

# EPICS Control of Wireless Sensors

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*Code:*

<https://github.com/epicsNSLS2-sensors/XBeelIOC>

<https://github.com/epicsNSLS2-sensors/ThingyIOC>

<https://github.com/epicsNSLS2-sensors/ThingyMeshIOC>

<https://github.com/epicsNSLS2-sensors/ThingyAggregatorIOC>

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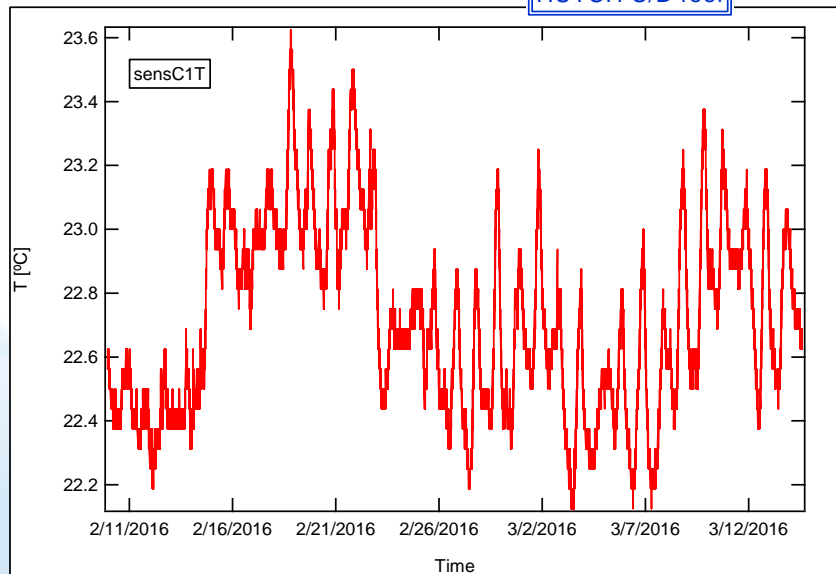
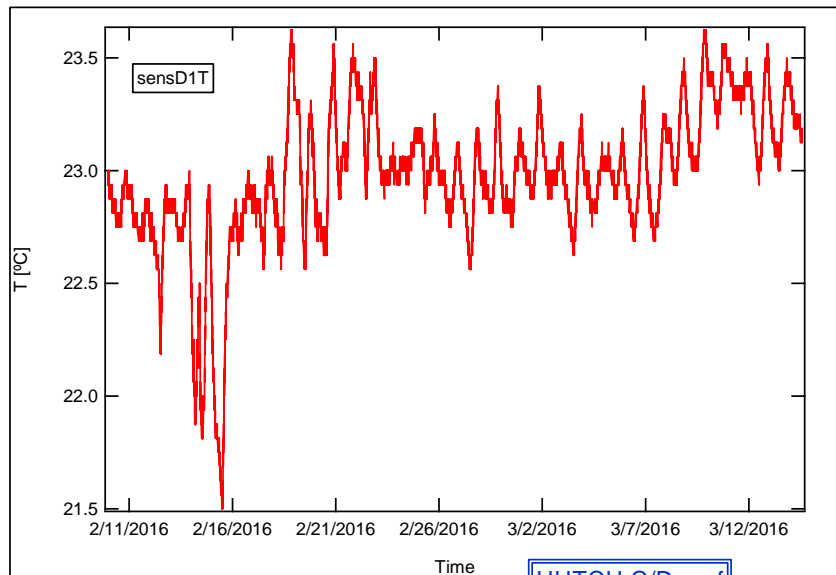
*a passion for discovery*



