COMP6733 Research Project, Term 2, 2024

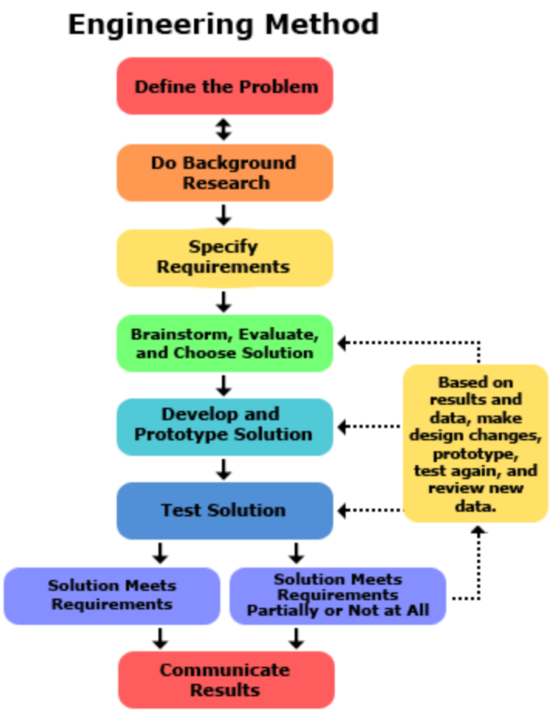
Version 1.0, 29 May 2024.

Team formation and preferences due: 17:00, Friday 14 June 2024 (Week 3)
Class Presentation (1): lecture hours, 24, 26 June 2024 (Week 5)
Preliminary Report Due: 17:00, Friday, 28 June 2024 (Week 5)
Class Presentation (2): lecture hours, 15, 17 July 2024 (Week 8)
Intermediate Report Due: 17:00, Friday, 19 July 2024 (Week 8)
Report and Code Due: 17:00, Sunday 4 August 2024 (Week 10).
Demo date: 5 August 2024 (Week 11).

NOTE: Updates to this assignment, including any corrections and clarifications, will be posted on the course website. Make sure that you check the website regularly for updates.

1. Overview

The project component of COMP6733 aims to give you an opportunity to solve a real-life problem in IoT. The format of the project aims to emulate the classical engineering design process which is depicted in the below figure. This project will therefore test your ability to solve problems, propose solutions and analyse their suitability as well as your skills in implementing a solution, which includes planning, testing and programming. The scope of the project is fairly open to allow you to explore the subject area.



Section 2 of this document describes a number of projects that you may choose to work on, however you are free to propose your own project. You are expected to do the project in a team of four students and bid for these projects by expressing your preferences. The Lecturer-in-Charge (LiC) will then allocate the projects according to your expressed preferences by Week 3. More details on the bidding process are described in Section 3.2.

The project consists of two stages. In the first stage, you should consider different options that you can use to solve the problem. You do this by analyzing the problem and perform research on possible solutions. Based on your research and analysis, you are required to propose how you plan to tackle this problem. You are required to submit a preliminary report and give a project presentation (in Week 5) to explain your proposed solution. Your report should include:

1. A discussion on how you plan to tackle the problem with your justification.

2. The implementation that you plan to do with timeline.

3. The goals of your demonstration. You will need to specify goals on what you will be demonstrating in the final demonstration.

The second stage of the project will be devoted to working towards the goal that you have set for yourselves.

The LiC will go through your preliminary report and provide feedback on the work that you plan to do. In all cases, you should be aware the University expects students taking a 6 UoC course to devote about 14 hours per week to each course. Given the above expectations on the amount of time you will be spending on the project and to ensure that all projects meet a common standard, the LiC may choose to add, remove or change tasks from your proposed plan.

