COMP6733 Research Project, Session 2, 2018

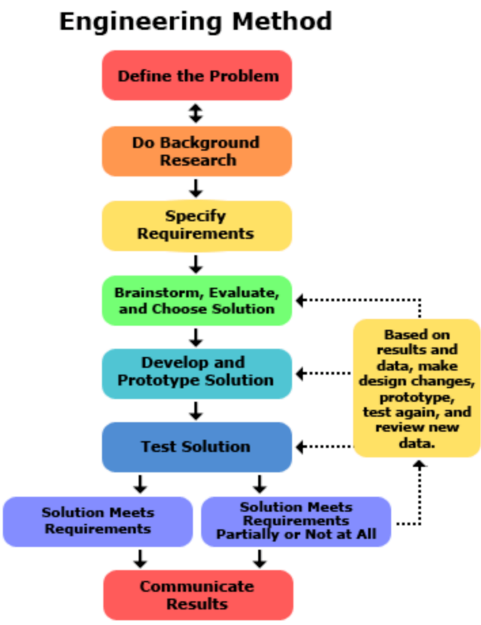
Version 1.0, 1 August, 2018.

Team formation and preferences due: 12 noon, Friday 17 Aug, 2018 (Week 4)
Preliminary Report Due: 11:59pm, Friday, 14 September 2018 (Week 8)
Class Presentation (1): Weeks 7 (5 Sept) and 9 (19 Sept) during lecture hours
Intermediate Report Due: 11:59pm, Friday, 26 October 2018 (Week 13)
Class Presentation (2): Weeks 11 (9 Oct) and 12 (16 Oct) during lecture hours
Report and Code Due: 11:59pm, Tuesday 20 Nov 2018.
Demo dates: 21-22 Nov 2018.

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 adjoining 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 prototype solution, which includes planning, testing and programming. The scope of the project is fairly open to give you a lot of flexibility in exploring the IoT design space.



Section 2 of this document describes a number of projects that you can choose to work on. However, you are free to propose your own project. You are expected to do the project in a team of three students and bid for these projects by expressing your preferences. The Lecturer-in-Charge will then allocate the projects according to your expressed preferences by Week 5. 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 (in Week 8) and give a project presentation (in Weeks 7/9) to explain your proposed solution. Your report should include:

1. A discussion on how you plan to tackle the problem along with proper justifications.

2. The implementation that you plan to do with a detailed 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 12 hours per week to each course. In addition, since the project is meant to take the place of a formal examination, you are expected to allocate time to work on the project during the examination period. 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

Note that, for all the projects, we assume that the topology is multi-hop. This does not mean that you need to create a multi-hop network by placing the motes several meters apart. You are allowed to use topology control (e.g., reduce the transmit power of the nodes) to create a multi-hop topology.

2.1 Project 1: Motion-based Key generation for Wearable Devices

With the rapid development of technology, wearable devices such as smart watches and smartphones have become increasingly popular in our daily life. One fundamental problem is to pair two devices together, for example, pair your smart watch with your smartphone. In the paper entitled *Walkie-Talkie: Motion-Assisted Automatic Key Generation for Secure On-Body Device Communication*, the authors propose a method to generate keys from accelerometer signals for on-body devices.

In this project, you will need to explore the sensor signals (e.g., IMU, pressure) recorded from different devices (i.e., sensorTags), and propose methods to generate secret keys from the signal. The aim of this project is to come out with an orientation-free method to generate keys for different devices worn on different positions such as arm, pocket, and waist.

Demo video: https://www.youtube.com/watch?v=YBFBJrNZy48

2.2 Project 2: 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 and radios embedded in the ball 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 without calibration or training.

Reference paper: *Bringing IoT to Sports Analytics*

2.3 Project 3: Tooth brushing Monitoring using Wrist Watch

Daily tooth brushing is essential for maintaining oral health. However, there is very limited technology to monitor the effectiveness of tooth brushing. 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 (e.g., a person may always start brushing their teeth in the top left region) may also be utilized to improve the surface recognition.