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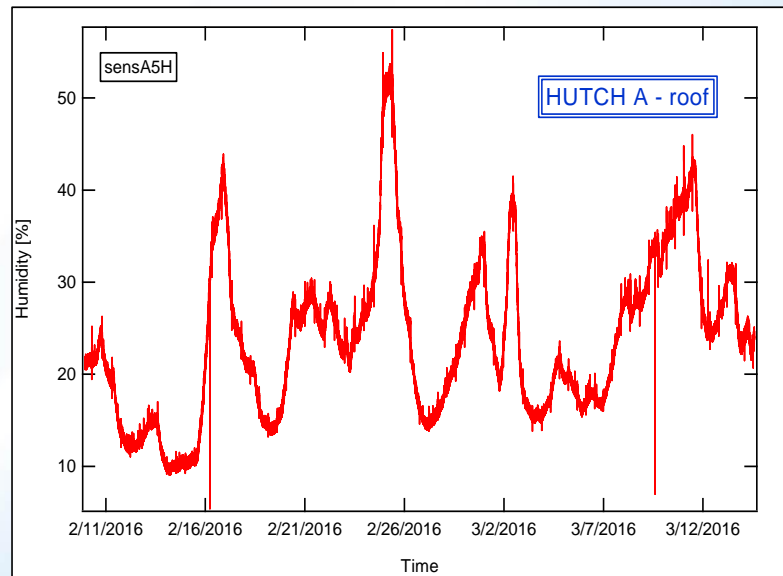
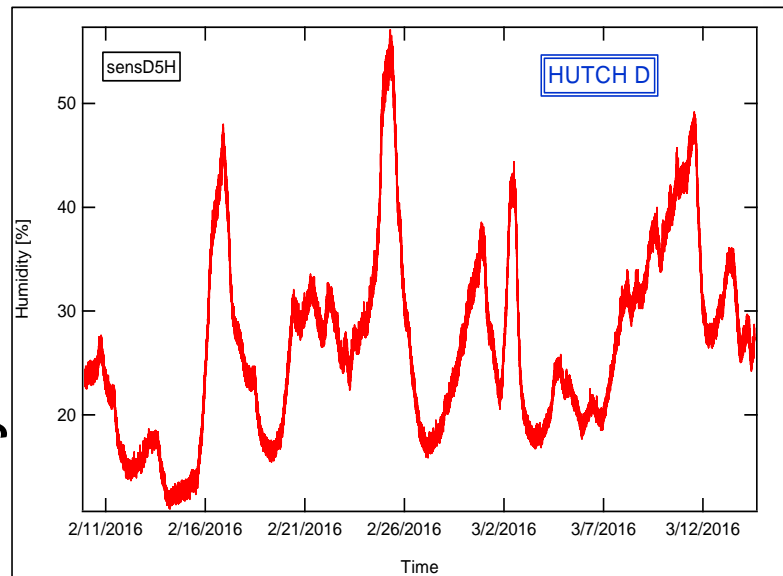
# Experimental Hall environment – one wire



Temperature

Humidity

10ID



# The Need for Wireless

- Goal: Monitor environmental conditions of beamlines (eg. temperature, humidity, pressure) for extended periods of time
  - Wireless devices offer a portable, easily deployable solution
  - Bluetooth low energy allows for extreme battery life
  - Eliminate need for threading wires through hutches, converters, ports
    - 10ID Previous solution: oneWire sensors, streamDevice IOCs
  - Cost effective; \$40 for a full suite of sensors (Thingy:52)



# ZigBee: Digi XBee L/T/H Sensor

- Light, temperature, humidity
- Uses proprietary Zigbee mesh protocol
  - Extreme range w/ enough nodes
- \$100, powered by 3 AA batteries
- Restricted to use with Digi hardware
  - Gateway, USB dongle

