

4CeeD Lecture Series

Lecture #4:

SENSELET: Sensory Network Infrastructure for Scientific Lab Environments

March 30th, 2023

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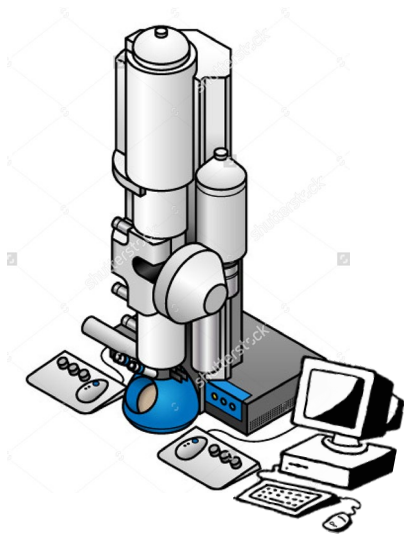
A timely and trusted curator and coordinator of scientific data

Lecture Series Learning Objectives

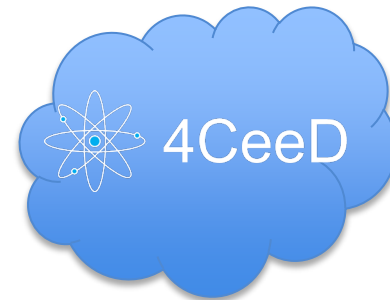
- Lecture 1 (3/21): Overview of 4CeeD
- Lecture 2 (3/23): Workshop (Cont.) & Advanced Features
- Lecture 3 (3/28): 4CeeD Backend Services
- **Lecture 4 (3/30): SENSELET**
 - Background & Motivation
 - SENSELET Architecture
 - Components of SENSELET
 - Live Demo of SENSELET Visualization

Recap of 4CeeD

- Address Scientific **Digital Data Acquisition, Curation and Sharing** prior to Scientific Publication of Results via **Private Cloud Storage Facility**

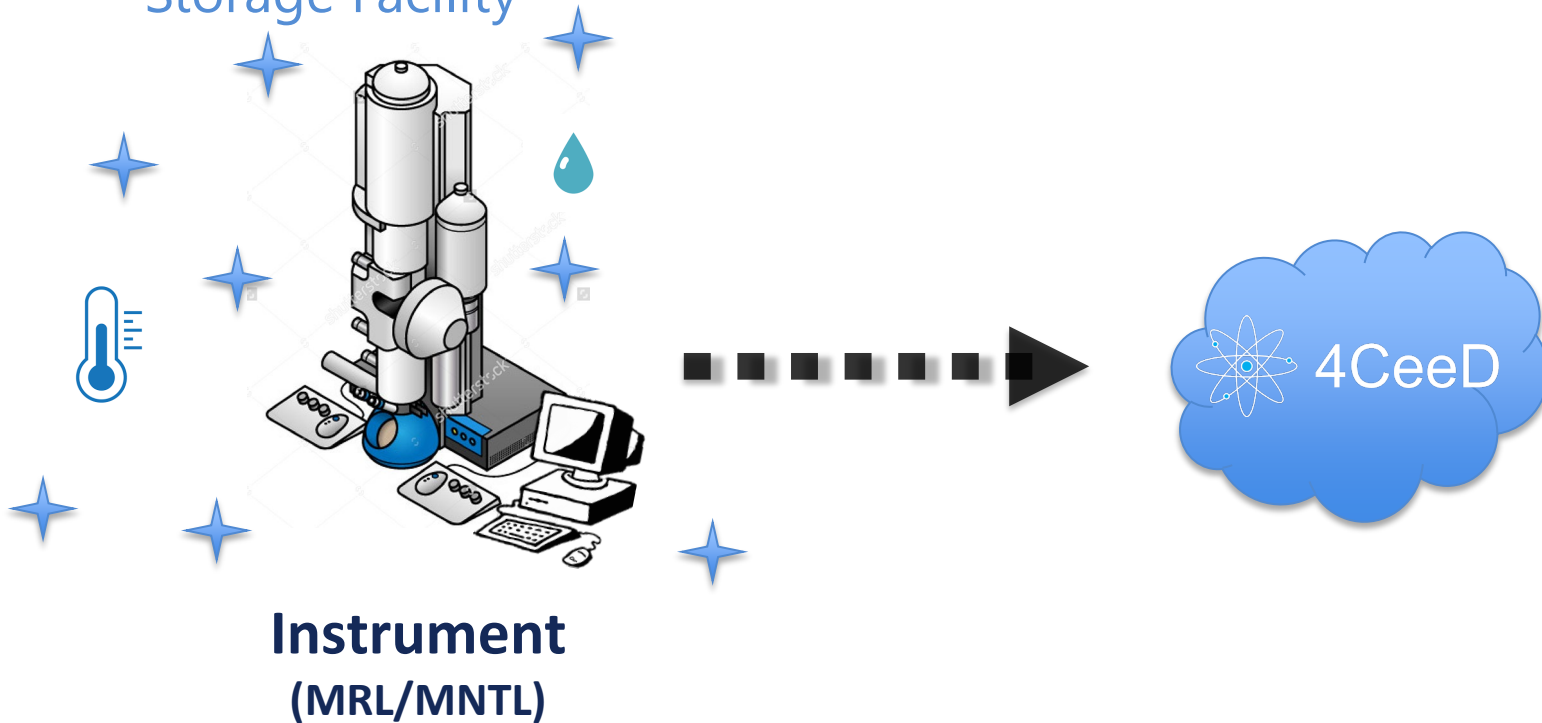


Instrument
(MRL/MNTL)



Recap of 4CeeD

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Outline

- Background & Motivation
- SENSELET Architecture
- Components of SENSELET
- Live Demo of SENSELET Visualization

Outline

- **Background & Motivation**
- SENSELET Architecture
- Components of SENSELET
- Live Demo of SENSELET Visualization

Digitizing the Research Laboratory

- University equipment is utilized well-beyond its expected lifetime
- Many do not offer means for digitalizing feedback data during experiments



30+ year old Plasma
Etcher



25+ year old Plasma Deposition

Consequences of Uncontrolled Environments

- Excess humidity in un-controlled and un-monitored environments can lead to failure modes
 - Photoresist delamination
 - Critical dimension (CD) fluctuation [1]
 - Photoresist thickness variation [1]

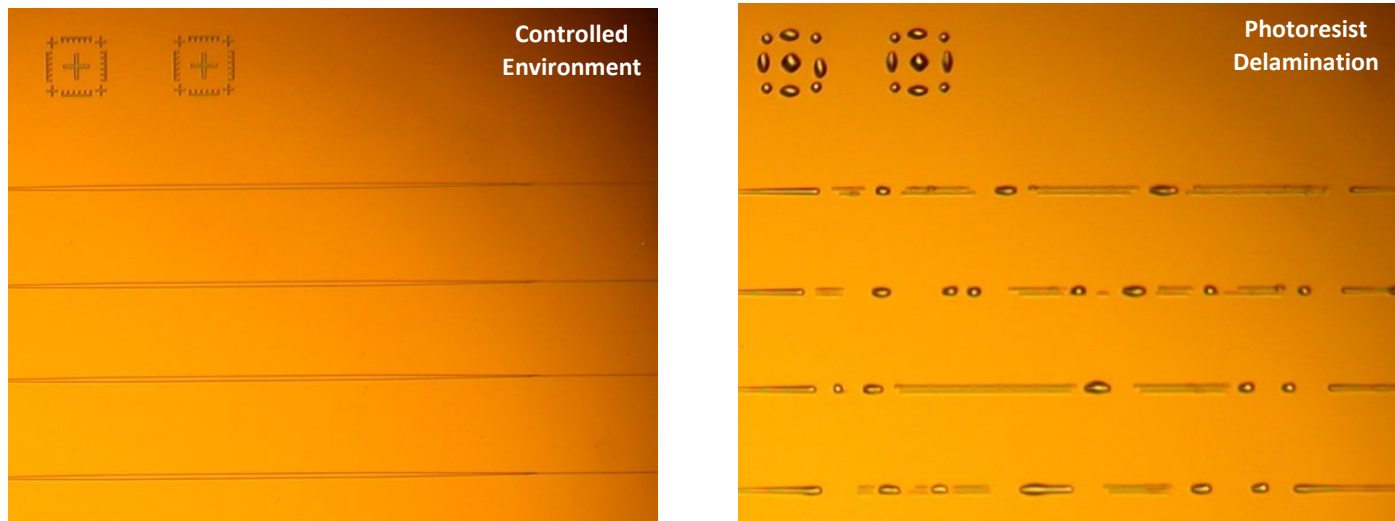
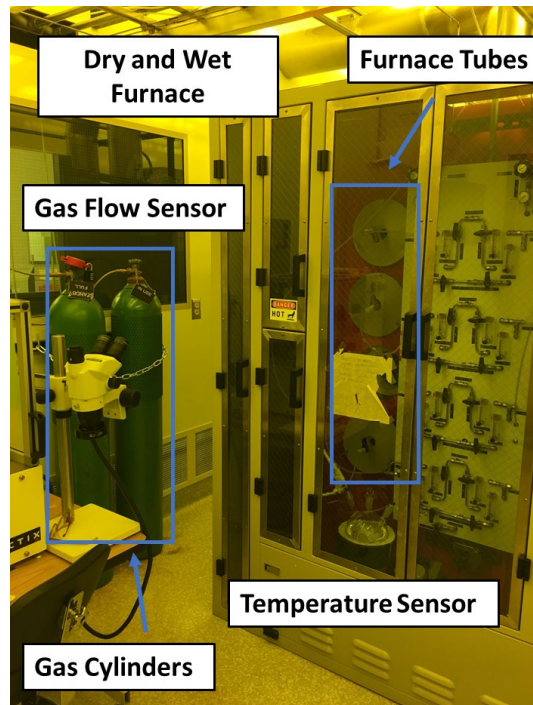


Fig. 1 Comparison between an optical microscope image of developed photoresist that form sharp waveguides (left) and photoresist showing delamination caused by excess humidity of the cleanroom (right).

Automatic Data Logging of Lab Environments

- Real-time environmental data logging is time-consuming when conducted manually
 - Large-scale commercial sensor networks are expensive
 - Implement variety of sensors on lab equipment (ex. furnaces)



Monitoring of long duration experiments:

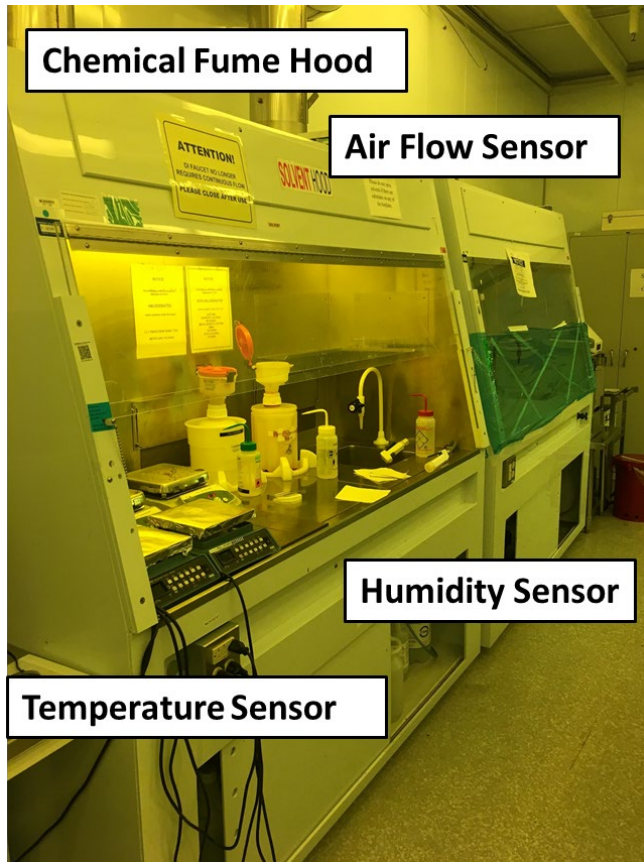
- Diffusion
- Oxidation
- Annealing

Monitoring Sensors:

