G52GRP Final Report

Proximity Based Attendance Management via Bluetooth Low Energy

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1 Abstract

The aim of this project is to develop an Android app which uses proximity range detection to register the attendance of students in classrooms. Imagine a student entering a classroom, as the student with a smartphone moves into the proximity Bluetooth range of another student's phone when they have already registered their attendance, their phone will automatically connect to the nearby student's phone. This will trigger the user's automatic attendance recording system. This cascade of registrations will initiate with the course lecturer opening the course for registration and a first round of students getting registered by coming into the range of the lecturer's phone. This first round of students will then be able to act as proxy for registering other students, so that not every single student has to enter the lecturer's Bluetooth transmission range (typically around 10m).

The app will use Bluetooth Low Energy for proximity detection of nearby smartphones, and for data exchange. This project attempts to leverage a technology that lets phones within a certain location collaborate to perform certain tasks. One current application of this technology is contact tracing of COVID-19 cases.

2 Introduction

2.1 Problem Description

University of Nottingham Malaysia has a mobile application called *UNM Instatt* to aid lecturers and students take attendance during academic sessions. Instead of signing on paper, students will press an icon within a limited time frame to indicate themselves as present after the lecturer has turned on the signing-in feature. Students will get to monitor their attendance rate and check their timetable schedule in the application and likewise for lecturers.

However, some students might forget to sign-in even though they attended the class. In that case, lecturers need to sign in manually for them. There is also no notification when attendance is opened to be signed and students might miss the signing time frame. The process of attendance taking is also disruptive to the academic process as students need to open the application every time to record attendance.

2.2 Proposed Solutions

This project aims to create an application called Beam that can automatically record attendance of students in class. This application will run in the background and use Bluetooth Low Energy (BLE) to detect the students' proximity to lecturer or students who already recorded attendance. Once the lecturer enabled sign-in of attendance on his device, that device will send a token through BLE to other BLE-enabled devices nearby. The application will communicate with a server once the token has been received and the server will record attendance for the students. Once the student's attendance is recorded, the student's device will act as a beacon which shares the lecturer's token to nearby devices so that students whose devices are out of the lecture's device Bluetooth range could receive the lecturer's token. There will be a separate website which handles the timetable scheduling and registration of lecturer and student details.

Furthermore, the application will notify students to turn on Bluetooth once attendance is open to sign in. When the device received a token from the lecturer or from other present students, the application will record timestamps to ensure attendance record matches the actual timetable.

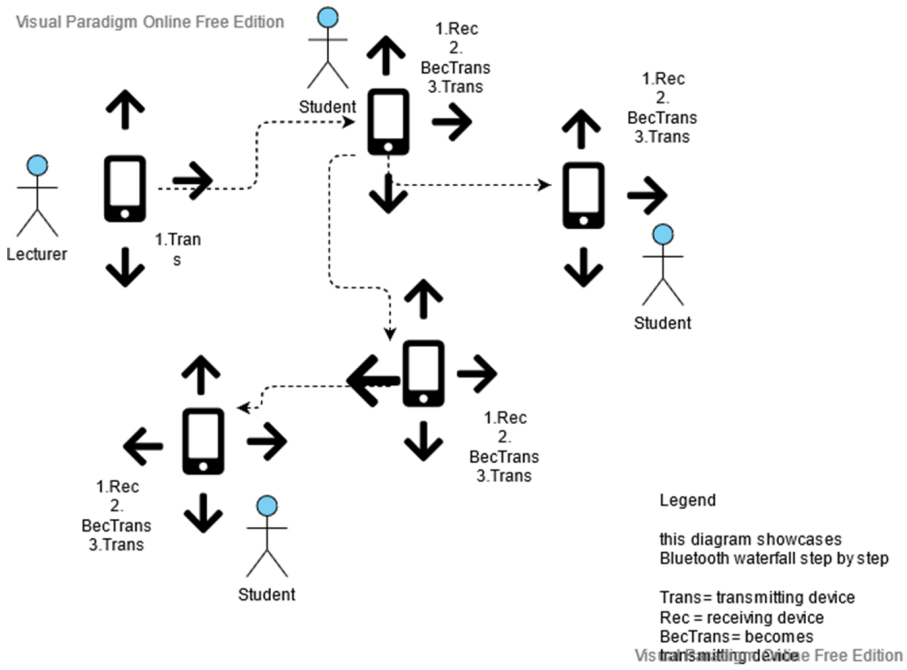


Figure 2.2.1: *Trans=Transmitting device, Rec=Receiving device, BecTrans=Becomes Trans*

2.3 Qualifications and Limitations

One of the limitations of this application is that it could not detect proxy devices. Students who will not attend class can just hand their devices over to their friends who will attend to sign their attendance. Unless the lecturer counts the number of physical students in the class and tally with the number of students in the attendance record, which is a time-consuming process, students can take attendance with the application on behalf of their friends. If there is a separate device, such as an infrared sensor, that can detect the number of physical students in class automatically, then proxies can be eliminated, albeit at a high monetary cost. Furthermore, students who have already taken attendance can bring their devices to their friends outside the classroom to record attendance for them. Some students may turn off Bluetooth after taking attendance to save on battery consumption. Without Bluetooth, the device cannot act as a beacon for other students' who have not taken attendance.

2.4 Development Constraints

Since this project is not commissioned by University of Nottingham Malaysia (UNM), the application will be linked with an artificial database instead of the real UNM student registry. Even though the data used in this project does not identify with any real user, the data processed will be encrypted as a good practice of data handling.

Testing cannot be performed in the university making it significantly harder to test for security requirements such as leakage of personal data to unauthorised parties amongst others.

The use of an artificial database and the fact that the app will not be used by multiple students means that the app will never be tested on many devices making it considerably harder to test for several performance requirements, for instance how smooth the app runs on different Android devices or different networks.

2.5 Target Audience

This project aims to improve the existing attendance management application of *UNM Instatt*. Hence, this application is created for UNM lectures and students.

3 Literature Review

3.1 Using Android Devices and BLE

There are some existing solutions that utilizes BLE to record attendance. One of them is to attach a sensor to each students' identity card which could interact with the application installed in the lecturer's Android device. This sensor contains a unique string that can be associated with the student card it is attached to. During class, the lecturer will open the application to scan the sensors to collect the students' data into the application. To avoid attendance taken by proxy (students carrying more than one identity card or students standing outside the classroom during class), an infrared sensor could be installed in each classroom at the correct location and angle that can count the number of students who are physically present in the class. If the number of present students recorded by the application does not match the data recorded by the infrared sensor, the lecturer will receive an error message from the application [1].

Another way is to install BLE beacon in each classroom that transmit a "magic number" to each nearby Android devices with the required application installed. Through a web-based attendance management system, the lecturer could set the ID and name of the class prior to the class. During class, the lecturer will turn on the BLE beacon to send a "magic number" to students' Android devices nearby. Furthermore, the lecturer also turns on registration for attendance on the web-based attendance management system, which offers some basic management features such as list of attendance rate and records and import, export, and manual alteration of attendance records. The application installed in students' device allows the students to scan their student identity cards through Near Field Communication (NFC) reader. It is also not necessary to scan their cards with their own device and any device with the application installed could scan their student card. Meanwhile, the Android devices will receive the "magic number" from the BLE beacon. To record students' attendance, the application will send the "magic number" and the scanned student card and name to the server [2].

Other than that, Bluetooth beacons can be installed to each room so that students' device can scan their presence and extract the beacon's UUID. The students will install an application which logs them into their respective user account and scan their surroundings in search for Bluetooth beacon's UUIDs. Each room will be represented by a beacon's UUID. The administrator server will then match the extracted UUID, retrieval timestamp, and user account, all which are sent from the application installed in the student's device, with the database to check if the student is present in the correct room during academic sessions [3].

3.2 Using BLE Indoor Positioning Technology

There is also an alternative method of attendance management which does not require any mobile application. The university could install four Bluetooth station modules in strategic locations in a room. The Bluetooth module is a sensor system programmed in Python over Raspberry Pi which is also equipped with Bluetooth USB dongles. They are installed in the walls of each room to connect with powerlines and the Local Area Network (LAN). In this system, the lecturer could set the classes and list of students on the web-based attendance management system. On the other hand, students will also register the media access control (MAC) address of their device on the web-based system.

During academic sessions, the web-based system will send the list of student MAC address based on the timetable registered by the lecturer to the Bluetooth modules. The Bluetooth modules will then scan for Bluetooth devices nearby and detect their RSSI and MAC address. The RSSI data will be processed using fingerprint localization method based on Artificial Neural Network (ANN) to estimate the location of the student in the classroom and the MAC address

can be associated with a student. The data collected will be sent to the server and matched with the records in the database to register the students' attendance [4].

3.3 Android Bluetooth Low Energy

Android introduced Bluetooth Low Energy (BLE) functionality in Android 4.3 (API level 18). BLE has a lower power consumption in comparison to Classic Bluetooth. The transfer of data (known as attributes) between two BLE capable devices is based around the Generic Attribute Profile (GATT) which is built on top of the Attribute Protocol (ATT) [5].

ATT defines a standard protocol for attribute transfer between BLE devices by defining how attributes are formatted for transfer. Each attribute is uniquely identified by a Universally Unique Identifier (UUID) which is a standardised 128-bit format for a string ID. Attributes that are transferred are formatted as either services, characteristics, or descriptors. A service is a collection of characteristics. A characteristic contains a single value and any number of descriptors which are attributes for describing the characteristic. These descriptors may specify the characteristic's use, minimum and maximum values, unit of measurement, etc. A GATT profile specifies what kind of attributes are transferred. Bluetooth SIG provides existing profiles (such as Alert Notification Profile and Heart Rate Profile) for common BLE devices, but custom GATT profiles may also be written by developers. Custom GATT profiles defines a new service and characteristics of the service.

Android documentation specifies roles taken by two BLE capable devices that are connected. Regarding making a connection between two BLE devices, there exists two roles, the central and peripheral roles. The device that acts as the central scans for devices by looking for advertisements of services. Once a device is found, the central device is responsible for initiating a connection. The peripheral device is responsible for sending out advertisements of its services defined by a GATT profile. After the connection is created, the devices take on two new roles, either GATT client or GATT server. Usually, the central device takes the client role while the peripheral takes the server role. The GATT client is responsible for making requests to read or write into the characteristics inside the server's service which are defined by a GATT profile. The GATT server is responsible for notifying the client of characteristic changes and responding to client requests.

3.4 Firebase

Firebase is a platform developed by Google for creating and maintaining mobile and web applications as their Flagship product for app development [6]. There are 18 products available split into 3 groups, namely Develop, Quality and Grow. For our application we are using Firebase to host our application as well as the Authentication and Realtime Database features available on the firebase platform.

We decided to use Firebase Hosting to host our app not only because it's free, but also because of the simplicity of using Firebase to understand our backend statistics such as the amount of data downloaded, the amount of storage used as well as the ease of using the built-in authentication features available. Since Firebase is cloud-hosted and free, it is both cost effective and the risk of losing data is minimal.

Firebase Authentication provides a way for developers to identify the users who access the application or website. There are many different types of authentication but project we have used the "email and password" based authentication type. We have decided to make use of a function that allows users to create accounts either on the firebase console itself or in their mobile apps. Developers or System Administrators update or register data on the Firebase Realtime Database after successfully signing into the website. Every user account in the system has a corresponding User ID whether they are a lecturer or a student. Admin accounts also have User IDs but they are not useful in this project.

Firebase Realtime Database is a NoSQL cloud-hosted database whereby data as JavaScript Object Notation (JSON) tree and can be synchronised in realtime to every connected client. The database is structured as a JSON tree with parent and child nodes with their respective keys. For cross-platforms apps (e.g. Android and Web), every client shares the same data instance and simultaneously receive the same updates made in the database [7]. We keep the data denormalized in the database so that the data can be downloaded efficiently as separate queries instead of fetching all the data nested in a particular location. This is because when client fetches data, all the child nodes are retrieved. If too much data is nested in a location, the client might end up downloading data which is not needed. Granting users read and write access to a location also grants read and write access to all child nodes, so we try to keep the data structure as flat as possible [8].

Note that all the Firebase Services used within this project encrypt data in transit with HTTPS and in the Google Servers [9].

3.5 Vue.js

Vue is a framework for building user interface of a website and is especially useful in creating single-page application (SPA). Developers can write templates, which are based in HTML syntax, and bind them with the components instance data of a website. The component templates most useful in this project is a type called x-template, which allows the developer to write HTML code inside a script tag [10]. Instead of creating multiple html files and redirects, they can be written in a single JavaScript file or a single HTML file under script tags. They can also create a navigation bar and allow users to switch between different templates by using the Vue-router-library. Routes can be created as paths to templates so that the router can link to the items in the navigation bar to their respective templates [11]. The main purpose of using Vue in this project is to allow the user to access multiple templates without refreshing the webpage.

3.6 Selenium Browser Automation

Selenium WebDriver simulates how a real user would use a browser, on local or remote machines. It works with all major browsers, including Chrome, Edge, Firefox, etc. This WebDriver also refers both to the language binding and implementations of the browser controlling code. It is an objected-oriented API designed as a compact programming interface [12]. In this project, we will use Python to implement the WebDriver and create a script to drive browser automation. The script will be used to populate the database and test the functionalities of the administration website.

