COMP6733 IoT Design Studio
Problem Set, 2023

June 11, 2023

Instructions for candidates

(1) **Due date and time: Friday 28 July 2023, 17:00.**

(2) Total number of questions: Three (3). Total number of pages (including this cover page): Four (4).

(3) Answer all questions.

(4) In answering the questions, it is important for you to show us your intermediate steps and tell us what arguments you have made to obtain the results. You need to note that both the intermediate steps and the arguments carry marks. Please note that we are **not** just interested in whether you can get the final numerical answer right, but we are **more** interested to find out whether you understand the subject matter. We do that by looking at your intermediate steps and the arguments that you have made to obtain the answer. Thus, if you can show us the perfect intermediate steps and the in-between arguments but got the numerical values wrong for some reason, we will still award you marks for having understood the subject matter.

(5) Answers must be submitted electronically via *give*. The only format accepted is Acrobat pdf. The recommended file name is your student number. The submission command (assuming your student number is 1234567) is:

`give cs6733 problemSet 1234567.pdf`,

or via the WebCMS web interface.

(6) Individual work ONLY. Please check the plagiarism policy in the course outline on the webpage.

Question 1: IoT Design (4 marks)

UNSW has joined “Race to Zero”[1], which is a global campaign to rally leadership and support from businesses, cities, regions, investors for a healthy, resilient, zero carbon recovery that prevents future threats, creates decent jobs, and unlocks inclusive, sustainable growth[2].

As part of the “Energy and Water” strategy, you are tasked to help to achieve 1)“By 2030, substantially increase water-use efficiency across all sectors”, 2) “By 2030, double the global rate of improvement in energy efficiency.” (see Fig. 1), by monitoring/controlling energy/water usage, occupancy, temperature/humidity, HVAC and lighting in these buildings. Therefore, your proposed solution should include the sensors, the actuators, smartphones (e.g., for human inspection), and communicate the sensor data/control commands from/to an IoT cloud platform. Describe a solution to this problem: choose of hardware, protocols for different communication layers (Physical/MAC, routing, transport and application), sensing strategy, backend handling, and the cost of your solution. Also explicitly state all assumptions that you make. (page limit: 1 page)

Resource efficiency

Highlights

> Introduced the Plastic Free Dining Awards to recognise campus retailers.
> Expanded food waste collection to office kitchens and introduced a soft plastics collection system.
> Furniture reuse program diverted 84% of surplus UNSW furniture from landfill to beneficial reuse.

Sustainable Development Goal(s)

Our activities in this area contribute to the following SDGs: 6,7 and 12

We are especially focused on these targets:

> 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
> 7.3 By 2030, double the global rate of improvement in energy efficiency.
> 12.2 By 2030, achieve the sustainable management and efficient use of natural resources.
> 12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
> 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
> 12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities.

Goal: Conserve resources by reducing consumption, prioritising reuse and responsibly managing waste.

Why this matters

University campuses and activities are significant consumers of energy, water and other natural resources, and generators of waste. Our *Resource efficiency* theme includes programs to optimise the energy and water efficiency of buildings, promote reuse over single-use and improve our recycling systems. By minimising waste and improving waste systems and behaviours, we aim to conserve natural resources, minimise contamination, reduce costs and support sustainable waste management practices amongst our students and staff.

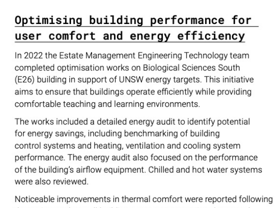
How we are responding

Energy and water efficiency initiatives and waste management systems are managed by Estate Management in collaboration with contractors and the wider student and staff community. We aim to promote reuse and eliminate single-use plastics from campus through initiatives such as Plastic Free Dining and associated communication activities.

The Waste Management Plan guides improvements to our recycling systems, reuse initiatives such as the furniture reuse program, and efforts to optimise waste segregation.

Targets	Status	Comment
Reduce energy intensity by 5 per cent	Not on track	Energy intensity increased compared to 2021 due to the return of students and staff to campus and is not on target.
Reduce water intensity by 5 per cent	On track	Water intensity increased compared to 2021 due to the return of students and staff to campus but is lower than the target.
Divert at least 85 per cent of general waste from landfill	Not on track	82 per cent of general waste was diverted from landfill in 2022, slightly short of the target.
Reduce general waste by 20 per cent	On track	General waste volumes increased slightly due to the return of students and staff to campus, but are 30 per cent lower than the 2018 baseline.
At least 80 per cent of retailers achieve Plastic Free Dining Gold Award status	On track	Seven out of 26 retailers (27 per cent) achieved Gold award status, while 14 achieved Silver and three achieved Bronze. In total, 88 per cent of retailers have achieved a Plastic Free Dining Award.

(a) Resource efficiency.



Optimising building performance for user comfort and energy efficiency

In 2022 the Estate Management Engineering Technology team completed optimisation works on Biological Sciences South (E26) building in support of UNSW energy targets. This initiative aims to ensure that buildings operate efficiently while providing comfortable teaching and learning environments.

