TrackMate: Real-Time Public Transport Locator

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FINAL YEAR DESIGN PROJECT REPORT

This Report Presented in Partial Fulfillment of the Requirements for the **Degree of Bachelor of Science in Computer Science and Engineering**

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APPROVAL

This Project titled **"TrackMate: Real-Time Public Transport Locator"**, submitted by **Jahirul Islam (213-15-4266)** and **Md Abdullah Al Mazed (213-15-4478)** to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on **16 September, 2025**.

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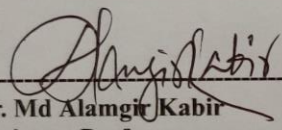

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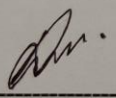

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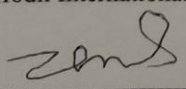

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DECLARATION

We hereby declare that this project has been done by us under the supervision of **Mushfiqur Rahman, Assistant Professor,** Department of Computer Science and Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Even individuals that stop at transit points have significant difficulties in transportation coordination. The reason behind this is that they are not aware of any time of arrival of vehicles and thereby end up spending a long time waiting hence making poor plans on the trips. To create a real-time way to track vehicle locations by being a volunteer user. This project presents a flutter and dart-written application called TrackMate, which assists in creating a cooperation-based transportation network by allowing travelers to exchange the details of their trip: the type of vehicle, the route, the expected arrival time. Sharing in the system can be increased in two ways; private tracking which will only reveal itself to an auto-generated passkey readable by a limited number of people and public sharing which anyone can read [5]. The application takes advantage of Google Maps API to provide correct GPS position indications and display the route. It also supports a variety of other modes of transport, including some buses, trains, planes, and even water launches [1].Most users find it easy to employ with both track viewers and location sharers having easy access to the program. Inter-platform capability with Flutter framework due to the fact that some features it has are crucial, real-time updating of the location through GPS, [1], calculating the expected arrival time, [2], and early sharing termination control. These features reduce unnecessary time wastefulness at transit stations and enable the users to make informed choices regarding the time to take off. Results of its implementation indicate that it is able to locate things in real-time, decode GPS coordinates precise, come up with secure passkeys and trans-synchronize data among multiple users [5]. This system ensures that the user has the ability to control location-sharing preferences, scalability and privacy of the information (9). TrackMate is eventually very supportive to making people experience sustainable mobility because they reduce artless waiting, reduce the waiting time of passengers and encourage community-initiated solutions.

Keywords: Mobile Application, Real-time Tracking, Transportation Management, Flutter Development, GPS Integration, Location Sharing, Voluntary Participation, Cross-platform Development.

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Chapter 1

Introduction

1.1 Introduction

In this day and era of fast steps taken, the availability of the right and updated availability of transport information is, therefore, pertinent in the process of boosting ease and efficiency in travelling [7]. But in the case of many people, in developing regions in particular, access to real-time updates of the vehicle location is frequently slow or untrustworthy. TrackMate is planned to fulfill this need by providing an easy solution but with a powerful technology when watching the position of people from a bus, train, or ferry with an aircraft that is not mandatory but will help people by sharing their live position [3].

It works on the principle of community involvement, a traveler must share their live location, people can make plans according to that, and it is possible to monitor the vehicle in real time as well. That does not only make commuting more foreseeable but also decreases the nonessential was layer ship and problems that come as a result of that. TrackMate was developed on Flutter as a platform allowing cross-platform functions: therefore, it ensures the unrestricted access to the information and its exchange between Android devices [10].

1.2 Motivation

The TrackMate concept has its origins in the struggle anyone would feel on a daily basis about being unaware of the specific time when a specific mode of transportation is coming or when it is going. The problem is that a lot of people are wasting hours because they are at the airport, waiting because they do not have access to an online tracking system [7].

In most developing states, the transport companies might not be able to deploy the use of GPS in their fleets. This puts the passengers under minimal or no real-time information on their trip. As smartphones become increasingly popular [10], an untapped opportunity to use the devices as location sharers exists [2].

TrackMate is driven by the concept of collective participation to provide a solution to a common problem. When one out of every few passengers he or she traveling provides his or her live position this would be scarce to the advantage of tens or dozens of other passengers; lived to be passively updated or given accurate and real time information on their whereabouts without any infrastructure costs incurred by those running transport infrastructures [1].

1.3 Objectives

The main goal of TrackMate is to offer passengers real-time location information in the most accurate way possible about different types of transport so that they could better plan their travels.
Certain goals are:

- Live location sharing of buses, trains, ferries and planes by their passengers (voluntary location sharing).
- Cross-platform interoperable with Flutter framework to make it accessible on all Android devices.
- Connection with Google Maps API to visualize routes, approximate arrival time and convenient navigation.
- User-friendly design to offer an easy user-friendly interface to both the sharers and the viewers of the location.
- Privacy and control of data, where users control the access to their shared location.
- Scalability to accommodate many concurrent users without affecting the performance.

1.4 Methodology

The process of the development of TrackMate was based on a systematic program combining both knowledge and practice. The second stage is the methodology, which is in turn broken down into several phases, among them the requirement analysis, design, implementation, and the testing. The next level was meticulously implemented so as to make sure that the application is practical, user-friendly and based on its main aim of providing a voluntary real-time tracking of vehicle feature.

Requirement Analysis:

During inception, the requirements collected were based on the observation done of actual transportation issues affecting work-a-day commuters. The absence of available and precise real-time transportation updates in most areas led to an idea to develop an application in which users will themselves provide live locational information. The functional requirements here were as below:

- Choice of transport (Bus, Train, Air, Ferry).
- Sharing of destination in the real-time.
- Finding and monitoring common medical transport in real-time.
- Reproductive controls that allow control of who can access the information shared.

System Design:

The design stage involved the development of a basic, but effective architecture of the app. Flutter was the choice of the development framework because of the cross-platform approach, rapid development cycle, and rich UI orientation. The backend was to be interconnected with a real-time database (like Firebase), that will take feedback on live location sharing and updates. The user interface has received special consideration, being designed to be user-friendly, interactive and easy to use with an absence of technical knowledge.

Implementation:

The application was developed using Flutter and Dart as front-end and Firebase as real time data storage and synchronization in the course of the implementation stage. The application was made Android compatible, and modules are made based on:

- Authentication of the user (logging in and confidentiality access).
- Location services in the sharing and updating of the current coordinates.
- Continuous path transport module to select and show details of vehicle in a line.
- Weaving maps to display vehicle positions in course of action.

Testing and Validation:

The tests were done in various phases where in an initial stage; unit testing of individual modules was done then followed by integration testing of the entire system. Live trials were also conducted through the participation of volunteers who shared their position in the real world during a real adventure. Accuracy, usability, and performance were also the subject of feedback, and the system was optimized on the basis of this feedback.

Deployment and further development:

After being tested the application was now ready to go to Android devices. TrackMate is currently developed as a voluntary system, thus, in the future, it will be enhanced with bigger transport operator features and better privacy selection, as well as provide predictive analytics, with better travel planning.

1.5 Project Outcome

The effective use of TrackMate is supposed to provide the following quantifiable results:

Live Android App - This is a functional Android app that runs on Flutter allowing users to share and track real-time vehicle locations.

Multi-Mode Support - Four transport modes, Bus, Train, Air and Ferry, are tracked.

Intuitive Interface - Easy and user-friendly interface to choose the type of transport, share live and look at vehicle information.

Community-Driven Tracking - This is a service that allows users to volunteer information regarding the places they visit during a journey and share this information publicly without needing extra GPS equipment.

Private Location Sharing - Choice of confidential and limited sharing with friends, family, or individuals of choice.

Real Time Updates - Vehicle positioning information that is accurate and visible to all the authorized viewers.

Less Travel Uncertainty - Assisting commuters to choose their travel better and cut waiting time.

Evidence of Concept - To show that smartphones can be used as much cost efficient replacement of GPS tracking devices.

Scalability - Support to add iOS or other more advanced transport management systems in future.

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1.6 Report Layout

The following project report is be structured as a development of TrackMate: Real-Time Public Transport Locator on conceptual level all the way up until its implementation and is further classified into seven broad chapters sharing cover:

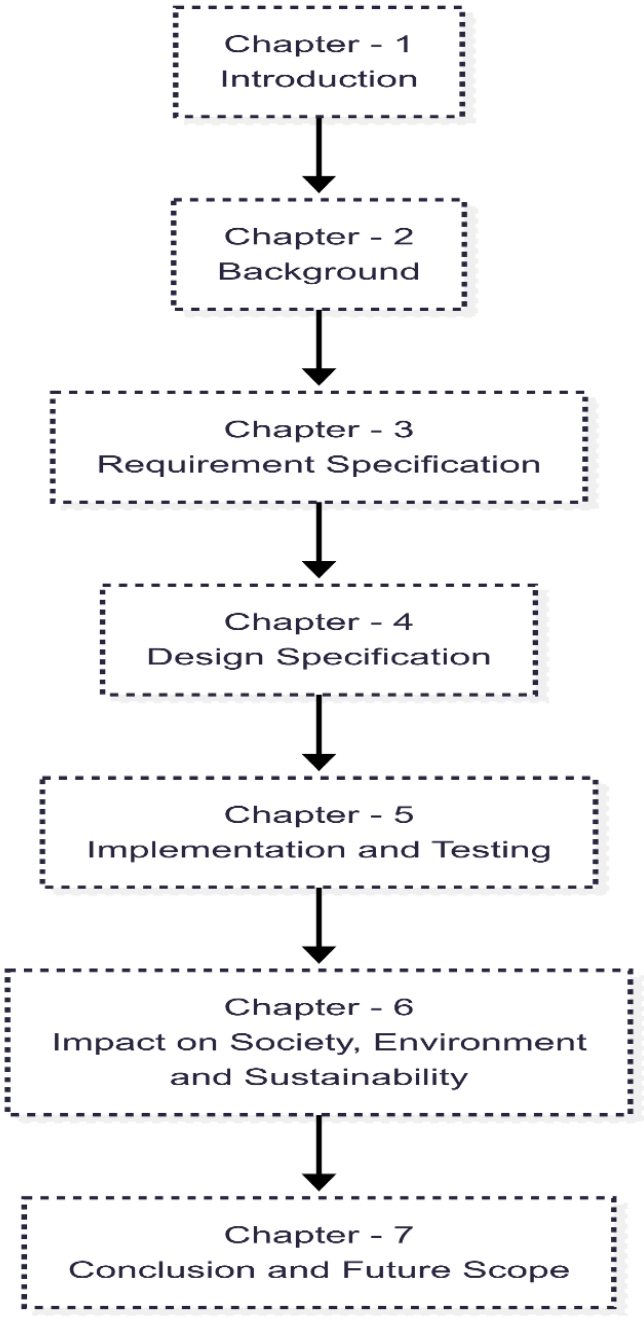


Figure1.6.1: Report Layout of this Project.