4 Requirements Specification

4.1 Functional Requirements

4.1.1 Authentication

i. Application will redirect user to login screen if user is unauthenticated

ii. User authentication state is saved and remains outside of app lifecycle

iii. Users authenticated using student credentials will enter *student mode*

iv. Users authenticated using lecturer credentials will enter *lecturer mode*

4.1.2 Display and Navigation

i. Within the main screen, users can swipe left and right to navigate between 4 different screens

ii. Within the 1st screen, users can view a pulsing animation of the BEAM logo

iii. Within the 2nd screen, users can view the daily schedule of sessions they'll be teaching or attending

iv. Within the 3rd screen, users can view the weekly schedule of sessions they'll be teaching or attending

v. Within the 4th screen, users can view attendance statistics for the module they're teaching or enrolled in

vi. Users can press the settings icon on the top right to navigate to a settings screen

vii. Within the settings screen, the user can logout delete existing authentication state

4.1.3 Lecturer Mode

i. On arrival at main screen, app will schedule background services for opening attendance when each session begins (Updating database, sending out attendance tokens)

ii. On arrival at main screen, app will schedule background services for closing attendance when each session ends (Updating database)

iii. During background service for opening attendance, lecturer will be notified that the device is sending out attendance tokens to other devices

iv. By pressing a row containing a session, lecturer can view the attendance statistics of a particular session

v. By pressing a module in the 4th screen, lecturer can view average attendance percentage of students enrolled

4.1.4 Student Mode

i. On arrival at main screen, app will schedule background services for taking attendance when each session begins

ii. During background service for taking attendance, user will be notified that the device is scanning for other devices and receiving tokens

iii. On successful taking of attendance, user is notified that attendance has been taken

iv. On successful taking of attendance, device switches to sending out tokens to other devices and user is notified of this

v. By pressing a row containing a session or module, student can view their detailed attendance history of the module

4.1.5 Bluetooth Requirements

i. App can open a GATT server to advertise a custom GATT Service

ii. App can scan for BLE devices that advertise a custom GATT Service

iii. App can read characteristics of the advertised service from other BLE devices

iv. App runs all Bluetooth functionality as a background service (doesn't require app to be open)

4.1.6 Administration Website

i. This is a website built to initialise the Firebase database with lecturer details, attendance record of each academic sessions by module, academic sessions of each modules, module details, academic plan consists of sets of modules, student details, attendance record of each student by academic module and academic session, timetable, and account user details.

ii. This website aims to simulate a university administration site where the admins can access and update the database.

iii. The landing page of this website only has only feature: admin account login.

iv. Successful logins will redirect the user to a single-page application with four main features: Student Registration, Lecturer Registration, Add or Remove Module, Update Timetable.

v. All four main features will load on the same page without any page refresh and can be accessed via the navigation bar.

4.1.7 Firebase Realtime Database

i. The system should store student data which can queried using student authentication account's UID. The data shall consist of first name, last name, programme, and email.

ii. The system should store lecturer data which can queried using lecturer's authentication account's UID. The data shall consist of first name, last name, faculty, position, and email.

iii. The system should store module data which can queried using module id. The data shall consist of module name, lecture ids and student ids.

iv. The system should store academic plan data which can queried using programme. The data shall consist of the module ids of the modules of a programme.

v. The system should store timetable data which can queried using date (YYYYMMDD). Academic sessions are recorded by module id and have details such as session type, status, time begin, and time end.

vi. The system should store attendance record data which can queried using module id and session id.

vii. The system should group each academic session by module id.

viii. The system should store the academic sessions attended by a student, grouped by module id.

ix. The system stores each user account details including programme, user role, and modules.

4.2 Non-Functional Requirements

4.2.1 Development Environment

i. Java SE Development Kit 8 will be the main programming language used for implementing app functionality

ii. XML will be used for defining views and layouts for the app

iii. Gradle build tools will be used for managing dependencies such as the Android SDK and Firebase API

iv. Android Studio will be the IDE used for developing the app

4.2.2 Application Dependencies

i. Android Software Development Kit will be used for developing the app

ii. Firebase API will be used for user authentication and storing and retrieving records in a cloud database

4.2.3 Availability

i. App will support Android devices with Android 5.0 or above

ii. App will only run on devices connected to the Internet

iii. App will only run on devices with Bluetooth enabled

4.2.4 Security Requirements[13]

i. Data transmitted between Firebase servers and the app should be encrypted with HTTPS

ii. Data stored in servers should be encrypted

iii. Password should be hidden on the interface

iv. Only attendance tokens are transferred between devices and received from other devices for the operation of the app

4.2.5 Performance Requirements[14]

i. App should open in 2 seconds after the user clicks on the app icon.

ii. UI frames must not take longer than 700ms to render.

iii. App UI should respond to user input in 200ms.

5 Final Design

5.1 Scheduled Attendance Taking Services

The attendance taking functionality will be implemented as Android background services that are scheduled to run at the time the session will start. Four different services will be implemented for each of the following functions: opening attendance, closing attendance, advertising attendance tokens, and scanning for devices advertising attendance tokens. The first two services will only run on a device with lecturer credentials. On app startup, the services will be scheduled by an Android AlarmManager.

5.2 Custom GATT Profile

A custom GATT profile (dubbed Beam Profile) will be utilised for data transfer between two devices using the app. The Beam Profile contains one custom GATT service (Beam Service) which contains one characteristic, known as Attendance Token, that holds a string value generated as the hash of a lecture session ID. The value of this characteristic can be read by the GATT client, written by the GATT server, and the GATT client can be notified of changes in the characteristic.

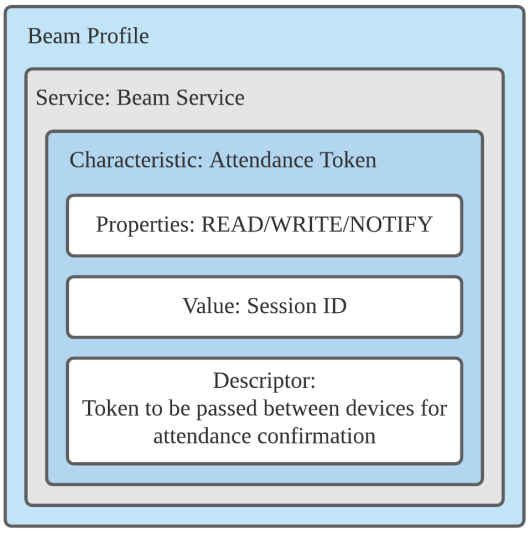


Figure 5.2.1: *Custom GATT Profile*

Regarding the peripheral role in the app, the lecturer's device acts as the first peripheral device. The session ID will be written into the service characteristic. The device will then advertise the Beam Service UUID and wait for connection request from a central device. Once a connection is established, the peripheral acts as the GATT server. Whenever the central device (GATT client) requests to read the value of the characteristic, the server will send a response containing the value. This is how the attendance token is passed between devices.

Regarding the central role in the app, the students' devices are central devices by default. Once the session has started (based on OS time), the central device will begin scanning for devices that advertise the Beam Service UUID. Once it detects one, it'll initiate a connection and begin acting as the GATT client. The device will immediately request to read the value of the characteristic within the service. Upon receiving the attendance token, the value is compared

to that in the database. Once attendance has been taken, the device closes the connection and switches to a peripheral role.

5.3 Database and Web Hosting Choice

The database used by the app will be Firebase Realtime Database, which is a cloud hosted database whereby data is stored as a JSON tree. All clients share one Realtime Database instance. The data stored by the app is estimated to take up a few GBs of space and only basic querying is required by the app. Additionally, only one instance of the database is needed for all clients. Thus, Firebase recommended Realtime Database as a better choice compared to Firebase Cloud Firestore, a NoSQL relational database, which is better suited for apps that require multiple databases, advanced querying, and hundreds of GBs to TBs of space. Firebase was chosen over other web services (such as Amazon Web Services) because it's hosting services are free (to a certain degree) and the API is estimated to be easier to learn and work with.

The website is hosted using Firebase Hosting: `https://beam-5845a.web.app/`. Email for authentication is admin@nottingham.edu.my and the password is *password*.

5.4 Firebase Authentication Design

There are three types of user accounts: student, lecturer, and admin. Student and lecturer accounts grant permission to access the application, while admin accounts grant access to the administration website. Each student and lecturer accounts will have their own User ID stored in Firebase Authentication[15]. The User ID will be used to query the database to search to student or lecturer details. The admin accounts are created on the console by the team and cannot be created in other way.

5.5 User Interface Navigation

5.5.1 Website

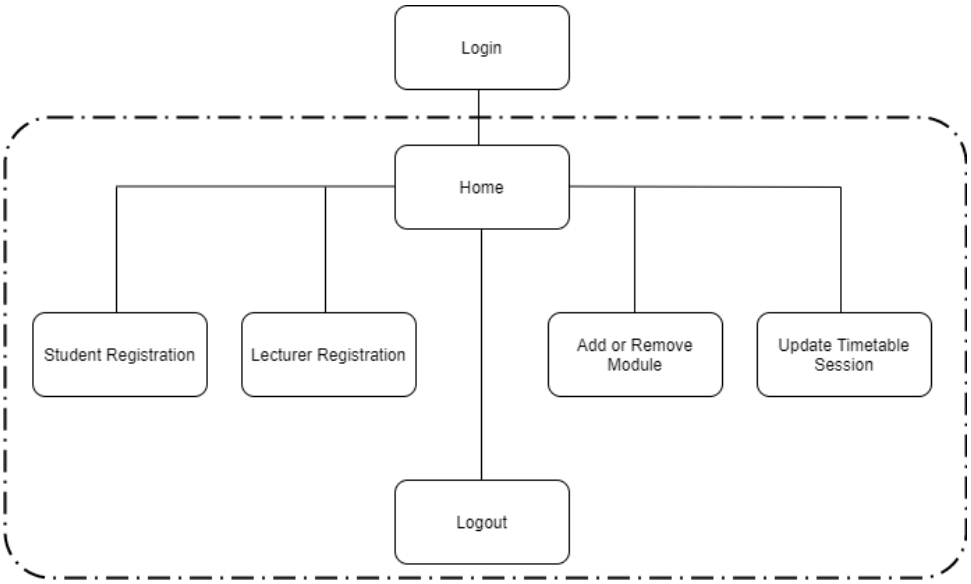


Figure 5.5.1: *Sitemap of administration website. Components inside the dotted box belong to a single-page application*

5.5.2 Application

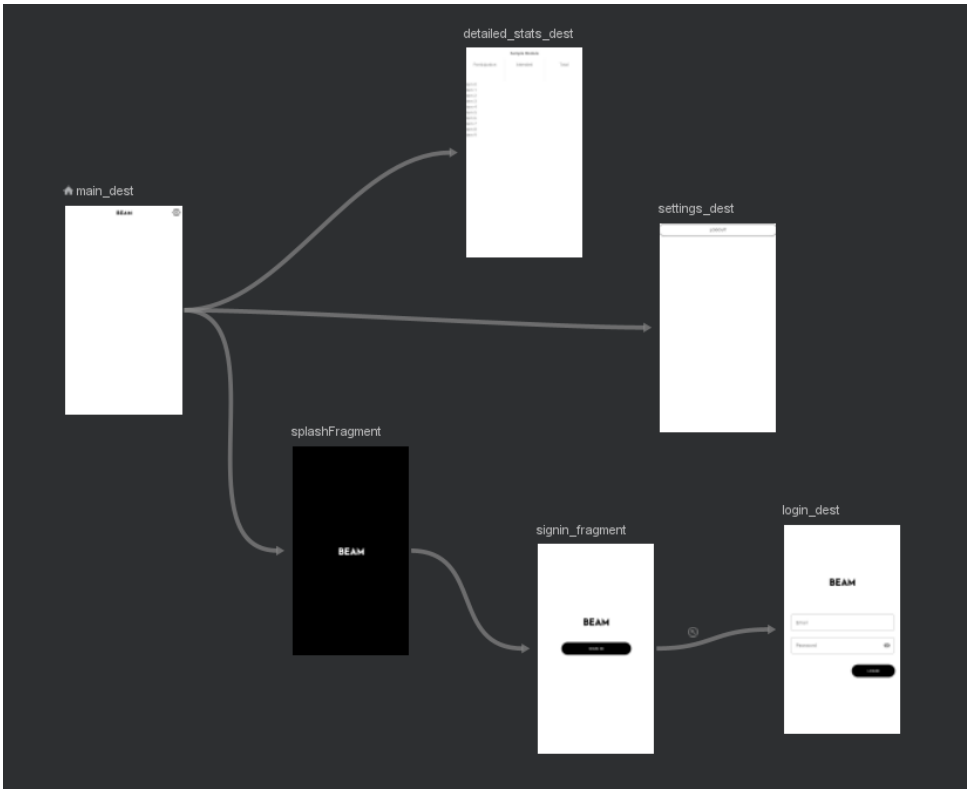
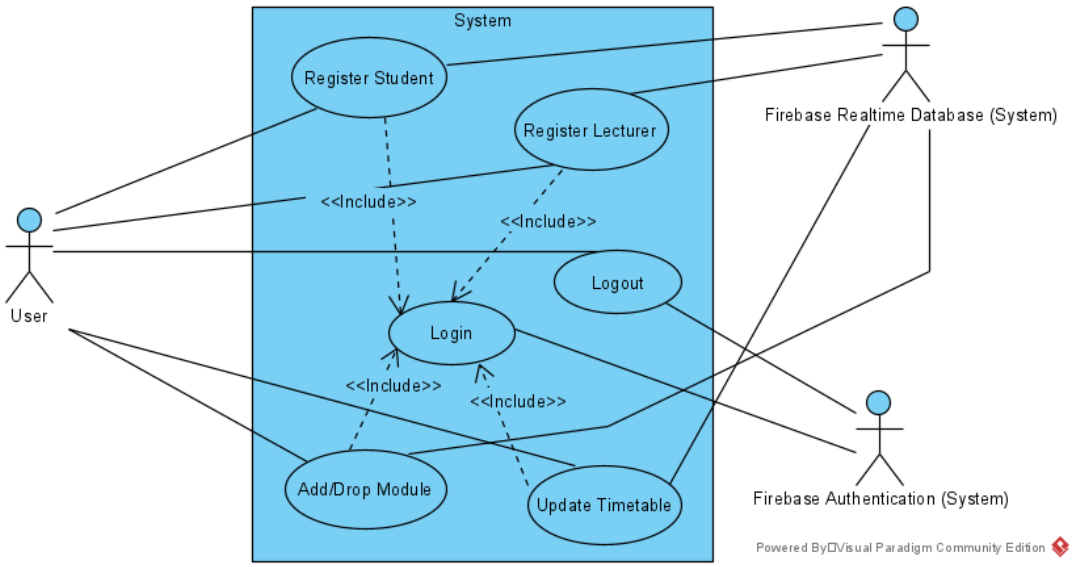