Reference paper: *Toothbrushing Monitoring using Wrist Watch*

2.4 Project 4: Hand washing quality monitoring with SensorTag

It is estimated that washing hands with soap and water could reduce diarrheal disease-associated deaths by up to 50%, and that if everyone routinely washed their hands, a million deaths a year could be prevented. Hand washing is one of the best ways to reduce infections, if done correctly (see adjoining figure). Unfortunately, not all of us wash our hands regularly. 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 sensorTag), 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 hands properly by providing a step-by-step guide and suggest corrections when non-compliance is detected.

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

2.5 Project 5: Ultra low power indoor localisation system for everyday items

You will combine the pressure and/or IMU sensor and iBeacon system to build an ultra-low power indoor localisation system for everyday objects (e.g., your TV remote control) powered by button batteries. The key idea is to trigger the iBeacon localization whenever an object has been moved (to conserve energy consumption). Your system will use the motion sensors (e.g., IMU and pressure sensors of SensorTag) readings to detect motions.

Your system should have a fail-safe procedure that updates the location of the object once per day at the minimum. The performance of your system will be measured by two metrics: localisation accuracy and battery lifetime.

Reference paper: *Using Mobile Phone Barometer for Low-Power Transportation Context Detection*.

2.6 Project 6: WiFi/Bluetooth localisation using RSSI Fingerprinting

You will implement an indoor WiFi/bluetooth localisation method based on RSSI fingerprinting. Wi-Fi fingerprinting 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 predicted (x,y) location.

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.

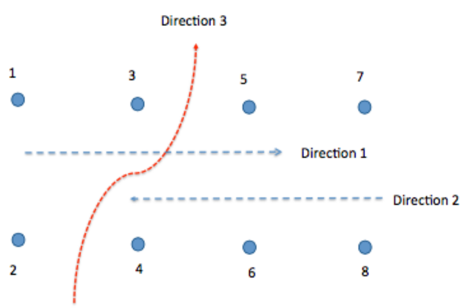
2.7 Project 7: Time synchronisation for activity monitoring

An application of wireless sensor networks is to monitor the activity pattern of people. In the paper entitled *Empath: A Continuous Remote Emotional Health Monitoring System for Depressive Illness*, the authors use a wireless sensor network to monitor the activities of subjects with clinical depression.

It is known that depressed subjects tend to have disrupted sleep patterns. As an illustration, let us consider a depressed subject, who wakes up in the middle of the night and goes for a walk in the house and then returns to his bedroom at some later time. If there is a sensor on his bed to tell whether he is on his bed, and there are sensors deployed in the house to tell his presence in each room (or zone), then by using all these sensors, we will be able to map out the activity of this subject, e.g. the wireless sensor network can inform us that he got off the bed at 2:10am, went to room 1 and stayed there for 10 minutes, went to room 2 and stayed there for an hour, returned to the bedroom and went to sleep again at 3:20am.

We can abstract this activity-monitoring problem by considering a multi-hop sensor network where each sensor node is able to detect an event. For example, leaving the bed is an event detected by a sensor node, the presence in room 1 is an event recorded by another sensor node, etc. However, in order for us to obtain the time sequence in which the events take place, we need to ensure that the clocks of these nodes are synchronised accurately.

The aim of this project is to come out with a protocol to synchronise a multi-hop IoT network and to be able to correctly order and time the events detected by the network. You will use the built-in accelerometers on the sensor device to determine how people are moving in an area.



Consider the adjoining figure where 8 sensor nodes, labeled 1–8. If a person is moving in direction 1, then it is expected that sensors 1 and 2 will detect a change of acceleration before sensors

3 and 4. Therefore, if a change in acceleration is detected by sensors 1 and 2, followed by 3 and 4, followed and 5 and 6, and finally 7 and 8, it may be concluded that the person has moved in direction 1.

Similarly, if a person has moved in direction 2 in the Figure, it will give rise to a different sequence of patterns. In fact, each path through the network of sensors will create a particular sequence of events. In this project, your goal will be to identify the different paths by using the events detected by the accelerometers. Time synchronisation is important because you need to find out the order of the events.