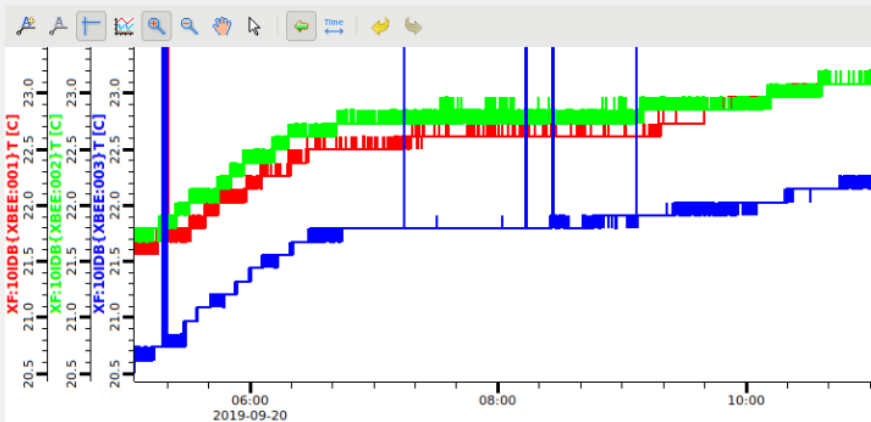


# XBeeIOC

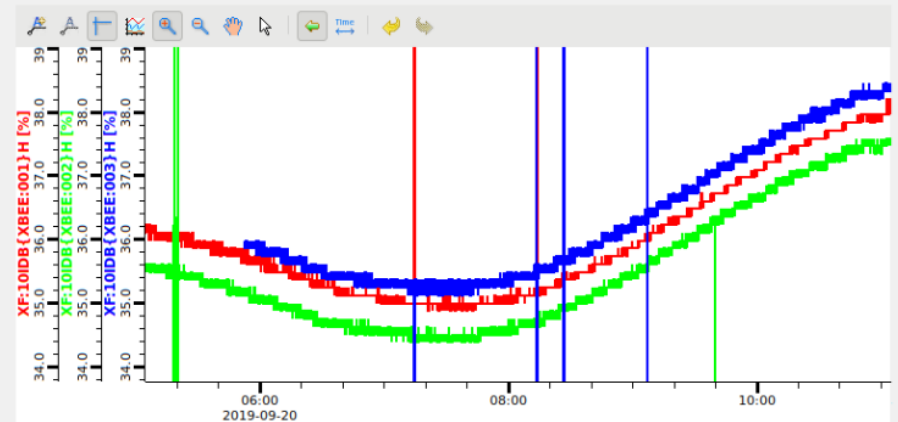
- StreamDevice IOC developed to interact w/ custom Python TCP server
  - Utilizes proprietary Digi Python packages
  - Script runs on either gateway or host w/ XStick
  - Finicky, unreliable

|           |                            |       |        |             |         |          |         |
|-----------|----------------------------|-------|--------|-------------|---------|----------|---------|
| Sensor ID | [00:13:a2:00:41:63:87:88]! | Light | 69.21  | Temperature | 23.20 C | Humidity | 37.95 % |
| Sensor ID | [00:13:a2:00:41:4f:ad:92]! | Light | 116.13 | Temperature | 23.08 C | Humidity | 37.58 % |
| Sensor ID | [00:13:a2:00:41:4f:ad:97]! | Light | 89.15  | Temperature | 22.26 C | Humidity | 38.44 % |