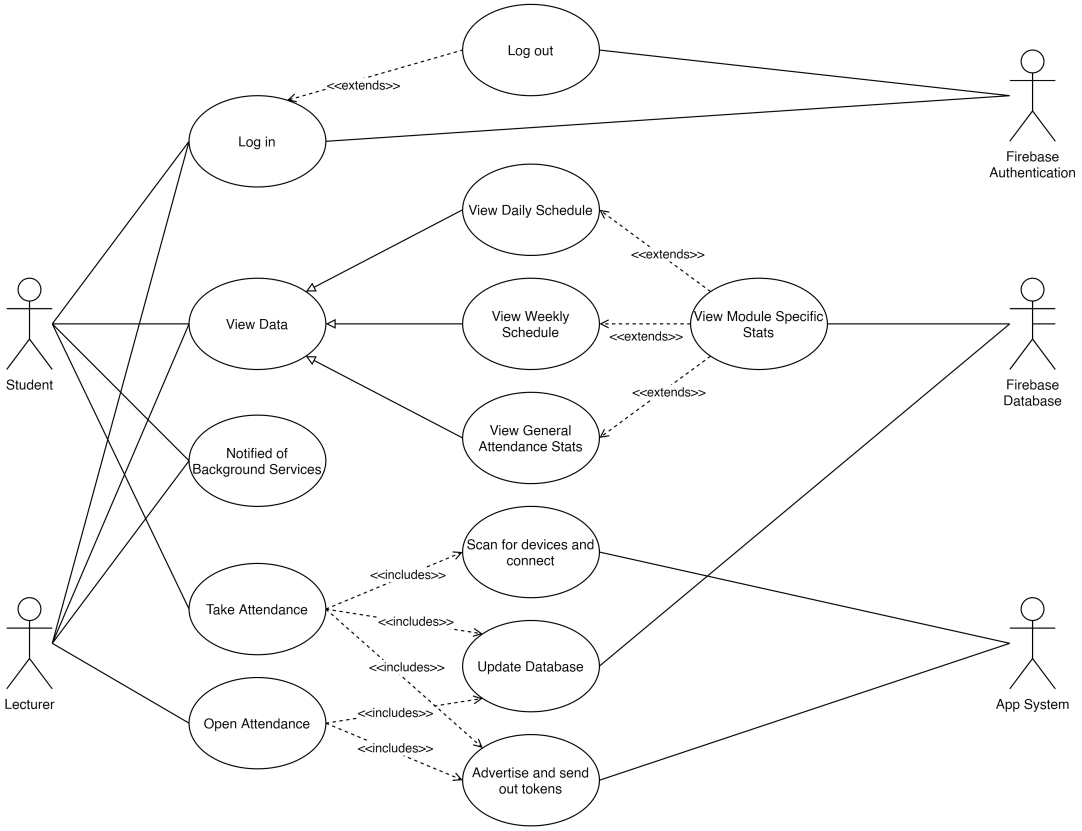
Figure 5.5.2: *Navigation graph that describes user navigation through the app*

