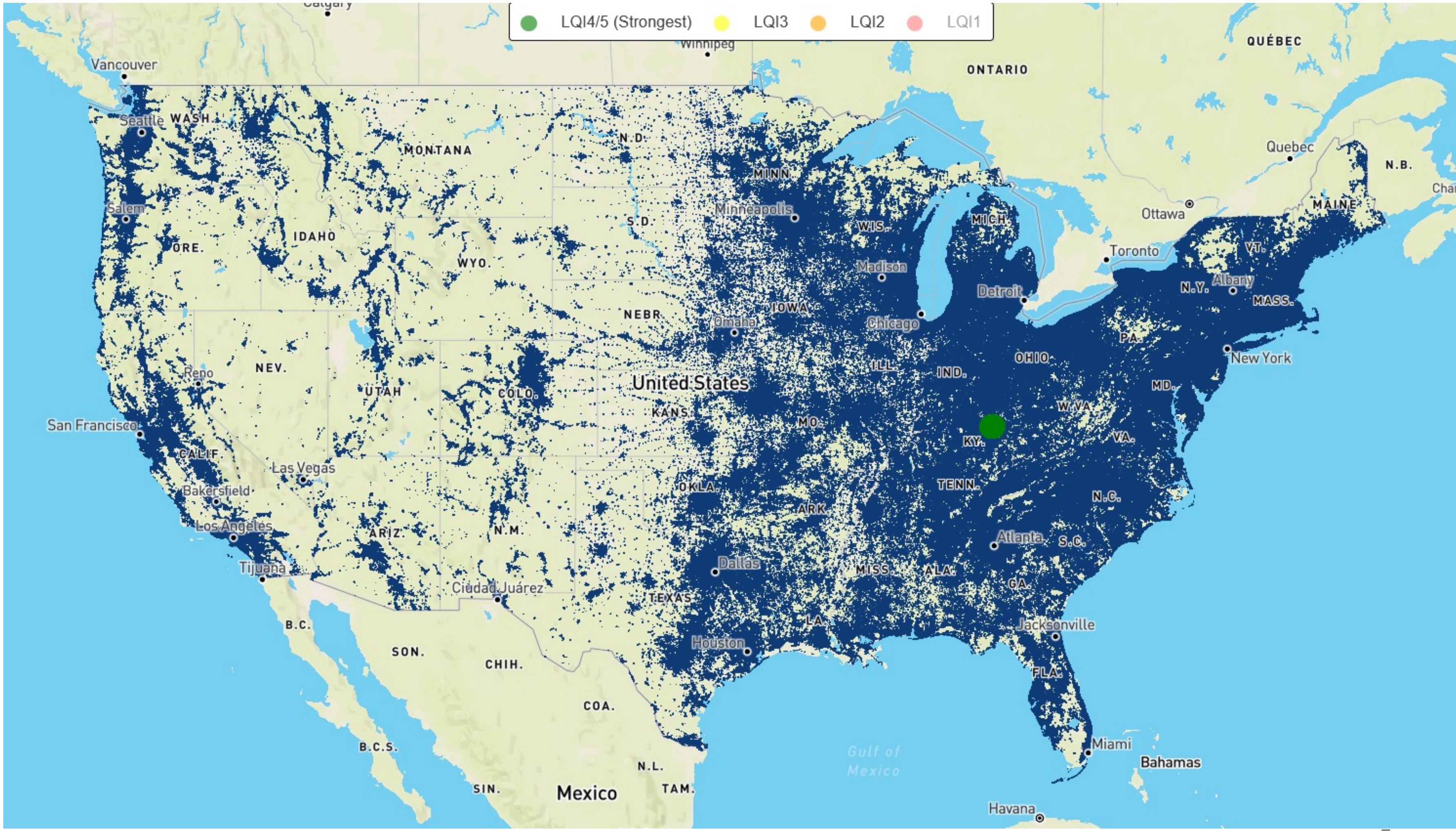
- Enables low-bandwidth and long-range connectivity at home and beyond using **Bluetooth Low Energy for short-distance communication and LoRa and FSK radio protocols** at 900MHz frequencies to cover longer distances.

- Network connection and data in ingestion are free, charges on downstream transfer/processing

https://www.amazon.com/Amazon-Sidewalk

Amazon Sidewalk US

- Available to 90% of U.S. population



Amazon Sidewalk Test Kit

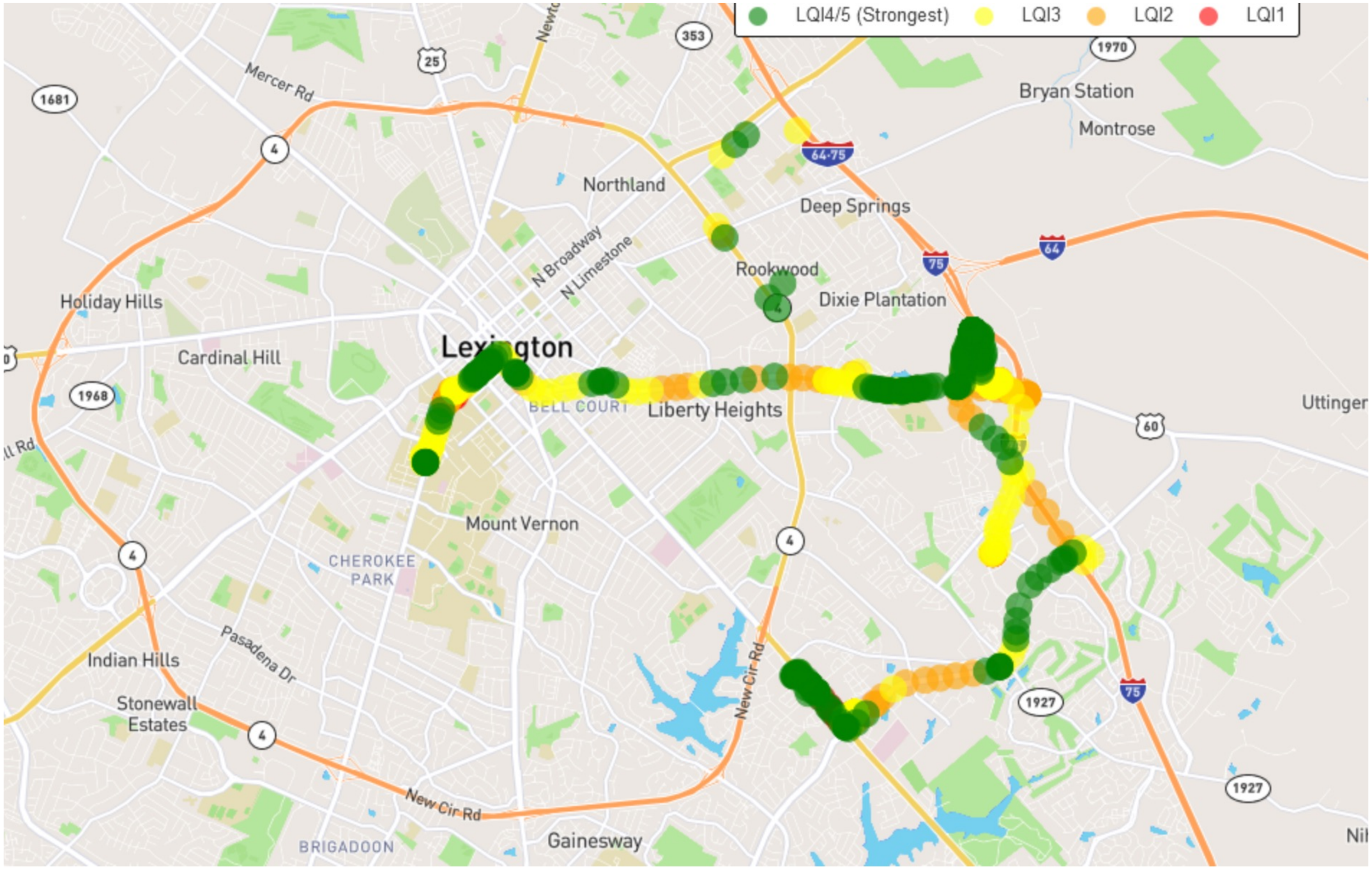


Figure 1: GPS tracking through Lexington using Sidewalk Test Kit

https://ai.uky.edu/2023/06/22/unleashing-the-power-of-amazon-sidewalk-for-comprehensive-tracking-environmental-monitoring-and-healthcare-insights/