### Temperature



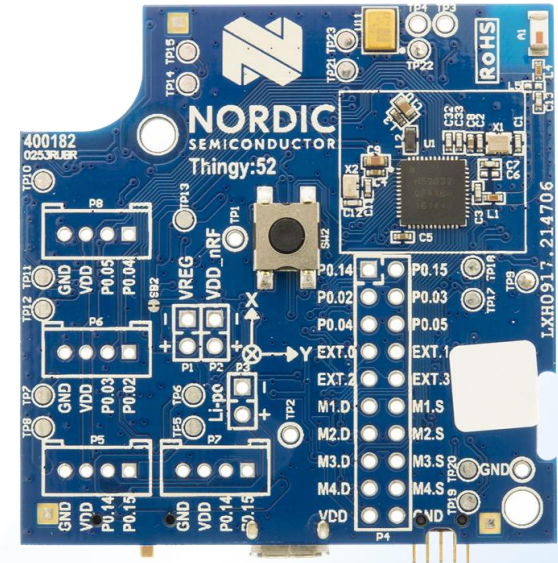
### Humidity



# Bluetooth: Nordic Thingy52



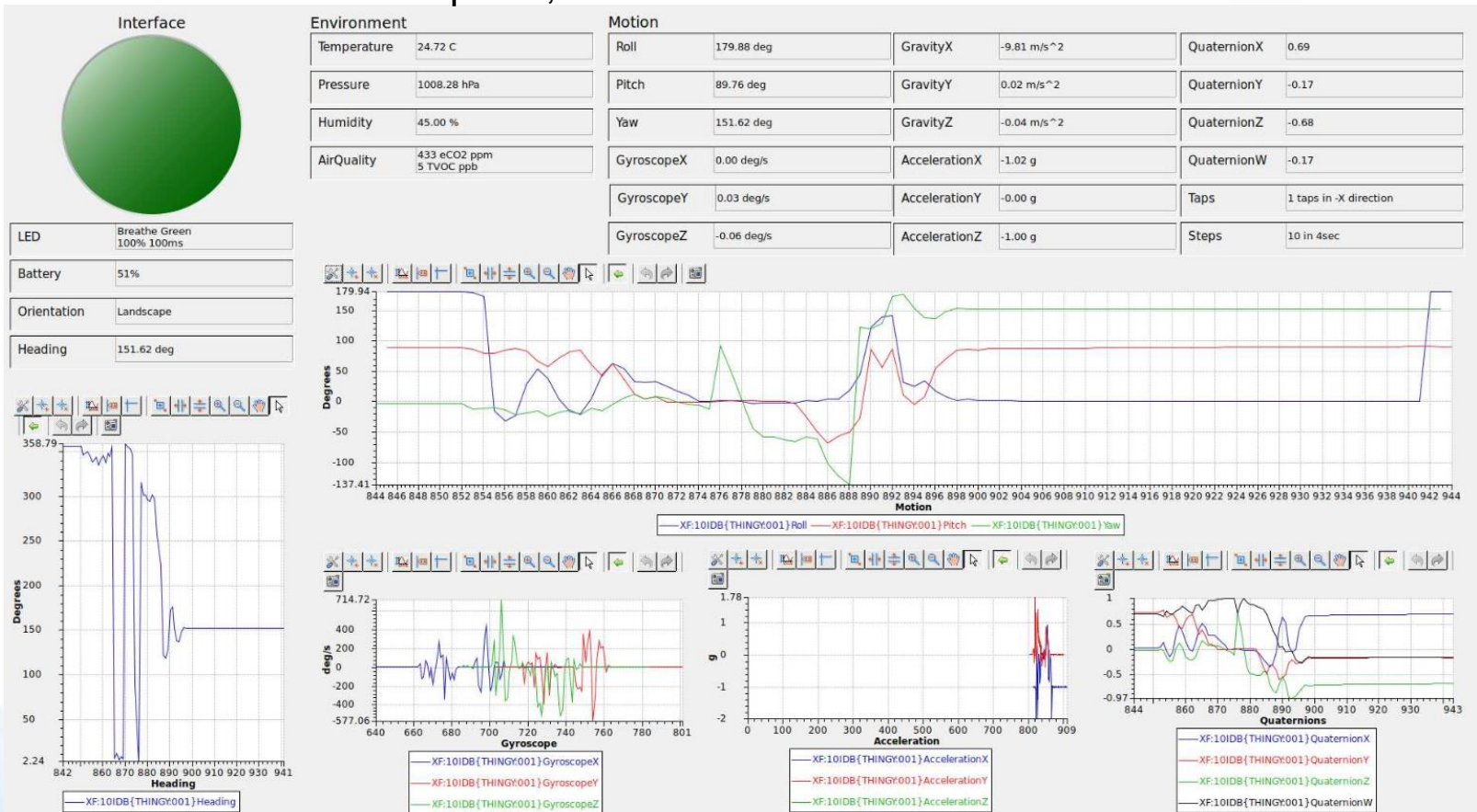
- Low-cost suite of bluetooth low energy sensors, \$40
- Lithium battery charged by micro USB
- Bluetooth 4 LE has a range of ~100m outdoors
  - Line-of-sight; blocked by objects
- Programmable with Nordic development kit
- One-to-one default firmware