- Gas flow sensors
- Temperature sensors

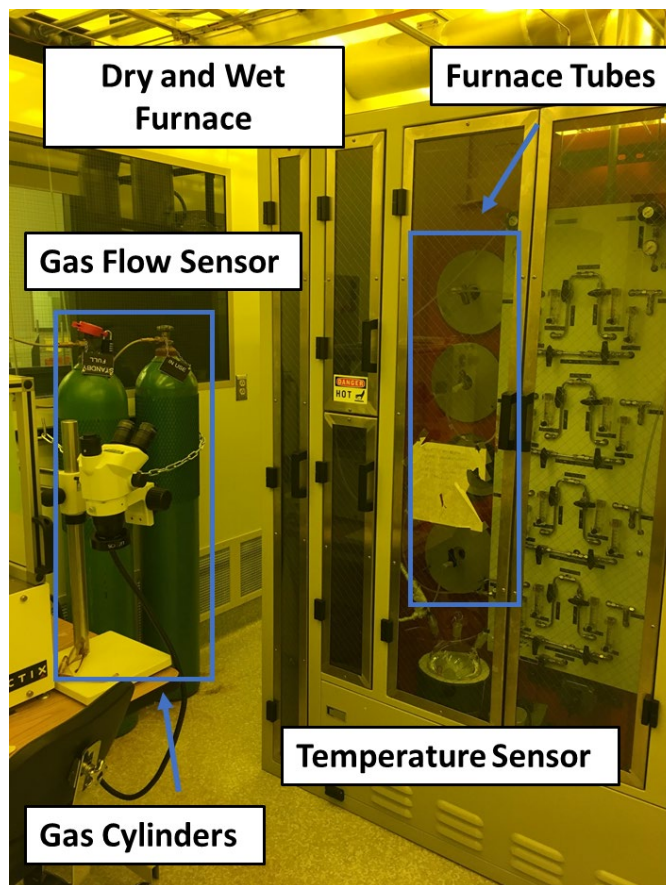
Environmental Logging: Chemical Fume Hood

- Automatically log/track humidity, temperature, gas flows, and others



- **Temperature/Humidity Sensor:** real-time tracking to ensure optimal performance during lithography processes
- **Air Flow Sensor:** Threshold tracking to notify cleanroom users for out-of-spec performance
 - Eliminates downtime of the fume hood if it doesn't pass safety audit inspection

Environmental Logging: Furnaces/Gasses



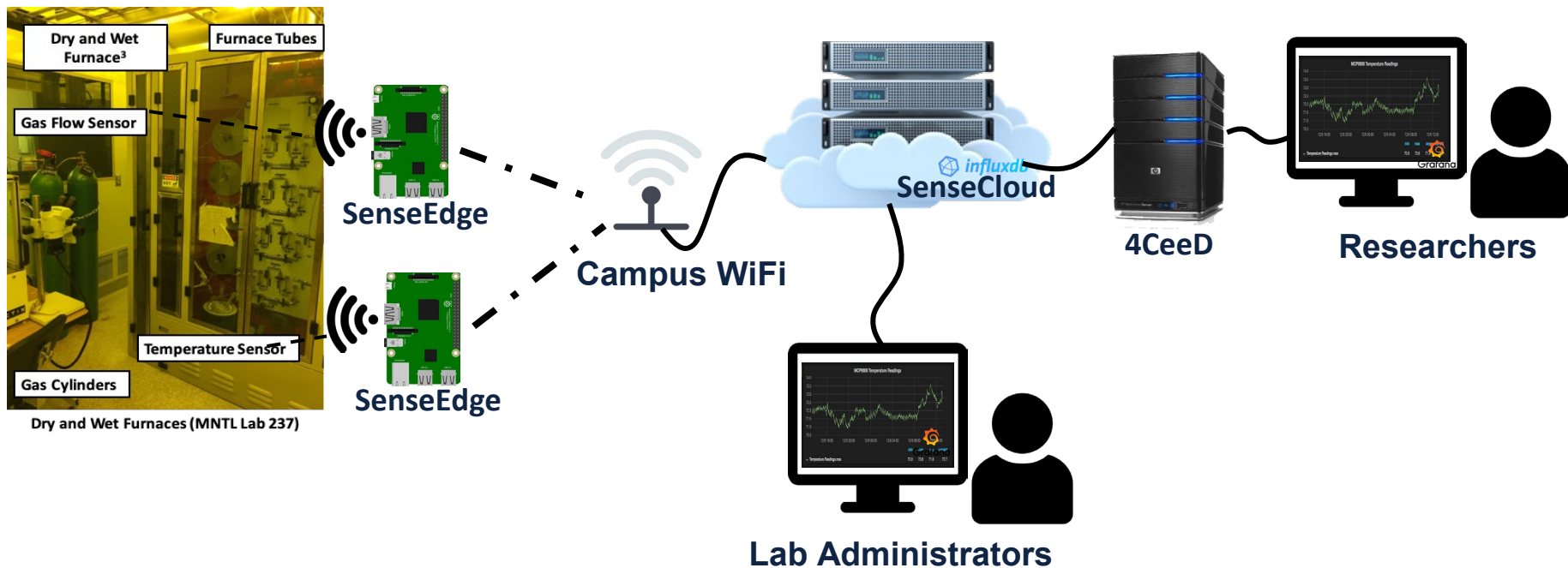
- **Gas Flow Sensor:** real-time tracking of oxidation experiment or determining the remaining amount of gas
- **Temperature Sensor:** real-time tracking of sensitive oxidation, annealing, or diffusion processes
 - Aids in troubleshooting or guaranteeing reliability of long experiments (2-3 hours)

Outline

- Background & Motivation
- **SENSELET Architecture**
- Components of SENSELET
- Live Demo of SENSELET Visualization

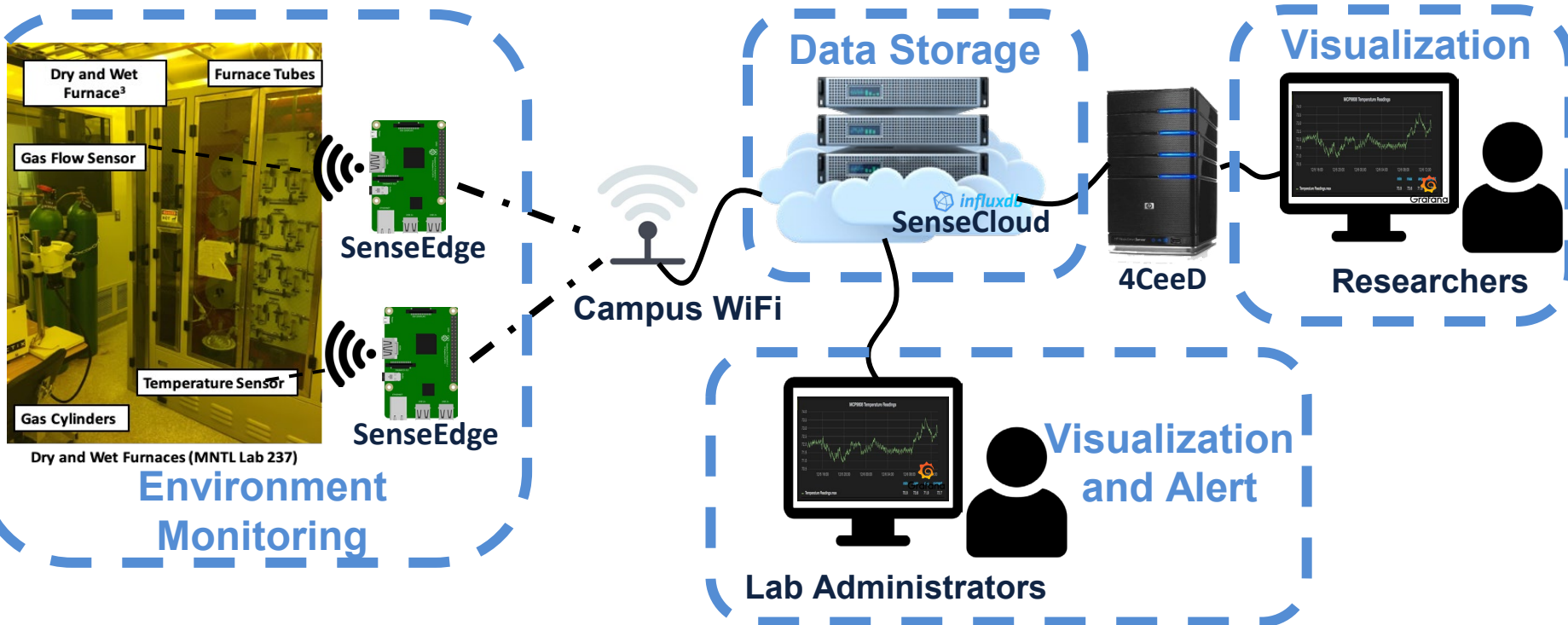
What is SENSELET?

- A system of wireless, automated sensors that monitor the cleanroom environment, together with the central server which manages the sensory data



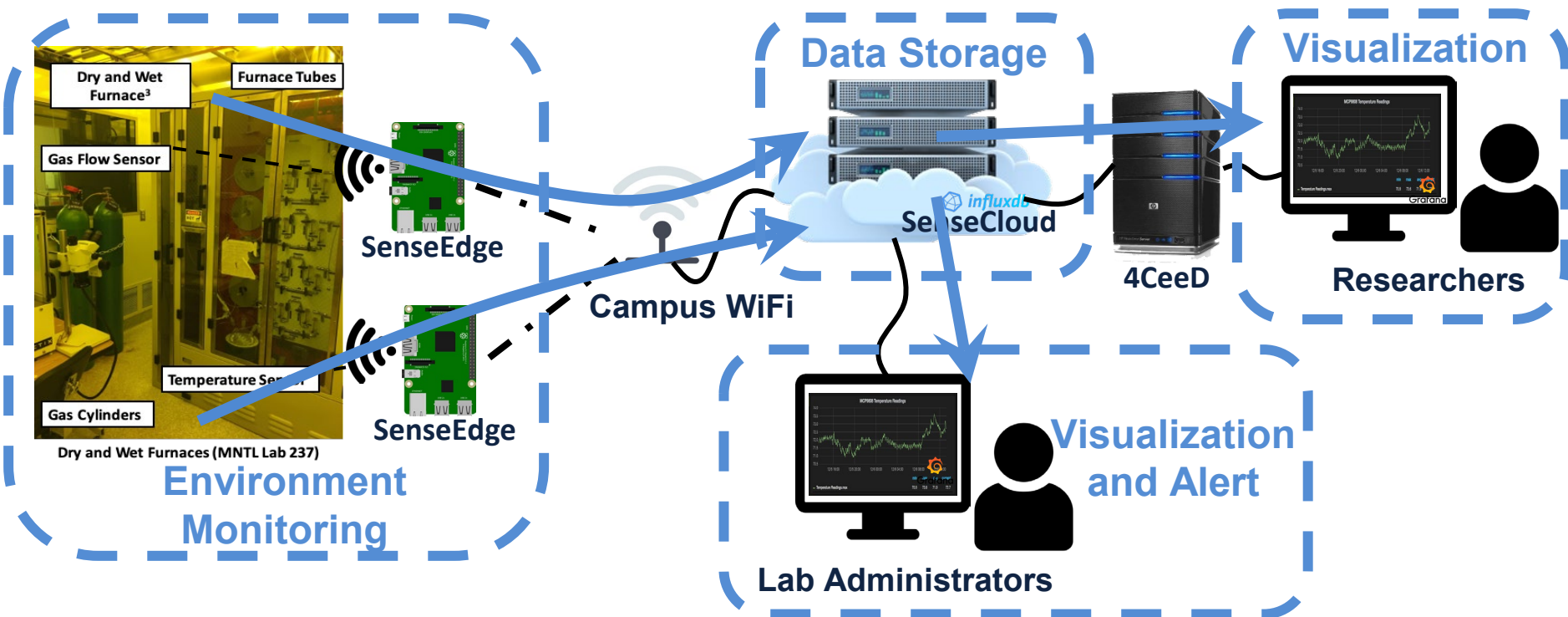
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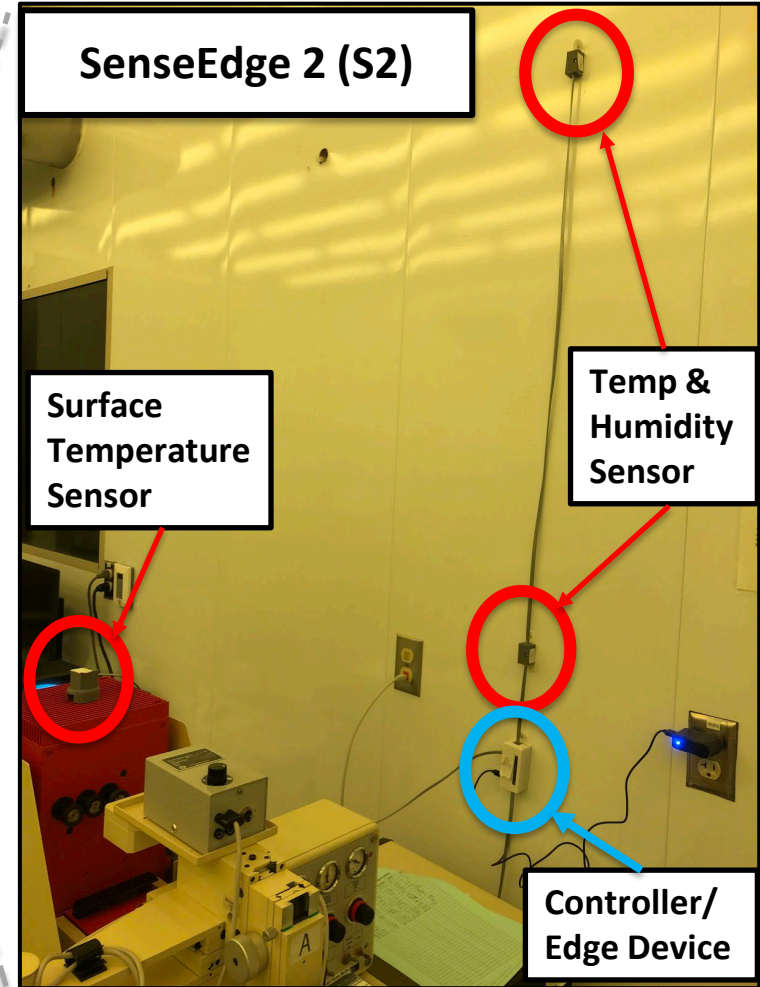
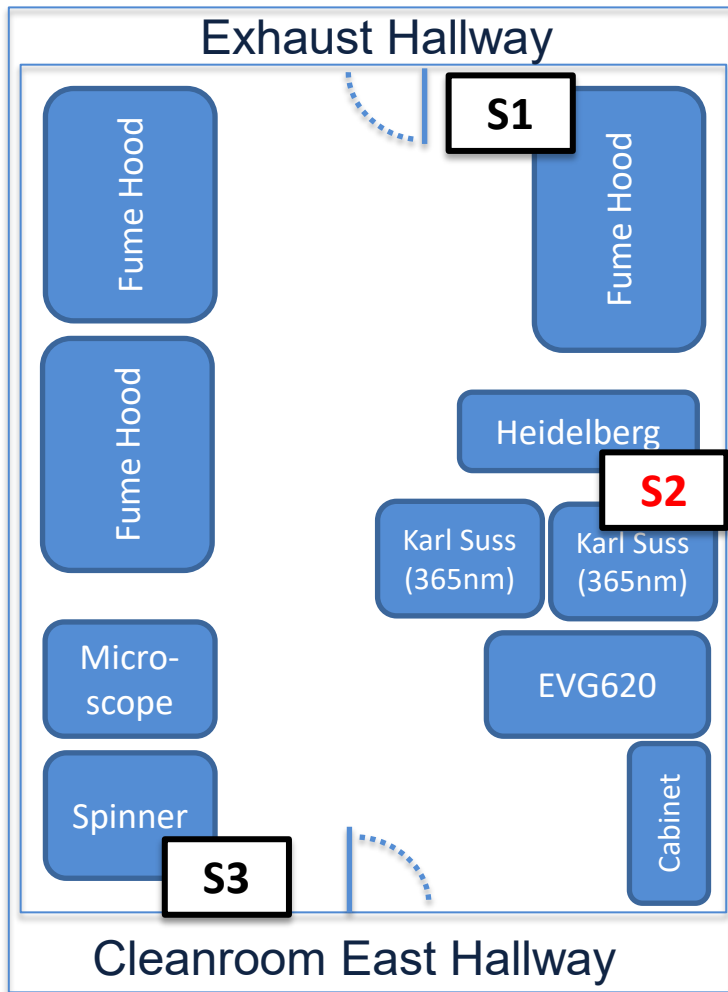