5.6 Use Case Diagrams

5.6.1 Website



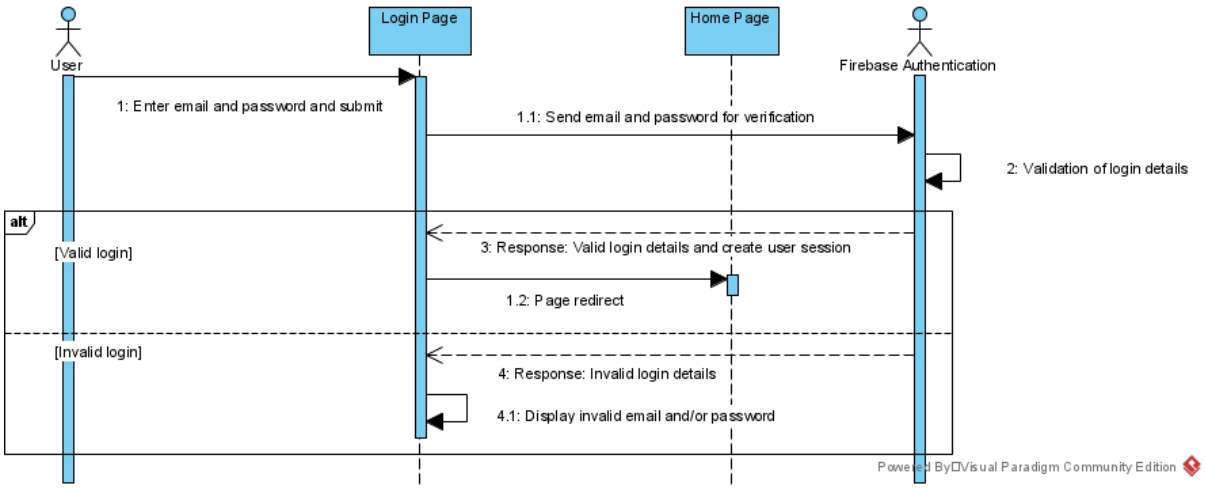
5.6.2 Application



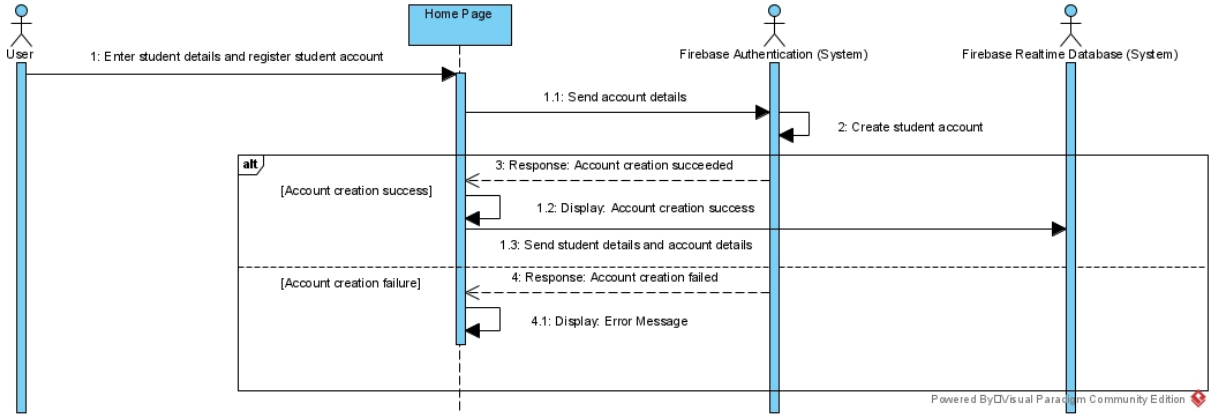
5.7 Sequence Diagrams

5.7.1 Website

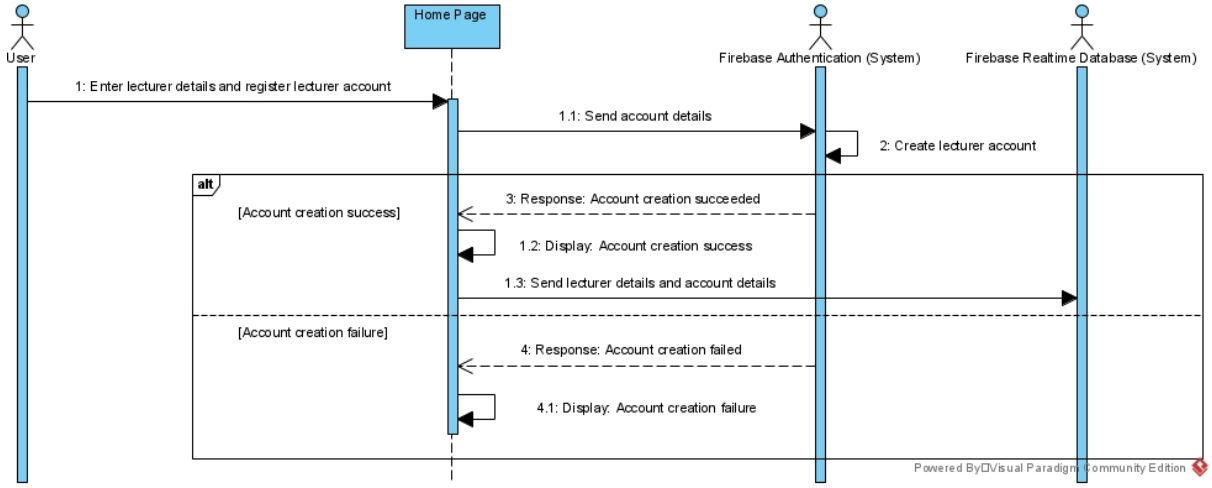
a. Login



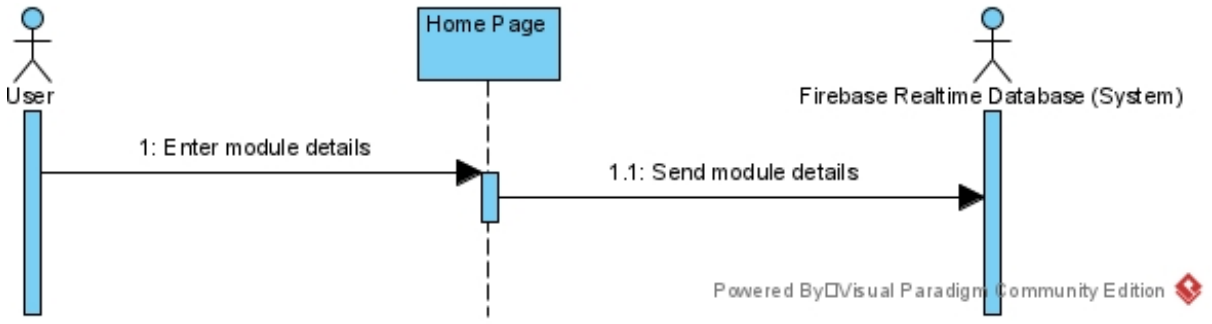
b. Student Registration



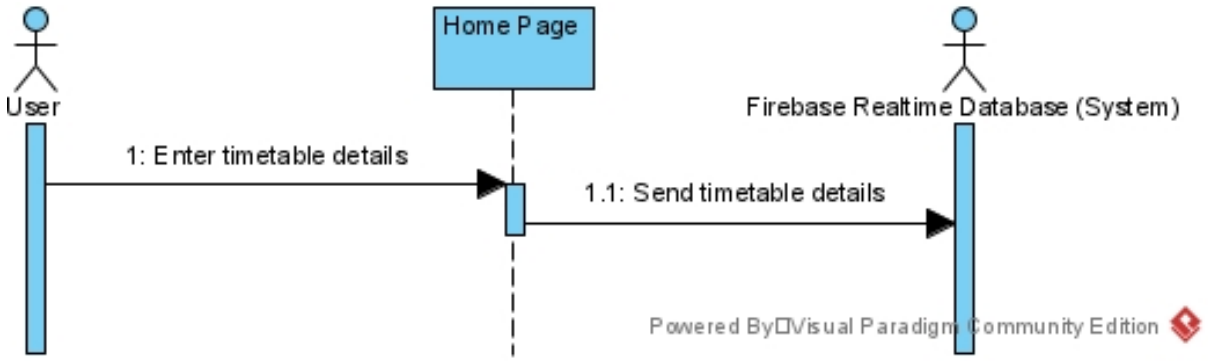
c. Lecturer Registration



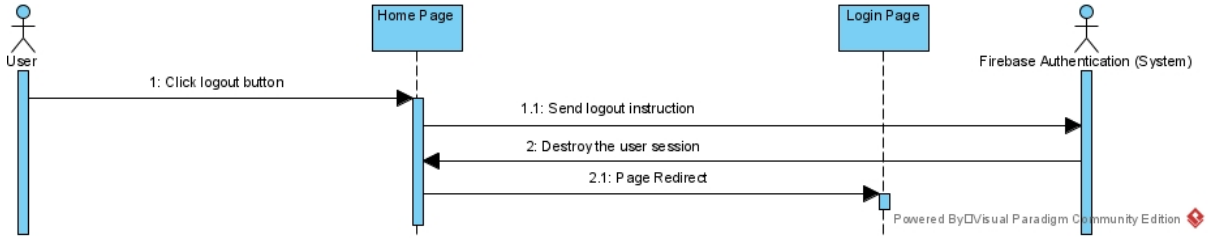
d. Update Module Information



e. Update Timetable

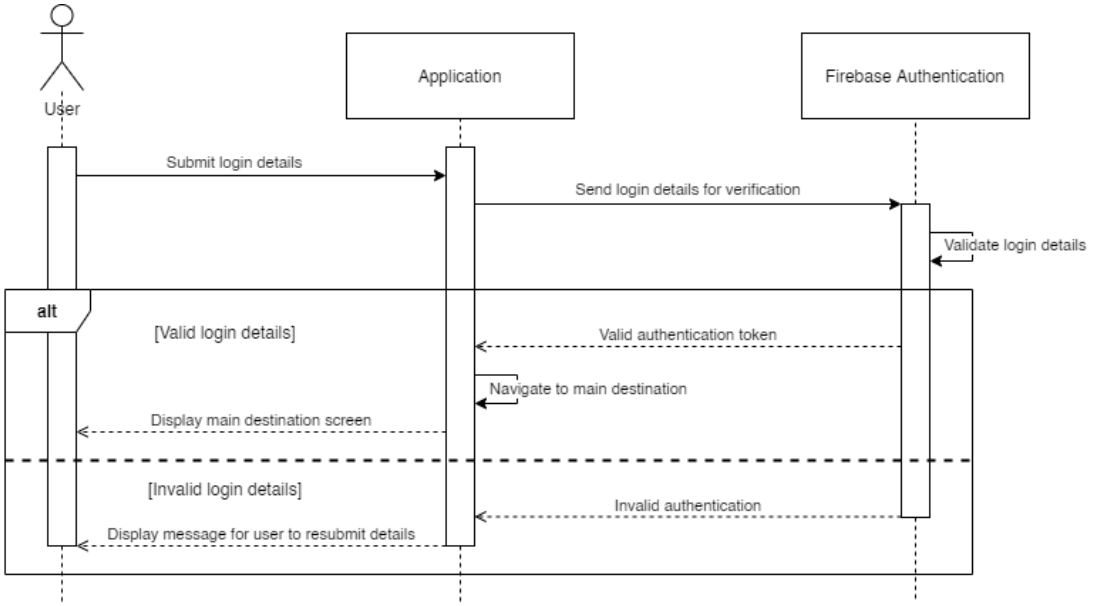


f. Logout

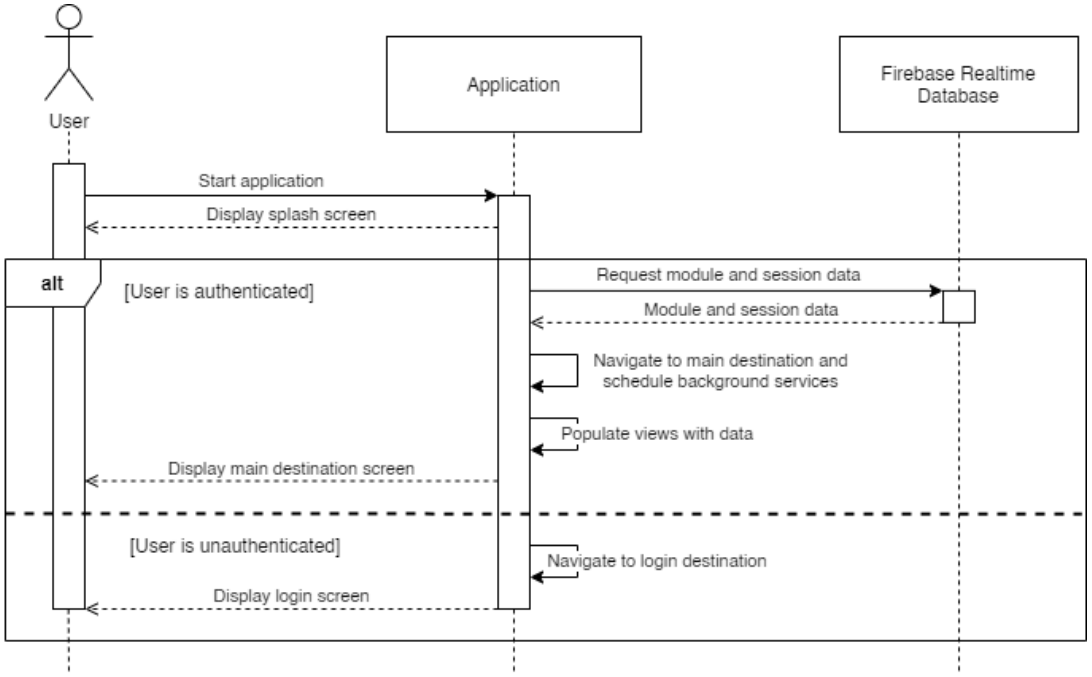


5.7.2 Application

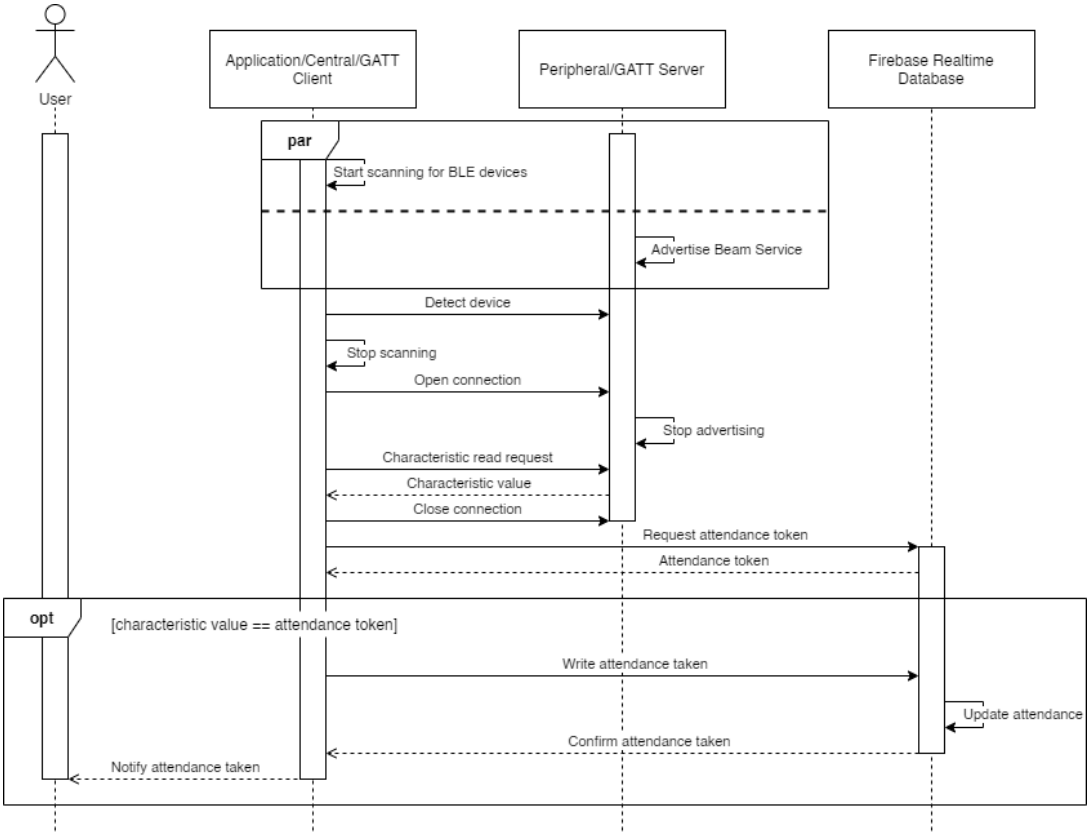
a. Login



b. Application Start



c. Attendance Taking



5.8 Firebase Realtime Database Design

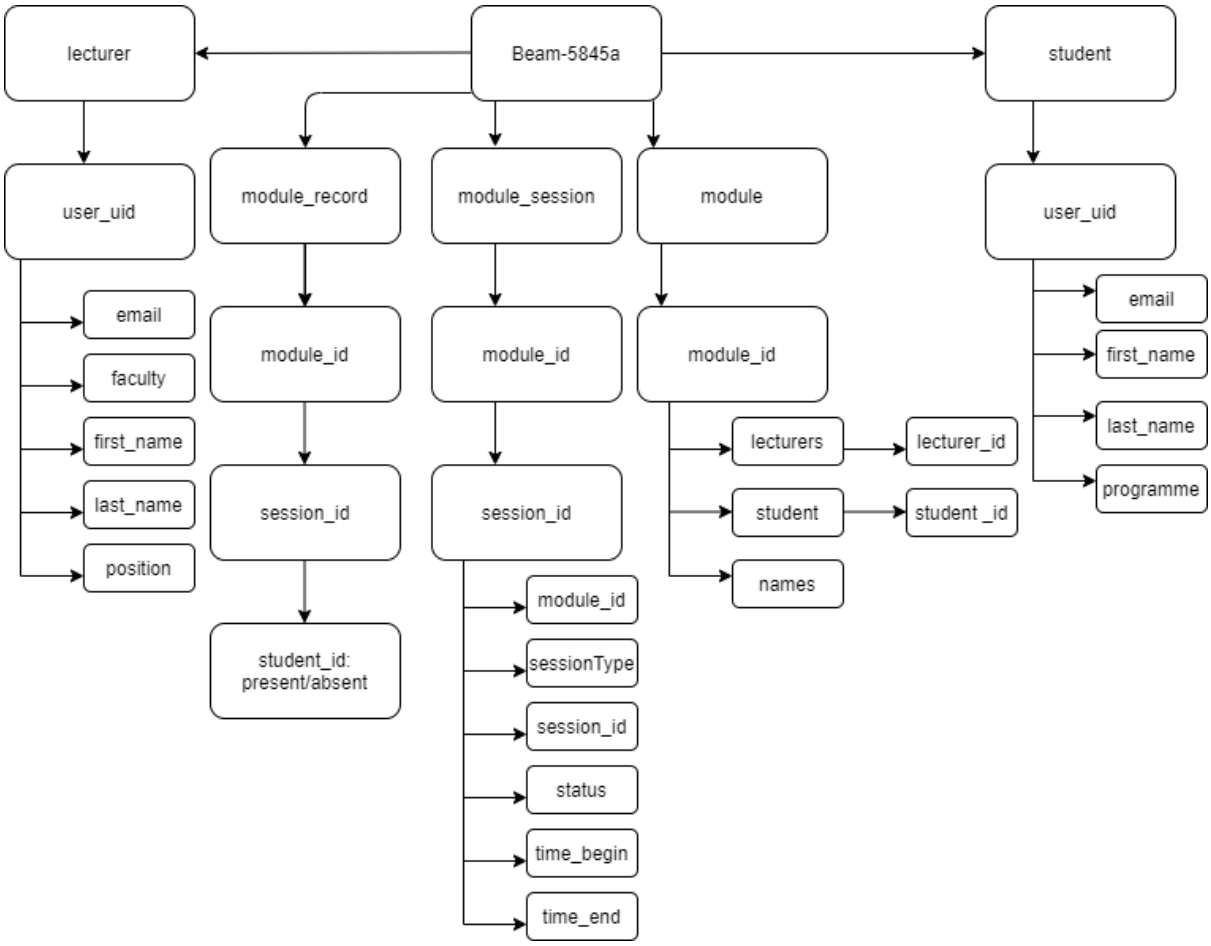


Figure 5.8.1: *Database design part 1*

The *lecturer* node groups the lecturer details by *user_uid*, which will be fetched to populate the profile in the app. The *module_record* node stores the students who attended an academic session by *module_id*. The app will calculate the percentage of students who attended the session. The *module_session* node groups each session by their module. The *module* node groups module details by *module_id*. The *student* node groups the student details by *user_uid*, which will be fetched to populate the profile in the app.