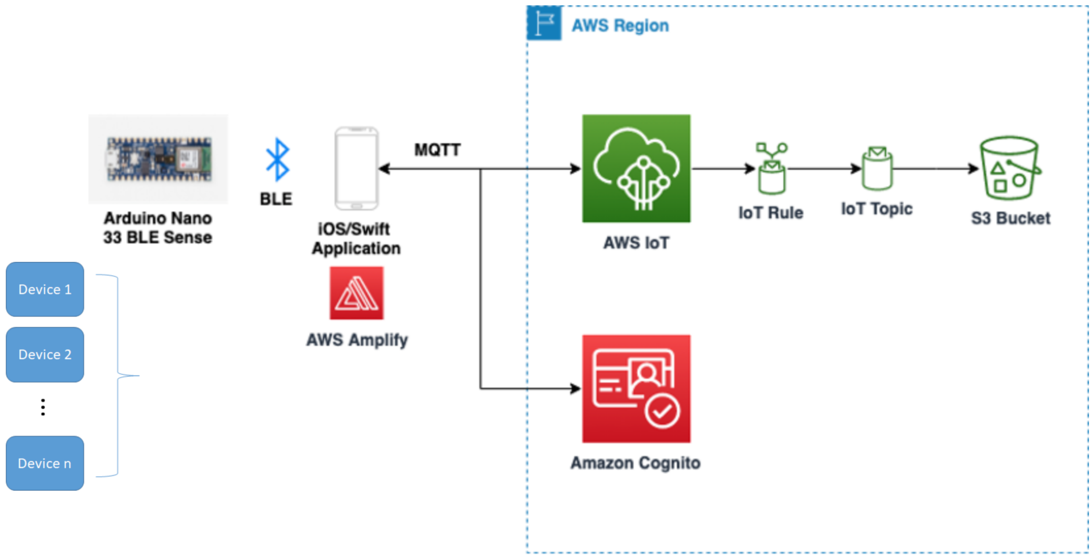
2. Project description

2.1 Project 1: *Android/iOS smartphone AWS IoT (MQTT)/Bluetooth Low Energy (BLE) gateway*

In the labs, you have used a notebook computer as a (MQTT) gateway (e.g., Bleak) to bridge the communications between BLE-based IoT devices and the AWS IoT cloud service, and use a smartphone app (e.g., nRF Connect) to communicate with the IoT devices via BLE.

In this project, you will design and implement an Android OR an iOS smartphone gateway to bridge the communications between BLE-based IoT devices and the AWS IoT cloud service via MQTT messaging by referring the design and functionality of Bleak and nRF Connect, and investigate its performance such as throughput, latency, resource (energy) consumption and cost. You may also consider how to choose the WiFi or cellular interfaces in the smartphone phones for Internet connection.

Please see below of one possible solution architecture and steps.



1. Configure Bluetooth connection to the BLE device:
   - On Android, use such BluetoothAdapter and BluetoothGatt classes to scan, connect, and communicate with BLE devices. On iOS, use the CoreBluetooth framework (or refer to tutorial 4). Establish a BLE connection and handle data exchange with the BLE devices.

2. Exchange data from the BLE devices:
    - Implement the necessary code to exchange data from the connected BLE devices. This could involve reading, writing, synchronisation, etc.
3. Install and configure MQTT client on the smartphone:
    - Install an MQTT client library or application on your smartphone. For Android, you may use Eclipse Paho. For iOS, you may use libraries such as MQTT-Client-Framework or Moscapsule.
    - Set up the MQTT client with the appropriate connection parameters (e.g., AWS IoT endpoint, client ID, certificates/keys).
4. Exchange data with the AWS IoT core via MQTT

5. Develop smartphone GUI for a user to input BLE Generic ATTribute profile (GATT) for their BLE services (please refer to the design of nRF Connect in Tutorial 4) and AWS IoT CORE connection parameters such as AWS IoT endpoint, client ID, certificates/keys.

We have experience with Eclipse Paho MQTT in Android Studio and there are also multiple ways to design the project such as the AWS Amplify in the figure above.

[1] Tutorials 4 and 5.