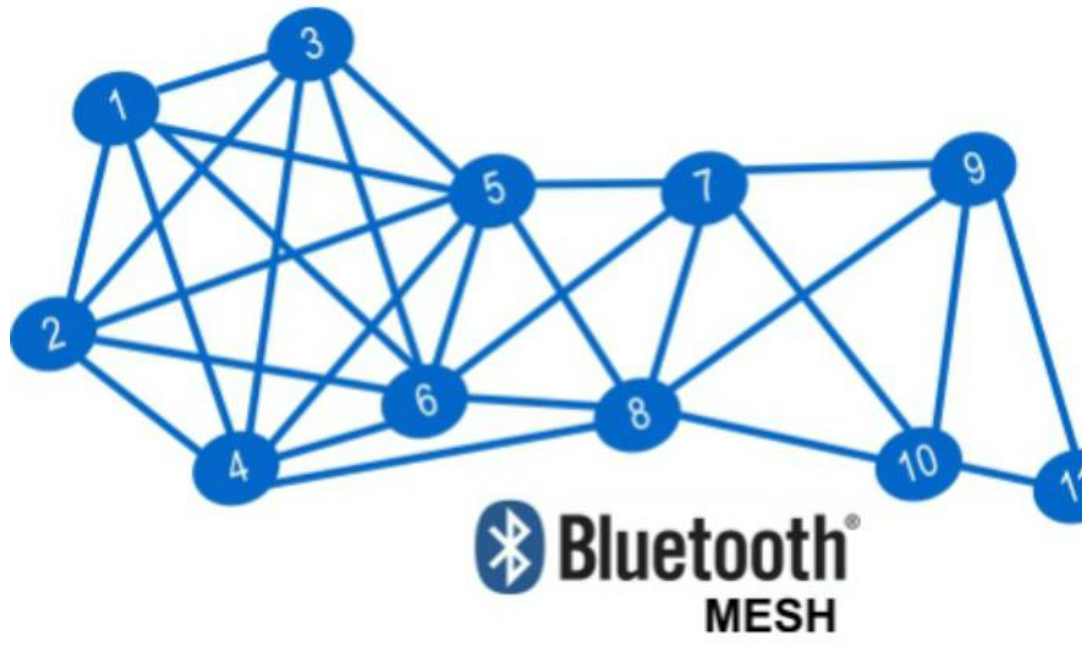
# ThingyIOC

- Supports nearly all Thingy sensors
- Low energy; extreme battery life
- One-to-one; only connected to one Thingy at a time
- Several sensors required; non-scalable solution