Chapter 2

Background

2.1 Terminologies

In order to relate the functionality and importance of the TrackMate application, one has to first formulate some important labels employed within the project:

Real-Time Location Sharing - This is the real-time sharing of current geographic location of a device or user so that it can be viewed on a map by other users as it tracks live.

Transport Modes - Various means of transport or means of transportation that the app could offer such as Bus, Train, Air (aircraft) and Ferry.

Flutter - The Google-developed open-source UI software development kit, designed to develop applications based on the woven code into either natively compiled mobile, web, or desktop applications.

Firebase Real time Database - Google offers a cloud hosted NoSQL database called Firebase Real Time Database which enables users and stores data in real-time and synchronizes it between the devices.

API (Application Programming Interface) - Collection of guidelines and standards with the help of which various software applications interact and communicate with one another [3].

Privacy Controls - Options and privacy methods in the application enabling users to decide which people to share their location and data with and make it secure and confidential sharing [9].

Incremental Development - In software development, incremental development is a method in which the software is planned, created, and debugged until the complex system completes.

GPS (Global Positioning System): A satellite guided navigation, which gives location and time data all over the world. There is the use of smartphone location instead of the conventional GPS devices that are attached to vehicles.

2.2 Literature Review

Real-time transportation information has emerged as an increasingly popular research topic in intelligent transport systems, mobile computing, and crowdsourced data platform research. Although the literature supports the government on the importance of timely location updates to reduce uncertainty in commuters, enhance travel optimization and efficiency of various transport modes [1][2].

A number of others are dedicated to the GPS-based vehicle-tracking systems that are directly mounted in buses, trains or other automobiles. They commonly make use of embedded systems and centralized servers to give location information to the passengers [3]. Although these solutions are effective, they are sometimes expensive and require that the infrastructure be available and maintained by the willingness of transport operators. This has caused a lot of discrepancies in the transportness and dependability in many areas especially in developing nations [4].

Over the past couple of years, the emerging cheaper alternative has become the mobile-based tracking applications. Google Maps, Moovit, Transit App are part of the applications that can provide people with live data on transit [5]. Nevertheless, all of them rely mainly on official collaborations with transportation agencies or towns. That makes it an obstacle in the areas that have a weaker transport organization or are not digitally structured [6].

The second notion of the crowd-sourced location sharing has received its share of literature as well. Research has emphasized that one of the effective means of generating community-based transport can be by voluntarily sharing locations of mobile devices [7]. Applications, such as Waze, have shown that user- contributed data could be very helpful in enhancing navigation and route planning [8]. These applications however are mostly aimed at road traffic and individual cars contrary to large scale transport modes like public transport.

Also, in real-time tracking systems, privacy has been an issue of concern. Indeed, as far as it has been researched, users can appreciate true transport information; however, they are also interested in how their personal location information is used and shared [9]. Privacy-saving measures like sharing not too much and making sharing abilities by users have been suggested to be fundamentals of any tracking system-crowd sourced [10].

In brief, the literature shows that the gaps in the literature endure a complete vacuum in the solutions that are not only cost-effective but can also be relevant to different regions where the level of transport digitization is limited. Although there are structured solutions through GPS based and agency driven platforms, they may not be always available to the general population. Potentially promising concepts of

crowd-sourcing do not take into account multi-modal transportation and privacy requirements. TrackMate fills this gap with My TrackMate providing transport location in real-time, on a voluntary and privacy-conscious mobile application offering through four different modes--bus, train, air, and ferry- which it provides without necessarily relying on a GPS system on the operator side.

2.2.1 Similar Applications

A number of applications are available that provide the functionality of real-time tracking, mainly used in individual sectors of transport:

Google Maps - It is a popular navigation application and map-sharing tool enabling a user to share their current position with the contacts in real time [1]. Nevertheless, it is also intended to primarily be used in a personal navigational mode and social sharing, which does not necessarily include the tracking of transport vehicles.

Life360 - A app that is family-centered and location-sharing which aids to connect with trusted people and maintain an understanding of where they are at any given time. It does not have the dedicated mode of transportation and in depth vehicle tracking.

Moovit - A transportation app that enables live arrival times, bus, train, or any other means itineration, to track on the transportation system. It combines information of transport operators but makes use of official GPS positions as opposed to locations of passengers being shared.

FlightAware- A flight tracking web site and application, which provides both live status and tracking information of commercial flights around the globe on a foundation of official aviation information and on-board GPS devices.

Open Source Projects - There are various open-source car locating projects, including Tracker, which offers software of GPS tracking servers. These normally involve installation of GPS devices on automobiles [4].

2.3 Comparative Analysis

Comparative Analysis of TrackMate and Existing Solutions:

Feature / Aspect	TrackMate	GPS-Based Vehicle Tracking Apps	General Location Sharing Apps (e.g., Google Maps, Life360)	Public Transit Apps (e.g., Moovit)
Tracking Source	Passenger smartphones sharing real-time location voluntarily	Dedicated GPS devices installed on vehicles	User smartphones sharing personal location	Official transit operator GPS data
Transport Modes Supported	Bus, Train, Air, Ferry	Varies (often buses, taxis)	Not transport-specific	Buses, trains, subways
Cost of Setup	Low (no extra hardware required)	High (GPS device installation and maintenance)	None (personal use only)	None (data provided by operators)
Privacy Controls	Public and private sharing options	Limited, usually public tracking	Sharing limited to trusted contacts	Mostly public transit data
Platform	Android app built with Flutter	Varies, often platform-specific	Android and iOS	Android and iOS
Community Driven	Yes, relies on voluntary sharing	No, centralized GPS tracking	Yes, social/family sharing	No, relies on official data feeds
Real-Time Updates	Yes	Yes	Yes	Yes
Scalability	High potential for growth	Depends on GPS hardware deployment	Limited to social circles	Limited to supported transit networks
Use Case Focus	Affordable, user-driven transport tracking	Professional fleet management	Personal location sharing	Public transit navigation and timing

Table 2.3.1: Comparative Analysis

Summary:

TrackMate is a very new low-cost vehicle tracking system that uses the free share of smartphone location services [2] as opposed to the more expensive classical GPS-based solution. It also offers transport sharing facilities of various modalities and allows users to share privately and publicly (as compared to general location sharing apps) and is

concerned about privacy issues. TrackMate can allow user induced data entry unlike public transit apps, as it is flexible to informal or less digitized transport infrastructures.

2.4 Scope of the Problem

Problem Scope Breakdown:

- Absence of the systems of inexpensive real-time tracing of vehicles to small transport providers and passengers.
- Current GPS-related tracking systems tend to be expensive and demand special computer hardware integration point-sets [1].
- In most areas particularly in the developing world, transport locations are not available as accurate data.
- Passengers also experience a lack of confidence because of the reduced instant information on the position of their cars and delays.
- The privacy issue represents an official constraint on the readiness to provide users with location information on the current set-ups .
- At present transport tracking requires are not provided by existing location sharing applications [5].
- Should have a community-based, open-access platform in favour of multiple modes of transport.

2.5 Challenges

In the process of designing and developing TrackMate, a number of difficulties were met:

- To guarantee correct and up-to-date real-time positions form smartphones of passengers who may have different GPS strengths and different network signals.
- Striking a balance between user privacy and affording transparent and shareable location data.
- Real-time information synchronization and scalability of her data between multiple users, and different modes of transportation.
- Tight integration of backend systems so as to store and update real time data without failure.
- Creating a convenient interface that will host any types of transport and modalities of sharing.

- Free APIs and services along with the loss of performance and reliability.

- Promoting voluntary sharing of location with users as a way of achieving significant and holistic tracking.

- The management of battery and data use on mobile gadgets in real-time communication of location sharing.

Chapter 3

Requirement Specification

3.1 Business Process Modeling

1. Process Overview

TrackMate is a system which allows sharing of location in real time without any user having to log in [7]. One user (Tracker) transmits his current position [5], and another (Viewer) can display it immediately on a map [4]. To achieve Real Time syncing, the data is stored and updated on Firebase Real Time Database [5].

2. Actors

- Tracker (Sender) - Shares position with built in GPS and mobile information of the device.
- Viewer (Receiver) - Several sees the shared location in real-time live on the map.
- Firebase Real time Database - Stores and synchronize location coordinates.

3. High-Level Workflow

- GPS and mobile data parameters are enabled.
- App Captures Location - Location updates (through GPS sensor) periodically.
- Place Data sent to Firebase - Data is saved under distinct session/ID.
- Viewer Opens App – Without any session/ID to get to location.
- Data is Fetched available in Firebase - The Firebase map is updated in real time.
- The viewer monitors the motion of Tracker- Keeps on up until the session is over.