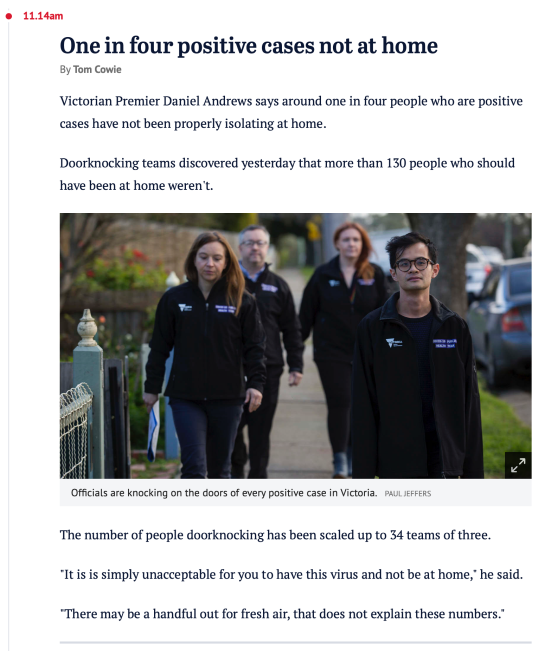
[2] https://docs.aws.amazon.com/iot/latest/developerguide/iot-sdks.html#iot-mobile-sdks

[3] https://developer.android.com/guide/topics/connectivity/bluetooth/ble-overview

[4] https://developer.apple.com/bluetooth/

2.2 Project 2: *virtual fencing technology for home quarantine*

Effective quarantine of possible COVID-19 cases (e.g., traveller from overseas, close contact of a previous case) is a very important step to prevent the spread. In Australia, home quarantine is one important component. However, up to 25% of positive cases violate the home quarantine policy (see Figure 1). Current method of home visiting is labour intensive and has limited temporal coverage. In this project you will implement an indoor WiFi/bluetooth localisation method based on RSSI fingerprinting with a smartphone and smart wristband (i.e., Arduino Nano) and detect the wearer's location in real time. If a wearer is outside her/his home (a virtual fence), a message will be sent to the authority (e.g., policy), who will conduct home visiting and interview. You will use Wi-Fi/Bluetooth fingerprinting that creates a radio map of a given area based on the RSSI data from several access points and generates a probability distribution of RSSI values for a given (x,y) location. Live RSSI values are then compared to the fingerprint to find the closest match and generate a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One in four positive cases not at home

By Tom Cowie

Victorian Premier Daniel Andrews says around one in four people who are positive cases have not been properly isolating at home.

Doorknocking teams discovered yesterday that more than 130 people who should have been at home weren't.

Officials are knocking on the doors of every positive case in Victoria. PAUL JEFFERS

The number of people doorknocking has been scaled up to 34 teams of three.

"It is is simply unacceptable for you to have this virus and not be at home," he said.

"There may be a handful out for fresh air, that does not explain these numbers."

Figure 1: The need of effective quarantine at home methods

predicted (x,y) location. You will evaluate such systems with real smart deployment in real environment (e.g., your residence).

The reference paper, *RADAR: An In-Building RF-based User Location and Tracking System* proposes one particular algorithm but you are free to implement other algorithms.

2.3 Project 3: *Gait-based authentication in wearable Devices*

A person may ask another person to wear the smart wristband (Arduino Nano 33 BLE Sense) developed in Project 2.2 to break the quarantine order. In this project, you will develop and implement a biometric (gait) authentication method to ensure the identity of the wearer by making use of the IMU/motion sensor available in the Arduino Nano 33 BLE Sense. Specifically, your system will observe the walking pattern of a person (IMU measurements) and try to match it with the one stored in the database to decide the identification of the wearers.

Papers:

[1] Unobtrusive Gait Verification for Mobile Phones

[2] Gait-watch: A context-aware authentication system for smart watch based on gait recognition

2.4 Project 4: *Heartbeat-based authentication in wearable Devices*

The gait-based authentication system developed in Project 2.3 requires a person to walk to be identified, and it won't operate if a person is static (e.g., sleeping at home). In this project, you will use the sensor signals (e.g., IMU, pressure) recorded in Arduino Nano 33 BLE Sense to measure heartbeats of a person and to identify her/him.