Amazon Sidewalk Gaps

- 83% of U.S. population (KY 56%) lives in urban areas
- 97% of the U.S. is rural, only 19.3% of population

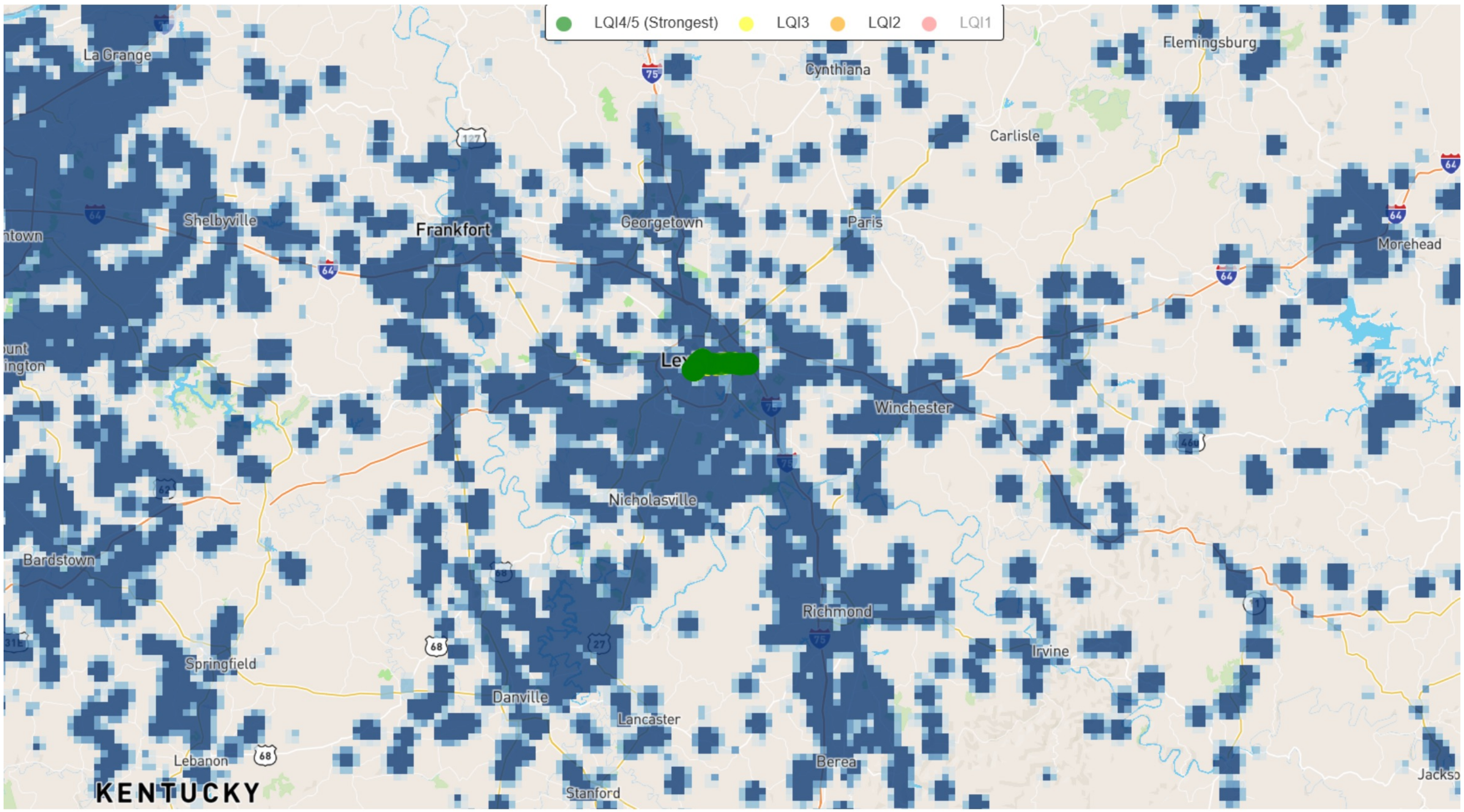
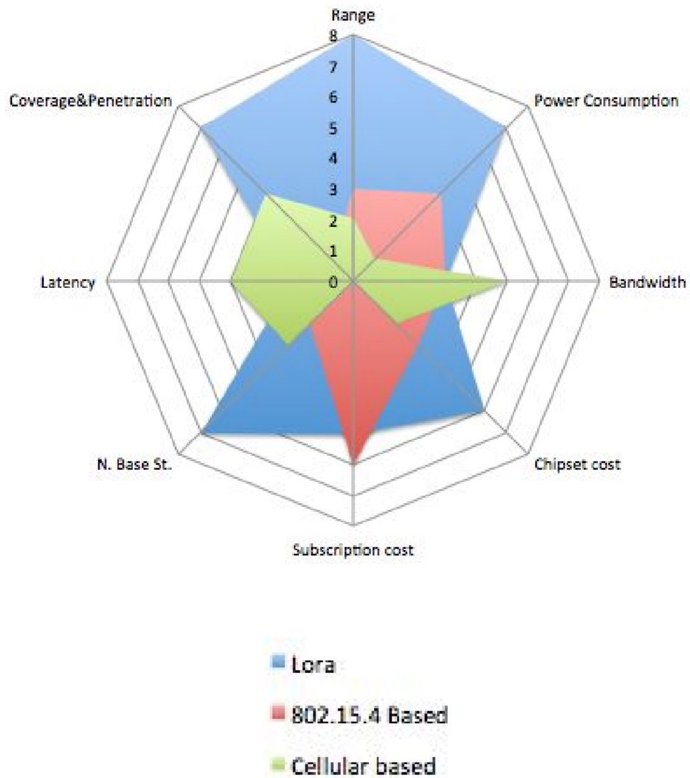
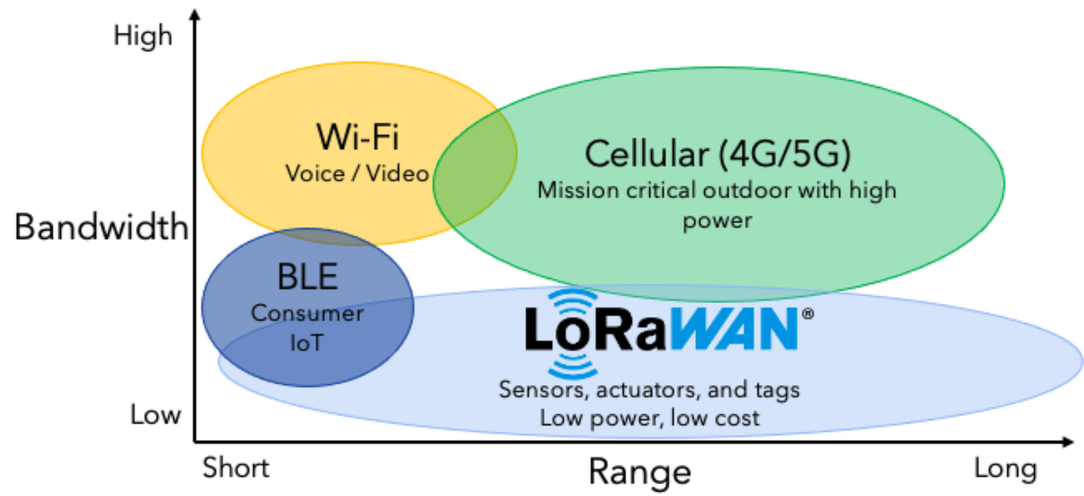