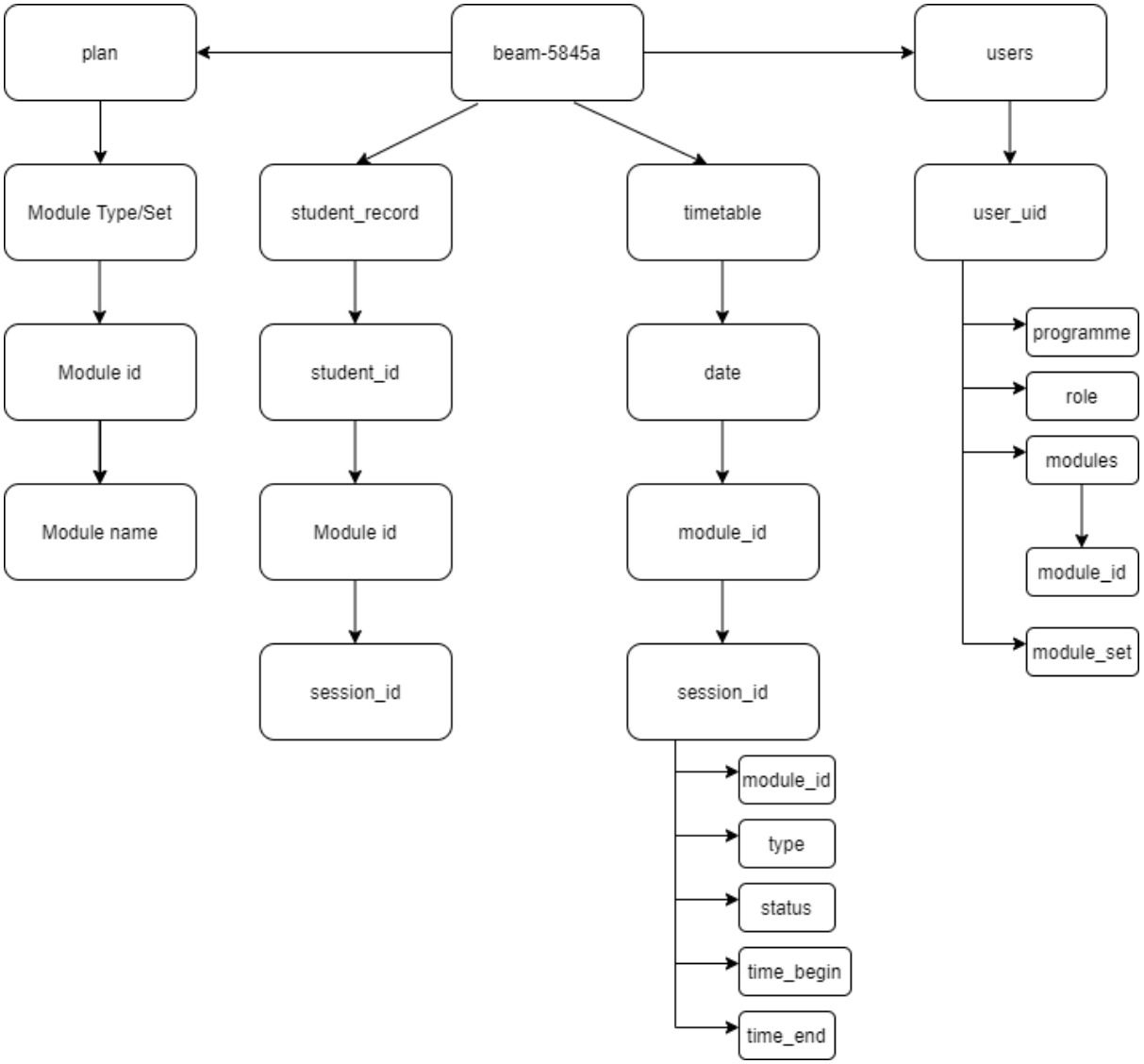


Figure 5.8.2: *Database design part 2*

The *plan* node stores the modules by programme. Modules in a programme are group by module type or set. Module type such as Core and Elective are applicable for students, while module set groups the modules taught by a lecturer. Grouping modules in this way allows the admin to perform only one data entry (by type or set) instead of entering each module one-by-one. The *student_record* node stores all attended academic sessions of a student, grouped by module id. The *timetable* node stores each academic session and its module id for every date when there is an academic session. The *user* node stores important identification details. The *programme* node groups all the modules a student is taking in an academic plan. The *role* node identifies whether a user is a student or lecturer. The *module* set groups all the modules a lecturer is teaching.

6 Testing Methodology

6.1 Website

Selenum WebDriver will be used to run test suites written in Python, which also populate the database of the attendance management system and automate the data entry process, in Microsoft Edge Browser.

```
def login():
    driver.find_element_by_id("email").send_keys("hcyyk1@nottingham.admin")
    driver.find_element_by_id("password").send_keys("123456")
    driver.find_element_by_id("login").click()
```

This function tests the login function on the landing page. The script enters email and password before clicking the login button to submit the user credentials.

```
def student():
    WebDriverWait(driver, 10).until(EC.element_to_be_clickable((By.ID, 'Student
    ')))
    driver.find_element_by_id("Student").click()

    for x in range(10):
        driver.find_element_by_id("fName").send_keys(get_first_name())
        driver.find_element_by_id("lName").send_keys(get_last_name())

        programme = ['Computer Science', 'Business', 'Engineering']
        driver.find_element_by_id("programme").send_keys(random.choice(
    programme))

        driver.find_element_by_id("email").send_keys(random_char(7) + "
    @nottingham.edu.my")
        driver.find_element_by_id("password").send_keys("123456")

        driver.find_element_by_id("submit").click()
```

This function registers 10 student accounts. It waits for the student tab to become clickable before clicking it. The script will enter the first name, last name, choose the student's programme randomly, enter email and password, and submit all details, for 10 times.

```
def lecturer():
    WebDriverWait(driver, 10).until(EC.element_to_be_clickable((By.ID, '
    Lecturer')))
    driver.find_element_by_id("Lecturer").click()

    for x in range(10):
        driver.find_element_by_id("LfName").send_keys(get_first_name())
        driver.find_element_by_id("LlName").send_keys(get_last_name())

        select_pos = Select(driver.find_element_by_id('position'))
        position = ['Assistant Professor', 'Associate Professor', 'Professor']
        select_pos.select_by_value(random.choice(position))

        select_fac = Select(driver.find_element_by_id('faculty'))
        faculty = ['Computer Science', 'Business', 'Engineering']
        select_fac.select_by_value(random.choice(faculty))

        module_set = ['Set1', 'Set2']
        driver.find_element_by_id("set").send_keys(random.choice(module_set))

        driver.find_element_by_id("Lemail").send_keys(random_char(7) + "
    @nottingham.edu.my")
        driver.find_element_by_id("Lpassword").send_keys("123456")
```

```
22
23          driver.find_element_by_id("Lsubmit").click()
```

This function registers 10 lecturer accounts. It waits for the lecturer tab to become clickable before clicking it. The script will enter the first name, last name, choose the lecturer's position randomly choose the lecturer's faculty randomly, choose the lecturer's taught module set randomly, enter email and password, and submit all details, for 10 times.

```
def module():
    WebDriverWait(driver, 10).until(EC.element_to_be_clickable((By.ID, 'Module'
    )))
    driver.find_element_by_id("Module").click()
    module_codes1 = ["COMP1001", "COMP1002", "COMP1003", "COMP1004"]
    module_codes2 = ["BSC1001", "BSC1002", "BSC1003", "BSC1004"]
    module_codes3 = ["ENG1001", "ENG1002", "ENG1003", "ENG1004"]
    module_names1 = ["Computer Fundamentals", "Software Engineering", "Discrete
     Maths", "Software Maintenance"]
    module_names2 = ["Business Communication", "Leadership", "Business
    Principles", "Business Writing"]
    module_names3 = ["Thermodynamics", "Natural Mechanics", "Electricity", "
    Computer Skills"]
    module_selector("Computer Science", module_names1, module_codes1)
    module_selector("Business", module_names2, module_codes2)
    module_selector("Engineering", module_names3, module_codes3)
```

This function adds modules to the database. It waits for the module tab to become clickable before clicking it. The code snippet above contains all the module codes and names that will be entered on the website. The *module_selector* function will send the module details to the database, as shown below.

```
def module_selector(plan, modules, module_code):
    for n in range(4):
        driver.find_element_by_id("mID").send_keys(module_code[n])

        driver.find_element_by_id("mName").send_keys(modules[n])

        driver.find_element_by_id("mPlan").send_keys(plan)

        select_type = Select(driver.find_element_by_id('moduleType'))
        module_type = ['Core', 'Elective']
        select_type.select_by_value(module_type[0])

        module_set = ['Set1', 'Set2']
        driver.find_element_by_id("mSet").send_keys(random.choice(module_set))

        driver.find_element_by_id("Add").click()
```

The function above sends the module id, module name, the programme of the module (plan), chooses the module type for the students (in this case all modules are 'Core', choose s the module set for the lecturers, and submit all the details.

```
def timetable():
    date = 20210401
    WebDriverWait(driver, 10).until(EC.element_to_be_clickable((By.ID, '
    Timetable')))
    driver.find_element_by_id("Timetable").click()
    module_codes1 = ["COMP1001", "COMP1002", "COMP1003", "COMP1004"]
    module_codes2 = ["BSC1001", "BSC1002", "BSC1003", "BSC1004"]
    module_codes3 = ["ENG1001", "ENG1002", "ENG1003", "ENG1004"]
    for x in range(5):
        timetable_selector(module_codes1, date)
        timetable_selector(module_codes2, date)
        timetable_selector(module_codes3, date)
        date += 1
```

This function updates the timetable on the database. It waits for the timetable tab to become clickable before clicking it. The code snippet above contains all the module codes that represents. The *module_selector* function will send the module details to the database, as shown below, for 5 days: April 1st 2021 to April 5th 2021.

```
def timetable_selector(codes, date):
    for x in range(4):
        date_entry = str(date)
        driver.find_element_by_id("date").send_keys(date_entry)

        driver.find_element_by_id("module_id").send_keys(codes[x])

        session_type = ["Lecture", "Tutorial", "Lab"]
        driver.find_element_by_id("sessionType").send_keys(random.choice(
    session_type))

        driver.find_element_by_id("status").send_keys("Closed")

        if x < 2:
            time = ["0900", "1100", "1300"]
            driver.find_element_by_id("time_begin").send_keys(time[x])
            driver.find_element_by_id("time_end").send_keys(time[x + 1])
        else:
            time = ["1400", "1600", "1800"]
            driver.find_element_by_id("time_begin").send_keys(time[x - 2])
            driver.find_element_by_id("time_end").send_keys(time[x + 1 - 2])

        driver.find_element_by_id("Tsubmit").click()
        x += 1
```

This function enters the date, module id, chooses session type randomly, session status, time of each sessions, 4 in a day (0900-1100, 1100-1300, 1400-1600, 1600-1800) and submit the details.

```
def logout():
    WebDriverWait(driver, 10).until(EC.element_to_be_clickable((By.ID, 'logout'
    )))
    driver.find_element_by_id("logout").click()
```

This function logs out the user from the website, after clicking the 'Logout' buton.

6.2 Application

Application testing was conducted in two different ways, testing via emulators and manual device testing using real devices. For functionalities such as the UI functionality and fetching from the Firebase Database, testing was done using emulators provided by Android Studio. For the UI, a test suite was created where each possible user action and its corresponding application response was tested. For database functionality, manual testing was conducted whereby data was inputted into the database (via the website), and the applications ability to fetch data and populate the UI was tested.

Regarding the testing of the attendance taking functionality, real life testing was conducted using a minimum of 2 Android devices. Attendance taking relies on Android background services and Bluetooth Low Energy connections between devices. Real life testing was conducted because Bluetooth is not available on emulators so physical devices must be used.

Regarding Android background services, testing was done by monitoring notifications posted by the app to the user. If the specific notification for the service was posted, the app's background services were functioning normally. A test suite was created for the scheduled background services where we monitored notifications to determine whether tests passed or failed. We tested whether the services started within the correct time frame and whether subsequent services were started.

A test suite was also created for app's Bluetooth functionality. There were some issues that occurred during testing. To monitor connections using Bluetooth Low Energy, Toast messages were used to monitor the connection state, devices scanned, and Bluetooth services discovered. However, Toast messages were an unreliable method for monitoring tests as not all Toast messages were displayed despite the app functioning properly. To solve this issue, tests were instead monitored using changes to the database. All Toast messages used for testing were converted to updates/writes to the database. By monitoring the database, we could see whether the Bluetooth functionality was working as expected.

