A Project Report on

Guardian Sync: Real-Time Tracking with Face Recognition and Attendance Monitoring System

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CERTIFICATE

Certified that the Project Report entitled **"Guardian Sync: Real-Time Tracking with Face Recognition and Attendance Monitoring System"** submitted by **Abhishek Rajpoot (2100820100011), Ajay Kumar (2100820100019), Ankit Saini (2100820100034), Aleem Malik (2100820100024)** is their own work and has been carried out under my supervision. It is recommended that the candidates may now be evaluated for their project work by the University.

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ABSTRACT

This project report presents the design and implementation of **Guardian Sync**, an advanced **real-time attendance and location tracking system** aimed at enhancing child safety. The system leverages cutting-edge **mobile and web technologies** to provide an integrated solution for **child identification, attendance monitoring, and real-time location tracking**.

At its core, the system consists of a **mobile application developed using React Native** and a **web portal built on the MERN (MongoDB, Express, React, Node.js) stack**. The mobile app is primarily used by **drivers and school administrators** to register children, verify identities, and update attendance statuses, while the web portal provides a comprehensive dashboard for parents and school officials to monitor children's movement in real time.

One of the most critical aspects of Guardian Sync is its **live facial recognition feature**, which ensures that a child can only be picked up by an authorized individual. Upon **successful face verification**, the system updates the child's status to one of the following: **"Picked up," "Dropped," or "Not Come Today."** Additionally, to keep parents informed, **instant SMS notifications** are sent whenever a status change occurs. This automated communication feature enhances transparency, minimizes concerns, and fosters trust among parents and educational institutions.

By integrating biometric security, GPS tracking, and real-time notifications, Guardian Sync offers a holistic and robust child safety solution that meets the growing demand for secure and efficient school transportation monitoring systems. The project not only enhances security but also improves operational efficiency for schools and transportation providers, making child pick-up and drop-off processes more reliable, transparent, and stress-free.

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INTRODUCTION

Child safety during daily commutes to and from school is a growing concern for parents and educational institutions. Ensuring that children are picked up and dropped off securely while keeping parents informed in real time is a challenge that requires a modern technological solution. Traditional methods such as manual attendance and paper-based records are inefficient, error-prone, and lack real-time tracking. This has led to an increasing demand for an intelligent system that can automate and enhance child safety protocols.

Guardian Sync is a real-time attendance and location tracking system designed to address these concerns using advanced technologies such as GPS tracking, live face recognition, and real-time SMS notifications. It consists of a mobile application (built using React Native) and a web portal (developed with the MERN stack) that enable seamless monitoring and reporting of a child's status. The system provides essential functionalities such as child registration, authentication via face recognition, status updates (Picked up, Dropped, Not Come Today), and instant notifications to parents. By integrating biometric verification with real-time location tracking, Guardian Sync offers a secure, efficient, and user-friendly solution to improve child safety.

1.1 BACKGROUND RESEARCH

The need for an automated child tracking and verification system has become more apparent due to increasing concerns about child safety in school transportation. Studies have shown that traditional GPS-based tracking solutions provide location updates but lack identity

verification, making it difficult to confirm whether a child has been picked up or dropped off by an authorized person. Similarly, RFID-based attendance systems have been used to track children, but they fail to prevent unauthorized pickups due to the possibility of RFID tags being misplaced or misused.

Research in biometric authentication has demonstrated that face recognition technology can significantly improve security in child tracking systems. Unlike RFID and GPS, face recognition provides a robust verification mechanism, ensuring that only registered individuals are allowed to pick up a child. Several studies have highlighted the efficacy of real-time biometric identification in improving security and reducing errors in attendance systems. Guardian Sync builds upon these existing technologies by combining GPS, live face recognition, and real-time notifications, creating a comprehensive child safety solution.

1.2 MOTIVATION

The primary motivation behind Guardian Sync is the safety and security of children during school commutes. In many regions, incidents of misidentified pickups, unauthorized persons collecting children, and missing children cases have raised serious concerns. Traditional methods rely heavily on manual intervention, which is prone to errors, delays, and lack of accountability. Parents often lack real-time updates, leaving them anxious about their child's location and well-being.

Additionally, there is a growing demand for automation and digitization in school management systems. Schools and transport administrators require efficient, scalable, and secure solutions to manage student transportation without relying on outdated, paper-based methods. The emergence of technologies like biometric authentication, GPS tracking, and cloud-based management systems provides an opportunity to build a smart, real-time, and automated attendance and tracking system.