In order to test whether your synchronisation is working correctly, you will need to present different event sequences to the wireless sensor network and show that you are able to detect them. We are also interested to see how well your synchronisation protocol can deal with events happening at (nearly) the same time. We may do this by asking you to walk through the network at different paces. Note that casual walking may not be able to create a strong enough signal at the sensor nodes. If this is the case, you may need to stomp your feet.

2.8 Project 8: A robust step counter

It is well-known that a healthy lifestyle can reduce the risk of many diseases and thus save healthcare costs. Therefore, insurance companies have started to offer premium discounts to customers who adopt a healthy lifestyle as can be observed by wearable devices. For example, it is recommended that one shall walk more than 10,000 steps and exercise more than 30 minutes per day, as well as stand for 1 minute per hour. While these statistics are not difficult to obtain, a dishonest user may attempt to cheat the system by launching different attacks (e.g., data replay attacks, data modification attacks, Sybil attacks etc.). In this project, you will build a roust step counter system with sensorTag that can counter these attacks.

Hint: Gait is a biometric that can be used to identify a person

Reference paper: *Unobtrusive Gait Verification for Mobile Phones*

2.9 Project 9: Surveillance Tracking System

In this project, you will implement a surveillance system using IoT. The existence of people will be detected using passive infrared (PIR) sensors. These additional sensors can be purchased on request. Please talk to the LICs about your requirements.

One such system has been presented in the reference paper, *Surveillance Tracking System Using Passive Infrared Motion Sensors in Wireless Sensor Networks*. You may find other such examples on the Internet. You will have to demonstrate a fully functional implementation of your proposed system.

2.10 Project 10: Monitoring Building Occupancy

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 number 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*.

2.11 Project 11: Urban noise monitoring

In this project you will implement a system for monitoring urban noise pollution. Your system will use microphones in the smartphones to collect sound measurements. Android smartphones can be loaned on request. Please talk to the LiC about your requirements.

Almost everyone carries a smartphone today, and a community may be formed to collect urbane noise pollution measurements from the smartphones carried by the users in the community. Your system should calculate the noise levels from the sound measurements from microphones in the smartphones; then it transmits the location, time and noise levels information to a cloud server, which will use compressive sensing technique to recover noise information from spatiotemporal under sample measurements. Finally, your system will overlay the noise information with Google Maps with different colours indicating different urban noise levels, which can be viewed by users from a web browser.

Reference paper, *Ear-Phone: A Context-aware Noise Mapping using Smart Phones*.

2.12 Project 12: Deviceless localisation

Most of the localisation methods assume that the object to be localised is equipped with a wireless radio. The paper *See-Through Walls: Motion Tracking Using Variance-Based Radio Tomography Networks* proposes a method to localise people without requiring them to carry a wireless device on them. The key idea is that if a person is standing in the path connecting two wireless nodes, the signal strength of the link connecting these wireless nodes drops. Thus, by identifying which wireless links have a drop in their signal strength, it is possible to locate the person.

You may wish to go the web page http://span.ece.utah.edu/radio-tomographic-imaging and watch the video "Through wall tracking ..." (this is the second video from top) to see the localisation in action.

In this project, you will implement the deviceless localisation method to evaluate its accuracy in tracking the movement of a person. A possibility is to place the sensor devices as in Figure for Project 7 and use the deviceless localisation method to track the movement of people. You are of course free to investigate other configurations.

2.13 Project 13: Accurate body motion monitoring system

You will build an accurate body motion monitoring system using a network of sensorTags worn on different parts of body (wrist, arm, leg, waist etc.). The system should also consist of 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.

2.14 Project 14: WiFi-ID: Human Identification Using WiFi or RFID Signal

You will show that WiFi or RFID signal can be used to uniquely identify people because there is strong evidence that suggests that all humans have a unique gait. An individual's gait will thus create unique perturbations in the WiFi or RFID spectrum.

Your system will analyse the channel state information from commercial off-the-shelf WiFi or RFID reader to extract unique features that are representative of the walking style of that individual and thus allow us to uniquely identify that person reliably.