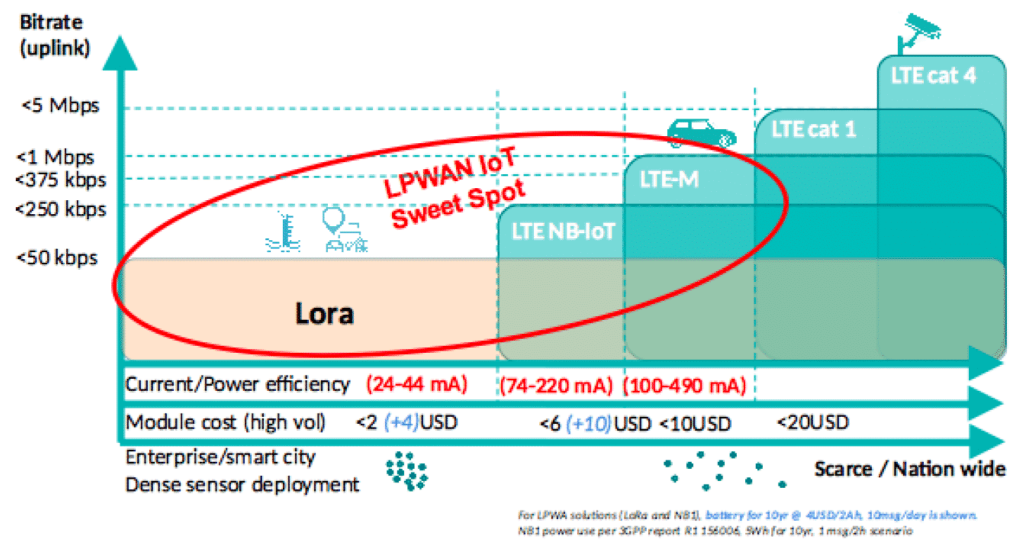
Figure 5: Sidewalk Coverage for Lexington, KY

Choosing the right network





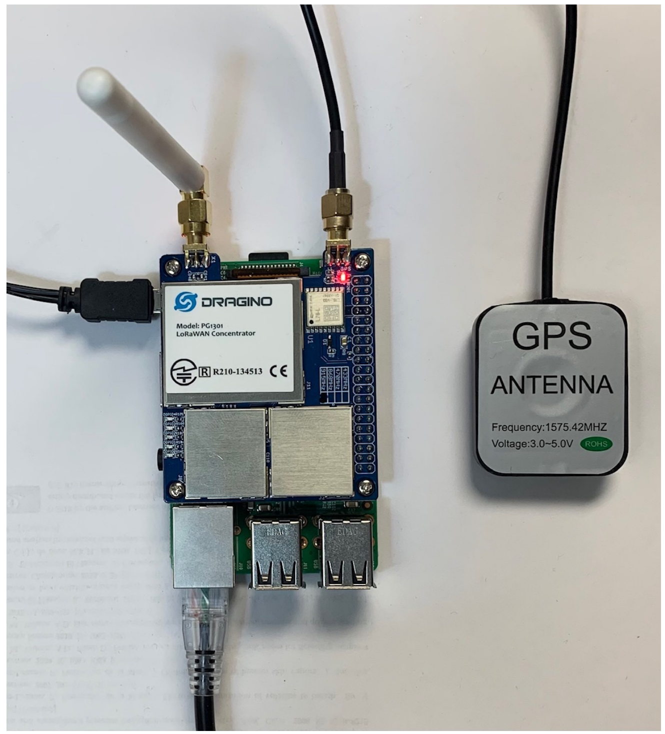
https://ovyl.io/insights-and-news/wireless-technologies



https://www.iotforall.com/service-providers-should-combine-lorawan-cellular-iot-nbiot-ltem

LoRaWAN and Sidewalk testing

https://ai.uky.edu/2021/12/14/creation-of-a-distributed-lorawan-network-to-cover-the-uk-campus



Milesight Ug67 LoRaWAN gateway

https://www.milesight-iot.com/lorawan/gateway/ug67

	Model	UG67
Hardware System	CPU	Quad-core 1.5 GHz, 64-bit ARM Cortex-A53
	Memory	512 MB DDR4 RAM
	Flash	8 GB eMMC
LoRaWAN®	Antenna	Fully Integrated Internal Antenna (Optional: 2 × 50 Ω N-Female External Antenna Connector)
	Channel	8
	Frequency Band	CN470/IN865/EU868/RU864/US915/AU915/KR920/AS923
	Sensitivity	-140dBm Sensitivity @292bps
	Output Power	27dBm Max
	Protocol	V1.0 Class A/Class B/Class C and V1.0.2 Class A/Class B/Class C
Ethernet Interface	Port	1 × RJ45 (PoE PD Supported)
	Physical Layer	10/100/1000 Base-T (IEEE 802.3)
	Data Rate	Rate 10/100/1000 Mbps (Auto-Sensing)
	Interface	Auto MDI/MDIX
	Mode	Full or Half Duplex (Auto-Sensing)
Wi-Fi	Antenna	Fully Integrated Internal Antenna
	Standards	IEEE 802.11 b/g/n
	Tx Power	802.11b: 18 dBm +/-2.0 dBm (11 Mbps)
		802.11g: 15 dBm +/-2.0 dBm (6 Mbps)
		802.11g: 15 dBm +/-2.0 dBm (54 Mbps)
		802.11n@2.4 GHz: 14 dBm +/-2.0 dBm (MCS0_HT20)
		802.11n@2.4 GHz: 14 dBm +/-2.0 dBm (MCS7_HT20)
		802.11n@2.4 GHz: 13 dBm +/-2.0 dBm (MCS0_HT40)
		802.11n@2.4 GHz: 13 dBm +/-2.0 dBm (MCS7_HT40)
Cellular Interface (Optional)	Antenna	Fully Integrated and Internal Antenna
	SIM Slot	1

GPS	Antenna	Internal Antenna
	Sensitivity	-167dBm@Tracking, -149dBm@Acquisition, -161dBm@Re-acquisition
	Position Accuracy	<2.5 m CEP
Software	Network Protocols	PPPoE, SNMP v1/v2c/v3, TCP, UDP, DHCP, DDNS, HTTP, HTTPS, DNS, ARP, SNTP, Telnet, SSH, MQTT, etc.
	VPN Tunnel	OpenVPN/IPsec/PPTP/L2TP/GRE/DMVPN
	Access Authentication	CHAP/PAP/MS-CHAP/MS-CHAPV2
	Firewall	ACL/DMZ/Port Mapping/MAC Binding/URL Filter
	Management	Web, CLI, SMS, On-demand dial up, DeviceHub, Milesight IoT Cloud
	Reliability	WAN Failover
Power Supply and Consumption	Power Supply	1. 1 × 802.3 af PoE input
		2. 1 × 12 VDC with M12 Connector
	Consumption	Typical 3.6 W, Max 4.8 W
Physical Characteristics	Ingress Protection	Protection IP67
	Dimensions	250 x 172 x 92 mm
	Mounting	Wall or Pole Mounting
Others	Reset Button	1 × RST
	Console Port	1 × Type-C Port
	LED Indicators	1 × SYS, 1 × LoRa, 1 × LTE
	Built-in	Watchdog, RTC, Timer
	Certification	CE, FCC
Environmental	Operating Temperature	-40°C to +70°C (-40°F to +158°F)
		Reduced Cellular Performance Above 60°C
	Storage Temperature	-40°C to +85°C (-40°F to +185°F)
	Ethernet Isolation	1.5 kV RMS
	Relative Humidity	0% to 95% (non-condensing) at 25°C/77°F

LoRaWAN gateway and sensors

- Will deploy Ug67 gateways at participating sites
- Sensors and supporting use cases are needed

Ug67 Gateways

https://www.milesight-iot.com/lorawan/gateway/ug67

Compatible sensor types

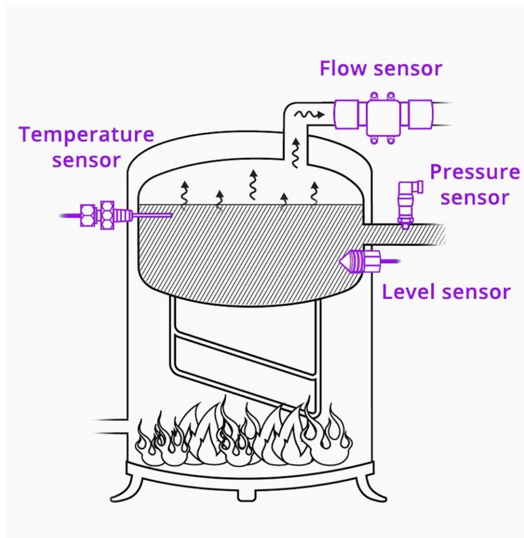
- Devices with native or embedded LoRaWAN or AWS Sidewalk connectivity
- Devices with wireless or wired connectivity, but no direct LoRaWAN module
  - Gateways exist for Bluetooth, WiFi, Cellular connectivity
- Devices with no connectivity that log locally (SD)
  - SD ”taps” and WiFi adapters exists
- BYOD: We would need a base LoRaWAN module/platform and one or more (sensor) inputs