# Bluetooth Mesh

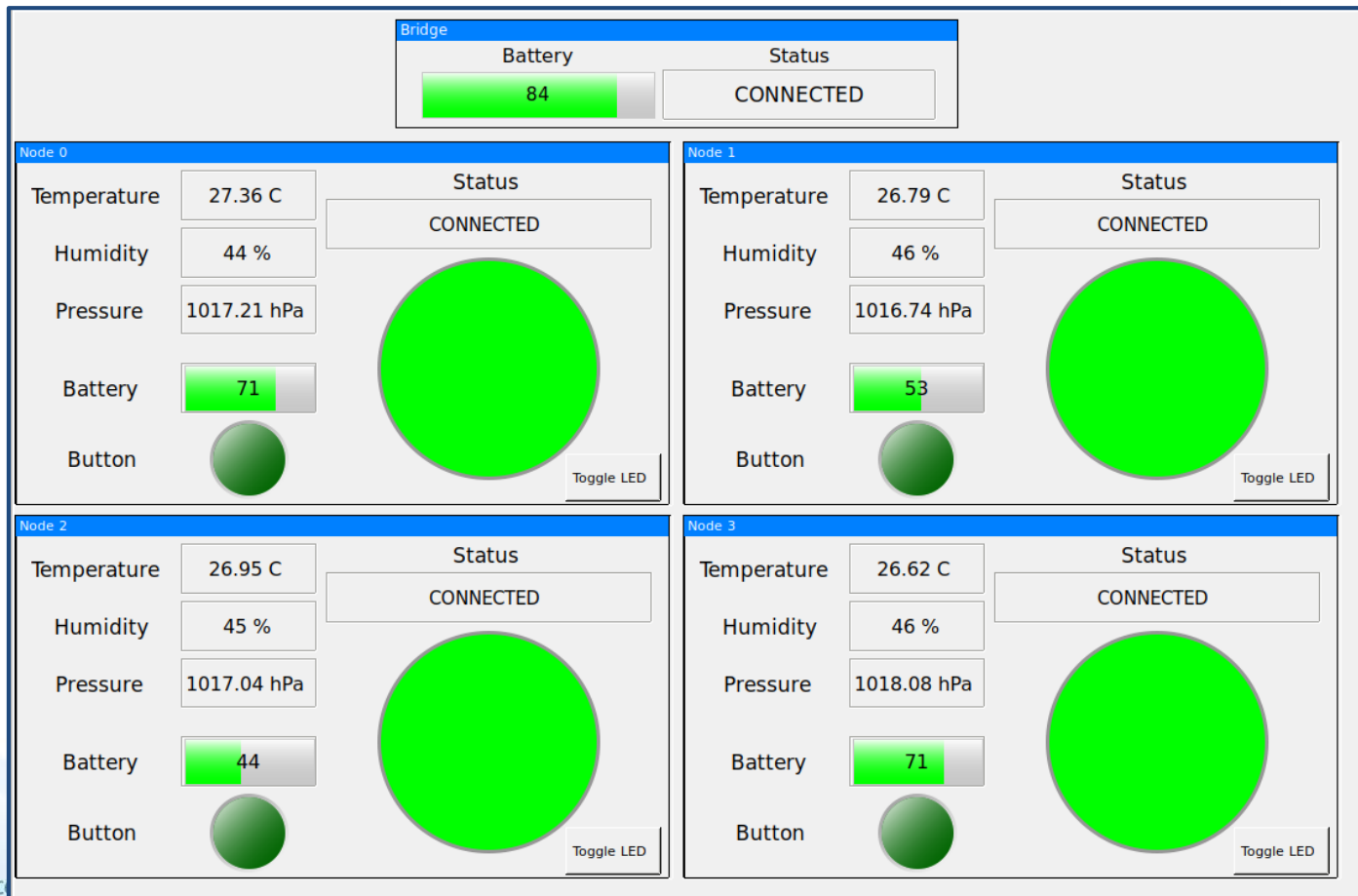
- Large areas require more sensors
- Purchasing a dongle and running IOC for each Thingy is a waste of resources and USB slots
- Thingy also supports Bluetooth mesh: many-to-many connection