1.3 LITERATURE REVIEW

Several existing child safety systems have been developed using GPS tracking, RFID, and biometric authentication. A review of the latest research reveals the advantages and limitations of these approaches:

1. GPS-Based Tracking

- GPS tracking is widely used in school buses to monitor location in real time.
- However, it does not verify who picks up or drops off the child, leading to security gaps.
- Examples: Zomato rider tracking, Google Maps location sharing, and school bus tracking systems.

2. RFID-Based Attendance Systems

- Schools use RFID cards or wristbands to mark student attendance.
- Drawbacks: RFID tags can be lost, stolen, or swapped, making them unreliable for security verification.

3. Biometric Face Recognition in Attendance Systems

- Face recognition provides higher accuracy in identity verification.
- Studies have shown that real-time biometric authentication can reduce attendance fraud and improve security.
- Challenges: Face recognition requires high-quality image datasets and may face issues in poor lighting conditions.

4. Hybrid Child Safety Systems

- Recent research focuses on combining multiple technologies (e.g., GPS + Face Recognition + RFID) for enhanced security.
- Guardian Sync is designed as a hybrid system, integrating GPS, biometric authentication, and real-time notifications to overcome individual technology limitations.

1.4 PROBLEM STATEMENT

Despite advancements in tracking and security systems, current child attendance and monitoring solutions have several limitations:

- Lack of identity verification in GPS and RFID-based systems.
- Manual attendance marking is prone to errors and inefficiencies.
- Parents do not receive real-time updates about their child's status.
- Unauthorized pickups remain a major security concern.
- Ineffective communication between schools, drivers, and parents.

Guardian Sync aims to solve these challenges by integrating a real-time attendance system with biometric face recognition and location tracking, ensuring a secure, automated, and user-friendly experience.

1.5 OBJECTIVES

The key objectives of Guardian Sync are:

- Implement a real-time attendance system that eliminates manual errors.
- Ensure secure identity verification using live face recognition.
- Provide real-time GPS tracking for parents and school administrators.
- Automate SMS notifications for real-time updates on pickups and drop-offs.
- Improve communication and security between parents, schools, and drivers.

1.6 SCOPE OF RESEARCH

The scope of this research includes:

- Development of a React Native mobile app for drivers and parents.
- Building a MERN stack web portal for tracking and managing attendance.
- Integration of face recognition technology for identity verification.
- Implementation of GPS tracking for real-time location updates.
- Deployment of SMS notification services for instant communication.

The system is designed for schools, universities and transport services that require an efficient, scalable, and secure child safety solution.

1.7 OVERVIEW AND BENEFITS

Guardian Sync combines GPS tracking, biometric face recognition, and real-time SMS notifications into a single, comprehensive platform. The key benefits include:

- **Enhanced Child Safety:** Ensures only authorized persons can pick up children.
- **Real-Time Tracking:** Parents can monitor their child's location anytime.
- **Automated Attendance:** Eliminates manual errors and inefficiencies.
- **Instant Notifications:** Keeps parents updated on their child's status.
- **User-Friendly Interface:** Designed for easy use by parents, drivers, and school admins.

By integrating cutting-edge technologies, Guardian Sync enhances security, reliability, and peace of mind for parents and schools.

1.8 PROJECT MANAGEMENT

The development of Guardian Sync follows an agile project management approach, ensuring continuous improvement, scalability, and user feedback integration. The project management phases include:

1. **Requirement Analysis**
- Identifying security and tracking needs for child safety.
2. **System Design**
- Architecture planning using the MERN stack and React Native.
3. **Development & Testing**
- Implementing and testing face recognition, GPS tracking, and SMS notifications.
4. **Deployment & User Training**
- Deploying the system for schools and training users for optimal adoption.
5. **Future Enhancements**

- Exploring AI-based predictive tracking, geofencing, and cloud scalability.

By adopting an iterative development process, Guardian Sync ensures high performance, security, and user satisfaction.

CHAPTER 2

SOFTWARE REQUIREMENT SPECIFICATION

2.1 INTRODUCTION

The Software Requirements Specification (SRS) document serves as a foundational guide for the development of the Guardian Sync system, ensuring that all stakeholders—developers, school administrators, parents, and drivers—have a clear understanding of the system's purpose, functionalities, and requirements.

Child safety has become a primary concern for parents and educational institutions, especially regarding school transportation. Traditional attendance and tracking systems have limitations, as they often rely on manual verification, RFID tags, or basic GPS tracking, which do not provide foolproof security. In many cases, children are picked up or dropped off without proper authentication, leading to potential safety risks.