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SENSELET in Lithography Room

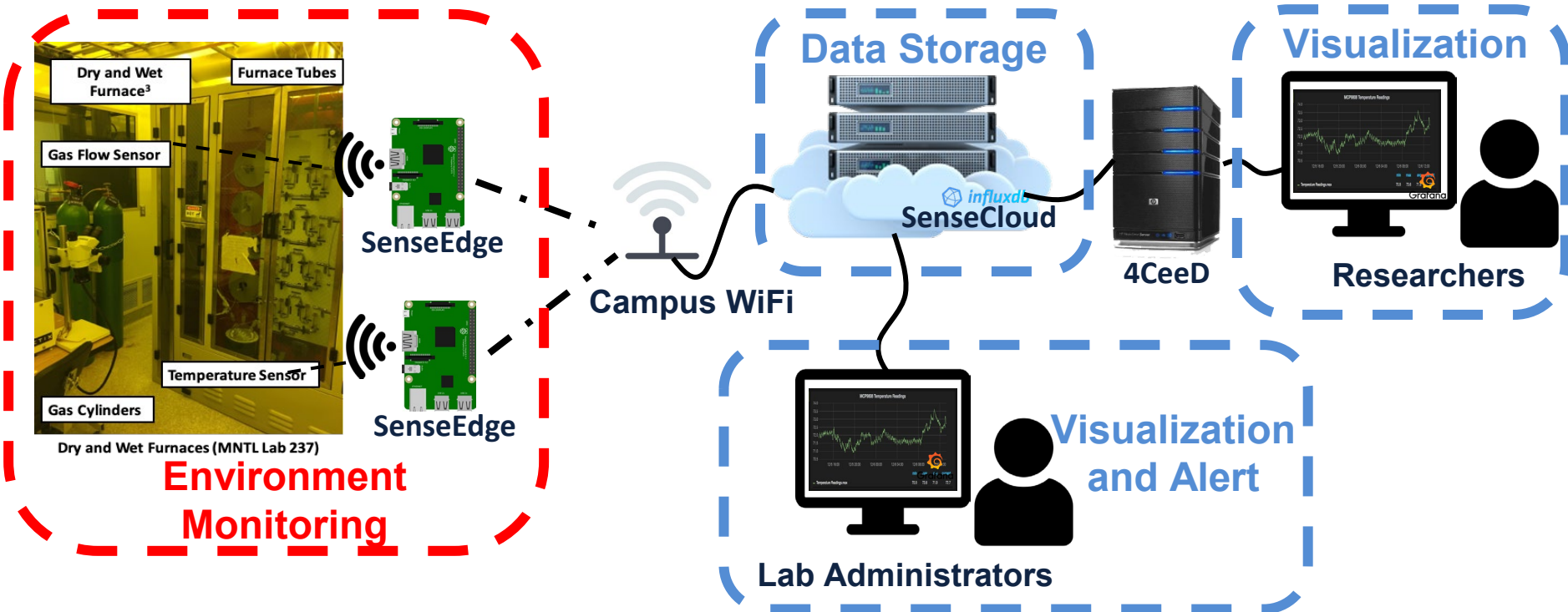


Outline

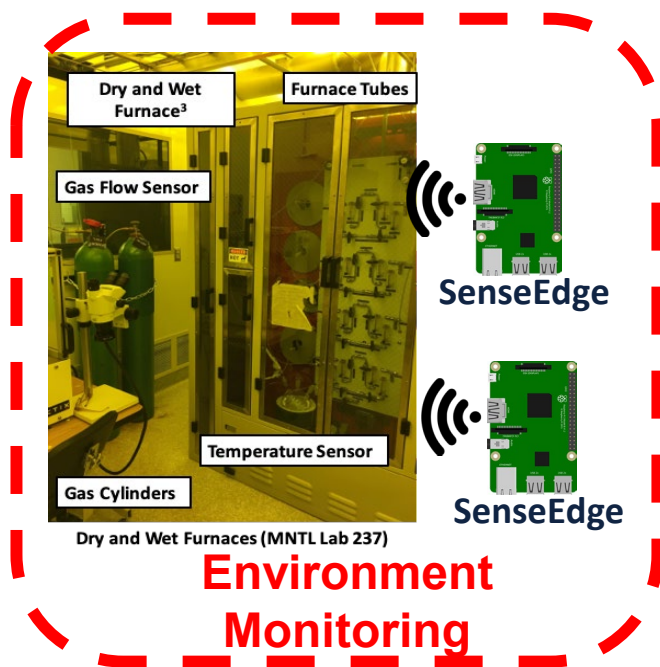
- Background & Motivation
- SENSELET Architecture
- **Components of SENSELET**
- Live Demo of SENSELET Visualization

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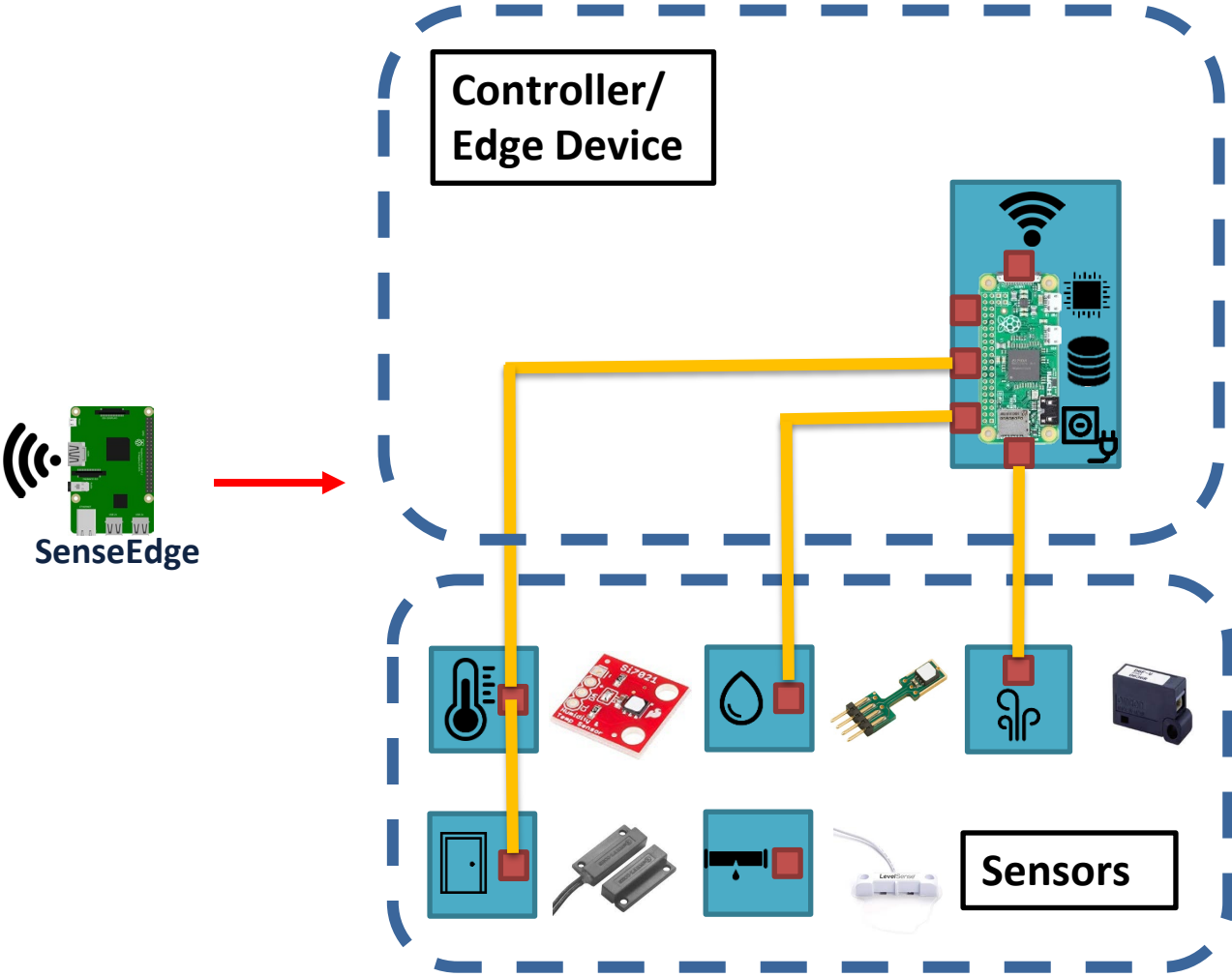
SenseEdge Functions



Functions of SenseEdge:

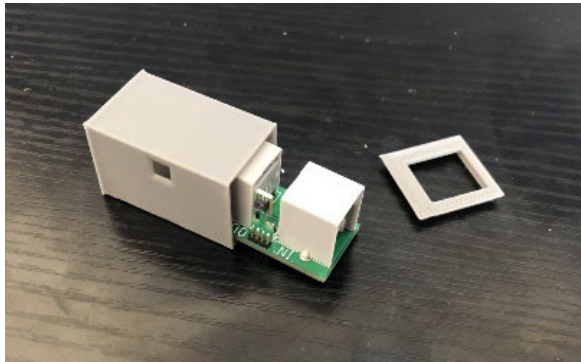
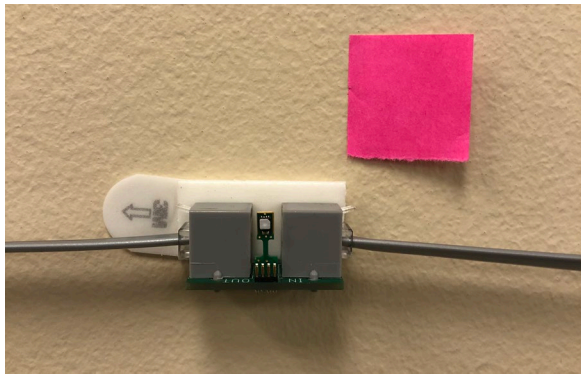
- Track temperature, humidity, (water leakage, air flow, door status etc.)
- Send data to central cloud server
- Recover from failures

SenseEdge – Structure



SenseEdge – Sensors

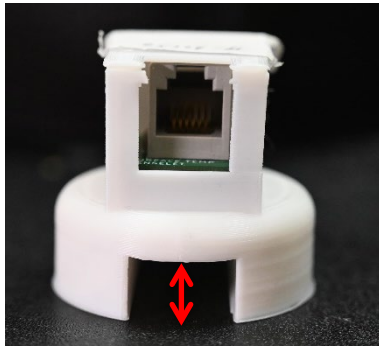
- Temperature and Humidity Sensor



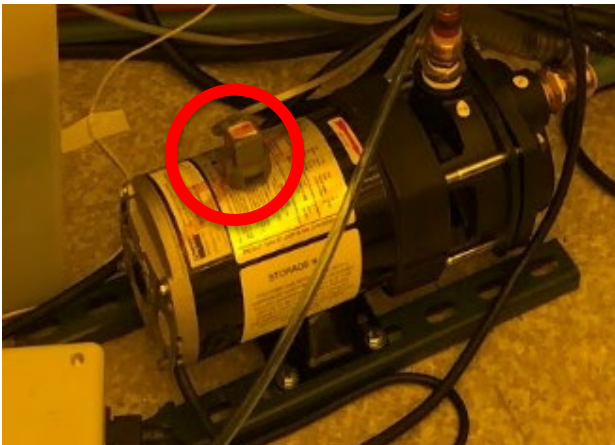
- Humidity Range: 0 ... 100% RH
- Humidity Accuracy: ± 1.5 %RH
- Temperature Range: -40 ... 105 °C
- Temperature Accuracy: ± 0.1 °C
(20 to 50 °C)

SenseEdge – Sensors

- Infrared Temperature sensor (Pump)