Demo video: https://www.youtube.com/watch?v=sEn-0RMxgBI2.15

Reference paper: *WiFi-ID: Human Identification using WiFi signal*

Note: Although the system in the reference paper and video was built using WiFi devices, there is evidence from literature that RFID readers can provide more stable channel state information and better recognition rates.

2.15 Project 15: Inferring Person-to-Person Proximity

We are surrounded by an ever-increasing number of telecommunication infrastructures, such as mobile phone networks, WiFi access points, or Bluetooth beacons. In addition to their intended function of providing connectivity, these infrastructures offer an unprecedented opportunity for sensing, modeling, and subsequent analysis of a wide range of human behaviors. In this project you will use signals from WiFi access points to infer our proximity iwth other people. Being able to infer person-to-person proximity events with high spatio-temporal resolution enables modeling of phenomena such as spreading of diseases and information, formation of social ties, as well as group dynamics.

Reference paper: *Inferring Person-to-person Proximity Using WiFi Signals*

2.16 Project X: Proposed your own project

2.17 Scope of the project

1. In your proposal, you will need to state how you wish to demonstrate your results. For example, assume that your project comprises of implementing a new transport layer protocol for IoT. You may program the nodes so that the forwarding nodes will light up the LED in a certain pattern if packets are received correctly and a different LED pattern if re-transmissions are needed. You may change the topology a few times in the demonstration and show that it works for all the topologies. You would also include some graphs in your final report that quantitatively study

2. If you require additional hardware, please discuss your requirements ASAP with the LiC. We can purchase some additional devices 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 the presentation in Week 12/13 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 two specialised conferences on sensor networks: SenSys and IPSN.

3) Other major conferences on mobile and ubiquitous systems include MobiSys, MobiCom, PerCom 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 Weeks 3 or 4.

3.2 Formation of project teams and bidding process

You are expected to do this project in a group of 3 students. You are free to form your own team. Please enter your team membership using the WebGMS function available at the course website.

Please email salil.kanhere@unsw.edu.au with the names of your team members (one person from each team should email) by **12 noon Friday 17 August 2018**. In your email, please also include your preferences for each of the proposed projects. You are asked to expressed your preference by giving each project a score of 1, 2 and 3 where '3' means a project that you most want to do and '1' 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 project 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 randomly form groups from students who have not responded.

3.3 Assessment

Note the following assessment and submission requirements:

1. You should submit a preliminary report (with your proposed solution, project plans, milestones for both Week 13 presentation and final demonstration) by **Friday 14 Sept 11:59pm** 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. Your project report must be in PDF format and named **project_prelim.pdf**. This is the only filename accepted by the system. The give command to use is: "give cs6733 project_prelim project_prelim.pdf".

2. In Weeks 7/9, each team will give a presentation on their proposed solution and their proposed work plan to the whole class. Each team member should do part of the presentation. LiC, guest lecturers, and fellow students will assess the presentations according to predefined marking criteria.

3. In Weeks 12/13, each team will give a presentation on their project progress and demonstrate the milestones achieved so far to the whole class. The aim is to ensure that you have made concrete progress on the project. Each team member should do part of the presentation. LiC, guest lecturers, and fellow students will assess the presentations according to predefined marking criteria. In Week 13, each team will need to negotiate with the LiC to decide on a time for the final demonstration. The intermediate report is to be submitted by **Friday, 26 October 2018 11:59pm (Week 13)** via *give*. The intermediate report should be named **project_intermediate.pdf**. This is the only filename accepted by the system. The give command to use is: "give cs6733 project_intermediate project_intermediate.pdf".

4. The project report and code is to be submitted by **11.59pm Tuesday 20 November 2017** via *give*. Your project report must be in pdf format and called **project_final.pdf**. You are also required to submit all your code. Please tar your final submission and call it **project.tar**. This is the only filename accepted by the system. The give command to use is: "give cs6733 project_final project.tar".

5. A final demonstration and interview will be held **21-22 November 2018**. Each team is given half-hour 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 Weeks 7/9: 15%
2. Project progress demo + class presentation in Weeks 12/13: 15%
3. Project final report: 10%
4. Project final demo: 20%

<u>The deadlines are hard. No extensions will be offered</u>.