7 Implementation Results

7.1 Website

7.1.1 Login Screen: index.html

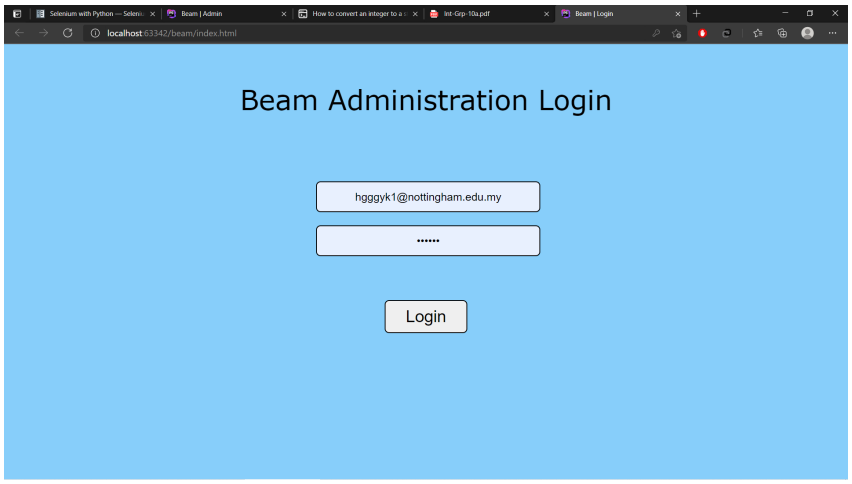


Figure 7.1.1: *Login interface of the website*

The login interface comprises of a title – Beam Administration Login, an input field for email, and an input field for password. Upon clicking to the login button, the *login()* function will be executed, as shown below.

```
function login(){
    var email = document.getElementById("email");
    var password = document.getElementById("password");
    const promise = auth.signInWithEmailAndPassword(email.value, password.value
    );
    promise.catch(e => alert(e.message));
}

auth.onAuthStateChanged(user => {
    if(user) {
        window.location.href = 'home.html';
    }
});
auth.setPersistence(firebase.auth.Auth.Persistence.SESSION).then(function() {
    return auth.signInWithEmailAndPassword(email, password);
});
```

The *login* function takes the email and password entered by the user and sends a promise to Firebase Authentication to check the login credentials. If the credentials are valid, the authentication state will be changed because of a successful user account login and the user will be redirected to *home.html*. The user will remain logged in unless the account is logged out or the user switched to a new tab or window. The state of being logged in will only persist in the current tab or session, and it will be cleared of the tab or window is closed.

```
function logOut(){
    firebase.auth().signOut();
    window.location.href = 'index.html';
}
var user = firebase.auth().currentUser;
firebase.auth().onAuthStateChanged(function(user) {
```

```
    if (user) {
        // User is signed in.
    } else {
        window.location.href = 'index.html';
    }
});
```

The *logOut* function logs the user out from the account and redirects the user back to the login page. If the user accesses the home page without going through the login page, the system will check if the user has logged in on Firebase Authentication. If not, the user will be redirected to the login page. The user will remain on the home page if Firebase Authentication detects that the user has performed a successful login.

7.1.2 Home Screen: home.html

a. Home Component

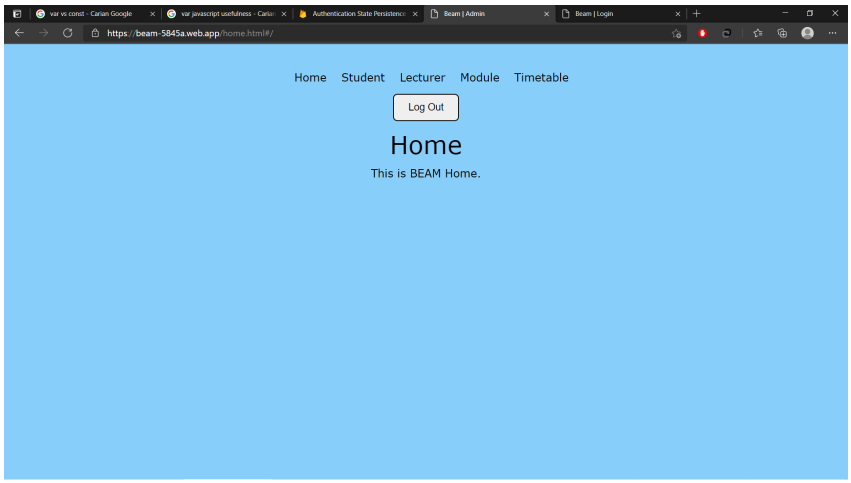


Figure 7.1.2: *This is the Home interface of the website. Note that it changed to any important announcement from the university*

```
var routes = [
    { path: '/', component: Home},
    { path: '/student', component: Student },
    { path: '/lecturer', component: Lecturer },
    { path: '/modules', component: Modules },
    { path: '/plan', component: Plan },
    { path: '/timetable', component: Timetable },
    { path: '', redirect: '/' },
];

var router = new VueRouter({
    routes: routes,
    mode: 'hash',
    base: '/'
});

var app = new Vue({
    el: '#app',
    router: router,
})
```

This home page is a *single-page application (SPA)* that contains all the features needed for the admin to enter data into the database. Vue.js functions are imported using CDN and used

to enable us to build a *SPA*. This Vue.js *SPA* is created in a * * with an id of *app* with a *router* to link each tab of the navigation with a path. The router will load the contents of each tab in *hash* mode, which means # is used before the navigation path is passed internally. Since this section of the URL is not sent to the server, no special treatment is required on the server level.

The code above directs each path to a component. Every component is an x-template, where the html elements (front-end) of a template in stored in a *<script>* tag in a HTML file. The router will redirect the tabs to their respective template.

b. Student Component

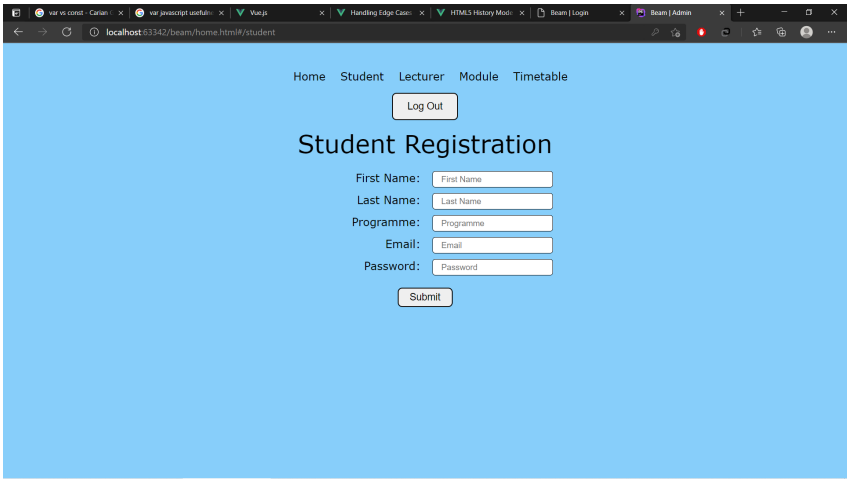


Figure 7.1.3: *This is the Student Registration interface of the website*

```
1   firebase.auth().createUserWithEmailAndPassword(email, password).then((
    userCredential) => {
2       var userUid = userCredential.user.uid;
3       var student = {
4           FirstName: fName,
5           LastName: lName,
6           Programme: programme,
7           Email: email
8       };
9       firebase.database().ref("student/" + userUid).set(student).catch(e =>
    alert(e.message));
10      var userRole = {
11          Programme: programme,
12          Role: "Student"
13      }
14      firebase.database().ref("users/" + userUid).set(userRole).catch(e =>
    alert(e.message));
15      var key = firebase.database().ref("plan/" + userRole.Programme);
16      var children = key.child("Core");
17      children.once('value', (snapshot) => {
18          snapshot.forEach((child) => {
19              firebase.database().ref("users/" + userUid + "/modules").push(
    child.key).catch(e => alert(e.message));
20              firebase.database().ref("modules/" + child.key + "/students").
    push(userUid).catch(e => alert(e.message));
21          });
22      });
23  }).catch(e => alert(e.message));
```

When the *email* and *password* are sent to Firebase Authentication to create a new account for the student, the *first name*, *last name*, *programme*, and *email*, are entered under the *student* node and grouped by the student account's *user uid*. Under the *users* node, the role of the account (Student) and the *programme* are entered, grouped by *user uid*. With the programme name, the system will fetch all the *module ids* of the core modules of the *programme* and store them in the *modules* node under *user uid* node, which is also under *users* node. The system will also register the *user uid* of the students under *students* node of each *modules* node.

c. Lecturer Component

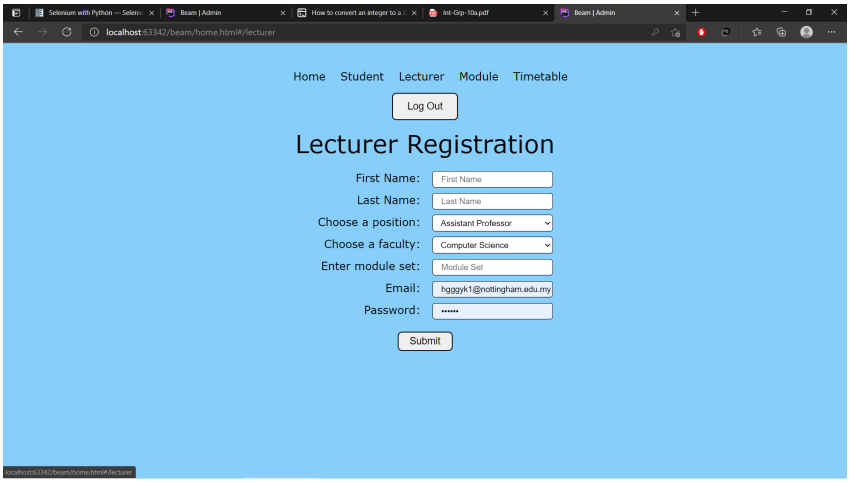


Figure 7.1.4: *This is the Lecturer Registration interface of the website*

```
firebase.auth().createUserWithEmailAndPassword(email, password).then((userCredential) => {
    var userUid = userCredential.user.uid;
    var lecturer = {
        FirstName: fName,
        LastName: lName,
        Position: position,
        Faculty: faculty,
        Email: email
    };
    firebase.database().ref("lecturer/" + userUid).set(lecturer).catch(e => alert(e.message));
    var userRole = {
        Role: "Lecturer",
        set: set,
        Programme: faculty
    }
    firebase.database().ref("users/" + userUid).set(userRole).catch(e => alert(e.message));
    var key = firebase.database().ref("plan/" + userRole.Programme);
    var children = key.child(userRole.set);
    children.once('value', (snapshot) => {
        snapshot.forEach((child) => {
            firebase.database().ref("users/" + userUid + "/modules").push(child.key).catch(e => alert(e.message));
            firebase.database().ref("modules/" + child.key + "/lecturer").push(userUid).catch(e => alert(e.message));
        });
    });
}).catch(e => alert(e.message));
```

When the *email* and *password* are sent to Firebase Authentication to create a new account for the lecturer, the *first name*, *last name*, *position*, *faculty* and *email*, are entered under the *lecturer* node and grouped by the lecturer account's *user uid*. Under the *users* node, the role of the account (Lecturer), module set and the *programme* are entered, grouped by *user uid*. With the programme name, the system will fetch all the *module ids* of the modules under the module *set* selected and store them in the *modules* node under *user uid* node, which is also under *users* node. The system will also register the user uid of the lecturers under *lecturers* node of each *modules* node.

d. Module Component

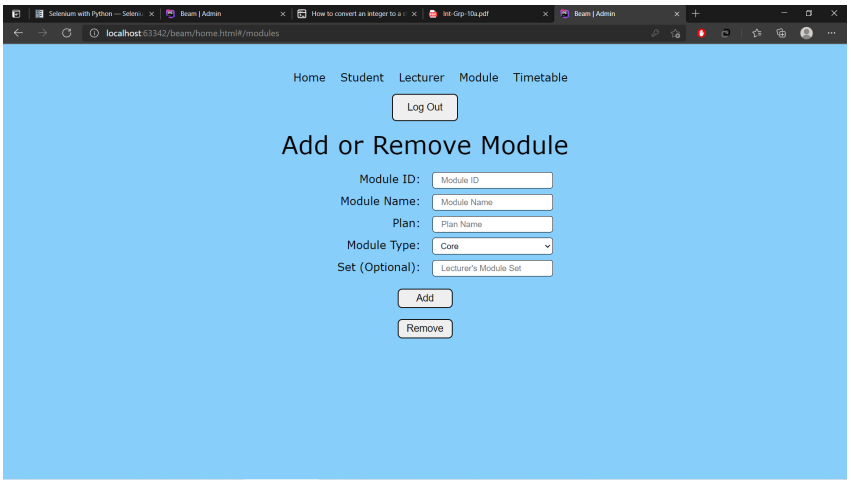


Figure 7.1.5: *This is the Add or Remove Module interface of the website*

```
function writeModulesData() {
    var mID = document.getElementById("mID").value;
    var mName = document.getElementById("mName").value;
    var mPlan = document.getElementById("mPlan").value;
    var moduleType = document.getElementById("moduleType").value;
    var mSet = document.getElementById("mSet").value;
    if (mID === "" || mName === "" || mPlan === "" || moduleType === "") {
        alert("Please fill in all fields");
        return false;
    }
    var modules = {
        name: mName
    }
    firebase.database().ref("modules/" + mID).set(modules).catch(e => alert(e.
    message));
    firebase.database().ref("plan/" + mPlan + "/" + moduleType + "/" + mID).set
    (modules).catch(e => alert(e.message));
    if (!(mSet ===""")){
        firebase.database().ref("plan/" + mPlan + "/" + mSet + "/" + mID).set(
    modules).catch(e => alert(e.message));
    }
    document.getElementById("mID").value = '';
    document.getElementById("mName").value = '';
    document.getElementById("mPlan").value = '';
    document.getElementById("moduleType").value = '';
    document.getElementById("mSet").value = '';
};
```