To address these concerns, the Guardian Sync system integrates real-time location tracking, biometric face recognition, and automated SMS notifications into a single, efficient platform. This system ensures that:

- Only authorized individuals can pick up a child from school or drop them off.
- Parents receive real-time updates about their child's journey, ensuring peace of mind.
- Educational institutions can monitor attendance and ensure safe transit operations.

The SRS document describes the functional and non-functional requirements of the system, including the necessary software, hardware, performance expectations, and system diagrams to illustrate the architecture. This chapter will define the scope of the system and provide an overview of its purpose and key functionalities.

2.2 PURPOSE

The purpose of this project is to develop a real-time child safety and attendance tracking system that ensures the secure transportation of children between home and school. The system will be used by parents, school administrators, and drivers to monitor the movement of students in real-time and authenticate their pickup using biometric face recognition technology.

The key objectives of the system are:

- Enhanced Child Safety: Prevent unauthorized pickups and ensure children are dropped off at the correct location.
- Real-Time Tracking: Provide live GPS updates to parents and school administrators.
- Biometric Authentication: Use face recognition to verify that only approved guardians pick up children.
- Automated Notifications: Send SMS alerts to parents when a child is picked up, dropped off, or absent.
- Secure Data Storage: Maintain attendance records, pickup/drop logs, and facial recognition data in a centralized database.

Unlike traditional RFID-based attendance systems, which only record a child's presence but do not verify identity, this system ensures double-layered authentication by cross-checking real-time location with biometric verification.

2.3 OVERVIEW

The Guardian Sync system is a web and mobile application built using the MERN (MongoDB, Express.js, React, Node.js) stack for the admin portal and React Native for the mobile app. It enables school administrators to register students, assign bus routes, and track attendance while allowing parents to receive real-time updates and track their child's movement on a live map.

The system workflow includes:

- Drivers log in via the mobile app and update the status of children being picked up or dropped off.
- Facial recognition scans verify the identity of each child before marking attendance.
- GPS tracking continuously updates the child's location on the admin dashboard and parent portal.
- SMS notifications are sent in real-time to inform parents of their child's safety.

The system comprises multiple modules, each responsible for a specific functionality: User Authentication: Ensures secure access for different roles (admin, parent, driver). Child Registration: Stores student details and biometric data. Live Location Tracking: Uses GPS to track vehicle movement. Facial Recognition Verification: Confirms identity before marking a pickup. SMS Alert System: Notifies parents instantly about their child's status.

By integrating these cutting-edge technologies, Guardian Sync provides a robust, scalable, and efficient solution to enhance child safety during school commutes.
This chapter will further explore the general description, user expectations, performance criteria, and system diagrams to provide a +comprehensive understanding of how the system functions.

2.4 GENERAL DESCRIPTION

This section provides a comprehensive overview of the Guardian Sync system, detailing its core functionalities, expected user interactions, and the environment in which it will operate. The system is designed to enhance child safety, real-time attendance tracking, and automated communication between parents, school administrators, and drivers.

Traditional tracking methods, such as RFID-based attendance systems or manual roll calls, have significant limitations. They only confirm that a student is present but do not verify whether the right person is picking up or dropping off the child. Guardian Sync addresses these limitations by integrating real-time GPS tracking with biometric authentication, ensuring foolproof verification before marking attendance.

The system consists of two main components:

- Web Portal (Admin Dashboard) – Used by school administrators to register students, monitor attendance, and assign bus routes.
- Mobile Application – Used by drivers and parents to track location, authenticate pickups, and receive SMS alerts.

By combining these technologies, Guardian Sync enhances security, improves communication, and simplifies attendance tracking for educational institutions.

2.4.1 PRODUCT FUNCTION

The Guardian Sync system performs the following key functions:

1. User Authentication

- Multi-role authentication system: Parents, drivers, and school admins have separate login credentials.

  Secure authentication using JSON Web Tokens (JWT).
  Password recovery and account management features.

2. Child Registration & Face Recognition

- Admin registers students with details such as name, class, roll number, and parent contact information.

  A photo of the child is captured and stored in the database for biometric authentication.
  During pickup, the driver's mobile app scans the child's face to verify identity before allowing the pickup.

3. Live GPS Tracking

- Real-time vehicle tracking using GPS technology.
  Parents can view the child's exact location via the web portal or mobile app.
  Route planning and deviation alerts ensure that school buses follow designated paths.

