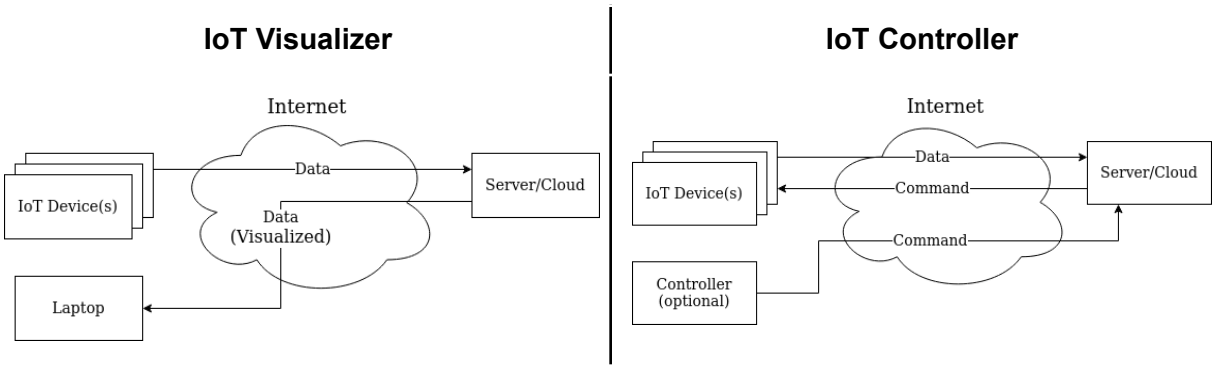
Final Project: End-to-End IoT System

Introduction

Over the course of EE-250 we've taught various concepts such as signal processing & basics of ML, TCP/IP, socket programming, and MQTT. In order to solidify your understanding of these topics, we use labs to apply these concepts into some concrete artifact. To this end, it is fitting that the final project incorporates a little of everything. This will also be beneficial as a review of the concepts that we have taught and serve as a lesson on how they connect together.

Objective

The objective of this lab is for you to build your own end-to-end IoT system using the tools and concepts we've taught you over the course of this project. We define an end-to-end IoT system to be one or more physical nodes connected to a central node for data collection/processing, control, and/or visualization (i.e. thus, **at least 2 nodes** must be involved). The nodes may be your laptop, raspberry pi, arduino, or even your smartphone. You're welcome to get resourceful and play around with any hardware you may have laying around at home or purchase other components as desired, though that is not necessary to achieve a full score.



Above we illustrate two different implementations of an end-to-end IoT system.

The first is a visualizer where the connected IoT device(s) send data to a server. From there a user on a laptop can access the data and visualize it on their laptop.

The second type is an IoT controller where data is transmitted from the IoT device(s) to a server and the server may or may not respond back with a command. Optionally, a controller may connect to it and command it to do something.

It's worthwhile to note that your nodes can vary significantly from others depending on your application. It could be a remote desktop running a python TCP server, or it could be an Azure VM instance running Influxdb. It is up to you to decide what technologies are most applicable to your IoT system. Part of the grading rubric will be on originality so get creative and see what you come up with!

Requirements:

You may work in teams of two

1. Two or more physical nodes (such as laptop, rpi and cloud)
2. Data collection
    - Can be from actual sensor or from a 'virtual' sensor
    - A 'virtual' sensor could generate simulated data or use a public data API
3. Signal or data processing (in real time) or some simple ML
    - Conversion to the frequency domain, or some filtering or event detection in the time domain.
    - Some simple queries from the user interface may be answered through ML techniques.
4. Node-to-node communication
    - Data must be transferred between the nodes (meaning you can't do everything on a virtual machine)
    - You can use any cloud components, such as AWS IoT, EC2 etc.
5. Visualization and/or control (simple web front end) element

If you have any concern about your choices meeting these requirements, just run it by one of the TAs or CPs.

Helpful Resources (For reference only)

To help you get started with this project, we've compiled a list of some resources that we feel you might find useful:

- Turn your android into an IoT device
- Use python to get sensor data from your laptop
- Connecting your raspberry pi to your home network
- Expose your local device to the internet
- Mosquitto, MQTT broker
- AWS IoT core (communication)
- AWS Lambda (processing, function as a service)
- AWS S3 (storage)
- AWS EC2 (general computing)
- Web Scraping for data
- Using RESTful APIs

Hardware Resources

- Amazon.com: HiLetgo ESP-WROOM-32 ESP32 ESP-32S Development Board 2.4GHz Dual-Mode WiFi + Bluetooth Dual Cores Microcontroller Processor Integrated with Antenna RF AMP Filter AP STA for Arduino IDE : Electronics
- Wio Terminal: ATSAMD51 Core with Realtek RTL8720DN BLE 5.0 & Wi-Fi 2.4G/5G Dev Board - Seeed Studio
- Amazon.com: MELIFE 0.96" OLED ESP-WROOM-32 for ESP32 Display 2.4GHz WiFi Bluetooth Dual Mode Development Board Display for Arduino Wemos AP STA: Computers & Accessories

Telegraf InfluxDB Grafana vs Logstash Elasticsearch Kibana

- Elastic Stack: Elasticsearch, Kibana, Beats & Logstash | Elastic
- TIG Stack — Powerful monitoring tool with detail Dashboard | by Lê Cao Hoàng | Medium
- ELK Stack and Configuring Logging, Explained | by Deepak Poojari | make it heady | Medium

Python to InfluxDB

- influxdata/influxdb-python: Python client for InfluxDB (github.com)

Visualization Resources

- Freeboard/freeboard: A damn-sexy, open source real-time dashboard builder for IOT and other web mashups. A free open-source alternative to Geckoboard. (github.com)

- grafana/grafana: The open and composable observability and data visualization platform. Visualize metrics, logs, and traces from multiple sources like Prometheus, Loki, Elasticsearch, InfluxDB, Postgres and many more. (github.com)

Additionally, to get you in the right mindset for this project here are some examples for this project. Please do not copy from these examples, they should only serve as a reference. Remember, we will be counting you on originality!