Paper: *Unlock with Your Heart: Heartbeat-based Authentication on Commercial Mobile Phones*

2.5 Project 5: *IoT for fever surveillance*

Fever surveillance is an important method to detect possible infectious cases before the COVID-19 spreads in crowdy places (e.g., shopping malls, buses, trains, cinemas, schools). Current practice involves a manual operated thermometer to measure the temperature of individuals, which is inefficient and cost ineffective. In this project, you will design a system to monitor temperature of people with a thermal camera and an RGB camera in Roseberry Pi. In this device, the RGB camera is used to detect faces, while the thermal camera will provide the temperature of the faces. Your system should also alarm the authority if people with fever are detected.

Reference paper: *A Thermal Camera based Continuous Body Temperature Measurement System*

Thermal camera: https://www.flir.com.au/products/lepton/

2.6 Project 6: *Hand washing quality monitoring with Arduino Nano 33 BLE Sense*

Hand washing is one of the best ways to stop the COVID-19 virus spread, if done correctly (see Figure 2) and properly. Unfortunately, not all of us wash our hands frequently. Out of those that do, it is estimated only 5% of us know how to do so properly.

In this project, you will build a wearable system (i.e., wristband based on Arduino Nano 33 BLE Sense), which can detect 1) how many times per day a person washes her hands, 2) the quality of these hand wash events. You will also develop an associated mobile app that can report these statistics to the user in real time. Furthermore, the app can coach a user to wash her hand properly via a step-by-step guild and corrections.

Reference paper: *Finger-writing with Smartwatch: A Case for Finger and Hand Gesture Recognition using Smartwatch*

Figure 2: How to wash hands?

2.7 Project 7: *Monitoring Building Occupancy*

The health authority suggests keeping a minimum distance of 1.5m between 2 people to stop COVID-19 spread. Therefore, every room has a maximum number of occupancy limit depending on its size. In this project you will implement a system for monitoring building occupancy. Your system will use WiFi and/or Bluetooth signals (transmitted by user's devices such as smartphones) as indicators of the amount of people present. Almost everyone carries a smartphone today, and these devices will periodically attempt to connect to WiFi and/or Bluetooth networks (often successfully e.g. when you are on campus your devices connect to the Uniwide network) in the surrounding by broadcasting beacon frames. Your system will consist of a network of IoT nodes that sniff and record the WiFi and/or Bluetooth messages exchanged between these devices and the WiFi access and/or Bluetooth beacon points. Your system should fuse data from multiple devices to arrive an estimate of the occupancy levels in a given area. You may also consider using triangulation to uniquely identify and locate each device within the building.

Reference paper: *Estimating Crowd Densities and Pedestrian Flows Using Wi-Fi and Bluetooth*.

2.9 Project 8: *Physical distancing with BLE*

Based on the founding of Lab 4, you will design a system to measure the distance between 2 BLE devices (e.g., one smartphone and one Arduino Nano 33 BLE Sense or two Arduino Nano 33 BLE Sense). If the distance is less than 2 meters, an alarm (buzzer) should be issued to the wearers and this close contact should be recorded. The key challenge of this project is accurate distance measuring with BLE radio in real life (different people will wear the sensortag differently) and the energy consumption of the system (an energy efficient protocol design).

Reference: please refer to Lab 3 for more technical details on radio ranging.

2.9 Project **9:** ***Hand washing quality monitoring with mmWave Radar***

Hand washing is one of the best ways to stop the COVID-19 virus spread, if done correctly (see Figure) and properly. Unfortunately, not all of us wash our hands frequently. Out of those that do, it is estimated only 5% of us know how to do so properly.

In this project, you will build a privacy-preserving device free system (i.e., radio sensing with TI mmWave radar), which can detect 1) how many times per day a person washes her hands, 2) the quality of these hand wash events. You will also develop an associated mobile app that can report these statistics to the user in real time. Furthermore, the app can coach a user to wash her hand properly via a step-by-step guild and corrections.