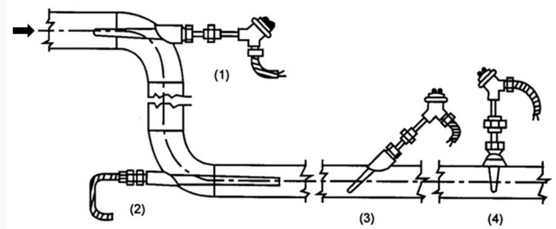
Examples: https://connectedthings.store/gb/lorawan-sensors/

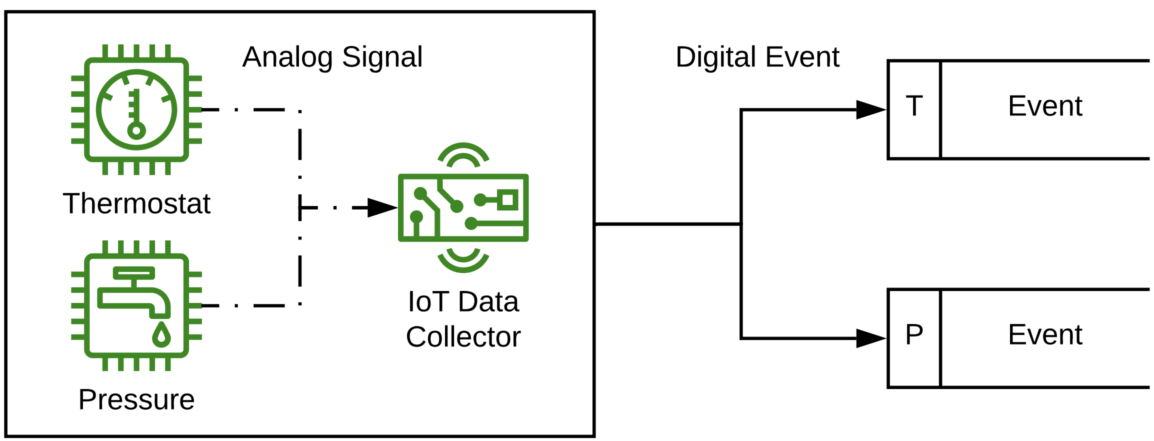
Data Management

- Direct sensor output (MQTT, HTTP/S) to local server
- Sensor output relay to central server
- Coordinate collection of data between locations
- Coordinate collection of data between services, such as distributed LoRaWAN gateways, AWS Sidewalk, and potentially other services
- Provide services for dataset curation and extraction

Sensor event generation



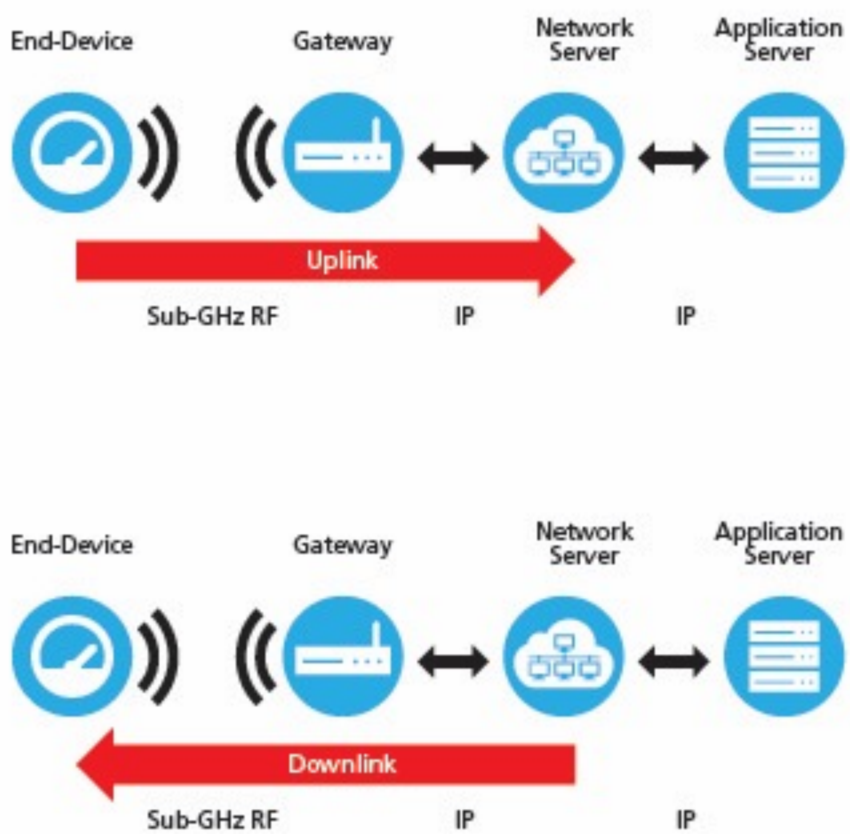


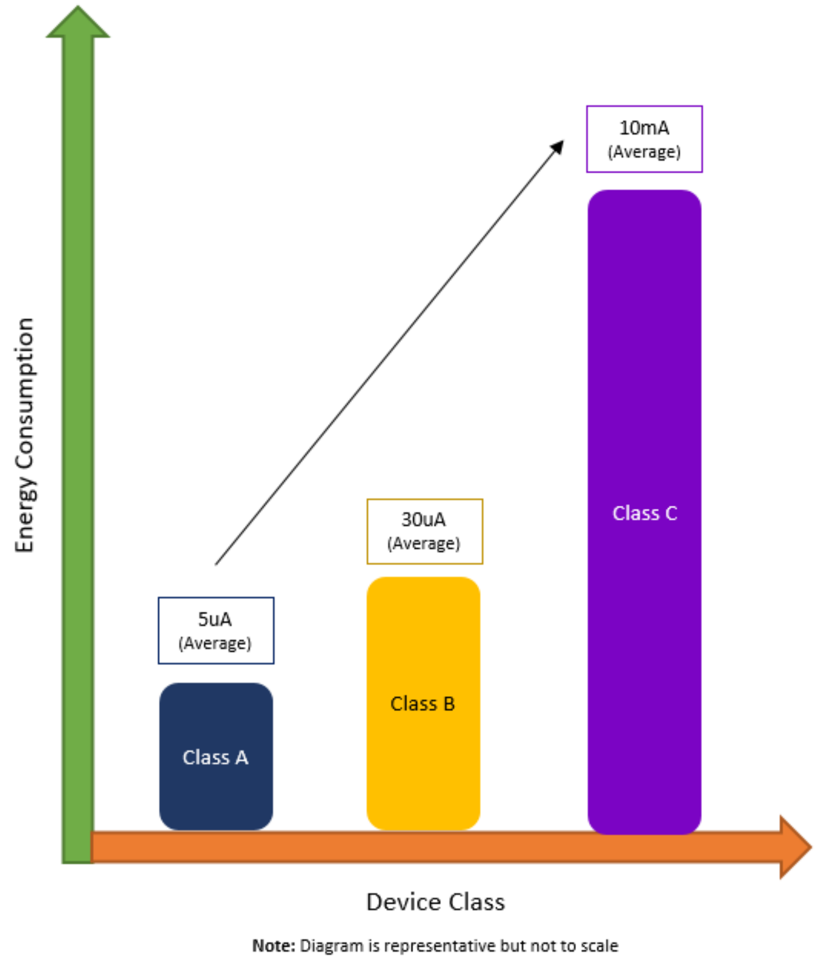


Sensor Array

Event Streams

Bi-directional communications



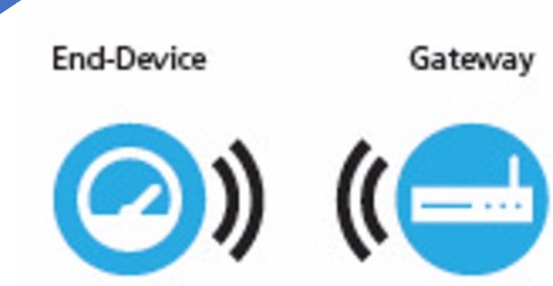


https://www.thethingsnetwork.org/docs/lorawan/classes.html

LoRaWAN payload from sensor

```
{
	"rxpk": [{
		"tmst": 27559372, //Internal timestamp for RX
		"time": "2021-02-24T19:42:00.404754Z", //UTC time of message
		"chan": 1, //Concentrator "IF" channel used for RX
		"rfch": 0, //Concentrator "RF chain" used for RX
		"freq": 904.300000, //RX central frequency in MHz
		"stat": 1, //CRC status: 1 = OK, -1 = fail, 0 = no CRC
		"modu": "LORA", //Modulation identifier
		"datr": "SF10BW125", //LoRa data rate identifier
		"codr": "4/5", //LoRa ECC coding rate identifier
		"lsnr": 9.8,  //Lora SNR ratio in dB
		"rssi": -55, //RSSI in dBm
		"size": 23, //RF packet payload size in bytes
		"data": "AAcBAAAAAACgXpaCYeRBQKjd2fxLgOY=”
			// Base64 encoded RF packet payload
	}]
}
```