To add module details to the database, the system will enter the *module names* under the *module id*, which is under the *modules* node. By the names of the *academic plan* which the

modules fall under, the *modules ids* of these *modules*, grouped by *module type*, will be placed under the *plan name*, which is under the *plan* node. For the modules taught by a lecturer, the *module ids* will be stored under *module set*, under the modules' *plan name*, which is also under the *plan* node.

```
function removeModulesData() {
    var mID = document.getElementById("mID").value;
    var mPlan = document.getElementById("mPlan").value;
    var moduleType = document.getElementById("moduleType").value;
    firebase.database().ref("modules/" + mID).remove().catch(e => alert(e.
    message));
    firebase.database().ref("plan/" + mPlan + "/" + moduleType + "/" + mID).
    remove().catch(e => alert(e.message));
    document.getElementById("mID").value = '';
    document.getElementById("mName").value = '';
    document.getElementById("mPlan").value = '';
    document.getElementById("moduleType").value = '';
    document.getElementById("mSet").value = '';
};
```

To delete module details from the database, fetch the *module id* from the website and query the modules and remove the data under the matched *module id*. The system can remove the same module ids from the database directory: *plan/plan name/module type*.

e. Timetable Component

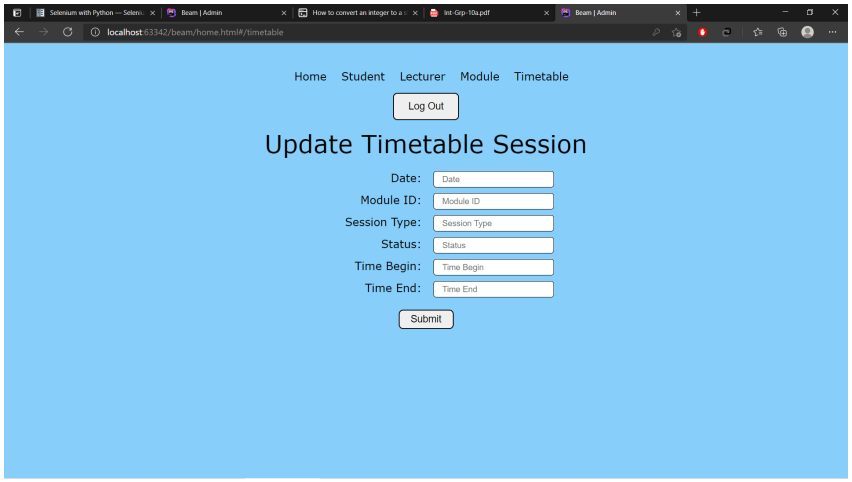


Figure 7.1.6: *This is the Update Timetable Session interface of the website*

```
function writeTimetableData() {
    var date = document.getElementById("date").value;
    var module_id = document.getElementById("module_id").value;
    var sessionType = document.getElementById("sessionType").value;
    var status = document.getElementById("status").value;
    var time_begin = document.getElementById("time_begin").value;
    var time_end = document.getElementById("time_end").value;
    if (date === "" || module_id === "" || sessionType === "" || status === ""
    || time_begin === "" || time_end === "") {
        alert("Please fill in all fields");
        return false;
    }
    var timetable = {
        module_id: module_id,
        session_id: "temp",
        sessionType: sessionType,
```

```
16          status: status,
17          time_begin: time_begin,
18          time_end: time_end
19      };
20      var newRef = firebase.database().ref("timetable/" + date + "/" + timetable.
    module_id ).push();
21      timetable.session_id = newRef.key;
22      newRef.set(timetable).catch(e => alert(e.message));
23      firebase.database().ref("module_session/" + timetable.module_id + "/" +
    newRef.key).set(timetable).catch(e => alert(e.message));
```

The system sends the *date*, *module_id*, *session type*, *session status* (Opened/Closed), *time_begin*, and *time_end* to the database. Under the *timetable* node, the module details will be entered, grouped by the *date*. Under the *modules_session* node, the module details will be entered, grouped by the *module_id*. This groups the sessions of a module under a *module_id*.

7.1.3 Test Results

The changes reflected in the database due to the Python script will be shown below in screenshots