The works included a detailed energy audit to identify potential for energy savings, including benchmarking of building control systems and heating, ventilation and cooling system performance. The energy audit also focused on the performance of the building’s airflow equipment. Chilled and hot water systems were also reviewed.

Noticeable improvements in thermal comfort were reported following the tuning; and overall building energy consumption decreased.

(b) Optimising building performance for user comfort and energy efficiency.

Figure 1: Environmental Sustainability Report 2022, UNSW. (Slides 17, 18)

[1] `https://www.sustainability.unsw.edu.au/unsw-joins-race-zero`, accessed on 10/06/2023

[2] `https://unfccc.int/climate-action/race-to-zero-campaign`, accessed on 10/06/2023

Question 2: Routing (3 marks)

Fig. 2 shows a network topology, where Node S is the source node and Node D is the destination node. A 0 to 1 number beside an arrow shows the link quality Packet Reception Rate (PRR) of an $asymmetric$ wireless link; for example, the PRR from Node a to D is 0.9 (90%).

If the nodes run RPL that uses expected number of transmissions (ETX) as routing metric. What is the path between Nodes S and D? What is the path ETX?

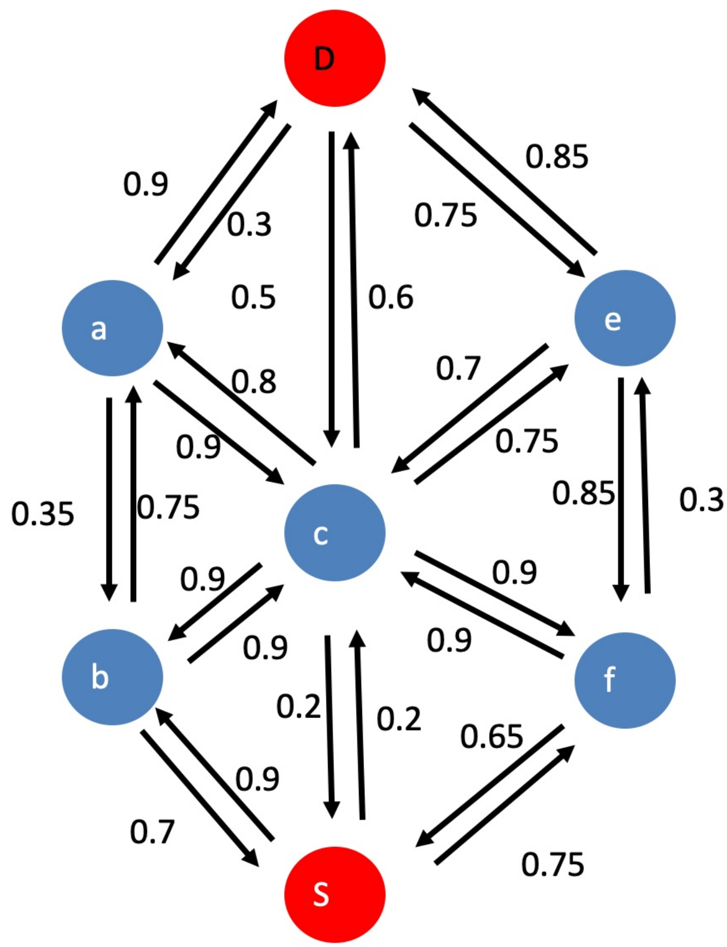


Figure 2: Figure for Question 2.

Question 3: Localisation (3 marks)

In this question, you will consider the problem of localising an IoT node (e.g., energy and water meters in Question 1 above during commissioning stage) using the time difference of arrival method.

We assume the nodes are located on the (x, y)-plane. There are three anchors (labelled as anchors 1, 2 and 3) located at (40,50), (30,25) and (60,30). (Note: co-ordinates are measured in metres.) The aim is to determine the location of the node X.

All the anchors and the IoT node X are equipped with an ultra-sonic sensor and a radio. Node X uses the ultra-sonic and radio signals to determine its distance from each anchor. The operation is as follows. The description here assumes that node X wants to measure its distance to an anchor A where A = 1, 2 or 3. At a certain time $t_{A,0}$, the anchor emits an ultra-sonic pulse and send a radio packet, i.e. both the pulse and the packet leave the anchor at the same time at $t_{A,0}$. The sensor node X measures the arrival time $t_{A,u}$ of the ultra-sonic pulse at node X and the arrival time $t_{A,r}$ of the radio packet at node X. Note that node X does not know what $t_{A,0}$ is and the value of $t_{A,0}$ is not needed at all because the speed of the radio is approximately six orders of magnitude faster than the speed of sound (see below) and the radio's travel time assumed to be ignored. Table 1 summarises the arrival times (in seconds) measured by node X.

By using the data in Table 1, and the speed of radio propagation is 3×10^8 ms^{-1} and the speed of sound is 340 ms^{-1}, determine the location of the node X.

	$A = 1$	$A = 2$	$A = 3$
$t_{A,r}$	11.5	48.5	27.9
$t_{A,u}$	11.56	48.55	27.98

Table 1: Arrival time of the radio and ultra-sonic signals from the anchors to node X.