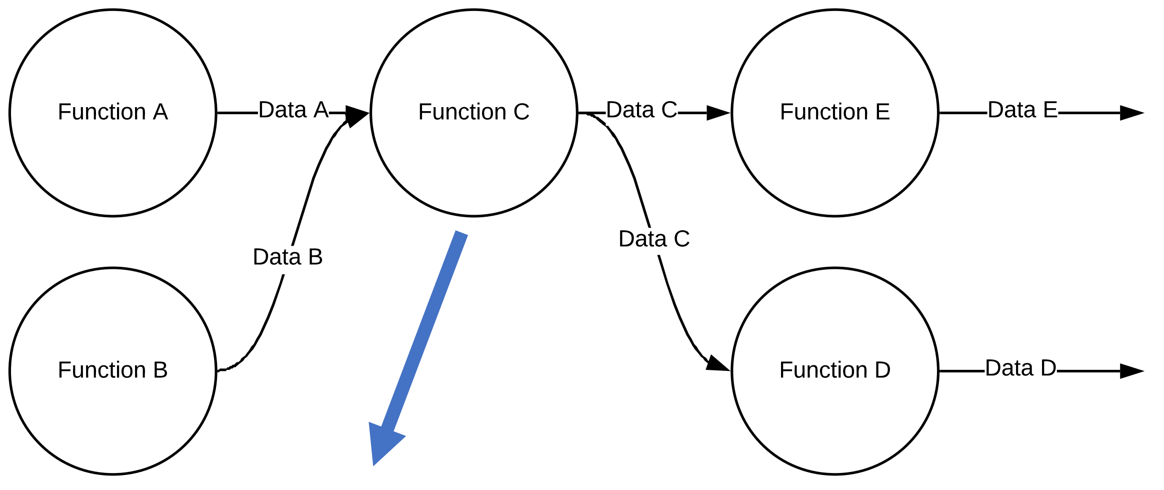
sensor data:
value:X



Event curation pipelines

{source:device_X,
value:8.1,
class:radon_A,
ts:1615092781,
lat:38.07, lon:-84.53}

Infer and enrich



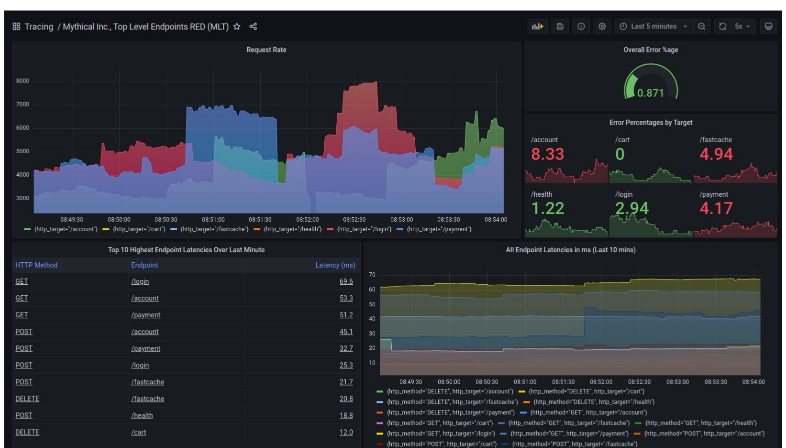
{source:device_Y,
value:2000.5,
class:co2_A,
ts:1615052781,
lat:37.81, lon:-82.81}

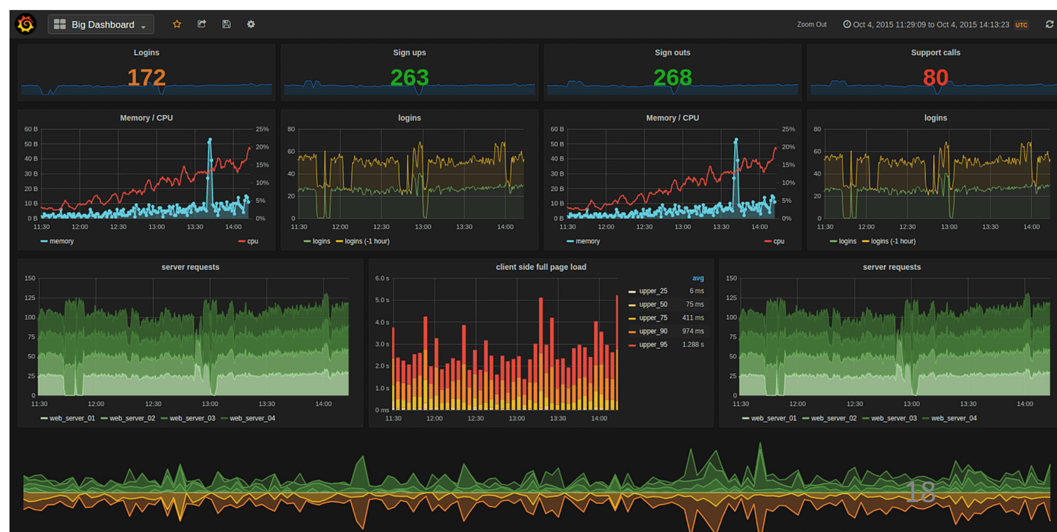
Combine data streams into single record, for inference and recording

Ingest into data warehouse

Managing timeseries data

- InfluxDB https://www.influxdata.com/
  - Will be used for backend metric storage
  - CERN: 800 PB stored, 600k metrics collected per second from 100k sources, with 2 million queries per day
- Cresco http://cresco.io/
  - Manage data flows
- Graphana https://grafana.com/
  - Data visualization