4. Pickup & Drop-off Verification

- The system prevents unauthorized pickups by ensuring that only verified individuals collect the child. If the face recognition scan fails, the pickup is denied to prevent security breaches.

  A driver cannot mark a pickup or drop-off without successful verification.

5. Automated SMS Notifications

- Parents receive instant SMS alerts when a child is picked up, dropped off, or absent.
  In case of delays, real-time notifications keep parents informed.

6. Admin Dashboard for Monitoring

- Web-based dashboard developed using React and Vite.
  School administrators can monitor all active vehicles, student attendance, and face recognition logs.
  Secure backend with MongoDB and Express.js for data management.

2.4.2 USER CHARACTERISTICS

The system is designed for use by multiple types of users, each with different roles and responsibilities:

1. Parents:

- Can log into the system to track their child's school commute in real time.
- Receive SMS notifications when their child is picked up, dropped off, or absent.
- Access attendance records and view historical pickup/drop data.

2. School Administrators:

- Manage student registration and assign transportation routes.
- Monitor real-time GPS data to track school buses and ensure compliance.
- Ensure that all face recognition logs are properly maintained for security audits.

3. Drivers:

- Use the mobile application to verify each pickup via face recognition.
- Update the child's status as "Picked Up" or "Dropped Off" based on successful verification.
- Receive route navigation assistance to ensure the correct pickup/drop points.

Each user type has a role-based access system ensuring security and proper function allocation.

2.4.3 PRODUCT ENVIRONMENT

The Guardian Sync system is designed to function in various environments, including web-based and mobile-based platforms. It consists of multiple components that interact seamlessly:

1. Web Portal (Admin Dashboard)

- Built using React (Vite framework) for a modern, fast, and responsive UI.

- Hosted on cloud-based servers for scalability.
- Integrated with MongoDB for data storage and retrieval.

2. Mobile Application (React Native)

- Used by drivers and parents for real-time tracking and verification.
- Utilizes device cameras for face recognition during pickups.
- Sends push notifications and SMS alerts.

3. Database (MongoDB & Firebase)

- Stores child details, location logs, pickup records, and face recognition data.
- Real-time data updates to ensure live tracking.
- Secure authentication using JWT tokens to prevent unauthorized access.

4. Communication Services (SMS & GPS APIs)

- Third-party SMS gateways send alerts to parents.
- GPS tracking APIs fetch real-time location data for vehicles and students.

5. Hosting & Deployment

- Cloud-based hosting (AWS, Firebase, or Digital Ocean) ensures high availability.
- Scalable architecture allows the system to handle thousands of users simultaneously.

2.5 ACTIVITY DIAGRAM

An **Activity Diagram** represents the **flow of processes** in the system. It visually describes the sequence of actions from user login to child pickup and SMS notification.