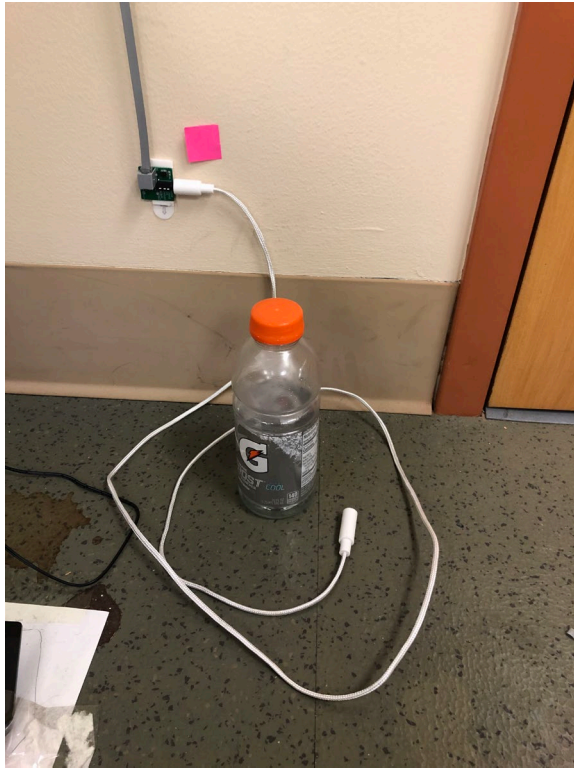


- Temperature Range: -70 ... 380 °C
- Temperature Accuracy: ± 0.5 °C



SenseEdge – Sensors

- Water Leakage Sensor Rope

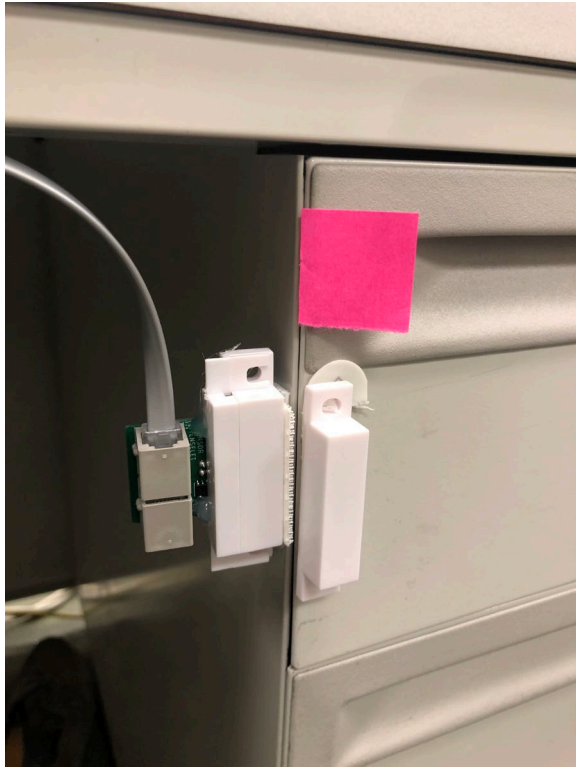


- Water Leakage Sensor Point



SenseEdge – Sensors

- Magnetic Sensor Large

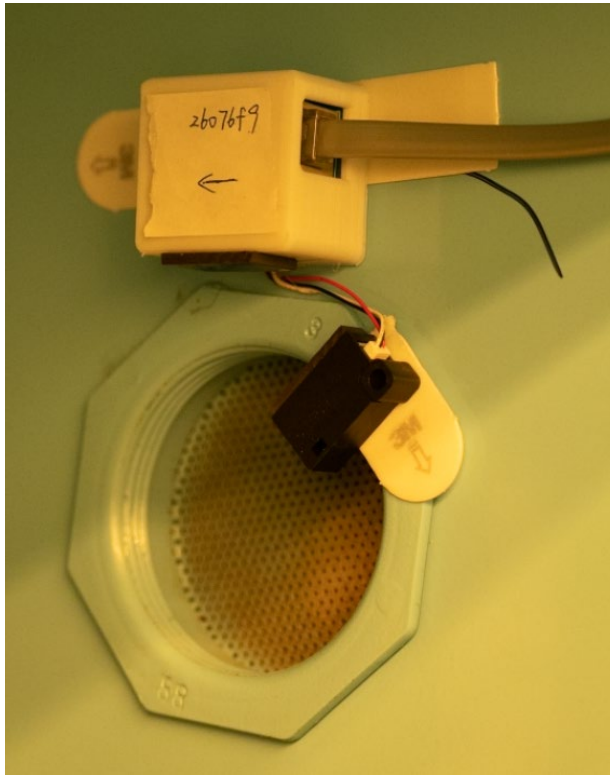


- Magnetic Sensor Small

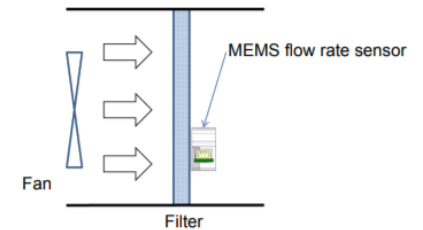


SenseEdge – Sensors

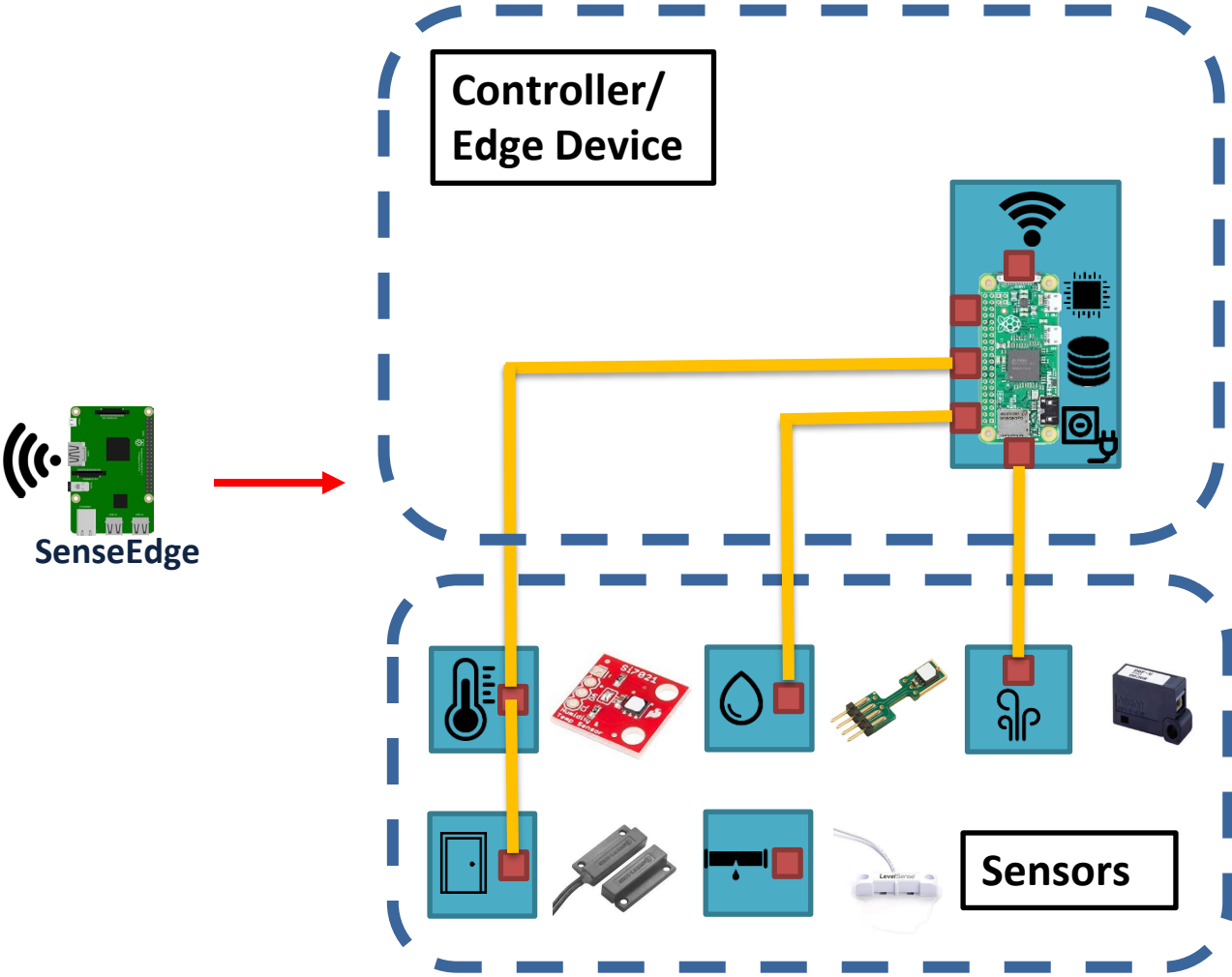
- Air Flow Sensor



Clogged Filter Detection

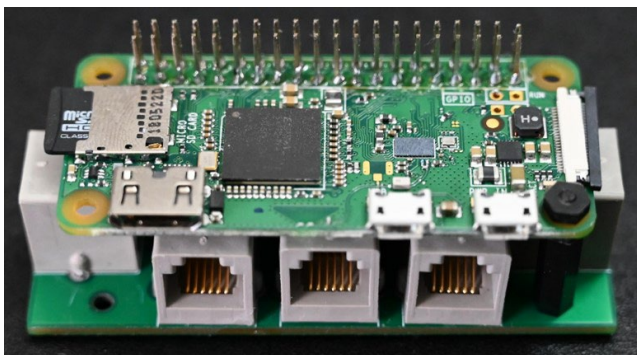


SenseEdge – Structure



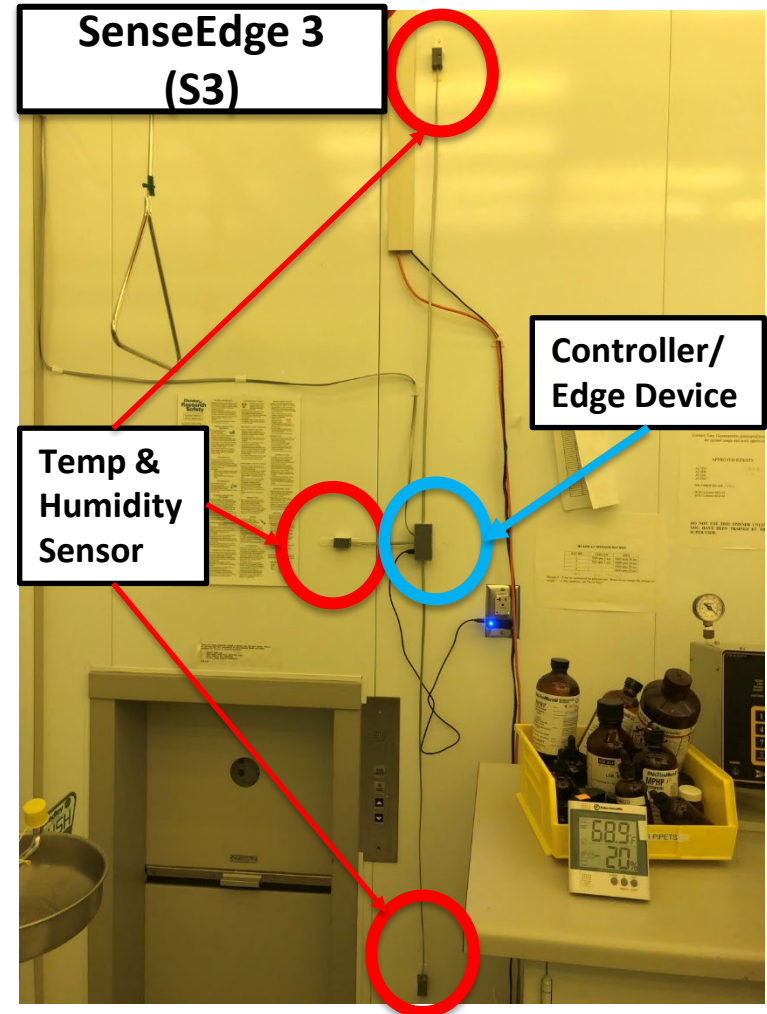
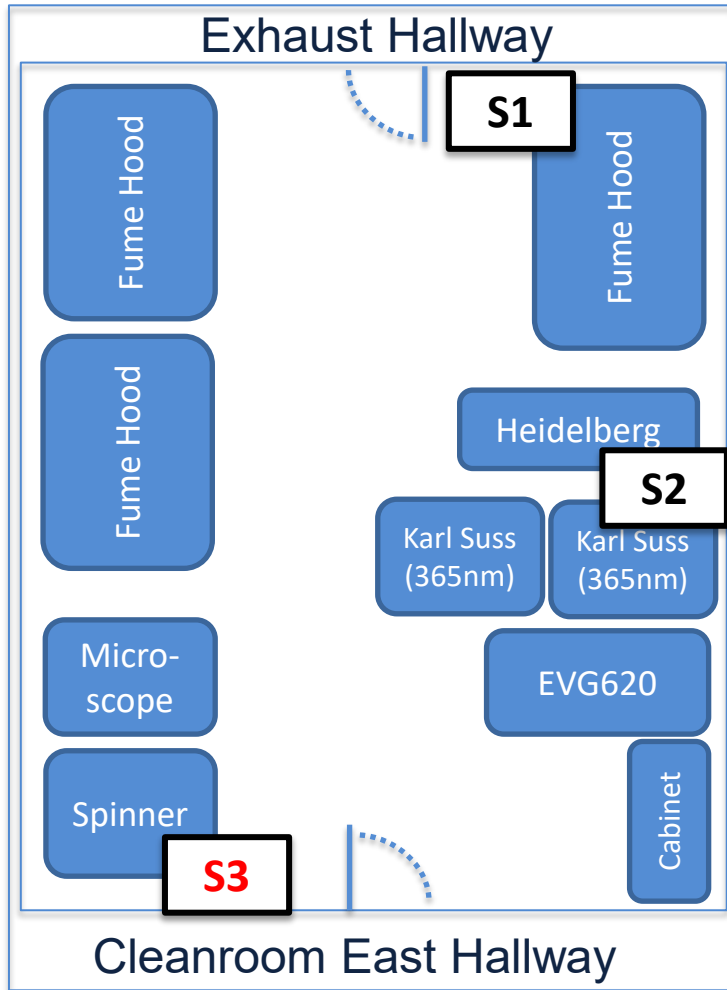
SenseEdge – Edge Device

- Edge Device

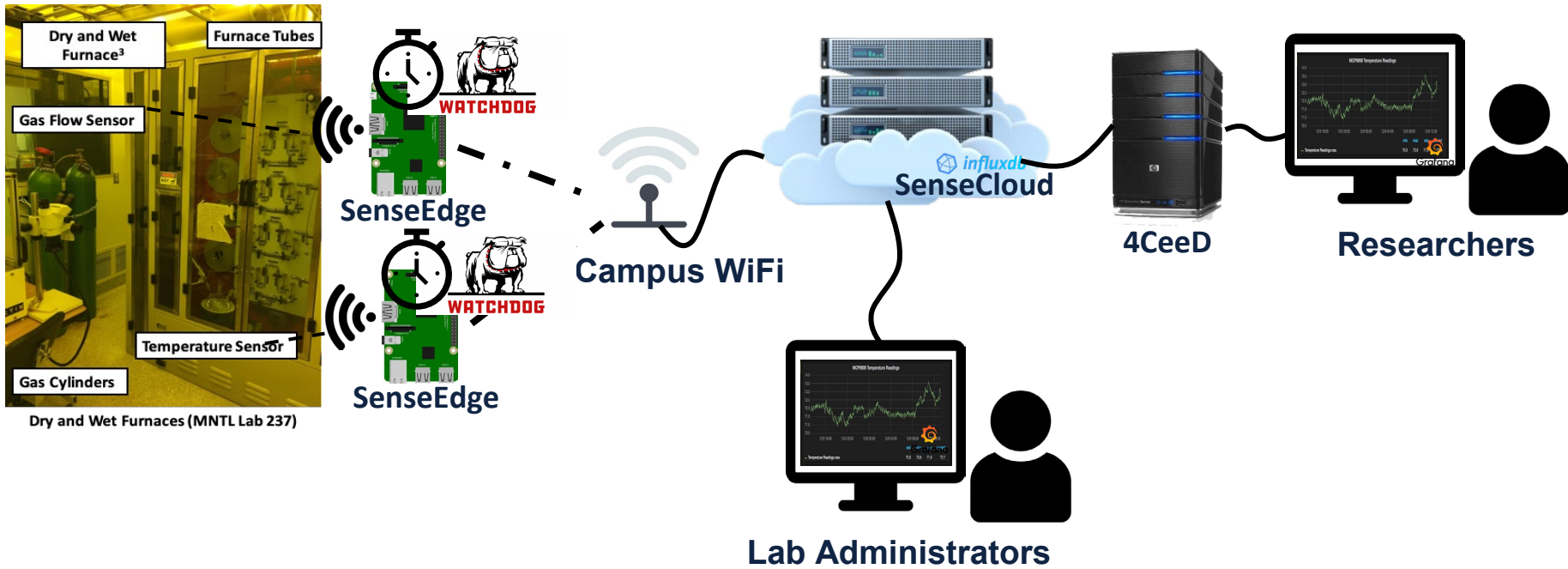


- Raspberry Pi --- “small single-board computers”
- Originally designed to “promote teaching of basic computer science”
- “now widely used even in research projects”
- Wi-Fi, Bluetooth, Ethernet, USB, Micro HDMI, GPIO header pins, CSI interface