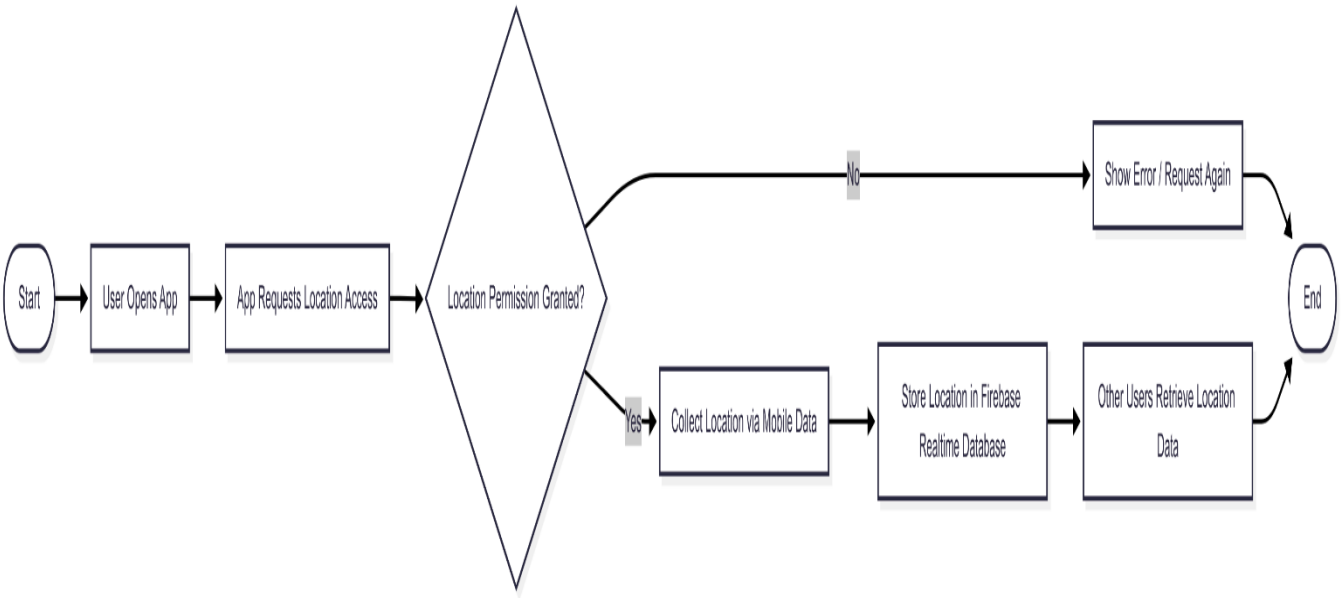


Figure3.1.1: Business Process Modelling

3.2 Requirement Collection and Analysis

1. Requirement Collection

In order to comprehend how extensive and functional the TrackMate application would be, the following are some of the sources of requirements that were gathered:

Interviews and Discussions: Interviews with the possible users who include drivers, delivery personnel, parents, and friends that require real-time tracking.

Existing Solution Observation: An Examination of location tracking apps (Google Maps location sharing, Find My, Life360) to determine the functionalities and shortcomings.

Questionnaires & Feedback: Engaging the peers in the university to get to learn their desired features and privacy anticipations.

Brainstorming: The team will talk during the project to find out its technical capabilities and limitations.

2. Functional Requirement

- Location Sharing
    - Users are able to tell their whereabouts in real time to the people that have been chosen.
    - Unsocial link or seem to share.
- Location Tracking
    - Live map tracking of users.
    - Timely updates of maps do not require any manual refresh.
- Map Integration
    - Locate and move upon an interactive map.
    - Enable zoom in, and zoom out and look at the path taken.
- Privacy & Control
    - One can switch off sharing of their location.
    - Control who can track them.

3. Non-Functional Requirements

- Performance
    - The delay required should be not more than 3-5 seconds to update location.
- Usability
    - User friendly interface and low learning curve.
- Scalability
    - Thousands of parallel users should be supported by the system.
- Security
    - Shared location data by end-to-end encryption.
- Compatibility
    - Cross platform on Android (later being able to extend to iOS).

4. Requirement Analysis

Upon the analysis of the gathered requirements, the priorities areas were:

- GPS Independence: The system will not use GPS to make it less expensive and more accessible in GPS restricted locations.

- Real-Time Performance: This is important to enable a map to display data in a timely fashion thus when used in tracking.

- Simplicity: To make sharing or tracking start, it is important to reduce

the number of user actions.

- Privacy: The location can be tracked only by users who have a shared link/the code.

According to the analysis, the architecture of the app requires two principle modules:

- Sharing Module: Deals with the routing of the location data.
- Tracking Module: Shows the real time movement in a map.

3.3 Use Case Modeling and Description

TrackMate application includes two main actors, i.e. the Tracker whose responsibility is to send the real-time vehicle positions to the Viewer, and the Viewer who receives and utilizes and tracks the positions. The system is based on Firebase Real time Database to store and synchronize location details.

Main use cases include:

Share Location: The Tracker opens up a new location-sharing session giving an overview of the vehicle and trip, selects between public and private sharing and can optionally create a passkey. The application keeps on relaying location data to Firebase.

View Location: The Viewer gets dynamic Firebase live location information. To reach the data a valid passkey will be needed in the case of private sessions.

Stop Sharing: The Tracker may be made to end the session at any given moment that ends location updates and makes the session inactive in Firebase.

Search Vehicle: The Viewer will be in a position to look up or search openly held vehicle areas by road or an alternative of transport.

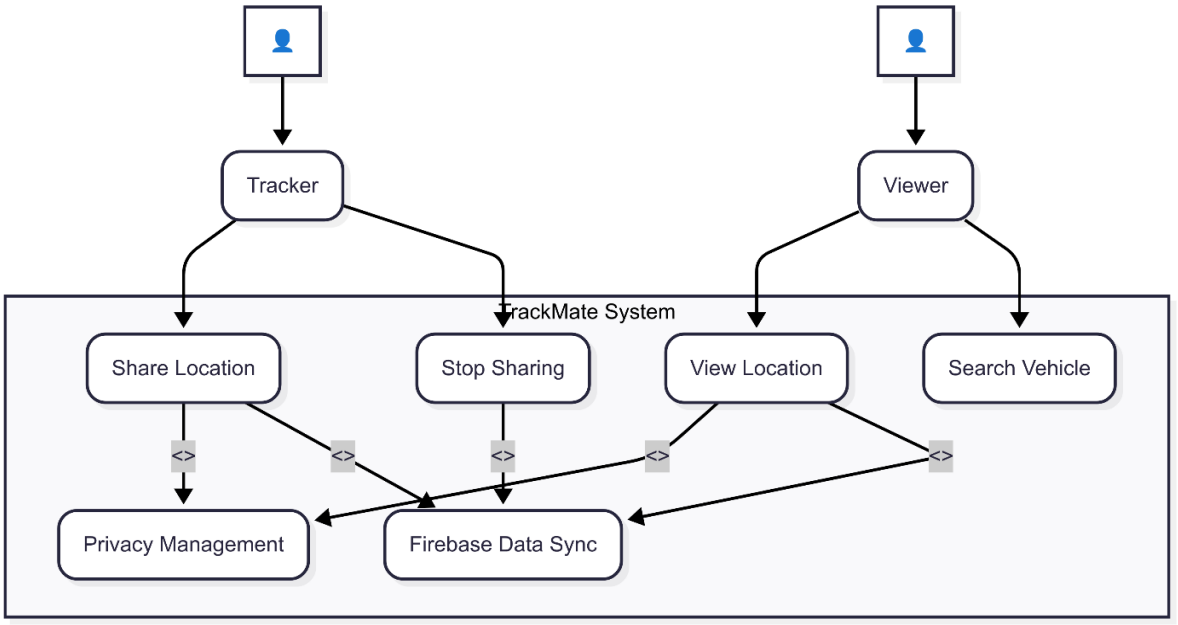


Figure3.3.1: Use Case Diagram.

Explanation of diagram elements:

Actors:

- Tracker User Tracker Recent locations Shares and ends location sharing.
- Viewer Views and searches position of vehicles.

Utilization within system boundary:

- Share Location
- Stop Sharing
- View Location
- Search Vehicle
- Privacy Management
- Firebase Data Sync

3.4 Logical Data Model

Logical data model of TrackMate illustrates the data flow in the system, including user-actions on the app to the back-end processing and storage. It is a layered architecture, that is, it separates the Presentation layer, the Logic layer, and the Data layer.
This modular architecture is highly maintainable, scalable and has high separation of responsibilities.

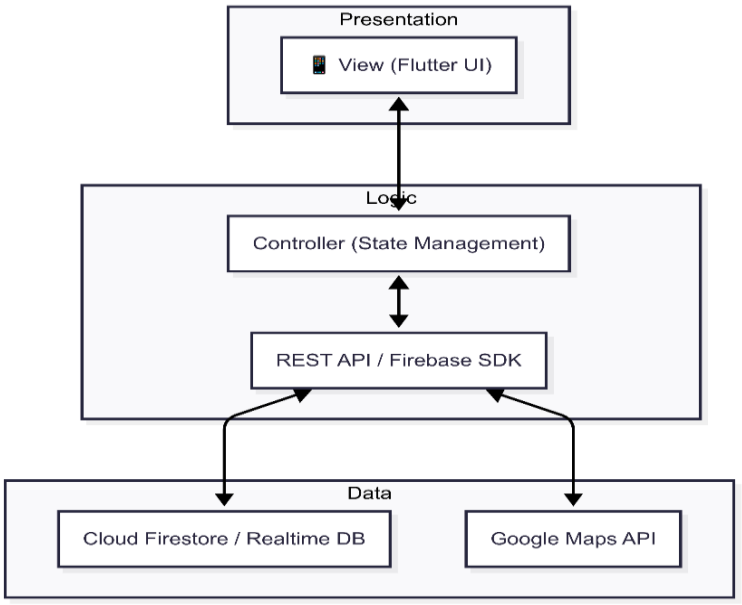


Figure3.4.1: Logical Data Modeling.

Layer Descriptions

- Presentation Layer
  - Types of all Flutter components of UI.
  - Shows real-time locations of vehicles, transport information, privacy settings to users.
- Logic Layer
  - Controller manages user input, changes of states in the UI and requesting data.
  - Firebase SDK mediates the app logic and backend services, and handles location updates, authentication and queries.
- Data Layer
  - Journey report, vehicle data, and location data are held in the database.
  - Mapping, routing, and geocoding services are offered through the use of third-Party API (Google Maps).

3.5 Design Requirement

The design specifications of the TrackMate - Real-time Public Transport Locator app require consideration of several features to guarantee a high availability of the Android users in terms of reliability, privacy set, and convenience when tracking their positions:

User Interface/UX: Build an easy to use, responsive, and appealing interface that enables users to share and see real-time vehicle locations without any problem. Make sure there is smooth interaction with the map, small and clear icons and as

little clutter as possible to create a smooth tracking experience.

Security and Privacy: Use Firebase to intensify authentication and protect information transport across HTTPS. Make sure that only users with permission would see your private trips with the help of special codes or invitation links, which would protect the user location data.

Scalability and Performance: Architecture to be in a position to support increasing traffic levels of users and updates on locations without a significant drop in performance. Automate real-time movements in order to update vehicle locations every 3 seconds and still have a smooth application of map data.

Personalization and Modification: User: Provides the option of Public and Private location sharing. Give the opportunity to add the details of journey and become creative with it like type of vehicle, vehicle number and other notes.