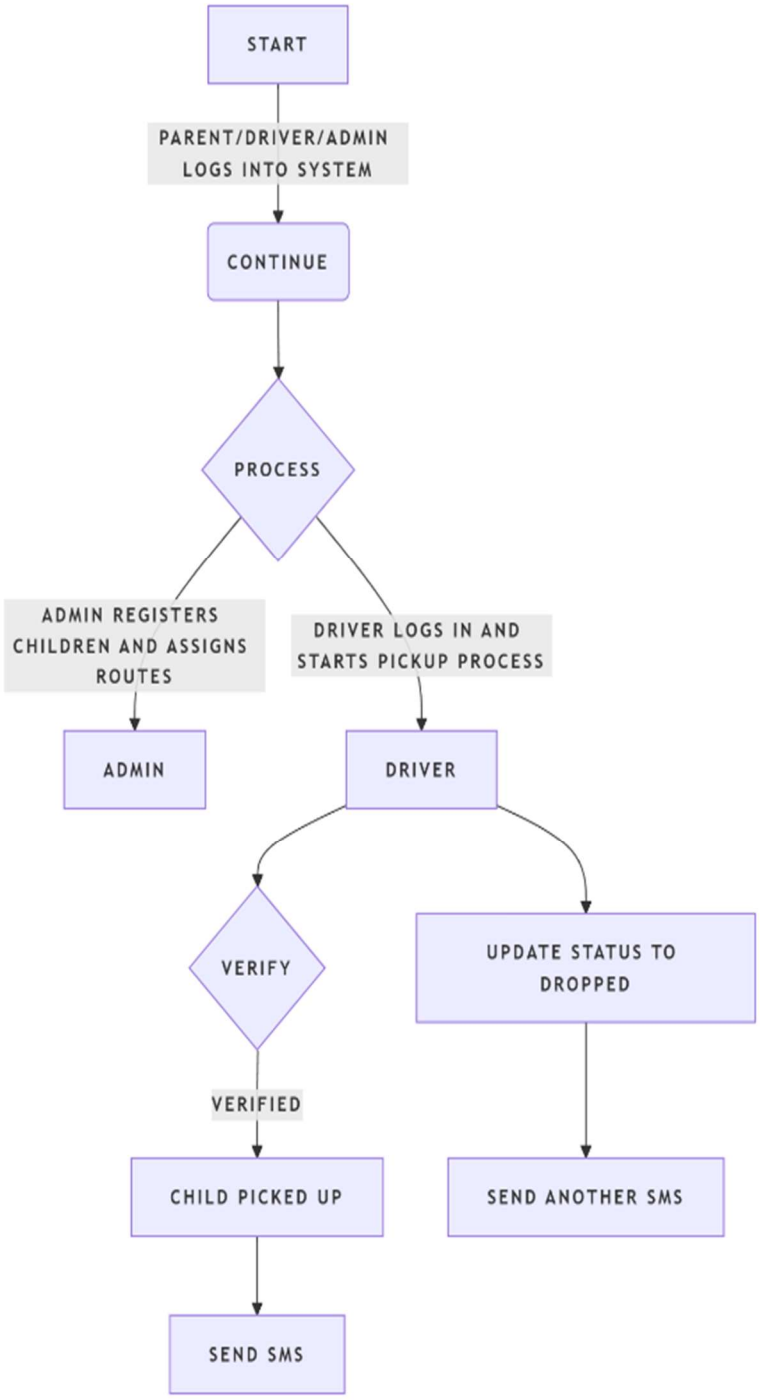

Fig:2.1 Activity Diagram

2.6 SEQUENCE DIAGRAM

A Sequence Diagram shows the interaction between system components over time. It describes how different entities (user, server, database) interact to process a request.

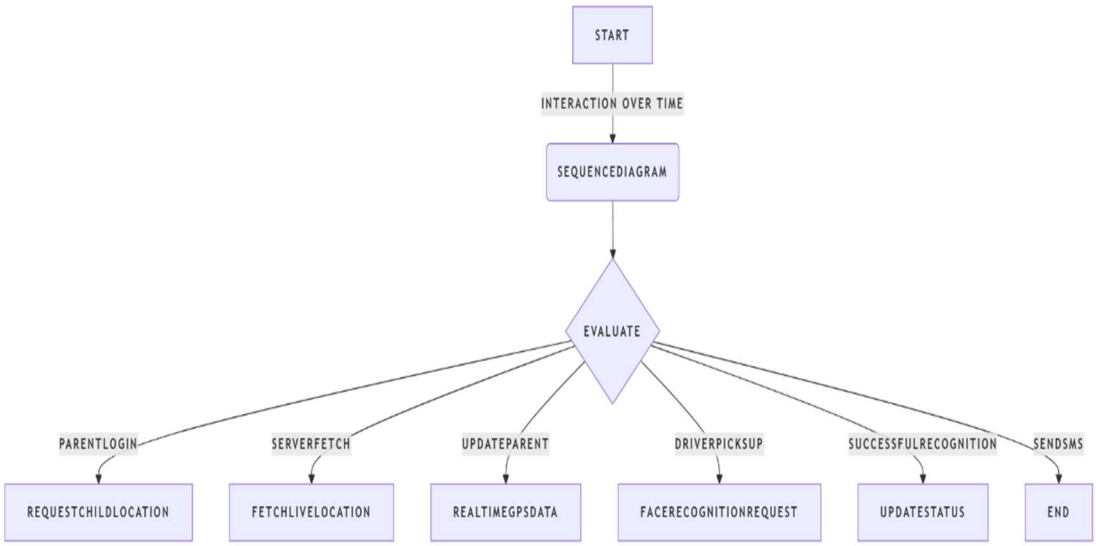

Fig:2.2 Sequence Diagram

CHAPTER 3

SOFTWARE AND HARDWARE REQUIREMENT

This chapter lists and describes the software and hardware necessary for the design, development, deployment, and execution of the **Guardian Sync: Real-Time Child Tracking with Face Recognition and Attendance Monitoring System**. Selecting the right set of tools and environment ensures that the system operates efficiently, securely, and with high performance.