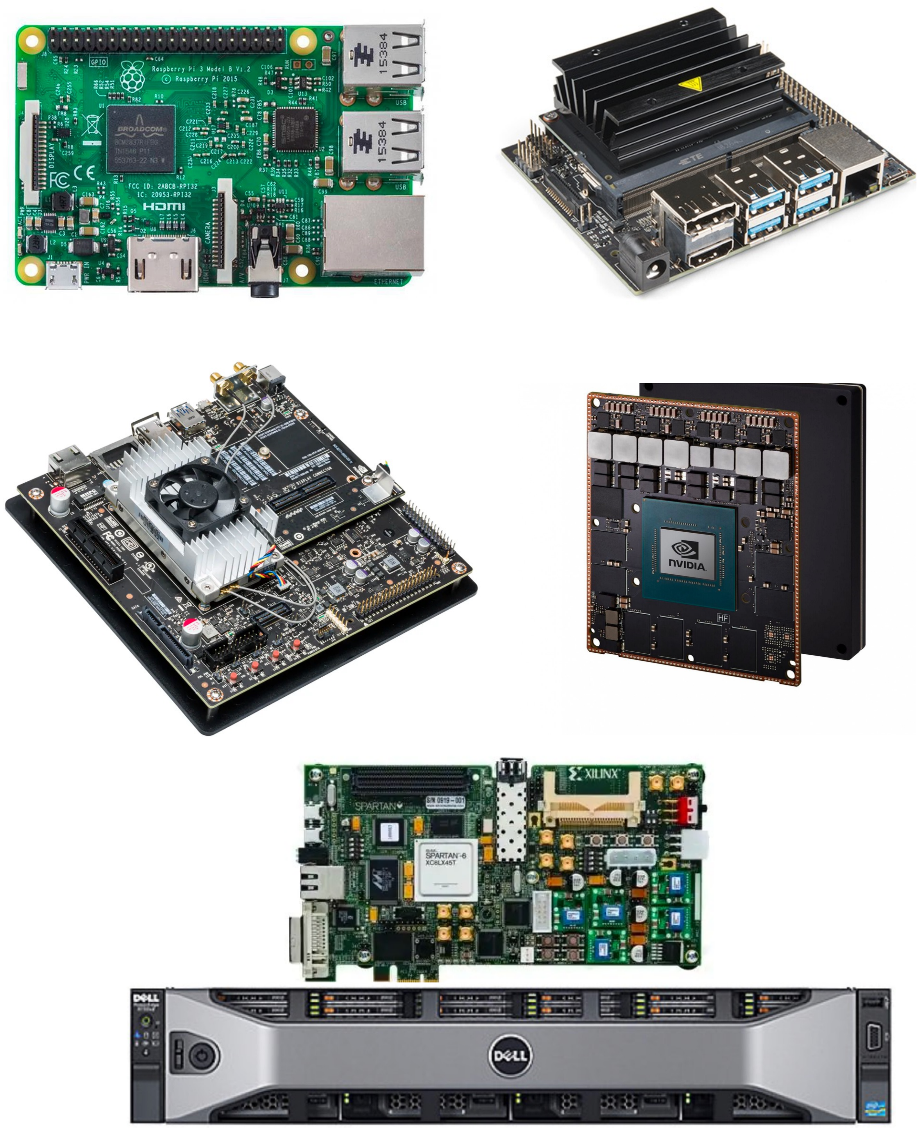


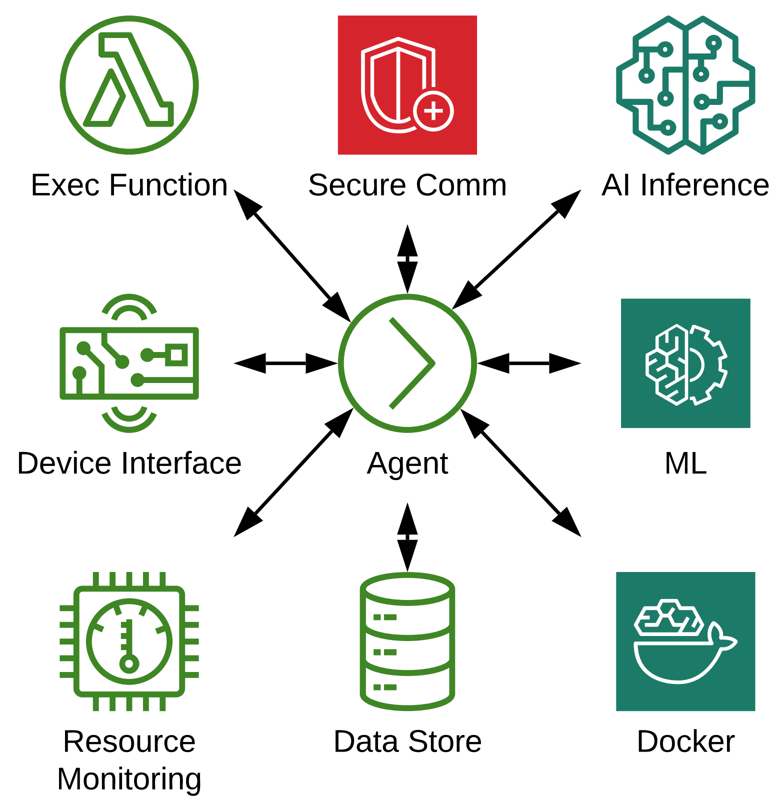


Computation

- Deploy computational resources closer to sources of data generation, provide an execution environment
- Securely manage and transport data across heterogeneous computational platforms and network protocols
- Semantically enrich data and metadata
- Develop distributed applications with autonomic (self-managing) characteristics