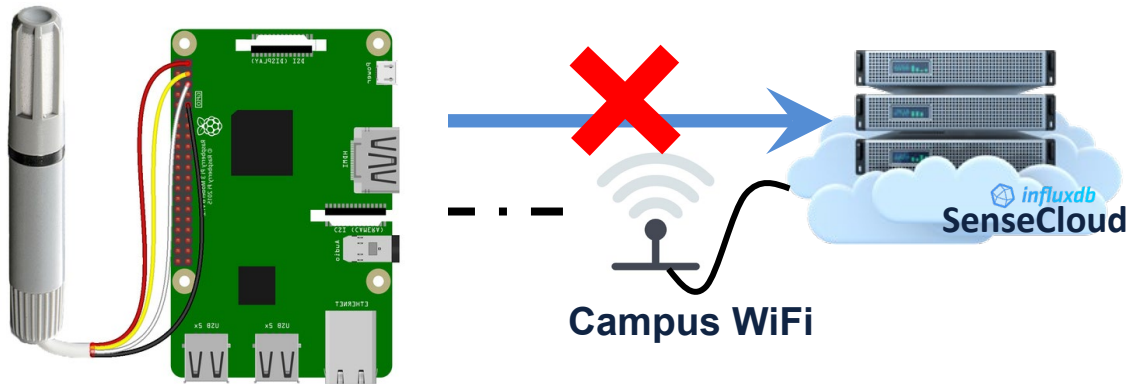
SenseEdge - Deployment



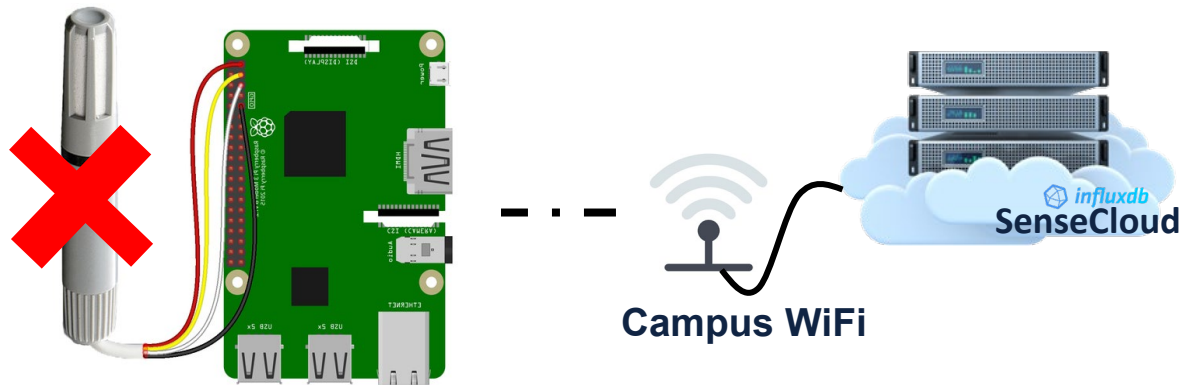
Reliability of SenseEdge



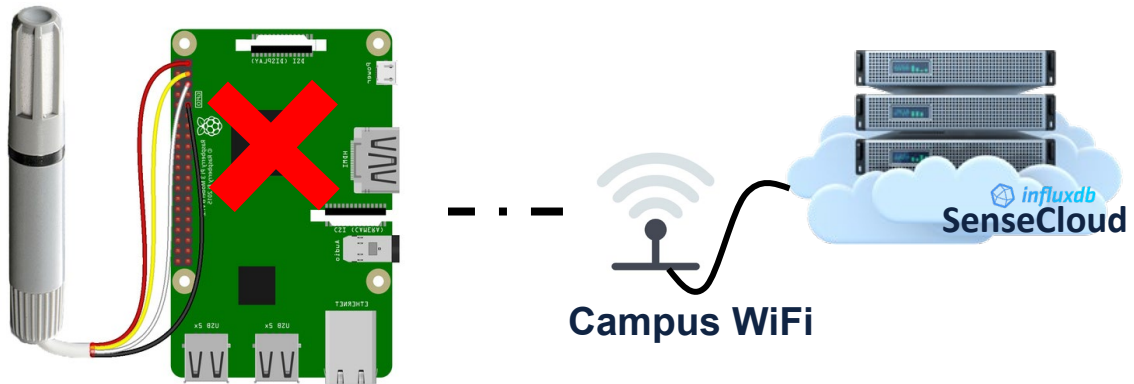
Reliability of SenseEdge



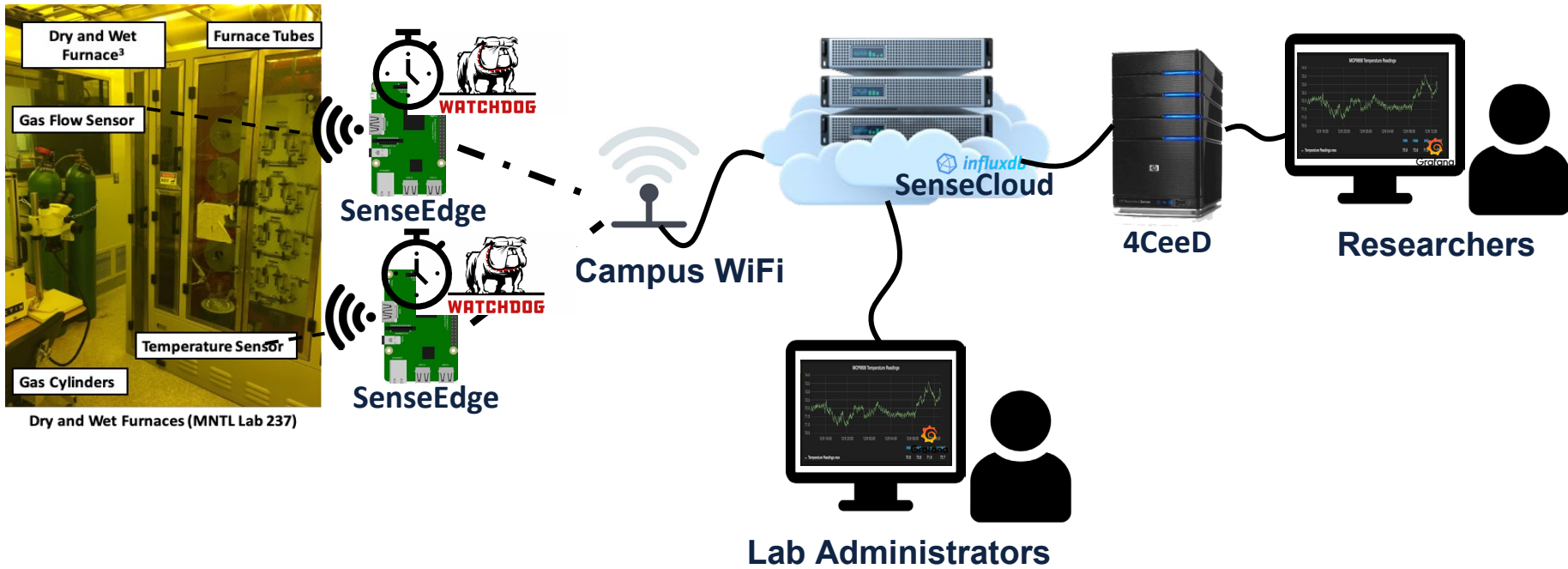
Reliability of SenseEdge



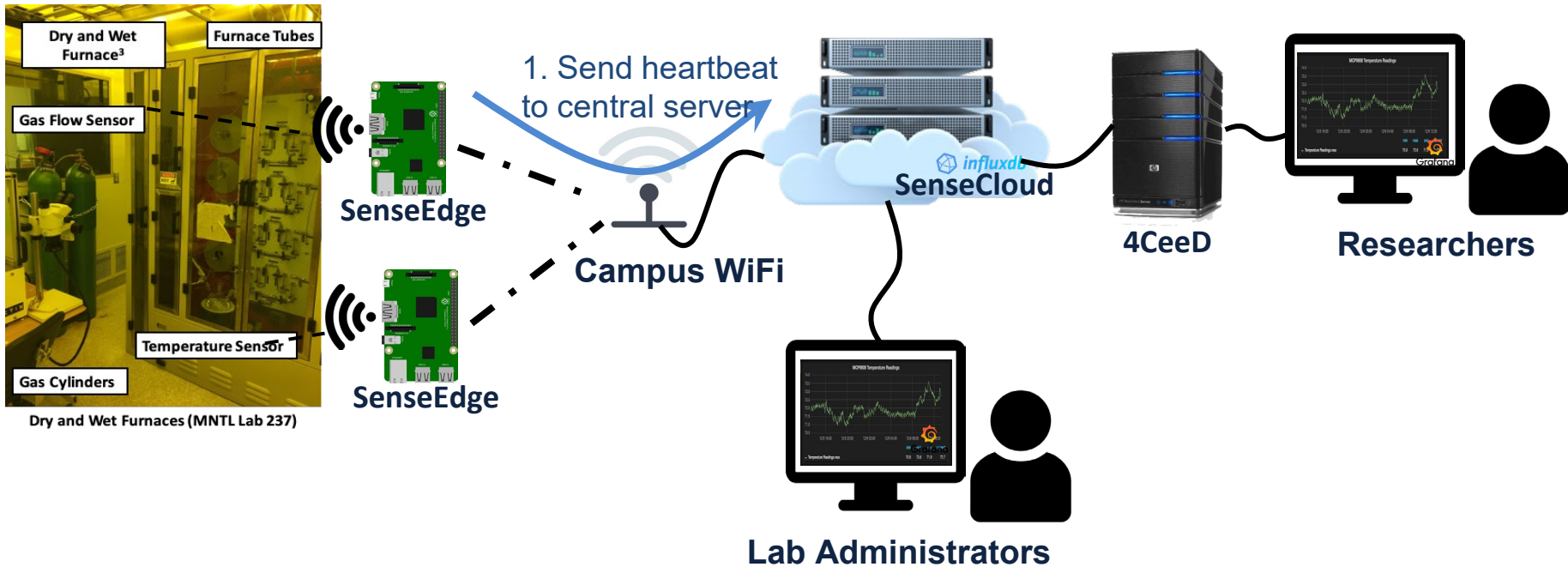
Reliability of SenseEdge



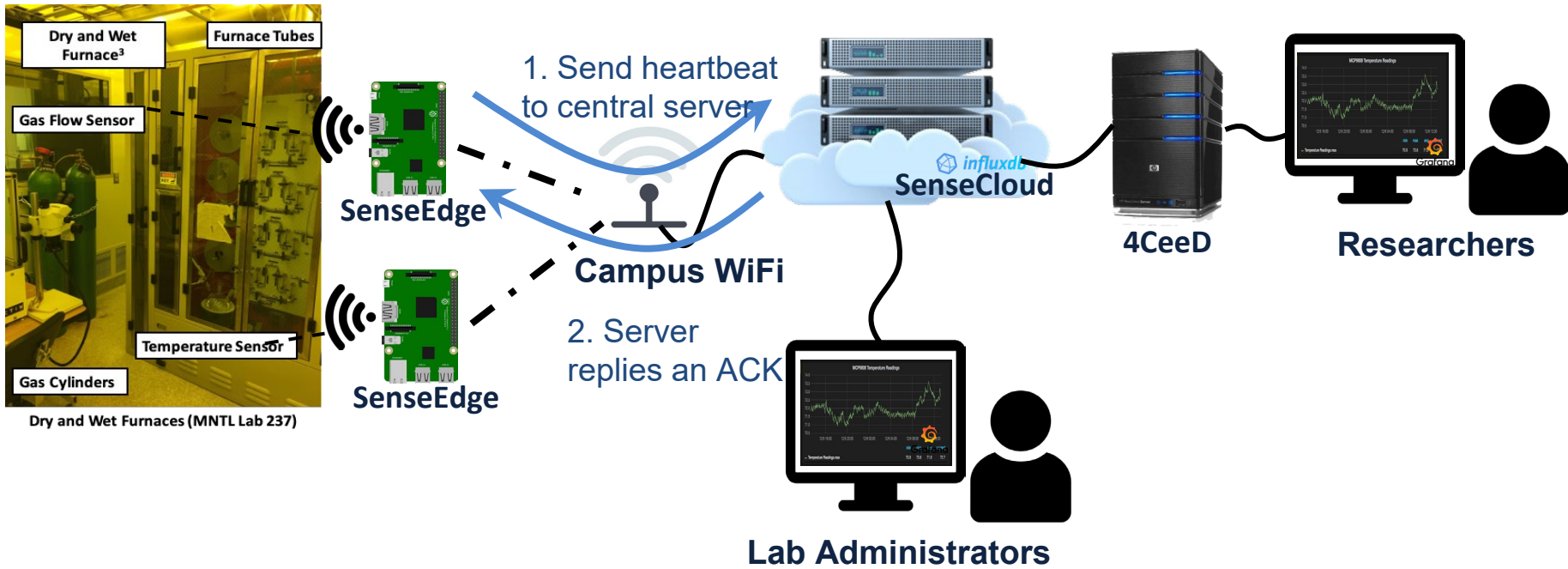
Reliability of SenseEdge



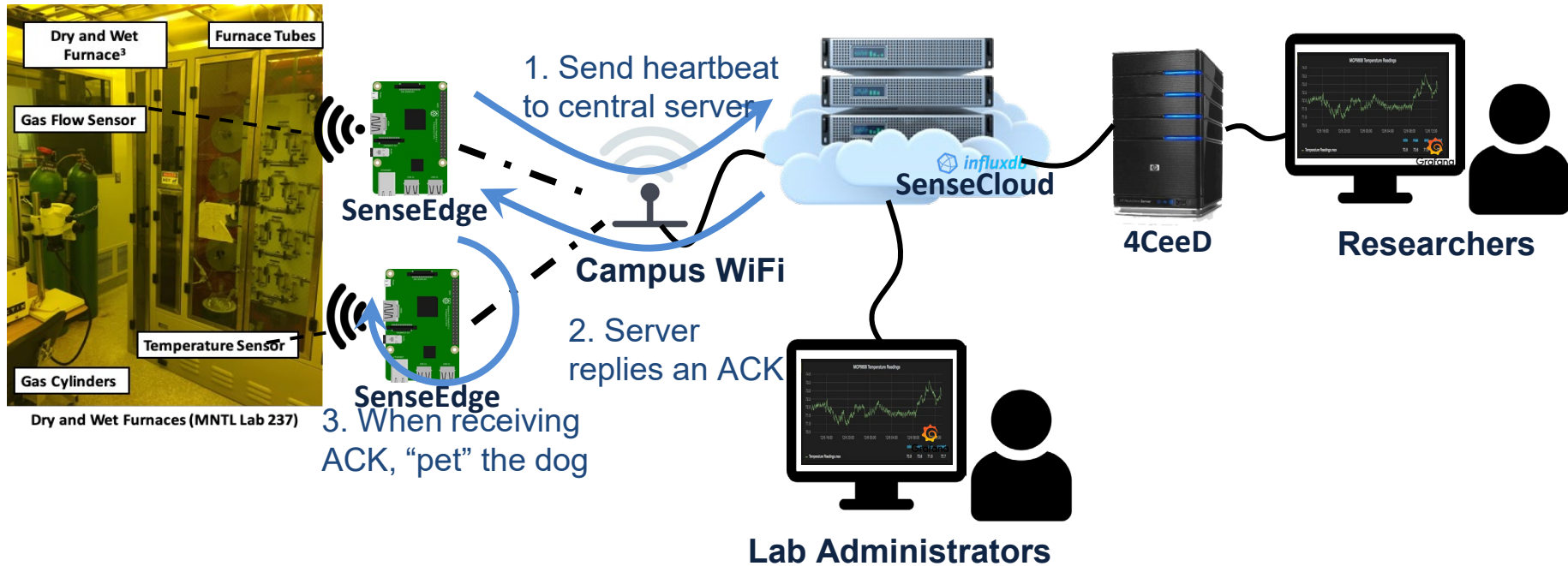
Reliability of SenseEdge



Reliability of SenseEdge

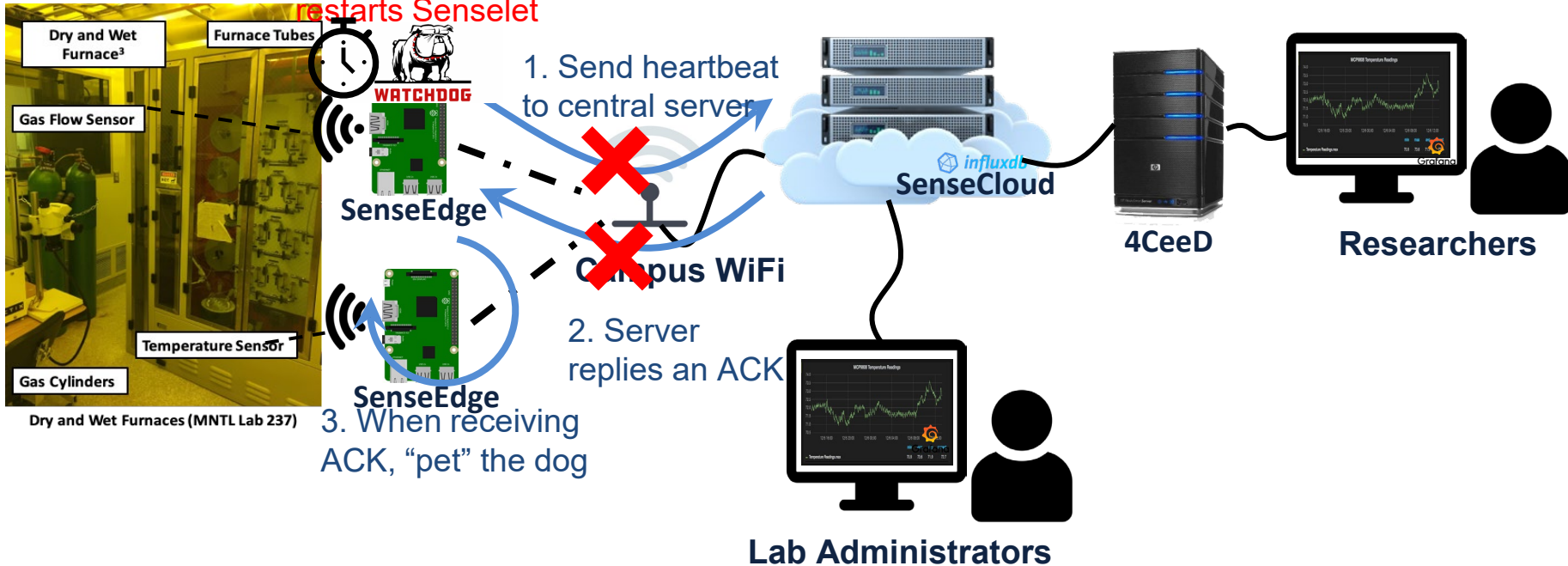


Reliability of SenseEdge



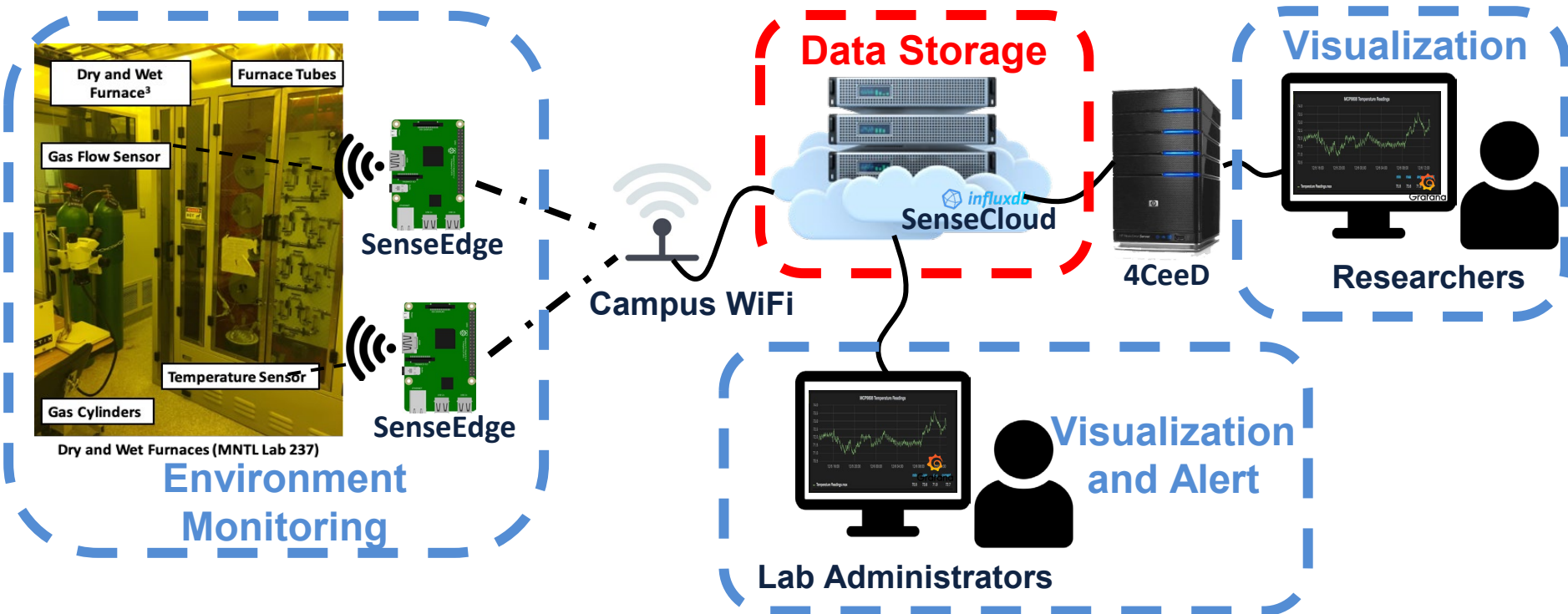
Reliability of SenseEdge

4. If any step goes wrong and Senselet does not receive ACK for a predefined time interval (eg. 1min), watchdog kicks in and restarts Senselet



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SENSELET

SENSECLOUD



- Time series database

SENSELET

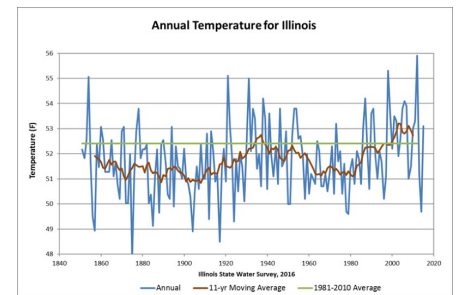
SENSECLOUD

Senselet (SenseCloud) Version 2

- Time series database



FOR



Relational Database (MySQL)	Time Series Database (InfluxDB)
General purpose	Optimized for time series data (storage, query)
Max ingest rate 155k writes/sec (on AWS)	Easily supports ingest rate of 1M writes/sec
Keys are usually item IDs	Keys are time stamps

SENSECLOUD Database Storage

InfluxDB time series
database

Timestamp

```
zhe@zhe-Precision-7510: ~/Senselet/db
name: temp_humi_measurement
```

	Field keys	Tag	Field keys
time	humidity	sensor	temperature
2020-03-02T06:04:12Z	47.112030029296875	0	21.60829833984375