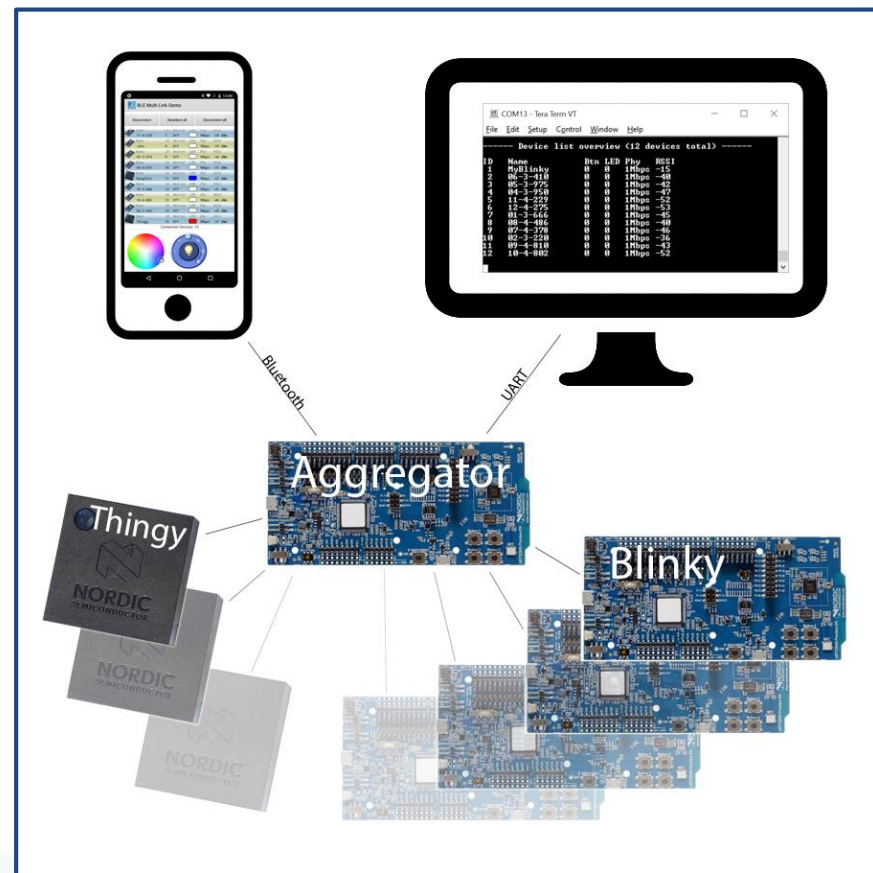
# ThingyMeshIOC

- Connect up to 9 node Thingy52s with one USB dongle
- Potential range increase with each node
- Poor battery life; only several days
  - Bluetooth radio active constantly