Compatibility and Integration: Should be compatible with all the modern Android devices. Install Google Maps SDK, Places API, Directions API, and Geocoding API and it will bring the right mapping, route planning and location information. Be less rigid so as to be integrated with a custom REST API server in the future.

Data and Analytics: Empower administrators (in future business-friendly versions) in order to understand which methods are being used, when, and where to plan resources and also enhance service delivery.

Accessibility: Adhere to mobile accessibility standards, to make sure that people with visual or motor challenges will be able to use the api. Add text that can be scaled, and color contrasts and tap able UIs.

Reliability and Maintenance: Design the application to run minimal downtime, automatically restart on intermittent loss of network, and to be easily updated or fixed during the testing stages and afterward after bugs have been detected.

Fastening and Maintenance: There should be easy in-app tutorials for how to use the program as well as guidance in how to sharing and viewing places. Keep developer documentation to aid in constant improvement especially when shifting to the custom REST API.

Collectively, these design requirements seek to produce a reliable, secure, and easily consumable real-time tracking system named TrackMate that puts privacy, efficiency, and affordability at the forefront of its design, and subsequently makes it scalable and commercially ready over time.

3.6 Task Allocation

Task Allocation by Team Members:

Task/Phase	Md. Jahirul Islam (213-15-4266)	Md. Abdullah Al Mazed (213-15-4478)
Requirement Analysis	Interviewed users, did user surveys, determined functional requirements.	Examined existing applications (Google Maps, Moovit, Life360), made out requirement specification.
System Design	Configured use case Gabling, logical data Gabling, database schema.	Planned UI/UX flow, developed interaction, wireframes.
Implementation – Frontend	Created Flutter UI screens (Home, Share location, View location).	Integrated navigation flows, implemented input forms and map views
Implementation – Backend	Firebase Real time Database, authentication and security rules are all configured.	Integrated Firebase with Flutter app, real-time syncing of location data
Integration	Linked frontend modules with backend services	Performed debugging and optimized real-time updates
Testing	Performed unit testing and compatibility tests of the device.	Performed integration testing, privacy control tests, and error handling
Project Report Writing	Written chapters include: Introduction, Background, Methodology, Implementation.	Drafted chapters: Literature Review, Challenges, Impact, Conclusion
Presentation Preparation	Designed PowerPoint slides and demo flow	Prepared presentation script and demonstration of live app
Project Management	Scheduled weekly meetings, monitored task progress	Maintained version control, tracked milestones

Table 3.6.1: Task Allocation

Project Time Allocation:

Tasks / Weeks	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
Requirement Analysis	■	■	■	■															
System Design				■	■	■	■												
Frontend Implementation						■	■	■	■	■	■	■							
Backend Implementation								■	■	■	■	■	■						
Integration & Testing										■	■	■	■	■	■				
Report Writing												■	■	■	■	■	■	■	
Presentation & Demo														■	■	■	■	■	■

Table 3.6.2: Project Time Allocation

Chapter 4

Implementation and Results

4.1 Implementation of Database

In the case of TrackMate, the Firebase Real time Database is used as a backend. This database scheme is created in such a way that it is used to store all journey data as well as real-time location update information. Every trip is saved as a child of a parent reference known as shared locations. This ensures that it is easily accessed, updated and it is can also be filtered as needed.

The data model includes fields such as:

- Journey description
- Estimated travel time (hours and minutes)
- Departure and destination points
- Vehicle details (name, number, type)
- Sharing preferences (public/private)
- Password for private trips
- Real-time location coordinates (latitude & longitude)
- Current journey status

The structure maintains fast read/write business and also ensures that related data is grouped in the structure. The database physically determines the live position of the audience, which can be tracked effortlessly in real-time without having to reload the whole dataset.

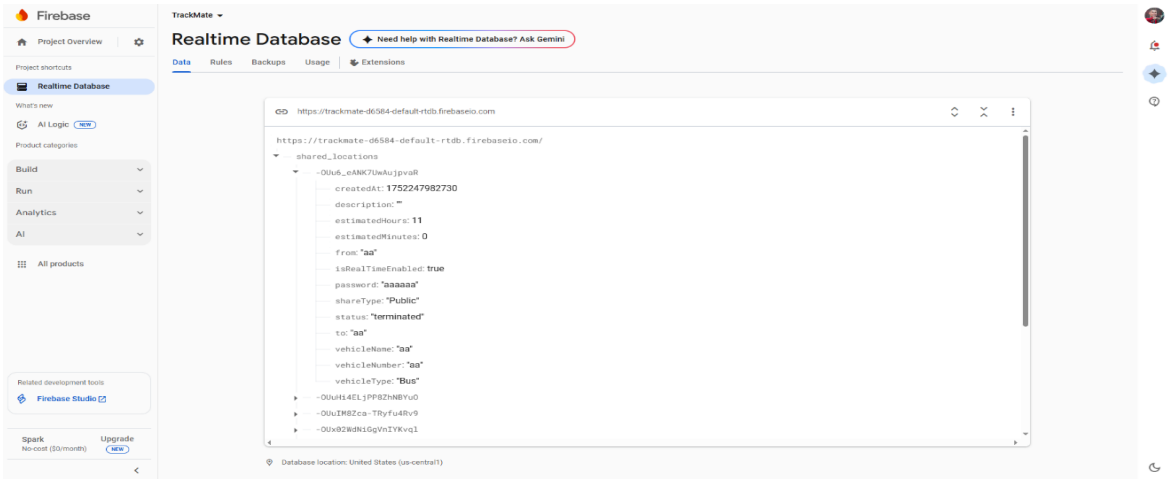


Figure4.1.1: Database Architecture.

4.2 Implementation of Front-end Design

TrackMate front end is built in Flutter to offer the enduser with a clean interface. It has been designed to be as simple as possible and users can share or track a vehicle with less effort depending on the purpose of the creation.

Key Design Pages:

Home Page - Here one may get access to the Share Location and View Location options without delay.
Transport Selection Page- Here, the user is asked to select the type of vehicle (Bus, Train, Air, Ferry).
Journey Details Form - Gathers trip related information including route, vehicle details, estimated time and sharing mode.
Map Tracking Screen - This shows the current position of the vehicle, in a map.
Check Access Screen - Requires a password to check on customary journey tacking.
Journey Status Page - Displays an active or terminated journey.

The design combines How-it-Works pricing, color ton down choices and employs massive action buttons to attract as many users as possible.

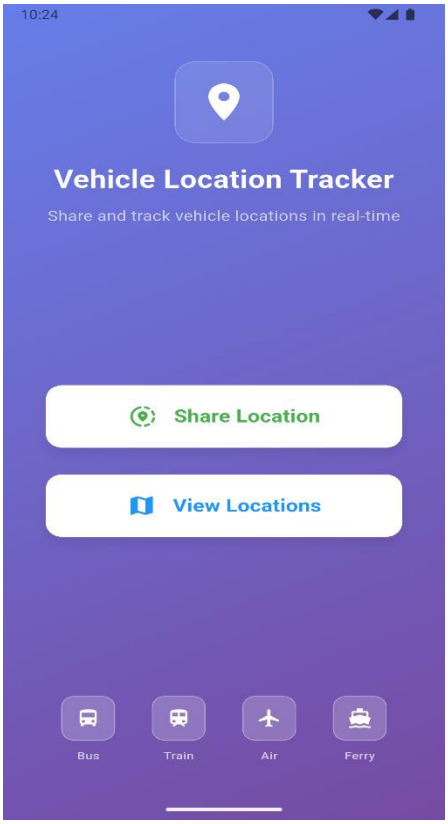
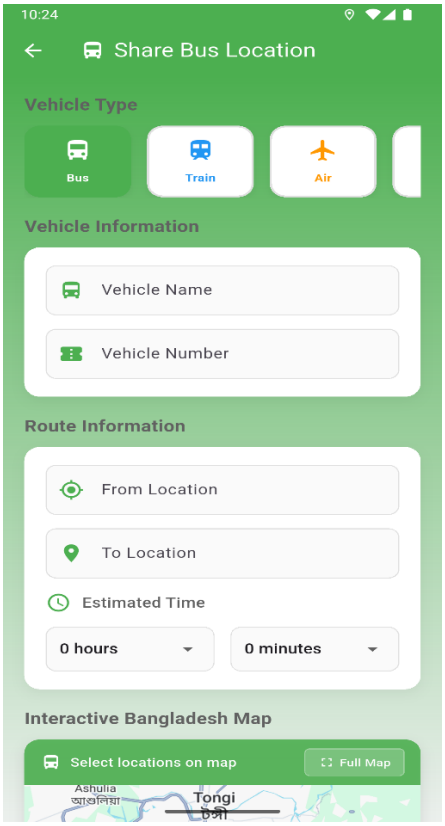


Figure4.2.1: Home Page



4.2.2: Journey Share Page.

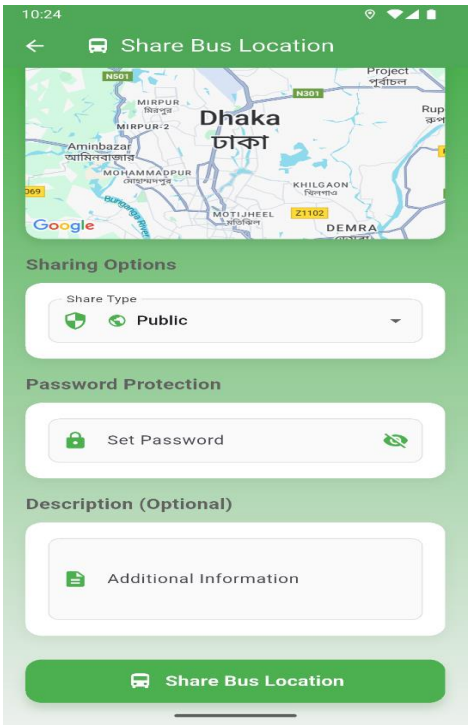


Figure4.2.3: Journey Share Page

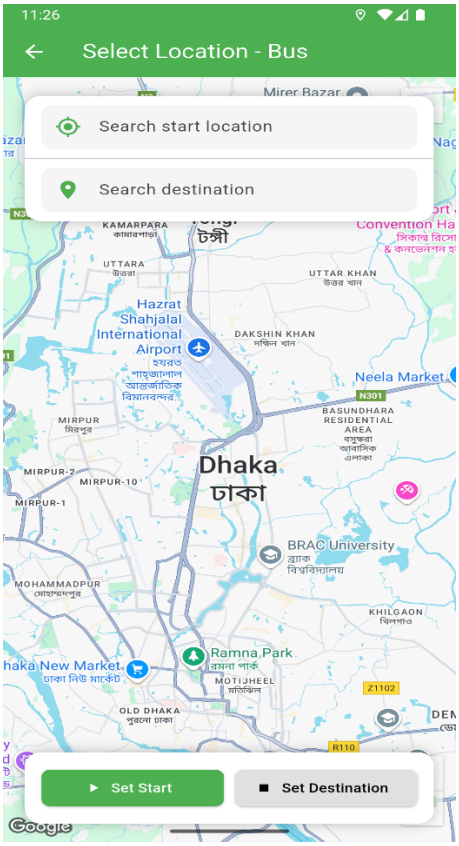


Figure4.2.4: Sharing Map Page.