2020-03-02T06:04:12Z	32.982391357421875	2	27.324775390625
2020-03-02T06:04:13Z	47.119659423828125	0	21.586848144531253
2020-03-02T06:04:13Z	32.982391357421875	2	27.335500488281248
2020-03-02T06:04:13Z	50.4	7	19.6
2020-03-02T06:04:14Z	32.997650146484375	2	27.346225585937496
2020-03-02T06:04:14Z	47.104400634765625	0	21.619023437499997
2020-03-02T06:04:15Z	32.997650146484375	2	27.31405029296875
2020-03-02T06:04:15Z	47.119659423828125	0	21.640473632812494
2020-03-02T06:04:15Z	45.5	6	21.3
2020-03-02T06:04:16Z	47.104400634765625	0	21.60829833984375
2020-03-02T06:04:17Z	50.4	7	19.7
2020-03-02T06:04:17Z	47.112030029296875	0	21.60829833984375
2020-03-02T06:04:17Z	32.974761962890625	2	27.324775390625
2020-03-02T06:04:18Z	47.127288818359375	0	21.5975732421875
2020-03-02T06:04:18Z	32.997650146484375	2	27.346225585937496
2020-03-02T06:04:19Z	47.127288818359375	0	21.60829833984375
2020-03-02T06:04:19Z	32.982391357421875	2	27.335500488281248
2020-03-02T06:04:19Z	45.5	6	21.3
2020-03-02T06:04:20Z	32.982391357421875	2	27.346225585937496
2020-03-02T06:04:20Z	47.104400634765625	0	21.5975732421875
2020-03-02T06:04:21Z	32.990020751953125	2	27.346225585937496
2020-03-02T06:04:21Z	47.119659423828125	0	21.60829833984375
2020-03-02T06:04:21Z	50.4	7	19.6

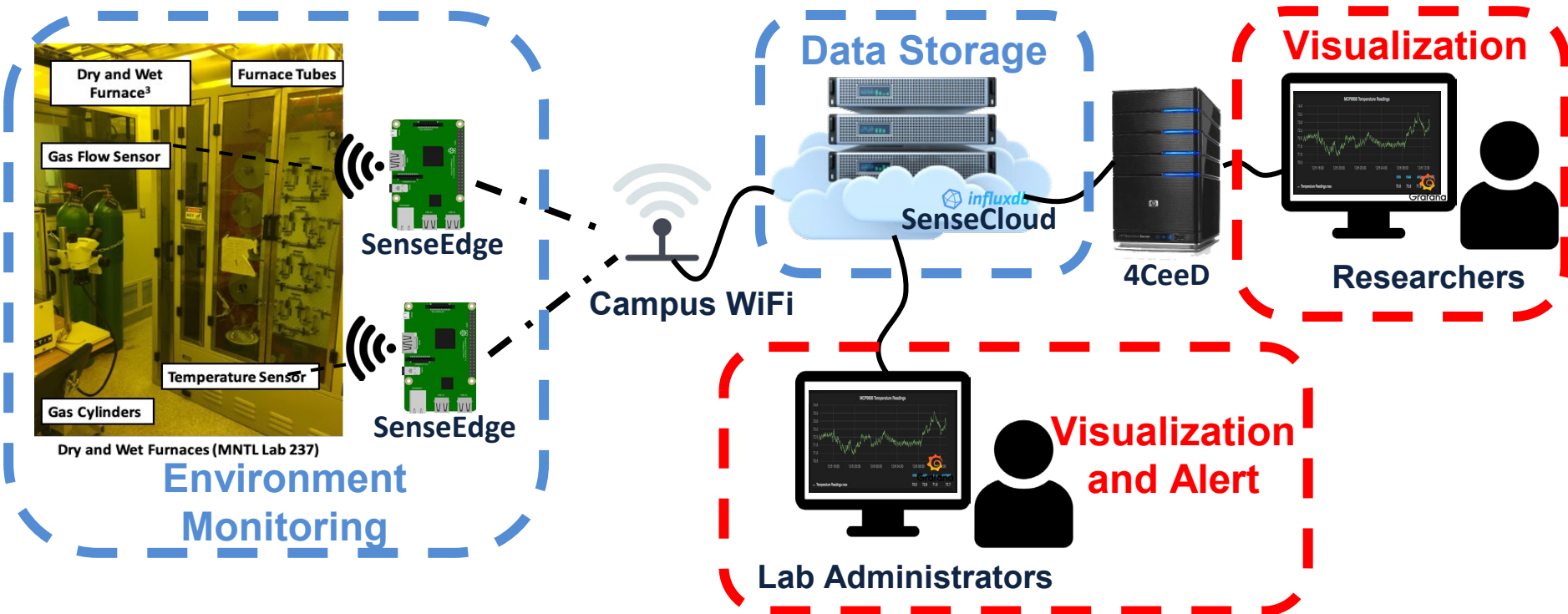
SENSECLOUD Database Storage

- InfluxDB uses InfluxQL, an SQL-like query language to interact with data in the database.

```
SELECT "humidity"  
FROM "temp_humi_measurement"  
WHERE ("sensor" = '19-00000003f4ee')  
AND time >= now() - 15m
```