Reference paper: ***RFWash: a weakly supervised tracking of hand hygiene technique***

2.10 Project 10: *Accurate body motion monitoring system.*

You will build an accurate body motion monitoring system using a network of Arduino Nano 33 BLE Sense worn in different parts of body (wrist, arm, leg, waist etc.). The system also comes with a mobile app that can show the body motion via an avatar in real time. The potential applications include different sports coaching and activity detection.

See Zepp Tennis (http://gadgetsandwearables.com/2015/04/04/zepp-tennis-swing-analyser/) and golf (http://www.zepp.com/en-us/golf/smart-coach/) swing analyzer for one example.

2.11 Project 11: *Bringing IoT to Sports Analytics*

You will explore the possibility of bringing IoT to sports analytics, particularly to the game of Cricket or any other ball games. You will develop solutions to track a ball's 3D trajectory and spin with inexpensive sensors (e.g., IMU, depth sensor such as Intel RealSense and cameras such as iPhone 12 Pro) by addressing the challenges of localization and motion tracking accuracy.

Your system may fuse disparate sources of partial information – wireless, inertial sensing, and motion models – into a non-linear error minimization framework, which achieves centimeter accuracy compared to ground truth.

Reference papers: [1] *Condor: Mobile Swing Tracking via Sensor Fusion using Conditional Generative Adversarial Network.*
[2] *SwingNet: A Ubiquitous Fine-Grained Swing Tracking Framework via Neural Architecture Search (NAS) and Adversarial Learning*

2.12 Project 12: Tooth brushing Monitoring using Wristwatch

Daily tooth brushing is essential for maintaining oral health. However, there is very limited technology to monitor the effectiveness of tooth brushing at home. In this project, you will build a system to monitor the brushing quality on all 16-tooth surfaces using a manual toothbrush and an off-the-shelf wristwatch. You may modify the toothbrush by attaching small magnets to the handle, so that its orientation and motion can be captured by the magnetic sensor in the wristwatch.

Your system will recognize the tooth brushing gestures based on inertial sensing data from the wristwatch. As the acoustic signal collected from the watch is correlated with the motion of tooth brushing stroke, you may use an acoustic sensing algorithm to assist in recognition. User-specific tooth brushing order may also be utilized to improve the surface recognition.

Reference paper: *Toothbrushing Monitoring using Wristwatch*

2.13 Project 13: *Fire Monitoring with WiFi*

In the scenarios such as Data Centres, WiFi traffic is omnipresent and temperature monitoring is important. WiFi Channel State Information (CSI) may be used for temperature sensing since the increased kinetic energy of ambient gas particles will affect the wireless link. In this project, you will build a low-cost temperature sensor based on inexpensive commercial off the shelf WiFi platform such as Raspberry Pi. Your system will return an ambient temperature reading based on the WiFi CSI.

Reference paper: *Thermal Profiling by WiFi Sensing in IoT Networks*

2.14 Project 14: *Real-time body mesh with mmWave radar.*

You will build a real-time body motion monitoring system using mmWave radar. The system also comes with a mobile app that can show the body motion via an avatar in real time. The potential applications include different sports coaching and activity detection.

Reference paper: *mmMesh: Towards 3D Real-Time Dynamic Human Mesh Construction Using Millimeter-Wave*

2.15 Project 15: *Leaf Moisture Monitoring with mmWave radar*

Accurately monitoring plant health is key for high crop yield. New sensors are required to remotely measure plant physiology. Current techniques require attaching sensors onto individual leaves which limits large-scale deployment. Radar is a new sensing technique to determine plant health by examining the reflected signal to extract water content in the plant. You will build a system to track the growth of plant using a camera with environmental sensors (temp, humidity, light etc) along with a new radar sensor.

Reference papers: *Leafeon: Towards accurate, robust and low-cost leaf water content sensing using mmWave radar*

2.16 Project x: *Proposed your own IoT project*

2.17 Scope of the project

1. In your proposal, you will need to state how you want to demonstrate your results. For example, you want to demonstrate that the physical distancing algorithm that you have implemented is working. You may program the nodes so that they will light the (red) LED up if the distance between two nodes is less than 1.5m. You may change the radio environment a few times in the demonstration and show that it works for different environments (e.g., outdoor and indoor).