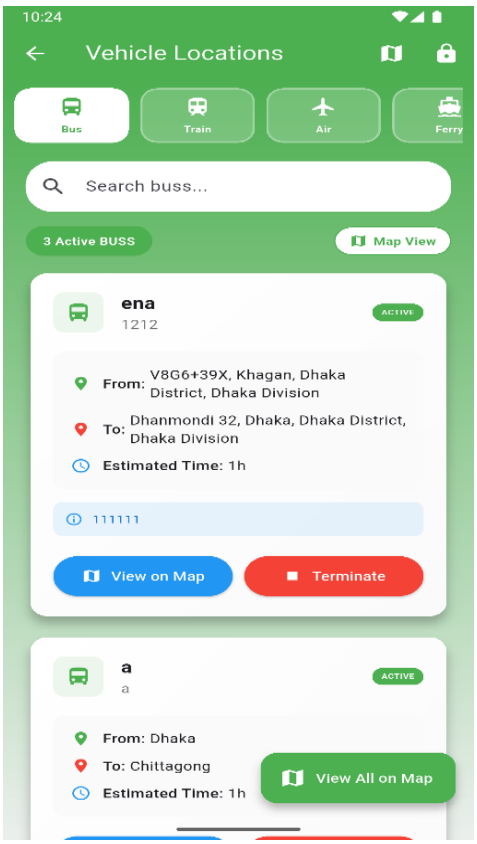


Figure4.2.5: Location View Page

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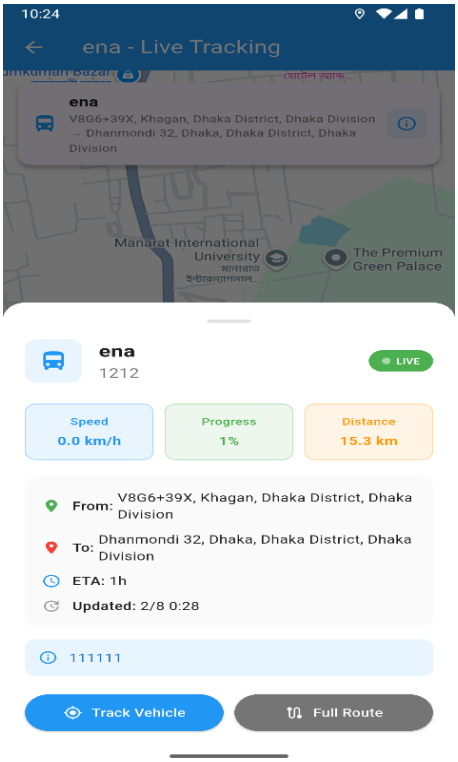
Figure4.2.6: View Map Page



4.2.7: Vehicle Details (from map) View Page.

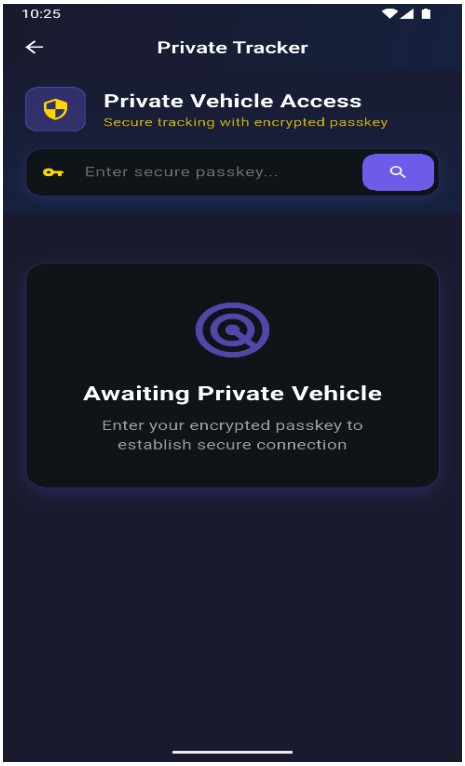


Figure4.2.8: Private View Page.

4.3 Testing Implementation

TrackMate testing was done in order to make sure that core features of the application were working as intended in different situations. The test methods that were used are as follows:

Unit Testing - Confirmed that individual components was handled correctly like database write/read functions are fine (as well as location update methods).

Integration Testing - verified the flow of data between screens and made sure data flow between the front-end and Firebase is successful.

Real-Time Test Tracking of a Sharer to a Viewer- Change The trivial change in these events will consist of simulated location updates of some device owned by a sharer, which have been confirmed as real-time updating on the map of a viewer.

Privacy & Access Control Test - Ensured that private journeys were only will be seen with proper password.

Device Compatibility Test - Tested compatibility of apps on various Android devices of different screen sizes.

Error handling Test - The test cases such as no internet access, improper password input and GPS turn off cases were tested.

4.4 Test Results and Reports

The application was tested on multiple Android devices and under different network conditions. Below is a summary of the results:

Test Case	Description	Expected Result	Actual Result	Status
Journey creation	User adds trip details and starts sharing	Journey saved in Firebase and visible to others	Successfully saved and displayed	Pass
Real-time update	Location updates every few seconds	Map updates smoothly without refresh	Map updated as expected	Pass
Public journey access	Any user can view public trip without password	Accessible without restrictions	Worked as expected	Pass
Private journey access	Requires password before viewing	Denies access on wrong password	Password protection worked correctly	Pass
GPS off scenario	GPS disabled on sharer's device	Location not shared and error message shown	Worked as expected	Pass
No internet	User goes offline while sharing	Updates paused and resumed when online	Functioned correctly	Pass

Table 4.4.1: Test Result and Reports

Overall, testing confirmed that TrackMate met its functional requirements and performed reliably in real-world conditions.

Chapter 5

Engineering Standards and Design Challenges

5.1 Compliance with the Standards

5.1.1 Software Standards

The construct of TrackMate includes specific software tools, platforms, and APIs that achieve seamless real time vehicle location tracking on Android devices running 8.0 (Oreo) and higher versions. The following describes the major implementation needs:

Development Environment

Flutter Framework – The main part of the application is created with the help of Flutter which uses the Dart programming language for cross platform development with an emphasis on Android devices .

IDE – Visual Studio Code (VS Code) serves as the primary development environment, providing lightweight, efficient code editing and debugging tools.

Native Code Integration – Despite the fact that most of the logic of the app is written in Dart [10], Kotlin is used for necessary native elements for Android, e.g. in build scripts via Gradle or in platform-specific functionalities.

Backend Infrastructure

- **Firebase Realtime Database:** This is a NoSQL cloud hosted database that tracks the real-time storage and retrieval of location information about vehicles so that all users receive low latency updates to the data. Firebase's inbuilt security rules and encrypted data transfer secure the privacy of the user.

Mapping and Location Services

- **Google Maps SDK for Android:** Embedded into the Flutter app to present detailed and interactive maps with smooth zoom and pan capabilities.
- **Google Cloud APIs:**
    - **Places API** means that users can search and identify locations along his/her route [3].

- **Directions API** creates best routes and directions for different modes of transport [2].
- **Geocoding API** converts between address and GPS coordinates to improve the data accuracy [4].

Platform Support

- The app is targeted at devices with **Android 8.0 (API level 26)** and newer to ensure that it will work with a wide range of modern smartphones..

Network Connectivity

- A stable internet connection is required to be able to send and receive real-time location data from the Firebase and access the Google maps and APIs.

This setup makes use of the power of Flutter and Firebase as well as Google's location services to provide a responsive and user-friendly experience that makes TrackMate a reliable and scalable solution for real-time vehicle tracking.

5.1.2 Hardware Standards

- The application is compatible with the Android platform of version 8.0 (Oreo) and above, which will cover the majority of new smartphones.
- No additional and dedicated GPS hardware will be needed; the system uses smartphones of users to exchange real-time position, which saves money and electronic waste.
- There was testing of various Android-based devices with varying screen sizes to make sure it is compatible and responsive.

5.1.3 Communication Standards

- Firebase has data transfer protocols that use encrypted data communication between the client devices and the data server, thus eliminating unauthorized access.
- Firebase as a platform ensures that location data is updated within seconds through event-driven communication, which ensures low latency between users.
- The application needs an active internet connection (Wi-Fi or mobile data) to transmit and receipt location information as well as to connect to Google Maps APIs.

- Privacy control in communication standards is another aspect that the company has established whereby users can decide on whether to share the data publicly or privately with unique access codes, which makes data access to location distinctive.

5.2 Interaction Design

5.2.1 Front-end Design

The front end of the TrackMate application was developed using the Flutter framework which helps in creating a user-friendly interface with a consistent behaviour for Android devices. Flutter's architecture based on widgets made it possible to design reusable components of the User Interface, leading to a tidy and structured layout.

The application is based on **Material Design principles**, which are very popular in the design and development of modern mobile applications to improve usability and consistency. With the help of these principles, clear visual hierarchy, intuitive navigation, and touch interactions can be achieved, while being responsive.

Main Interface Layout

- **Home Page**
  - There are two main options: **Share Location** and **View Location**.
  - Minimalist design with large and accessible buttons for easy and fast navigation.
- **Share Location Page**
  - Allows users to choose the type of vehicle: **Bus**, **Train**, **Ferry**, or **Air**.
  - Has the following fields for inputs of vehicle details like route, destination and relevant details.
  - "Share" button triggers real-time location sharing.
- **View Location Page**
  - Users choose the type of vehicle to use, and may choose to search for a destination, or scroll through numbers as available.
  - Volunteers goatherds must be paid wages at every level of the hierarchy.
- **Private View Option**
  - Separate input field to enter the generated code to access private location data.