- An IoT sensor system where audio data is recorded, processed using FFT, and then sent to server to be visualized
- An IoT system where a RPi is controlled to set the lighting in the house based on time of day and ambient light
- An IoT system where keystrokes on a laptop are logged to a server and then a graph displaying word frequency is tweeted out

Final Deliverables

Please ensure you clearly address the items in the Grading Rubric presented in the following section.

Here is what required:

- Source code(s) -
  - May be written in multiple programming languages as needed
  - You don't have to write all the code from scratch - it's ok to use existing libraries wherever helpful
  - We highly encourage you to **write as much of the code yourself as possible as an important part of your own learning experience**, however, it is acceptable to use an LLM / Coding-oriented AI tool to assist you.
  - If you are using ChatGPT or other LLMs to help with code development, **clearly** acknowledge that in your code (via comments) as well as in your writeup. It would be ideal to **include a link to your LLM session or at least have the prompts you used included in your code repo**. You will not be penalized for open and transparent use of LLMs / AI tools.
- README.txt
  - Team member names
  - Instructions on how to compile/execute program(s)
  - List of any external libraries that were used
- Writeup PDF -
  - 2 pages (at most)
  - Also include team member names
  - A short description of your project and its functionality
  - A block diagram that shows interaction between components

    - Briefly describes components, protocols used, key processing techniques, etc. along with important implementation/design choices.
    - Reflection on limitations and their causes as well as lessons learned.
- Presentation video
    - A youtube or other online link to a publicly available video with narrative audio, not to exceed 4 minutes, that walks through your final project in action.
    - Note that your video may be listed on a course webpage to share your work with other students this semester and may also be shared with students in a future semester - please make sure it is as professional as possible.
- Teamwork Assessment Survey
    - You will be each asked to complete a teamwork assessment survey (please see appendix below for the questions you will be asked in this survey). The link to this survey will be posted on Piazza.

Grading Rubric (30 points total)

Points	**Description**
Demo	(must be done to the CP's/TA's in person; you may have to answer questions)
2	Clearly identifies each node in the network.
2	Explains how data is collected and sent to the server node. Mentions specific protocols, sensors, or data sources that are used.
2	Describes how the data is processed (either on server or client). Mentions a specific signal/data processing technique.
4	Demonstrates correct operation of project features (i.e. assess the level to which the project works correctly and achieves the intended behavior)
Code	
3	Code correctness (no syntax errors/code compiles, sufficiently bug-free for the assignment, etc.)
2	README.txt file contains team member names, instructions to compile/execute your code, and list of any external libraries used as well as link to LLM/AI tool session or pointer to a file in the repo containing the prompts you used.
Writeup	
2	Clear description of what your IoT system is trying to achieve
1	Block diagram clearly shows relevant components and interactions

2	Description of components, platforms, protocols used, and processing/visualization techniques; open and transparent acknowledgement of use of any AI tools.
2	Reflection, discussion of limitations that demonstrates insights to their cause and possible remediation, lessons learned
3	X-Factor: Project originality and/or difficulty
Others	
4	Presentation video: clarity, creativity, professional communication, overall impact.
1	Completion of Teamwork Assessment Survey

Appendix: some questions asked in the teamwork assessment survey

Who was your partner/teammate (type 'individual' if you worked alone and then you can leave the remaining questions blank)? *

Your answer

How did you distribute work (check all that apply)?

- [ ] Each member worked on separate tasks based on the member's strengths and then integrated the parts
- [ ] Little distribution; worked together (pair work) a majority of the time
- [ ] Little distribution; did most of the work yourself.
- [ ] Other:

How would you rate your own leadership in the project?

	1	2	3	4	5	
Developing leadership	○	○	○	○	○	Very strong leadership

How did you demonstrate leadership on your team?

- [ ] Coordinated what tasks/work needed to be done
- [ ] Coordinated scheduling of tasks/work and meetings
- [ ] Took leadership in researching technical aspects
- [ ] Other:

What aspects did you mainly work on (check all that apply)?

- [ ] wiring and hardware related work
- [ ] embedded software and networking (interfacing to sensors/actuators)
- [ ] backend (web interface, data storage, visualization)
- [ ] report/writeup

To what extent do you believe your team's project met the objectives you set out?

	1	2	3	4	5	
Failed to meet objectives	◯	◯	◯	◯	◯	Fully met objectives

To what extent did your team demonstrate respect and create an inclusive environment to work?

	1	2	3	4	5	
Environment was disrespectful and non-collaborative	◯	◯	◯	◯	◯	Environment was respectful/inclusive and collaborative

How well did you manage your time and plan out the work that needed to be done?

	1	2	3	4	5	
Little planning ahead. Left a majority of work until last minute.	◯	◯	◯	◯	◯	Significant planning of the tasks to be done

In your self-assessment, what percent of the work did **you** do on your team's project?

	1	2	3	4	5	6	7	8	9	10	
10%	○	○	○	○	○	○	○	○	○	○	100%

In your self-assessment, what percent of the work did **your teammate** do on your team's project?

	1	2	3	4	5	6	7	8	9	10	
10%	○	○	○	○	○	○	○	○	○	○	100%

How would you improve your teamwork if you had to do it over again?

Your answer