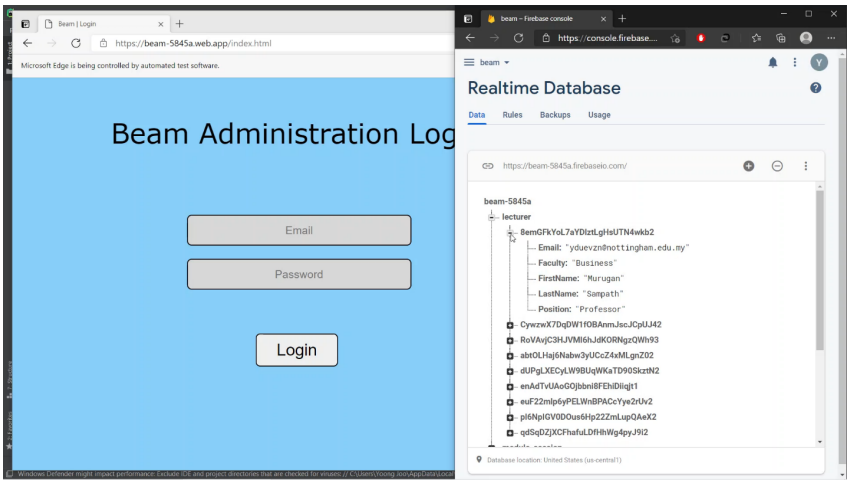


Figure 7.1.7: *Changes made to the lecturer node*

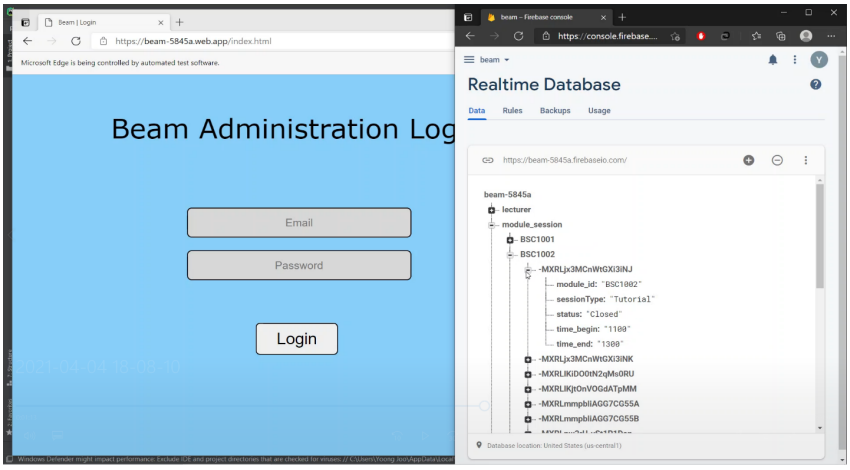


Figure 7.1.8: *Changes made to the module_session node*

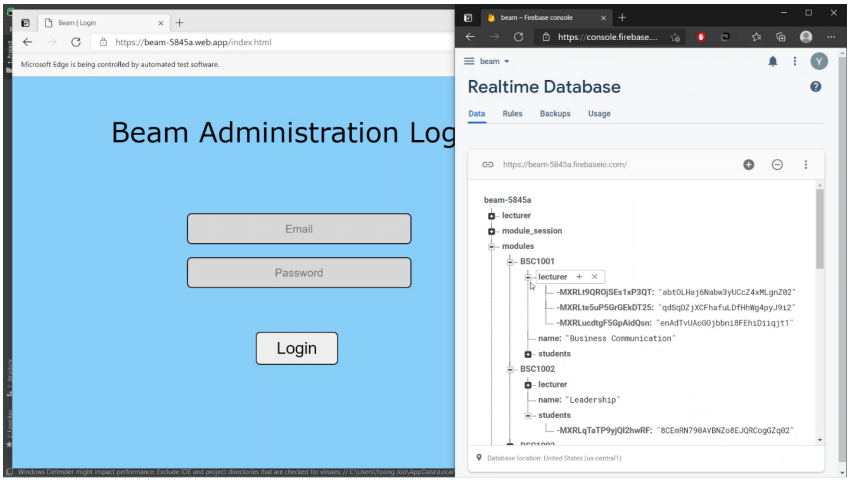


Figure 7.1.9: *Changes made to the modules node*

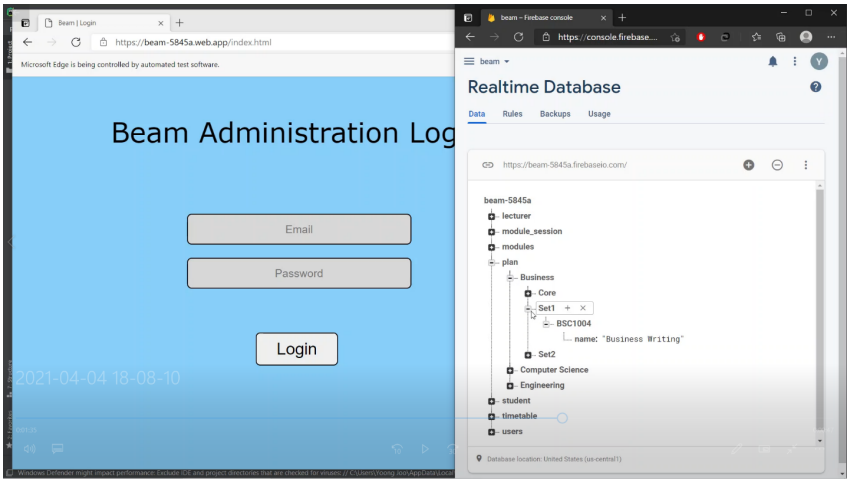


Figure 7.1.10: *Changes made to the plan node*

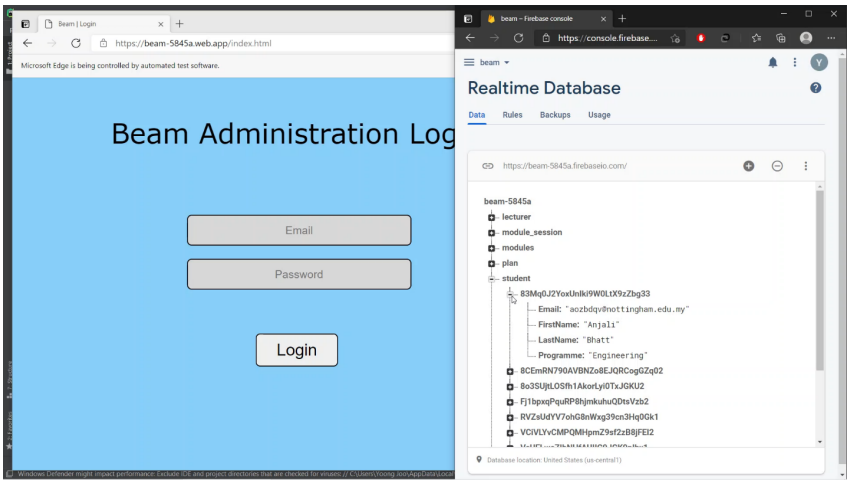


Figure 7.1.11: *Changes made to the student node*

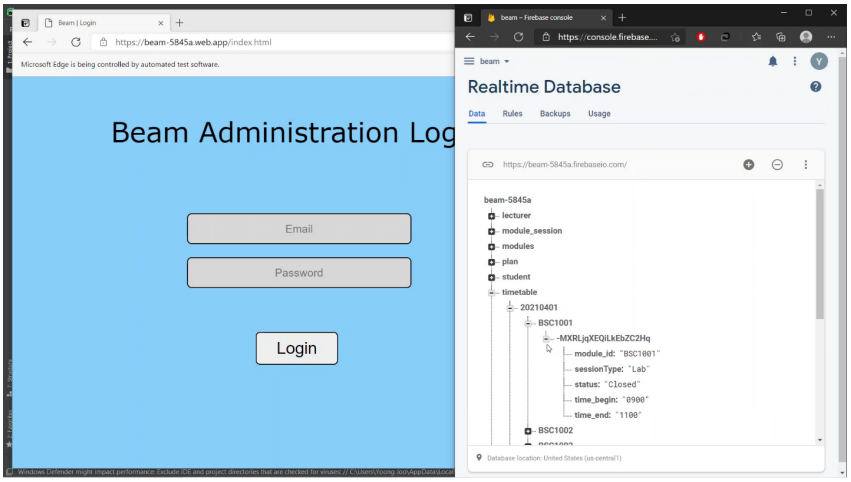


Figure 7.1.12: *Changes made to the timetable node*

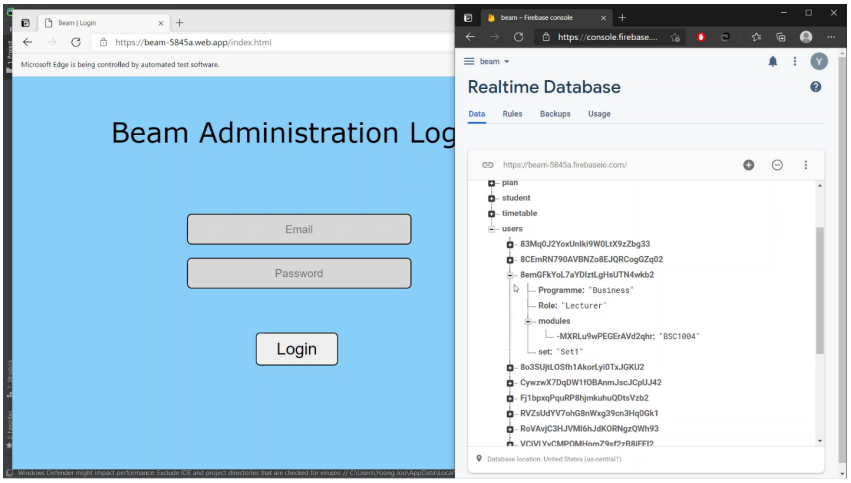


Figure 7.1.13: *Changes made to the users node*

7.2 Application

7.2.1 Overview of Classes

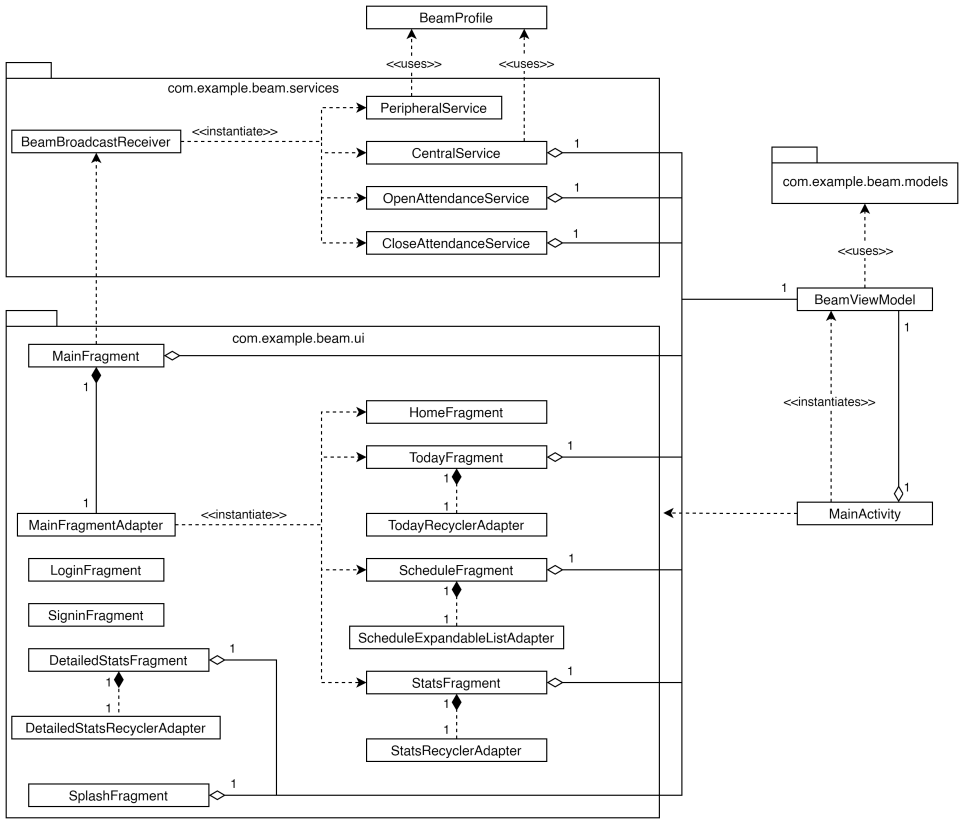


Figure 7.2.1: *Class diagram of custom classes*

The application has many dependencies on external libraries, so the class diagram above only contains relationships between custom classes for the app. The diagram is non-exhaustive and is instead meant to convey how the classes are involved in the 3 different functions of the app: UI, fetching data from the database, and attendance taking.

The *ui* package is self-explanatory in that its main purpose is for the application UI. *BeamViewModel* and classes within the *models* package are responsible for fetching data from the Firebase Realtime Database. Lastly, classes in the *services* package along with *MainFragment* and *BeamProfile* are responsible for the attendance taking functionality.

7.2.2 Splash Screen

7.2.3 Login Screen

```
1  private void login(){
2      String username = emailEditText.getText().toString().trim();
3      String password = passwordEditText.getText().toString().trim();
4      if(TextUtils.isEmpty(username)  TextUtils.isEmpty(password)) {
5          Toast.makeText(getContext(), Email and password required, Toast.
       LENGTH_SHORT).show();
6      }
7      else {
8          mAuth.signInWithEmailAndPassword(username, password).
       addOnCompleteListener(new OnCompleteListenerAuthResult() {
9              @Override
10             public void onComplete(@NonNull TaskAuthResult task) {
```

```
                if (task.isSuccessful()) {
                    NavHostFragment.findNavController(LoginFragment.this).
    popBackStack();
                }
                else {
                    Toast.makeText(getContext(), Error  + task.getException(),
    Toast.LENGTH_SHORT).show();
                }
            }
        });
    }
}
```

The login function gets the user input of email and password from the app and trim the input to remove whitespace from both sides of a string. It will send out an alert to the user if the user doesn't enter email or password before submitting. If the login is successful verified by Firebase Authentication, the user will be redirected to the Home Screen. If not, the function sends an alert which state the login error.

7.2.4 Home Screen

The home screen (implemented as *MainFragment*) is the "start destination" which the user arrives at first. However, if there is no authentication state or on first load of the app, the user is redirected to the splash screen. The home screen contains a *ViewPager2* that consists of 4 fragments: *HomeFragment*, *TodayFragment*, *ScheduleFragment*, and *StatsFragment*. These fragments can be accessed by swiping on the screen. *HomeFragment* just contains a rippling animation and no functionality.

TodayFragment utilises a *RecyclerView* to display the sessions of the day in a list. The data is fetched using an instance of *BeamViewModel* and the list of sessions is passed to the *TodayRecyclerAdapter* to populate the *RecyclerView*. *TodayRecyclerAdapter* inflates a layout for each row of the list and creates as many rows as needed.

ScheduleFragment utilises an *ExpandableListView* to display a multi-level list. The first level consists of 7 rows, one for each day of the week. Each row can be expanded into a second level that displays the sessions of the particular day. Data is fetched using an instance of *BeamViewModel* and the weekly timetable is passed to *ScheduleExpandableListAdapter* which is responsible for inflating a layout for each row of the multi-level list.

StatsFragment utilises a *RecyclerView* to display the attendance statistics of each module. Data of the student's attendance history is fetched via an instance of *BeamViewModel* and is passed to an instance of *StatsRecylerAdapter*. *StatsRecyclerAdapter* inflates layouts for each row and calculates the attendance percentage for each module.

7.2.5 Settings Screen

```
MaterialButton logoutButton = view.findViewById(R.id.settings_button_logout);
logoutButton.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View view) {
        FirebaseAuth.getInstance().signOut();
        NavHostFragment.findNavController(SettingsFragment.this).popBackStack()
    ;
    }
});
```

The settings screen (implemented by *SettingsFragment*) contains a single button for logging out. When pressed, the user's authentication state is deleted, and the user is redirected to the home screen. Due to lack of authentication state, the user is again redirected to the login screen.

7.2.6 Data Fetching Classes

The application has integrated google firebase within its code with specified ID, connecting it to the database. When the app first started, it will initialize its connection with the database, which is needed to send and receive data. The classes responsible for fetching data are those within the *models* package and the *BeamViewModel* class. The classes within *models* package are used to store data fetched from the database. When there is data to be collected, the app will request from the database, then it will create new objects (instances of classes in *models* package) to store the data. The main fetching of data is handled by *BeamViewModel*.

BeamViewModel extends Android's *ViewModel* and contains several *MutalbleLiveData* instances from which other classes (within the app) may observe changes in. Instances of *BeamViewModel* are unique to each Android *Activity*. The data stored includes user details, weekly timetable, attendance history, and enrolled modules. The class uses Firebase's *ValueEventListeners* to "listen" to changes in certain parts of the database.

7.2.7 BLE Services and Related Classes

The main attendance taking functionality is mainly handled by the classes declared in the services package except for *MainFragment* and *BeamProfile*.

BeamProfile describes the custom GATT profile which the app uses. The profile is exactly as described in Section 5.1. The class defines constants for UUIDs of the service, characteristics, and descriptors.

MainFragment in the *ui* package is responsible for scheduling alarms for each session during the day. On arrival at the *MainFragment*, the class schedules alarms (for upcoming sessions in the day) to broadcast the start of the BLE services. The broadcasts contain an Android *Intent* with extras (additional data) of request codes (of which service to start/stop), module ID, and session ID of the session taking place. The *BeamBroadcastReceiver* class receives the broadcasts (at the start of a session) and depending on the request codes, either begins a service for taking attendance or opening attendance. An *Intent* is passed to these services containing the extras of module ID and session ID. This is used as the attendance token (a concatenation of module ID and session ID).

There are 4 services declared for this app. The first is *CentralService* which is the service responsible for taking a student's attendance. The *CentralService* periodically scans for BLE devices that are advertising the *BeamProfile*. Once it detects a device, it stops scanning and attempts to connect with the device. It reads the attendance token from the device and compares with one it formed from the *Intent*. If it is a match, the service updates the attendance records in the database, notifies the user that attendance is taken, and starts the *PeripheralService*.

The *PeripheralService* is responsible for advertising the *BeamProfile* and allowing other devices to read the attendance token. The service "sends out" the attendance tokens for a certain time period. If no connections were made to any devices within that time period, the service automatically stops. If a connection is made, the service will refresh the timer for stopping the service.

The *OpenAttendanceService* is started only by lecturers' devices and responsible for updating attendance records in the database. For the session, the service initially sets the attendance for each student in the module as false. The service also updates the status of the session to "Open" in the database. The service then starts the *PeripheralService* and passes the module ID and service ID through an *Intent*. The *CloseAttendanceService* updates the status of the session to "Closed" in the database. This is scheduled to run at the end of a session.

7.2.8 Test Results

Regarding application UI, all tests in the UI test suite passed. Swiping between screens, pressing buttons, and back navigation worked as intended.

Regarding attendance taking functionality, most of the tests passed. The starting of scheduled background services at specific time windows functioned as intended. The test for advertising of the attendance by the initial peripheral device passed. Tests for initial and subsequent scans for BLE capable devices by the central device passed. BLE connection between peripheral and central devices along with writing attendance to the database functioned as intended. The only test to fail is the switching from central role to a peripheral role in the initial central device. After receiving the attendance token, the central device (now switching to a peripheral role) failed to start advertising the Beam Service UUID. This test failed on one device and passed on another device. However, the test did not consistently fail. A possible explanation is variations between Bluetooth components of the two devices. This is only speculation and has not been confirmed.

8 Conclusion

8.1 Summary of Achievements

We are proud to note that we have successfully managed to complete, run and test our application according to our stated user and functional requirements. According to our requirements, the app takes the log in information of the student or lecturer, opens the student mode or the lecturer mode of the BEAM app, then allows the user to take attendance automatically when the lecturer sends the attendance token, then the student device takes attendance and sends out an attendance token itself in a Waterfall system until no more devices with that timeslot are checked for in the area. Relevant notifications are sent to the lecturer and to the student:

i. Lecturer

- Opening Attendance
- Advertising Tokens for MODULE_CODE
- Closing Attendance

ii. Student

- Taking Attendance
- Attendance Taken
- Advertising Tokens for MODULE_CODE

For the display and navigation requirements, the students can see their relevant daily timetables when they swipe right on the main screen, if they swipe right again, they can see their weekly timetables and if they swipe right again they can see their attendance records successfully. There is also a log out button that allows users to log out. Only one user may use the phone to log in and register for a class, it does not allow the attendance token to take the attendance of multiple accounts, thereby limiting the amount of cheating currently done by students with attendance during class.

The lecturer on the other hand can schedule background services for opening and closing attendance for a set amount of time for each of their relevant classes. Their timetables can be seen same as the students displays above. By clicking a row containing a session, the lecturer can see the statistics of attendance of the session.

Of course, in the background, we have a stable and safe firebase database running as a data and information server for our attendance taking app. This Firebase Database has the relevant information for all the classes, timetables and attendance records. The records are successfully updated, retrieved and maintained according to the requirements of our app. The firebase database also acts as a maintenance tool for the record keepers of the university in order to keep updated lecturer and student personnel files, their subjects for the semester and their attendance records of their years in the University. It also has SQL features that can be accessed for data online. All data can be manipulated, including attendance records (for emergency sake) but the database can only be accessed by authorised personnel.

8.2 Future Developments

The application we have created is not perfect by far, therefore there will be new features and improvements added in the future. Integration to the Nottingham's database is also required for this application to be functionally used as well as development for iOS devices. Due to time restrictions, there are also some features that we have considered adding, however, unable to, such as implementation of AndroidX and Junit testing. As of the future development of the

application, many features have been implemented such as a cloud database messaging to start services, incorporating RSSI to measure distance between devices, allowing manual attendance taking and integrating the administrator's website with the Nottingham's administrator website. Finally, there is a feature that is being considered, which is the installation of an infrared device in each class to track student's physical presence, however, this requires cooperation from the University of Nottingham for it to be successful.

9 Reflective Comments

10 Appendix

11 References

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