UI/UX Considerations

- Color Scheme: Using a consistent primary and secondary color scheme to create better readability.
- Typography: Legible fonts with adequate spacing for clarity.
- Responsive Layout: The ability to auto-scale the UI elements in order to fit the different screen sizes.

- Feedback Mechanisms: Whereas visual cues (e.g loading indicators, confirmation messages) lead users through processes.

5.2.2 Back end Design

The backend of **Trackmate** is powered by the NoSQL, **real-time database**, Firebase Realtime Database, a cloud provider for storing and retrieving transport information in real threatens. This setup guarantees least possible latency between the creation of data and its availability to other users.

Data Flow :

- Location Sharing
    - The app gathers the following information when a user shares the location of a vehicle:
        - Type of vehicle (Bus, Train, Ferry, Air).
        - Route and destination details.
        - GPS coordinates in real-time.
    - Information is kept in Firebase under the appropriate vehicle type category.
- Private Sharing Mechanism
    - The system creates a random, one-of-a-kind access code when you choose private sharing.
    - The code and the related vehicle data are kept in Firebase.
    - The private location information can only be viewed by users who enter this code.
- Data Retrieval
    - Real-time data is retrieved from Firebase via the "View Location" page.
    - While private entries need an access code to be retrieved, public entries are accessible to all users.
- Security Measures
    - Firebase database rules are configured to limit unauthorized access.
    - Real-time updates are encrypted in transit to ensure data privacy.

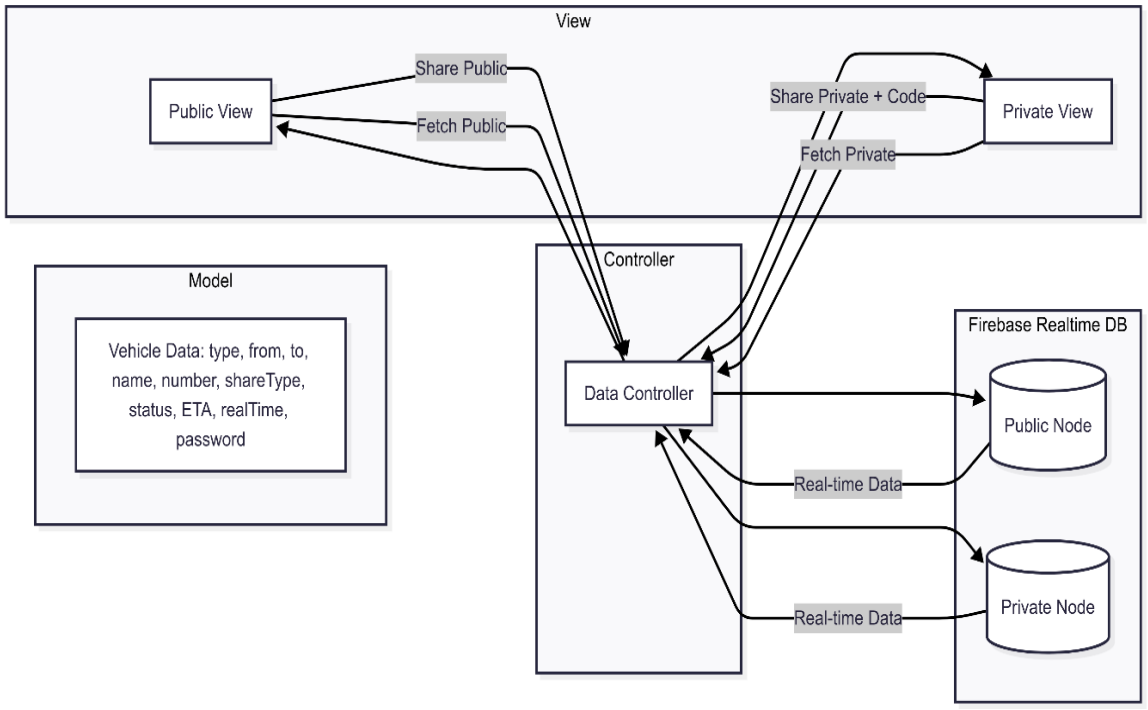


Figure5.2.1: MVC Architecture.

The diagram shows how **TrackMate's** backend handles real-time vehicle location sharing and tracking by adhering to the Model–View–Controller (MVC) pattern.

- The model is a representation of the structured vehicle data that is kept in Firebase. It contains information about the type of vehicle, the route, the estimated time of arrival, the type of sharing (private or public), and the security credentials for private access.
- View consists of two Flutter UI screens:
  - Public View – Shows the locations of vehicles that are publicly shared.
  - Private View – To show restricted vehicle locations, an access code is needed.
- The controller serves as a middleman, managing user data submissions and obtaining Firebase updates.
- Two distinct nodes are used by the Firebase Real-time Database to store data for both private and public sharing. Database updates are instantly reflected in the user interface thanks to real-time data synchronization.

All users can access public data, but private data needs a code to ensure **security** and **privacy** when sharing location data.

5.2.3 Interaction Design and User Experience (UX)

The interaction design of **TrackMate** focuses on simplicity and clarity, making it easy for the user to share and track the location of the vehicles and simple as well. The app has a logical and step by step flow which makes sense even for first time users:

Splash Screen - When people fire up the application, they will be greeted with a pretty clean-looking splash screen with the **TrackMate** logo. A brief loading animation helps to prep your app and help users feel a sense of brand identity while the app is loading.

Home Screen - We have two obvious choices on the home screen, **Share Location** and **View Location**. The layout is based on the principles of Google's **Material Design**-first, flat elements, clean typography, touch - intuitive targets so users will understand it easily if they have used Android before.

Mode Selection - Users can pick their transport mode from 4 choices namely **Bus, Train, Ferry, Air** which are represented by different pictograms. This visual approach helps speed up the decision-making process, and adds personality to the interface.

Sharing Mode

- Public Sharing: Defines the sharing of the journey in the public data base accessible to all users of TrackMate.
- Private Sharing: - Private Sharing: By this, a unique access code is generated and stored in Firebase for the same. Only users with the correct code are able to see the journey. Incorrect codes bring up a friendly error message to prompt the user to input the code again.

Tracking Map - The real-time tracking screen shows:

- The **vehicle icon** that moves along its route.
- **Route lines** to indicate the path to be taken.
- **Zoom-to-fit** functionality for automatically rotating the map view for the best possible view.
- **Vehicle filtering** options to only be relevant to certain transport types.

Real-Time Feedback - Live updates using firebase make sure that location markers and journey statuses are also modified instantly, making it a smooth, responsive experience. Animations for movements on markers and transitions make the tracking process flow and fun.

By using minimal design and the right mix of interactions, **TrackMate** presents the user with a frictionless experience of being useful and easy. Every touchpoint: from entering a route to the journey the vehicle is taking has been designed to alleviate the cognitive load while ensuring maximum clarity and satisfaction.

5.3 Impact on Life, Environment and Sustainability

5.3.1 Impact of Life

TrackMate is meant to help meet the real-world challenges faced by the daily commuter, transport operators, city planners and those traveling daily [9]. By allowing users to share and access real-time data that reflects the location of their vehicles [4] in an easy and privacy conscious way [7], the app creates a ripple effect of positive social and environmental benefits.

Improved Commuter Experience – For the countless people waiting for buses, trains, ferries or flights the uncertainty of the vehicle arrival time leads to stress and lost time [7]. TrackMate enables its users to monitor ongoing journeys in real-time , wait-times are reduced and users are better able to plan their trips [9]. This serves as a measure of convenience which helps to improve the daily routines by making commuting less frustrating and more predictable [8].

Community-Driven Transparency and Sharing – The app inculcates the spirit of cooperation because the user is encouraged to share the location of their vehicle voluntarily [1]. This is a community-driven approach that creates trust and collective awareness, to help improve transparency on public/private transportation. By using user-shared mobile locations, instead of more expensive GPS hardware [4], TrackMate reduces participation barriers by increasing its reach across a variety of user groups.

Environmental Benefits through Smarter Travel – Better visibility of transport options means travelers can make informed decisions [7] including unnecessary vehicle idling or early departure. This efficient travel planning helps reduce emission through a reduction in waste of fuel and congestion of the road, and positively contributes in cases of urban air quality, as well as mitigation of climate change.

Enhanced Safety and Privacy – TrackMate has a strong focus on user privacy [9], and does not collect any personal information other than the shared location information needed for real-time tracking. Private sharing features that enable users to control visibility with unique access codes can be used to make sure the journeys are as sensitive as possible. This commitment to security leads to trust and further adoption, ultimately of value to society as a whole by creating a safe yet trustworthy location sharing platform.

Accessible and Inclusive – Designed to be free and easy to use [10], **TrackMate** is available to a wide range of users - from every day commuters, tourists, to transport providers and transport planners. Concrete design elements include its intuitive interface [9], minimal set-up, etc., which encourages an inclusive use and brings individuals with (or without) technical background into contribution which grants individuals of equal combat benefit.

In sum, TrackMate provides a practical, community-based solution [9], leading to more efficient travel, social collaboration, user privacy protection and environmental sustainability -- making it a great tool for the modern urban labor.

5.3.2 Impact on the Environment

TrackMate can have a positive contribution to environmental sustainability by encouraging smarter and more efficient travel behaviours with reduced unnecessary emissions from vehicle movements [7].

By making real-time awareness possible of the location and estimated time of arrival of the vehicles, TrackMate helps users to avoid premature departures and long waiting times at stops. This reduction of vehicles idling and stop-and-go-traffic has a direct effect on the reduction of fuel consumption, which in turn also reduces greenhouse gas emission and air pollution.

Additionally, the app promotes making informed choices about transport behaviors, that could include choosing public or sharing transport modes, when their availability and timing was accurately tracked [4]. This shift can help to reduce the use of private vehicles, which are typically less efficient and more polluting per passenger.

Moreover by using users' mobile equipment in order to share their location [3] rather than relying on costly GPS equipment installed in vehicles [1], TrackMate minimizes electronic waste and the environmental footprint involved in the manufacture and maintenance of such equipment.

Overall, TrackMate supports the greater objectives for sustainable urban mobility [9], through facilitating improved travel planning, reduced emissions and encouraging eco-friendly travel behaviours, by aiding cities towards greener, healthier futures.

5.3.3 Ethical Aspects

TrackMate has been designed with strong commitment towards ethical principles, in particular user privacy, data security and transparency [7]. The app seems to favor the respect of the right of the individuals, but at the same time enables to provide valuable community driven location sharing [9].