2. If you require additional hardware, please discuss your requirements ASAP with the LiC. We can purchase some additional sensors provided that they are not very expensive.

3. The preliminary report should include a discussion on your research, how you plan to tackle the problem, work plan and milestones for Week 8 and final demonstration.

4. There are a number of good conferences and journals on the IoT.

    1) Both the digital libraries of ACM and IEEE will be excellent starting point of your research. Their URLs are respectively:

        a. http://portal.acm.org/portal.cfm

        b. http://ieeexplore.ieee.org/Xplore/dynhome.jsp?tag=1

2) ACM has serval IoT, mobile and ubiquitous systems conferences: IPSN (part of CPS-IoT Week), SenSys, MobiSys, MobiCom and Ubicomp.

3. General Requirements

3.1 Choice of project

You can do one of the proposed projects or propose your own project. If you want to propose your own project, please make an appointment to speak with the LiC with your proposal in Week 2 or 3.

3.2 Formation of project teams and bidding process

You are expected to do this project in a group of students. You are free to form your own team. Please enter your team membership using the WebCMS function available at the course website.

Please email cs6733@cse.unsw.edu.au your team membership or list it in webcms (https://webcms3.cse.unsw.edu.au/COMP6733/24T2/groups/, please make your group visible) by **17:00, Friday 14 June 2024**. In your email, please also include your preferences for each of the proposed projects. You are asked to express your preference by giving each project a score of 1, 2 and 3 where '1' means a project that you most want to do and '3' means a project that you least want to do. Please express your preference for all the projects. You can have any combination of 1 to 3, e.g. you can give all projects a '3' or you can give 2 projects a '3' and a project a '1'.

The LiC will attempt to allocate the projects according to your preference. The aim is to attempt to balance the number of groups doing each project.

If we do not receive your team membership by this time, we will do a random team formation for you.

3.3 Assessment

Note the following assessment and submission requirements (***one report from each group please***):

1. You should submit a preliminary report (with your proposed solution, project plans, milestones for both Week 8 and final demonstration) by **17:00 Friday 28 June 2024** via the *give* system. The report will be assessed based on the quality of the research that you have done, your explanation on why your proposed solution best fit the problem and the quality of your work plan. The give command to use is: "give cs6733 projectPlan". Your project report must be in PDF format. Please tar your report and call it "project0.tar". This is the only filename accepted by the system.

2. In Week 5, each team will give a presentation on their proposed solution and their proposed work plan to the whole class. Each team member should do a part of the presentation. LiC and fellow students will assess the presentations according to predefined marking criteria.

3. In Week 8, each team will give a presentation on their project progress and demonstrate its project milestones to the whole class. The aim is to ensure that you have made progress on the project. Each team member should do a part of the presentation. LiC and fellow students will assess the presentations according to predefined marking criteria. In Week 10, each team will

need to negotiate with the LiC on a time to demonstrate. The milestone report is to be submitted by **17:00 Friday 19 July 2024** via *give*. The give command to use is: “give cs6733 projectMilestone”. Please tar your final submission and call it “project1.tar”. This is the only filename accepted by the system.

4. The project report and code are to be submitted by **17:00 Sunday 4 August 2024** via *give*. The give command to use is: “give cs6733 projectFinalReport”. Your project report must be in pdf format. Please tar your final submission and call it “project2.tar”. This is the only filename accepted by the system.

5. A final demonstration and interview will be held on **5 August 2024**. Each team is given approximately 30 minutes for the demo, and this will also include a short interview with each student. You will be asked to express preference on the interview day later on.

6. The project in total is worth 60% of your final mark in this course. The breakdown is as follows:

1. Project Plan and preliminary report + Class Presentation in Week 5: 10%
2. Project progress demo + class presentation in Week 8: 10%
3. Project final report: 15%
4. Project final demo: 25%

The deadlines are hard. No extensions will be offered.