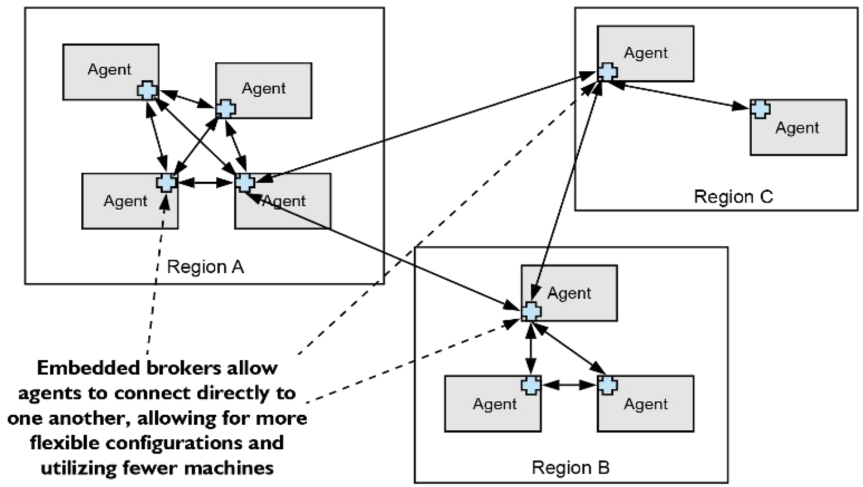
Heterogeneous agents and devices

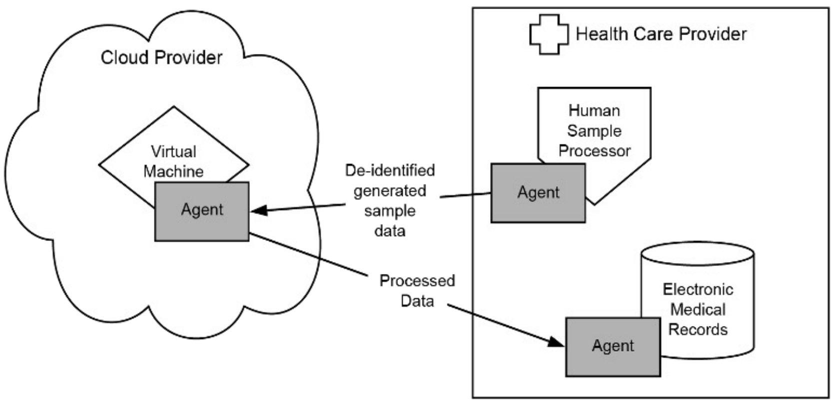




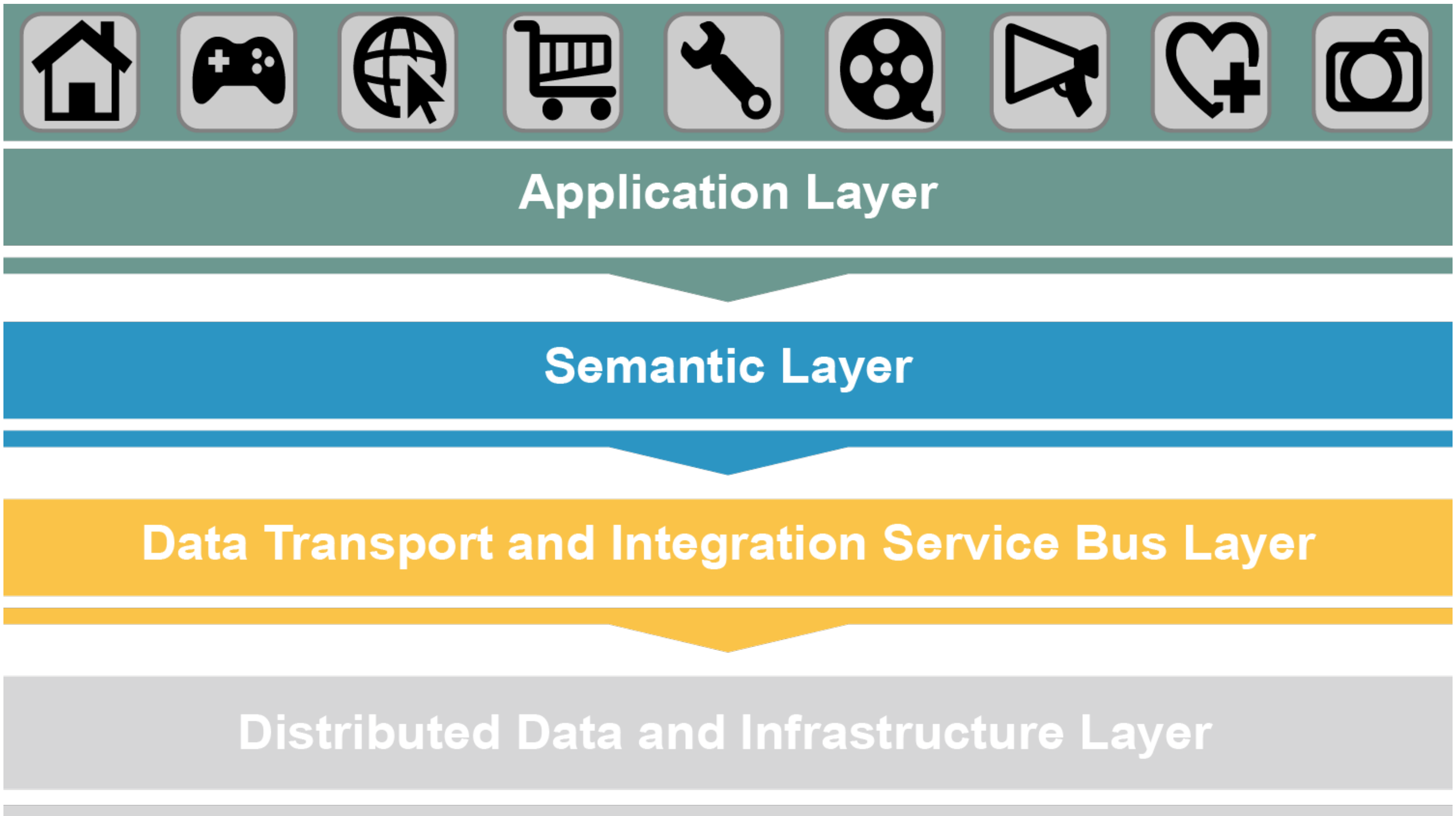
Distributed processing agents

- Distributed data collection and real-time processing across heterogeneous networks, systems, and applications
- Agent platform supports SoC (25MB ram) systems through the largest servers, capable of supporting thousands of clients
- Agents broadcast roles and capabilities across the computational network
- Agents provide in-band and out-of-band file transfer
- Agents provide task execution services



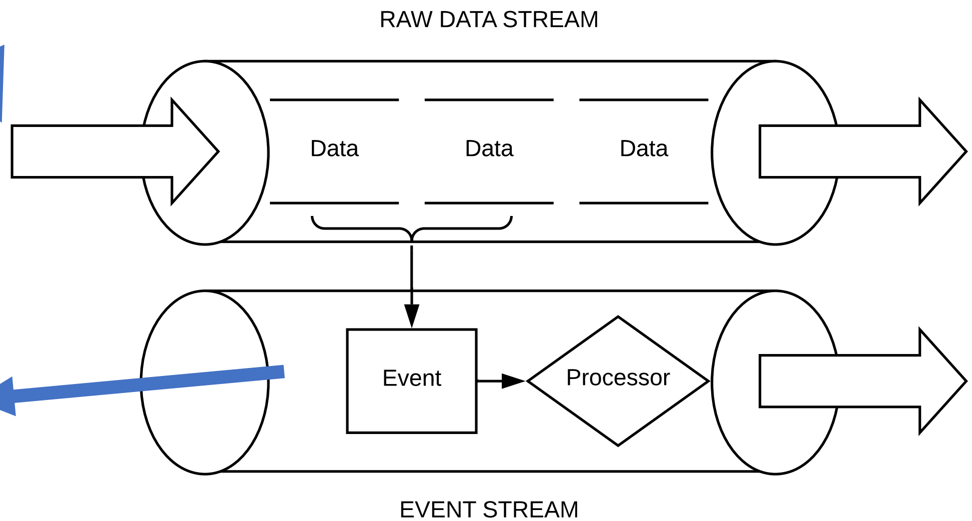


Computational sensor network



Event semantic enrichment

{source:device_X,value:8.1},
{source:device_Y,value:2000.5}



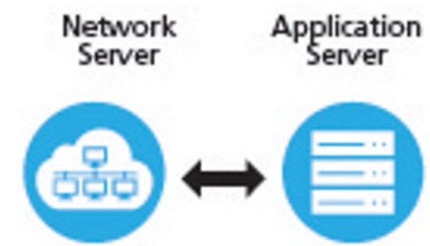
{source:device_X,
value:8.1,
class:**radon_A**,
ts:1615092781,
lat:38.07, lon:-84.53},

{source:device_Y,
value:2000.5,
class:co2_A,
ts:1615052781,
lat:37.81, lon:-82.81}

{class:**radon_A**,
m_class: **pCi/L**,
Attributes:
[value,ts,lat,lon]
max: 3000
alert: 3.5
warn: 1.5}

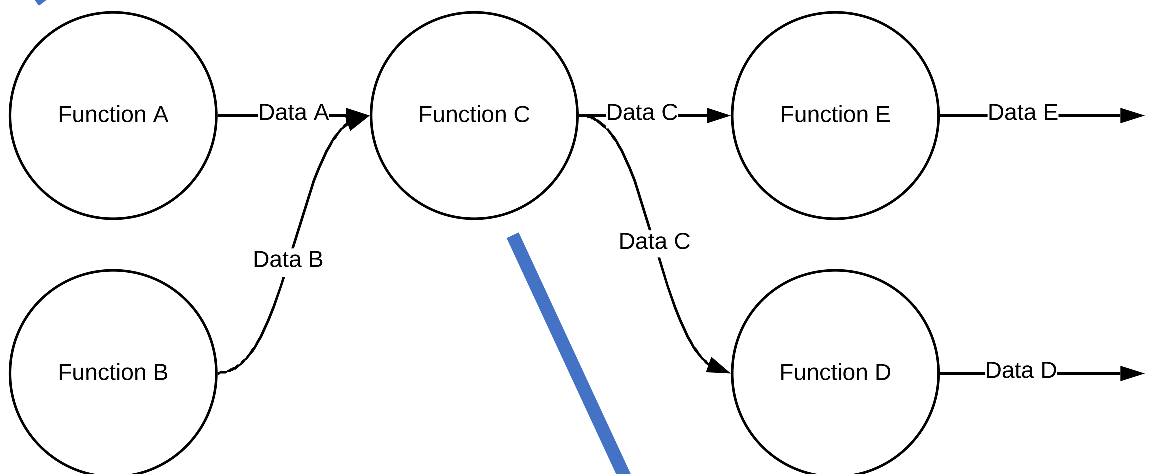
{class:**pCi/L**,
measurement: pCi/L,
description:
picocuries per liter of air}

Event processing pipelines



{source:device_X,
value:**8.1**,
class:radon_A,
ts:1615092781,
lat:38.07, lon:-84.53}

F(A): If device_X > radon_A.alert
alert=true



{source:device_Y,
value:**2000.5**,
class:co2_A,
ts:1615052781,
lat:37.81, lon:-82.81}