Privacy by Design – In contrast to the traditional vehicle tracking systems based on the usage of a GPS functionality, this is limited to the use of devices installed permanently in the vehicles [1], TrackMate instead uses the voluntary sharing of mobile location [4]. Users have control of what they share [and] when it is shared, also the app not getting person own identifiers other then that required information location and journey details [9]. This decreases the risks of misuse of data or unauthorized surveillance.

User Consent and Control – All sharing of location is deliberately initiated by the user [7], it therefore requires informed consent. The private sharing feature (protected as it is with unique access codes [9]) where the user has granular command of who can access information on their journey creates a sense of trust and confidence in a platform for sharing.

Data Security – Data transferred between the app to firewall is encrypted while it is in transit [5], and firewall security rules work to prevent unauthorized access [5]. These measures help to secure the location info of users from interception / exploitation hence consistent with the best practices of digital ethics.

Transparency and Accountability – The forestry firm Frontier Forestry, developer of Trackmate, is open about how they embed data [9], including communication to consumers on how they are using location data and how they are storing that data [5].

Inclusivity and Accessibility – The basic format of the app as well as the fact that it is free for everyone to use ensure that all populations get equal access to the technology, such as those who may not have access to the most advanced tracking technologies [9]. This is for digital inclusion, and social responsibility.

In essence, TrackMate aims at maintaining a balance between technological innovation and respect of ethical standards, that is, at each step of the development and use of this technology contentions between user welfare and societal values are kept at the forefront of its operation and development.

5.3.4 Sustainability Plan

To ensure TrackMate remains a valuable, reliable, and responsible tool over time, a comprehensive sustainability plan has been developed focusing on technical, environmental, and community aspects.

Technical Sustainability:

- The app also utilizes the Flutter and Firebase software, which are both actively supported and constantly updated software reducing the possibility of obsolescence [5].
- Modular and clean code practices will be adhered to [6], thereby enabling easy maintenance, updates etc, as well as integration of new features/s as user needs change.
- "Issues of the big data" by Adam Smith, capture some disadvantages of big data, and also keep in mind utilizing the database usage and API calls will keep operational cost manageable and performance efficient.

Environmental Sustainability

- TrackMate promotes optimal use of transport resources, playing a role in emission reduction and environment conservation issues according to the information outlined in the environmental impact section [7].
- The reliance on mobile devices controlled by users to share location-based information also obviates the need for using additional hardware, reducing levels of electronic waste and energy-intensive processes and materials used to manufacture and maintain specialty tracking equipment [10].

Community Engagement and Growth

- To establish a sustainable user pool a deft focus will be to develop communities focused on in-app invitations to volunteer location sharing to being respectful [8].
- Educational content to promote the benefits of transportation tracking sharing and privacy protection will be made available to increase users trade and participation.
- Feedback channels will be maintained to hear from the users and their suggestions and concerns, to go for the continuous improving vision to the alignment with the real world [9].

Security and Privacy

- Regular checks of security protocols as well as rules in the app (firebase) will be made to protect user data from developing threats [5].
- Transparent communication about the data handling will continue which establishes trust in ethical responsibility and trust even in users [9].

Going through this multifaceted approach, TrackMate seeks to provide not only sustainable benefits at the social level but also to guarantee operational excellence and environmental responsibility to guarantee a continued relevance and positive impact for the app well into the future.

5.4 Project Management and Financial Analysis

Project Management:

TrackMate project is a teamwork, which required two team members to work on it during four months. The constituent turned to incremental development approach to enable a lightweight and versatile process that best fit the team and academic initiatives to create something systematic [6]. These methods entail the project being broken down into smaller segments or steps and the team aims at planning, designing, developing, testing and refining at each stage and stage.

Below was the key nature of stages in the project:

Planning and Requirement Analysis - Identified the objectives of the app, target, and main features. Investigated available solutions and collected user requirements in terms of a real-time [7] vehicle tracking.
System Design and Architecture - Planned the system structure of the system including user interface [8] database schema, and API integration. Privacy and security 1 to protect the user data.
Development - Added basic functions, i.e., transport mode selection, location sharing, and real time tracking [1]. Price free map APIs and Firebase Real time Database that were incorporated into each other.
Testing and Quality Assurance - Manual testing through a small number of Android devices to check their reliability and usability [7]. Bugs that are fixed and performance optimized.
Deployment and Documentation - Readied the last app build to give out. Prepared documentation which comprised this project report to be evaluated in a scholarly way.

Even becoming a part of formal project management aids have not been employed, the team has still managed to keep a good alignment with each other in terms of regular meetings, task allocations, and checking milestones, to save consistent proceedings and delivery on time in project development. To ensure the task allocation process is more efficient, the team will also select project management platforms like Trello or GitHub Projects to enable better collaboration and improve task tracking, as well as version control in future stages or projects.

Finance:

At the moment, the developers fund the TrackMate project themselves and use available and mostly free resources and tools to keep costs at a minimum. Imperative costs were shunned by taking advantage of the free-tier services like:

- Real time Database Firebase and backend storage and synchronization.
- Free Location visualization and tracking Free Map APIs.
- Flutter and Android development software and development tools based on open source.

This project phase neither entailed a direct financial investment in hardware nor software license and paid APIs.

In the future, when the app is released and starts to go viral, the team is set to pursue

venture capital financing to assist in scaling the app [5], enhance infrastructure, and other functionalities. Possible methods of financing are to:

University Competitions or Grants - Applications to technology innovation grants or final year project funds that are provided by universities.

Crowdfunding Platforms - Organizing initiation of campaigns on such websites as Kickstarter or GoFundMe to promote mini-funds and buy-in among the community members and early adopters.

Angel Investors or Startup Incubators - Contingency on transportation technology solutions: a way of achieving this is through engagement of the local start up incubators, or investors.

Company partnerships with Transport Operators - Partnering with buses or ferry providers who can either sponsor or contribute funds towards bonus services in the app to support their lines.

The stooled funding model suits the long-term ambition of the team, to initially run a working prototype and then increase the scale of the app reach and functionality according to feedback and demands

5.5 Complex Engineering Problem

5.5.1 Complex Problem Solving

The engineering problem which is being dealt with by the undertaking of the research within the frame of this thesis, "TrackMate Real-Time Public Transport Locator" is a Complex Engineer Problem. It combines the integration of mobile app development (Flutter) and cloud-based real-time solutions (Firebase) as well as geolocation/mapping APIs and privacy-preserving systems into a single system.

EP1 Depth of Knowledge	EP2 Range Of Conflicting Requirements	EP3 Depth of Analysis	EP4 Familiarity of Issues	EP5 Extent of Applicable Codes	EP6 Extent Of Stake-holder Involvement	EP7 Interdependence
✓	✓	✓	✓	×	✓	✓

Table 5.1: Mapping with Complex Engineering Problem

EP1: Depth of Knowledge Required

TrackMate demands solid expertise in various fields: mobile applications (Flutter/Dart), real-time databases (Firebase), maps/geolocation APIs and data privacy/security guidelines. There should be basic skills in software engineering and systems architecture design also.

EP2: Range of Conflicting Requirements

Conflicts between it are in terms of performance and battery/data usage, frequency of updates and scalability cost, and user privacy and usability. An increase in the update rate results in a better tracking resolution but it adds devices drain and a load to the back-end. Weak privacy-preserving mechanisms may have negative effects on system usability.

EP3: Depth of Analysis

This project demanded thorough algorithm design analysis (adaptive update strategies), architectural capacity planning and data modeling. This tradeoff was analyzed on the choice of location accuracy, cost of the backend and responsiveness of the app. Located in simulated real-world traffic and connectivity testing were also done.

EP4: Familiarity of Issues

Although mobile apps development in general and use of Firebase are widespread, real-time, crowd-sourced, privacy-conscious multi-modal transport tracking is less widespread. The novelty is due to the need to work with large dimensional dynamic user data and abide by stricter privacy implications.

EP5: Extent of Applicable Codes

There is not much in the members of formal code and standard of this field. Standards related to the usability and the platform-based security standards can be applied, however, no common shelter transport-tracking framework is in existence.

EP6: Extent of Stakeholder Involvement

Stakeholders are also engaged, such as end-users (sharers and viewers), prospective transport operators, supervisors and third-party platform service providers (Firebase, Google Maps APIs).

EP7: Interdependence

The frontend map interface, backend real-time database of the system, the external APIs and user participation are well integrated with each other. One failure (e.g., API outage, bad GPS precision, database outage, etc.) can negatively impact the whole usability.

Mapping with Knowledge Profile

This section maps the overall problem and **EP1** to the Knowledge Profile.

K1 Natural Science	K2 Mathematics	K3 Engineering Fundamentals	K4 Specialist Knowledge	K5 Engineering Design	K6 Engineering Practice	K7 Comprehension	K8 Research Literature
×	✓	✓	✓	✓	✓	×	✓

Table 5.2: Mapping with Knowledge Profile

Justification for Knowledge Profile Mapping (Linked to EP1)

- **K2 Mathematics:** Used in interpolation, ETA computation and smoothing GPS noise. Used in interpolation, ETA computation and smoothing GPS noise.
- **K3 Engineering Fundamentals:** Basic on backend design, data structuring and networking.
- **K4 Specialist Knowledge:** Must be familiar with Flutter/Dart, Firebase integration and Maps APIs.
- **K5 Engineering Design:** Necessary to start the privacy features design, modular construction and usable interface.
- **K6 Engineering Practice:** It is applied on testing (unit/integration), CI/CD processes, and deployment.
- **K8 Research Engagement:** The project was based in the literature of crowdsourcing, real time systems and privacy preserving apps.

5.5.2 Engineering Activities

In this section, mapping with engineering activities is provided with added rationale.

EA1 Range of re-sources	EA2 Level of Interaction	EA3 Innovation	EA4 Consequences for society and environment	EA5 Familiarity
✓	✓	✓	✓	✓

Table 5.3: Mapping with Complex Engineering Activities

EA1: Range of Resources

Flutter SDK, Firebase cloud service, Google APIs (Maps/Directions), test devices and volunteer users who would test it in the real world were all different resources required in the system.

EA2: Level of Interaction

There was strong communication with third-party APIs (Firebase, Google Maps) and human users (voluntary location sharing). It was important to have a smooth integration of these interactions.