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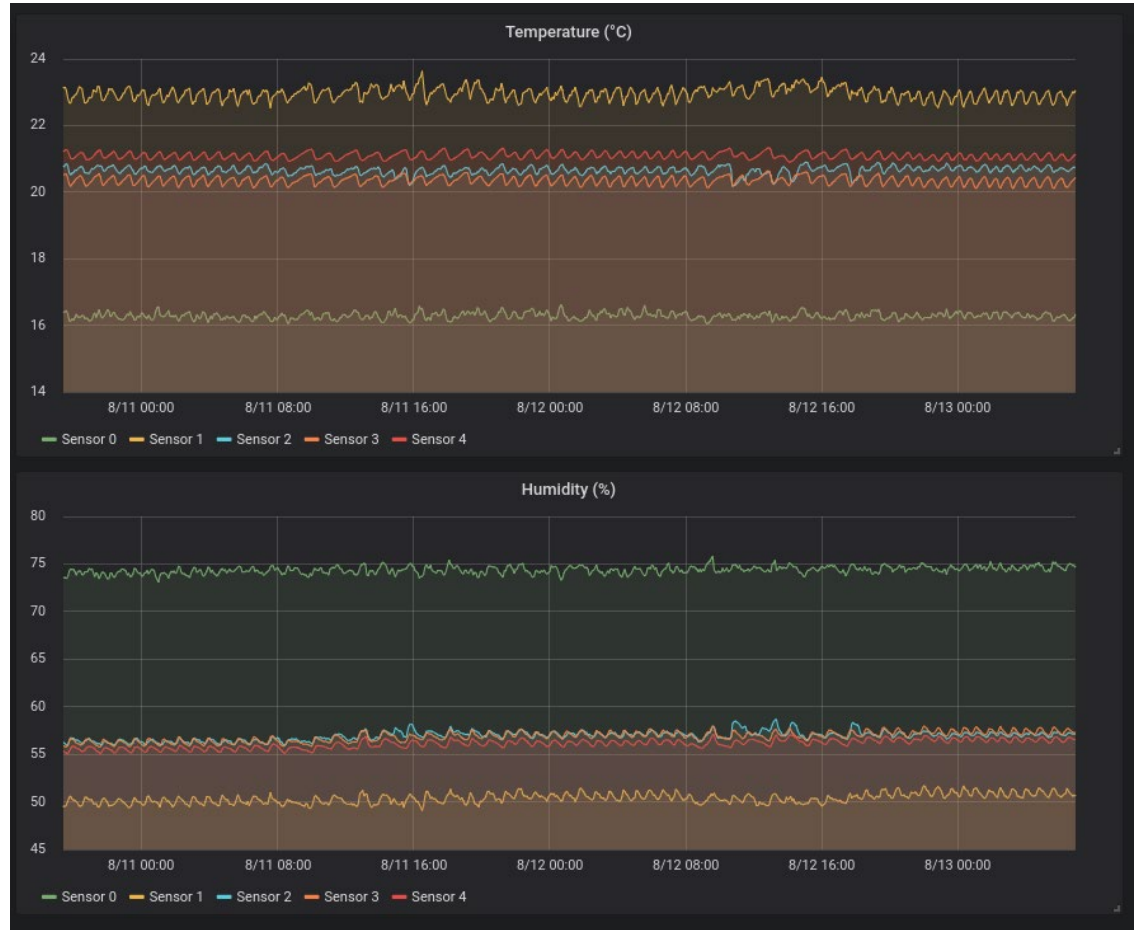
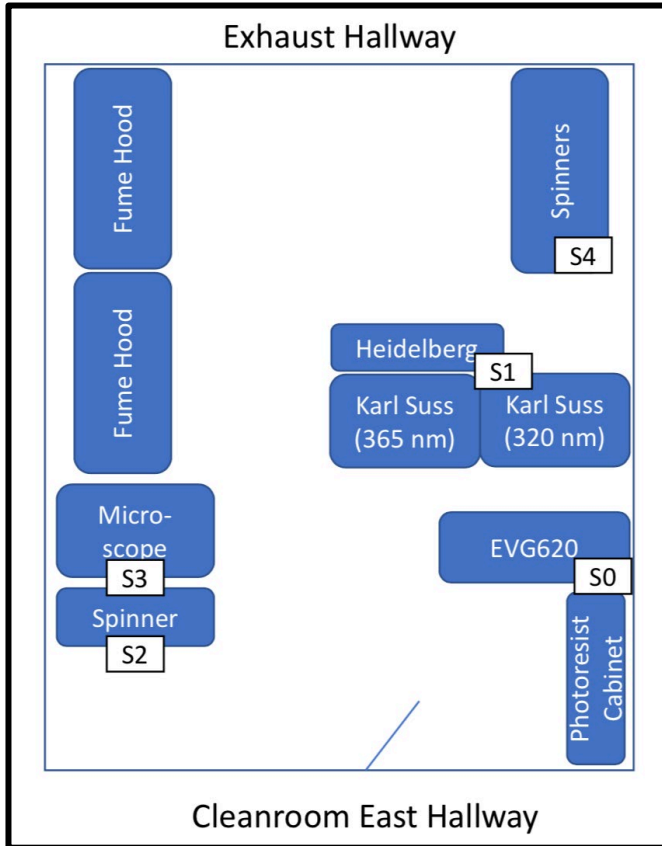


SENSELET Visualization & Alert



- Grafana: An open-source visualization tool
- Customize dashboards
- Monitor real-time or historical time series data, do simple analytics
- Can send alerts

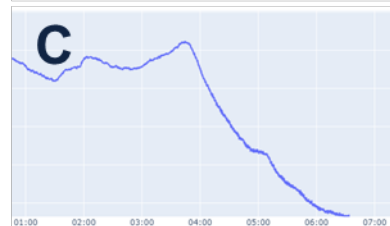
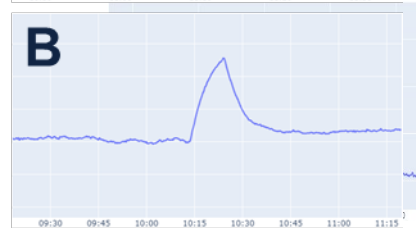
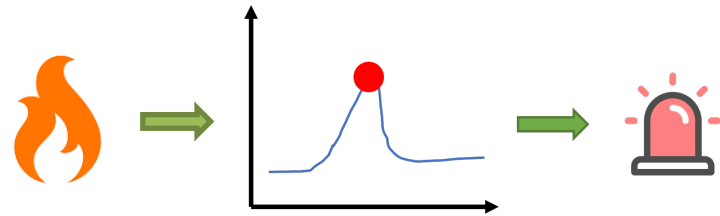
SENSELET Visualization & Alert



SENSELET Visualization & Alert

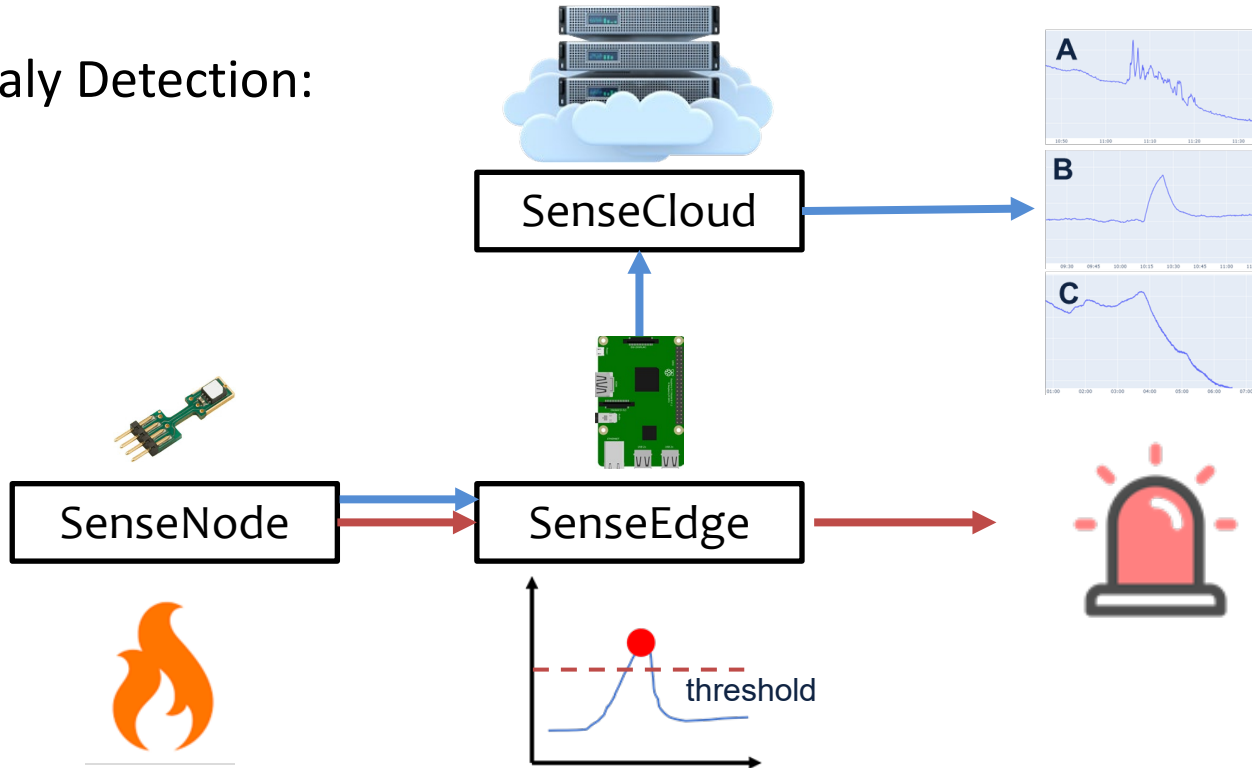
Types of anomaly:

- Critical Anomalies:
 - Fire; Water leakage
- Non-critical Anomalies:
 - Interesting patterns

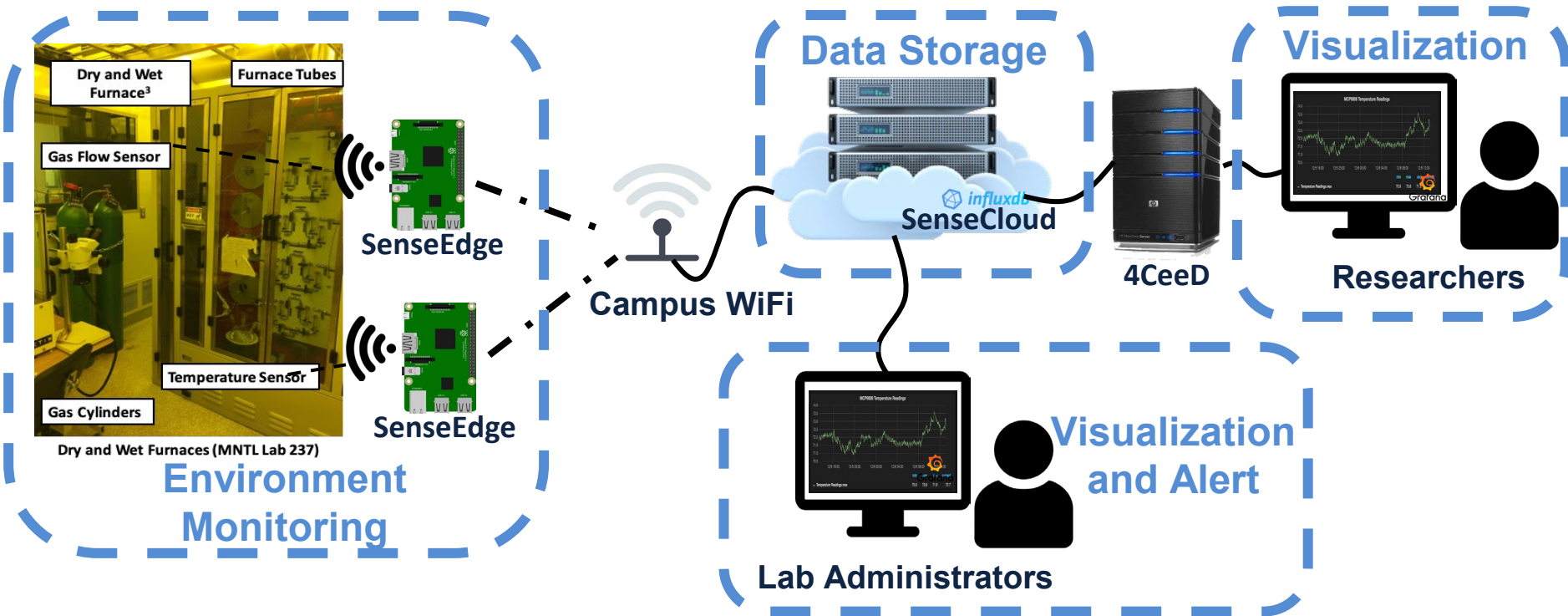


SENSELET Visualization & Alert

Anomaly Detection:



Summary



Outline

- Background & Motivation
- SENSELET Architecture
- Components of SENSELET
- Live Demo of SENSELET Visualization

- Introduction to Grafana web interface
- How to visualize sensory data of specific time range
- How to set an alert (If we have time)
- Try it yourself!