F(B): If device_Y > co2_A.alert
alert=true

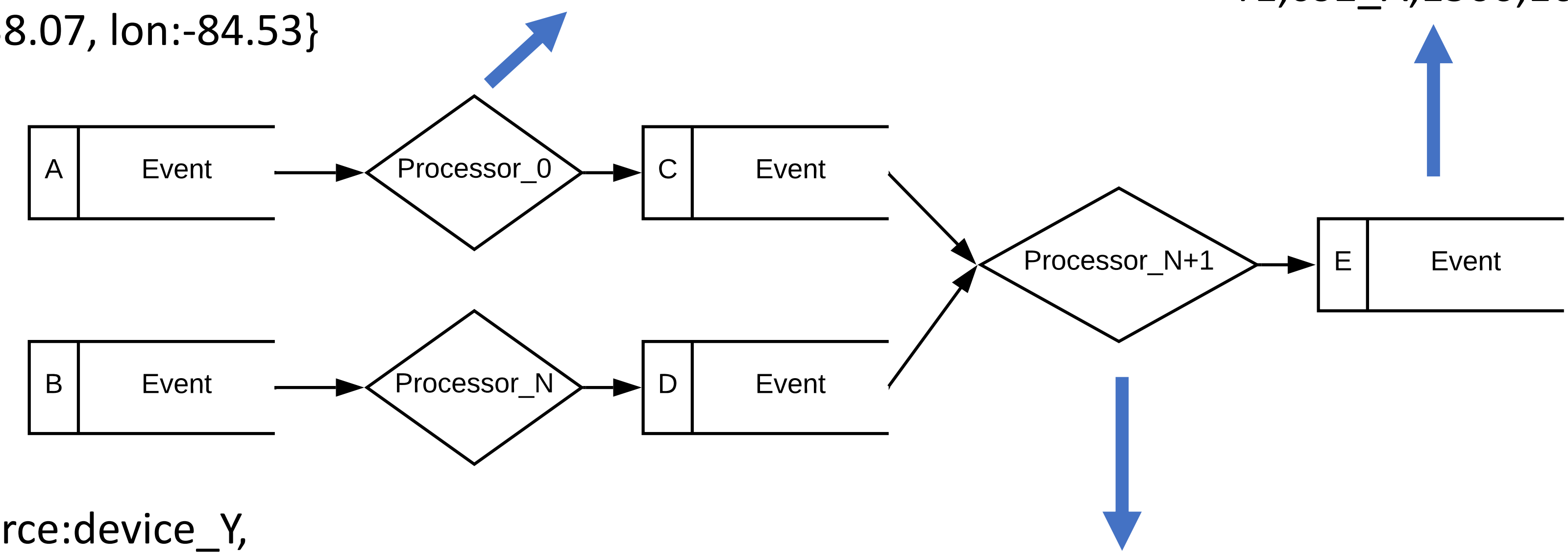
F(C):
If device.count.alert > 2:
alert=true

Complex event processing

{source:device_X,
value:8.1,
class:radon_A,
ts:1615092781,
lat:38.07, lon:-84.53}

5min Ave 5km from
region = lat:38.07, lon:-84.53

region,class,value,ts
----
r0,radon_A,6,161.
r1,co2_A,1500,161.

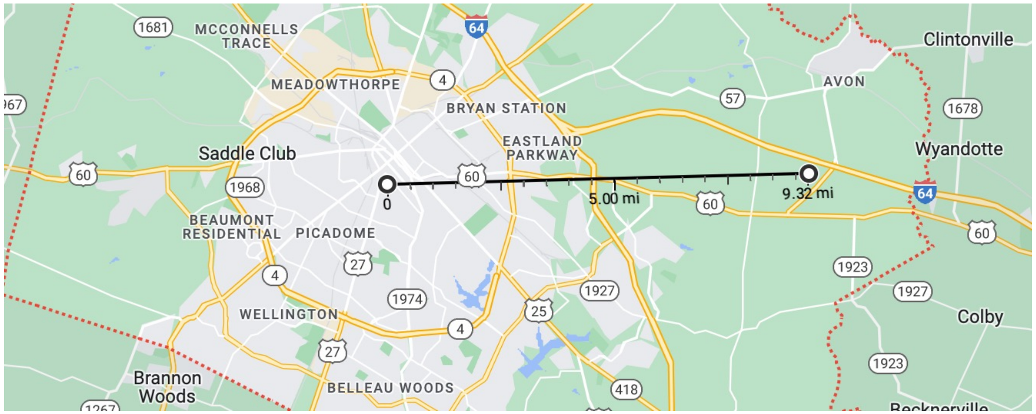


{source:device_Y,
value:2000.5,
class:co2_A,
ts:1615052781,
lat:37.81, lon:-82.81}

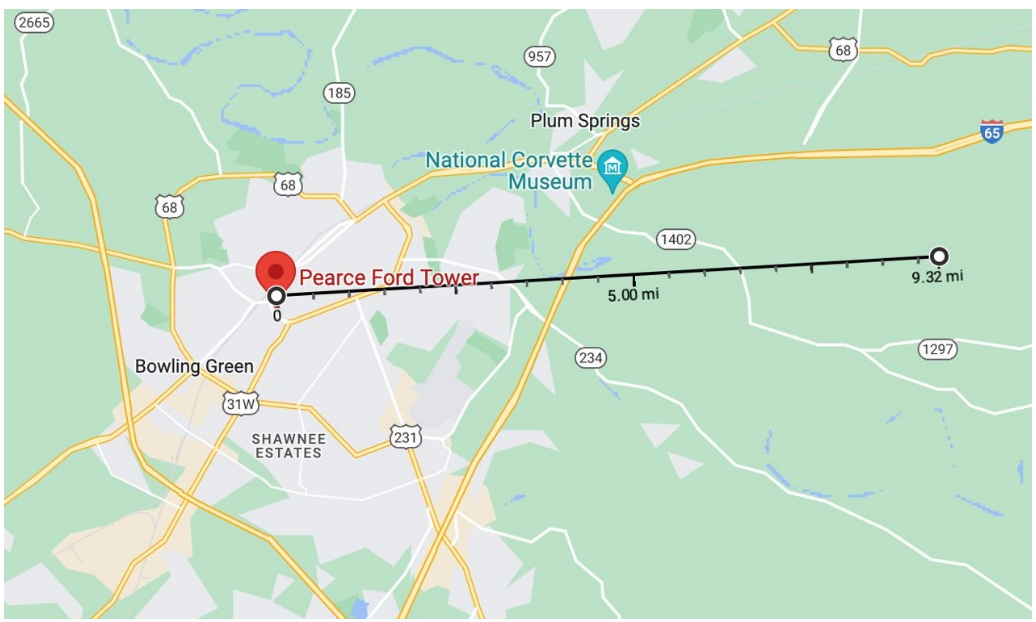
Emit last recorded value
all devices all regions
every Xmin

Where to deploy?

- As high as possible, close to city/town
- Farms, research areas



UK and Lexington, KY



WKU and Bowling Green, KY
Image by Derek Keeling, WKU

KCTCS locations

Current state

- Testing of LoRaWAN and AWS Sidewalk operations
  - One-way sensor upload to base station
  - Bi-directional sensor communication
  - MQTT data collection and message routing
  - Intagration with edge computing devices
- Purchased 12 x Ug67 Radios, funded by:
  - Jeff Talbert, PhD: UK Institute for Biomedical Informatics
  - Ken Calvert, PhD: UK Department of Computer Science
- Range of commercial radios from tall buildings is untested. Radio “line-of-sight” is best, but other signal propagations are possible:
  - Penetration: Go through it (trees, buildings, etc.)
  - Reflection: Bounce off a structure (building)
  - Diffraction: Waves bent around point (around hilltop into valley)
  - Good video: https://www.youtube.com/watch?v=2zIlWT0kui8

Proposed action plan

- Take advantage of new low-power, low-bandwidth, long-range radio technologies and multi-protocol technologies
  - Urban: Amazon Sidewalk
  - Urban/rural: LoRaWAN

- Partner with communities to identify locations, deploy initial (12) LoRaWAN radios, survey urban areas for Sidewalk coverage
  - Commitments to deploy radios from KCTCS (Kenny Burdine), UK (Cody Bumgardner), and WKU (Derek Keeling)
  - Previous smart-city collaborations with LFUCG (City of Lexington)

- Deploy (optional) small computational resources on remote sites along with radio transmitter (LoRaWAN)
  - Raspberry PI, Nvidia Nano, etc. for inline processing

- Provide initial high-level data management services
  - Borrowing from previous work, deploy GUI to build data pipelines and event alerting services

Next steps

- Build a project team and identify the following
  - **Researchers that could benefit from the proposed project**
  - **Operations and or smart-city applications**
  - **One or more specific operational and/or research problems this network intends to address, "Killer Apps"**
  - Participating sites and collaborators
  - AWS Sidewalk coverage in urban areas
- Deploy Gateways in the following areas
  - Indoor
  - Campus outdoor, with signal extending beyond campus boundaries
  - Rural environment, possibly research farm/campus
  - City-based deployment
- Identify funding sources
  - NSF programs like Smart and Connected Communities and Smart Health
  - NIH programs
  - University-based programs
  - Other