EA3: Innovation

The novelty is in its ability to provide community-oriented real-time multi- modal tracking of public transport through users with controls over their privacy which is not a common procedure in low-infrastructure setting.

EA4: Consequences for Society & Environment

The social impact of the project is positive: by ensuring a shorter waiting time, better commute planning, and, possibly, less emission, it can be decreased. Threats consist of the fact that shared information may be abused in case of loss of privacy.

EA5: Familiarity

The team had familiarity with development of mobile and backend services and were less conversant with compliance with privacy and the scaling to large population. This took the work into the new complex arena.

b. Summary

The TrackMate project is a challenging engineering problem as it entails a multi-disciplinary knowledge, extensive analysis, high intensity of stakeholder engagement and intense integration of the parts of the system.

- **Problem solving mapping (Table 5.1):** Sets forth knowledge level of depth, conflicting requirements and interdependence.

- **Knowledge profile (Table 5.2):** Reflects the dependence on the principles of engineering, specialist information, design, practice and research writing.

- **Engineering activities (Table 5.3):** Demonstrates extensive resources, high interaction, innovation, and real-world societal consequences.

Activities, which are engineering (Table 5.3): Reflects deep resources, and interaction, innovation, and manifestations in the real world.

Chapter 6

Conclusion

6.1 Discussion and Conclusion

Creating TrackMate offered an extraordinary experience of challenges to overcome and lessons to learn. The complex involved combining real-time sharing of location of four modes of transport i.e. Bus, Train, Air, and Ferry sharing at a given time was complicated [2]. The integration of free APIs with maps was particularly tough specially to facilitate such features like detailed route visualization and specific choice of location [1]. The design of the Firebase Realtime Database to store and access data efficiently also had to be properly designed as it has to fit within the limits of the free option.

At this point, the app is permitted to handle up to approximately 100 connected devices because of the free plan limitations offered by Firebase which limits data and information storage opportunities, as well as, the featured additional capacity of traffic detection. Free APIs allowed a functionality application, but paid-up tools would significantly increase scalability as well as accuracy and the general user experience.

Through these challenges, feedback and testing to users has been favourable . TrackMate is valued due to its intuitive features, good reliability and usefulness in everyday-planning of the travel. This stimulates even more trying to develop it further to make it better in terms of its features and performance.

To conclude, TrackMate manages to introduce a free privacy-centered vehicle tracking application in real time. It assists users to save time, minimize uncertainty and expedite their travels in more effective ways. As it gets better, it stands a good potential of becoming a universal traveling companion [10].

6.2 Limitation

Although TrackMate was successfully adopted, there are a number of limitations:

Reliance on Willing Sharing: The system is based on passenger detection of their live location by voluntarily. Unless users work towards sharing, then the coverage of tracking becomes inadequate and inconsistent.

Poor Platform Availability: As it is, TrackMate is limited to Android devices as IoS and web versions have not yet been created, which makes it less accessible to a larger number of people.

Free Firebase Constraints: The application is running on the free version of the Firebase Real time Database, which has a limit on the amount of simultaneous clients, storage, and bandwidth usage. This inhibits scalability when used in large-traffic capacity.

Internet Conditional Connectivity: TrackMate needs an internet connection that is uninterrupted to update and fetch real time data. The system can fail to give correct updates in places where there is poor mobile data coverage.

Accuracy of GPS Data: As the smartphone GPS and networks currency rely on the location precision depending on signal strength, poor signals, urbanization, or user device constraints can create an error.

Battery and Data Consumption: Constant GPS-tracking and data-synchover burns high levels of battery power and mobile data that can discourage its use by the user when used over long periods of time.

Privacy Concerns: Despite an inclusion of both public and non-public features of sharing live location, some users might also have hesitation toward sharing their live location based on trust and security issues.

Lack of Data Integration of Transport Authorities: Currently the services of TrackMate simply offer location information shared by users. It is not connected to any transport authority system and this may increase its reliability and accuracy.

6.3 Future Work

To improve TrackMate, many more opportunities exist to expand its functionality, scalability, and user experience to keep up with the changing technology and demands of the user:

Cross-Platform Availability- The creation of an iOS version would expand user base and anyone on the iPhone can give access to a platform while keeping the experience very similar among operating systems.

Premium Mapping and Traffic Services - The integration of premium Google Maps APIs or alternative services will give the opportunity to implement advanced features like multi-colored routes of different types of vehicles, live traffics and roadways congestions, budget and estimated delays, and predictive travel times. These will be great addons to the journey planning and user satisfaction.

Scalable Backend Infrastructure - switching off the free version of Firebase to a superior, scalable back-end, uses like Firebase Blaze plan, AWS, or Google Cloud Platform will remove the current device and data limits, allow thousands of users to interact simultaneously, and access superior data analytics features.

Connection to Authoritative Transport Data - Adding real-time schedules and status information of official transport services (trains, buses, airlines, ferries) with APIs or data feed will increase the accuracy of the app and lessen the dependency on the possibility of the user sharing such data. This mixed-mode type of scheme is able to enhance the trust and offer automatic updates on the way.

Strengthened User Authentication and Profiles - Privacy is important, but optional user

profiles and authentication system allows adding personalized functions like favorite routes, saved journeys, notifications, and tracking of their history without risking the anonymity of all.

Social Features and Community Building - Activities like group tracking, sharing Journey with friends/family or social forums, to add elements of social interaction may increase user interaction and expand engagement of the wider community [7].
High-tech Analytics and Insights -Offering artificial intelligence to users and transport authorities on travel trends, travel times, and popular routes would inform improvement of transport planning and resources allocation.

Offline Mode and Data Optimization - It will enable offline mode and caching of routes and current location to improve its usability due to low connectivity. Good data handling shall also save on the battery consumption, network usage.
Accessibility Improvements - To provide people with disabilities with a way to use the app, it is essential to make it accessible (e.g. voice commands, screen reader capability, custom fonts and similar).

Wearables and IoT integration - The wearables and IoT integration can provide quick noseglove updates and increase the functionality of the app in everyday trave.
Smart capabilities - AI would in the future be able to offer smart route recommendations, anomaly notifications (e.g., travel delays or scrolling along new routes), and custom on-demand travel advice on the basis of user preferences.

Strong Testing and Quality Assurance -Spinning the automated testing with effective continuous integration and frequent usability research will be essential in ensuring stability and a smooth user experience as the app gets bigger.

With these, and more, TrackMate is set to grow into a well-rounded, reliable traveler companion that, in addition to targets to benefit the individual user, also contributes to enhancing transport ecosystems more broadly.

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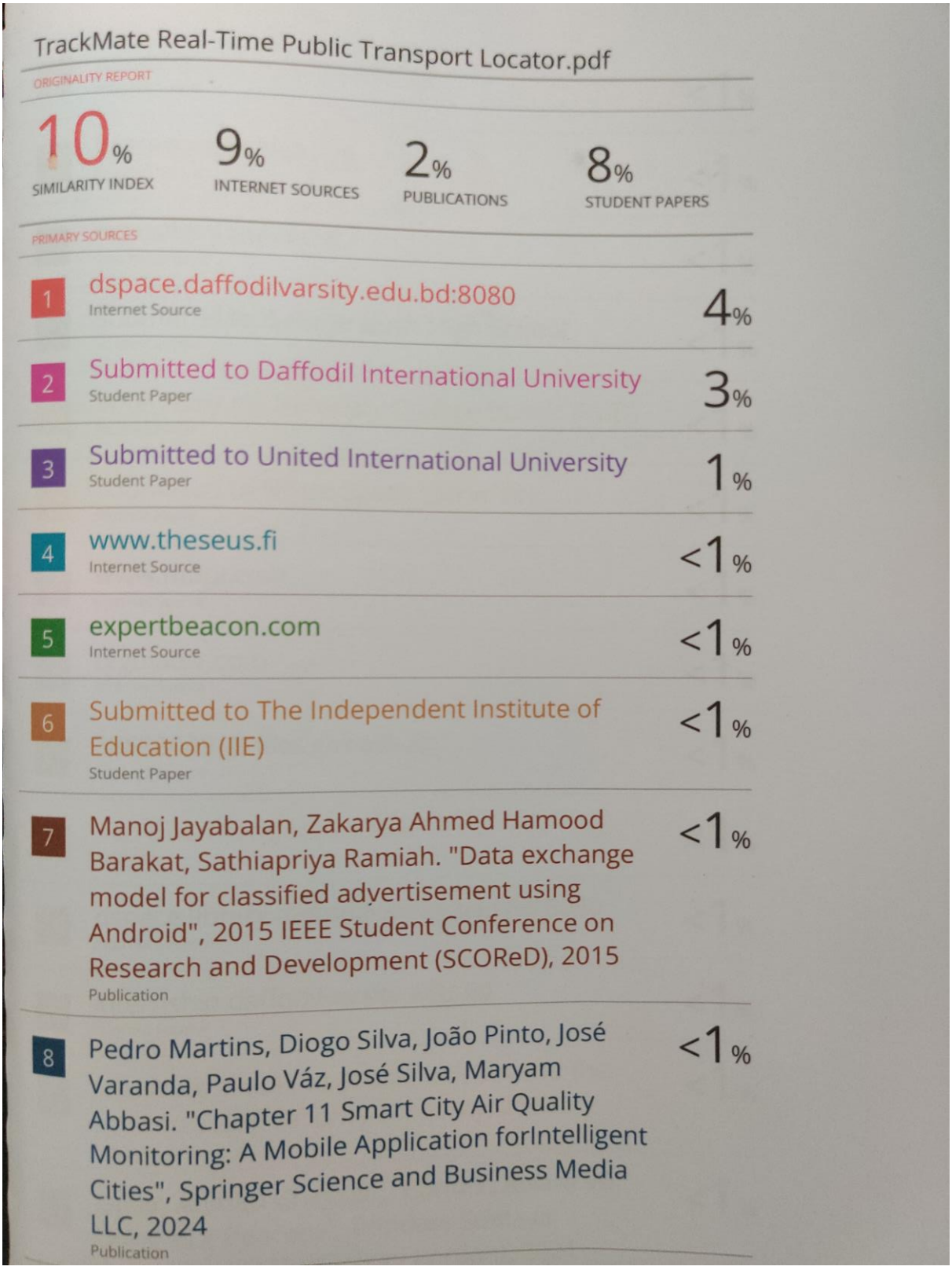

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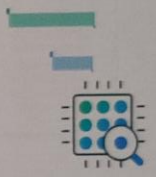

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