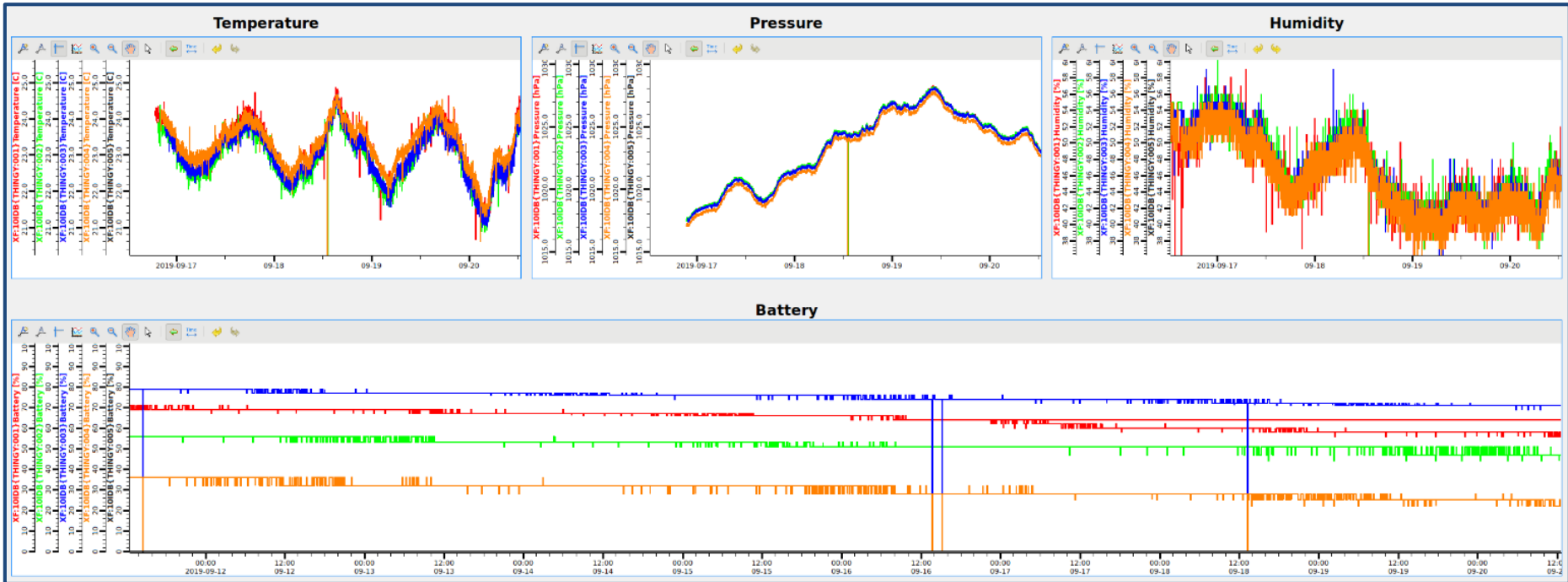


# Bluetooth Multi-Link

- Star network, NRF52 DK 'center' w/ Thingy52 nodes
  - Many-to-many -> Many-to-one
- Custom DK firmware, default Thingy52 firmware
  - Low-energy communication for Thingy
- Nordic firmware easily extensible
  - Added features:
    - Read all sensors
    - Read/write sensor config
    - Read/write connection parameters
    - Toggle sensors on/off



# ThingyAggregatorIOC



Node 0

|                                    |         |             |
|------------------------------------|---------|-------------|
| Step Counter Interval              | 1000 ms | 100 - 5,000 |
| Temperature Compensation Interval  | 500 ms  | 100 - 5,000 |
| Magnetometer Compensation Interval | 500 ms  | 100 - 1,000 |
| Motion Processing Frequency        | 10 hz   | 5 - 200     |
| Wake On Motion                     | 1       |             |

Read Write

Node 0

|                      |          |  |
|----------------------|----------|--|
| Temperature Interval | 60000 ms | 100 - 60,000                                     |
| Pressure Interval    | 60000 ms | 50 - 60,000                                      |
| Humidity Interval    | 60000 ms | 100 - 60,000                                     |
| Gas Mode             | 3        | 1 = 1 second<br>2 = 10 seconds<br>3 = 60 seconds |

Read Write

# ThingyAggregatorIOC

Node 0

Help

Temperature

Humidity

Pressure

Air Quality

Quaternions

Raw Motion

Euler Motion

Heading

Node 1

Help

Temperature

Humidity

Pressure

Air Quality

Quaternions

Raw Motion

Euler Motion

Heading

Node 2

Help

Temperature

Humidity

Pressure

Air Quality

Quaternions

Raw Motion

Euler Motion

Heading

Node 3

Help

Temperature

Humidity

Pressure

Air Quality

Quaternions

Raw Motion

Euler Motion

Heading

Node 1

|                             |          |              |
|-----------------------------|----------|--------------|
| Minimum Connection Interval | 7.5 ms   | 7.5 - 4000   |
| Maximum Connection Interval | 30.0 ms  | 7.5 - 4000   |
| Slave Latency               | 0 events | 0 - 499      |
| Supervision Timeout         | 3200 ms  | 100 - 32,000 |

Read Write

# Conclusion

- Connect up to 19 node Thingy52s with one dongle/DK using multi-link
  - Temperature, pressure, humidity, motion
- Approx. 3 months usage w/ full charge
- \$40 sensor, \$40 DK, \$10 dongle
- Extremely simple deployment
  - Plug in DK (USB), place Thingy52s, run IOC
- Customizable sensing
  - Set scan period, toggle sensors
- Lightweight IOC
  - Dependencies: EPICS base, gattlib
  - Easily run on Raspberry Pi
- Range limited by Bluetooth low energy
  - Sufficient for single hutch deployments