3.1 SOFTWARE REQUIREMENT

The software components required for the successful execution of the project are listed below:

3.1.1 FRONTEND DEVELOPMENT

- **HTML**

Hypertext Markup Language (HTML) is the standard markup language used to create the structure and content of web pages. It consists of a series of elements that define the different parts of a webpage, such as headings, paragraphs, images, links, and forms. HTML elements are structured using tags, which are enclosed in angle brackets. These tags define the semantics and hierarchy of the content, allowing web browsers to render it properly.

HTML elements are the building blocks of HTML pages. With HTML constructs, images and other objects such as interactive forms may be embedded into the rendered page. HTML provides a means to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes and other items. HTML elements are delineated by tags, written using angle brackets. Tags such as <img /> and <input /> directly introduce content into the page. Other tags such as ... surround and provide information about document text and may include other tags as sub-elements. Browsers do not display the HTML tags, but use them to interpret the content of the page. .

- **CSS:**

Cascading Style Sheets (CSS) is a style sheet language used to define the presentation and layout of HTML documents. It allows developers to specify the visual appearance of elements on a webpage, including properties such as colors, fonts, margins, padding, and positioning. CSS works by applying styles to HTML elements using selectors, which target specific elements based on their attributes, classes, or IDs. By separating content from presentation, CSS enables developers to create consistent and visually appealing user interfaces across different devices and screen sizes.

CSS is designed primarily to enable the separation of presentation and content, including aspects such as the layout, colors, and fonts. This separation can improve content accessibility, provide more flexibility and control in the specification of presentation characteristics, enable multiple HTML pages to share formatting by specifying the relevant CSS in a separate .css file, and reduce complexity and repetition in the structural content. Separation of formatting and content makes it possible to present the same markup page in different styles for different rendering methods, such as on-screen, in print, by voice (via speech-based browser or screen reader), and on Braillebased tactile devices. It can also display the web page differently depending on the screen size or viewing device. Readers can also specify a different style sheet, such as a CSS file stored on their own computer, to override the one the author specified.

One of the core concepts in CSS is the Box Model, which describes how elements are rendered in terms of content, padding, border, and margin. Understanding this model is essential for controlling layout and spacing in a web page. CSS also provides powerful layout systems such as Flexbox and Grid, which allow for the creation of responsive, complex layouts without relying heavily on floats or positioning. In modern web development, media queries are used to create responsive designs—layouts that adapt to various screen sizes and devices, ensuring a consistent user experience across desktops, tablets, and mobile phones.

- **REACTJS :**

React.js is a modern, open-source JavaScript library developed by Facebook for building fast, interactive, and scalable user interfaces, primarily for single-page applications (SPAs). Its core philosophy is based on the declarative programming paradigm, which allows developers to describe the *what* of the user interface rather than the *how*. This abstraction reduces complexity in UI logic and enhances developer productivity. React's unique advantage lies in its ability to render views dynamically using a Virtual DOM (Document Object Model)—an in-memory representation of the real DOM—which detects changes and efficiently updates only the parts of the user interface that need re-rendering. This leads to significant performance improvements compared to direct DOM manipulation.

One of React's fundamental architectural features is its component-based structure. In React, user interfaces are broken down into reusable, encapsulated components that manage their own state and can be composed to form complex UIs. This modularity promotes code reuse, readability, and testability, making large-scale application development more manageable. Components in React can be functional or class-based, though the modern trend is toward using functional components with React Hooks, such as useState, useEffect, and useContext, which allow developers to handle state and lifecycle events within functional components. The unidirectional data flow (one-way binding) ensures that data passed from parent to child components is predictable and

easier to debug, a crucial advantage when managing the dynamic and real-time data interactions of applications like *Guardian Sync*.

Furthermore, React.js is highly ecosystem-friendly and integrates seamlessly with other libraries and tools. It supports advanced development features such as JSX (JavaScript XML)—a syntax extension that allows HTML to be written within JavaScript code—offering an intuitive and expressive way to define UI structure. React also works well with routing libraries like React Router for managing page views, and with state management solutions like Redux or Context API for handling global state across components. These capabilities make React particularly suited for real-time, data-driven applications such as *Guardian Sync*, where the interface must respond instantly to events like location updates, pickup confirmations, and biometric verification. React's lightweight nature, combined with its flexibility and scalability, makes it one of the most widely adopted frontend libraries for modern web development.

- **REACT NATIVE:**

React Native is a powerful open-source framework developed by Facebook that enables developers to build cross-platform mobile applications using JavaScript and React principles. Unlike traditional mobile development, which requires writing separate codebases in platform-specific languages (Java/Kotlin for Android, Swift/Objective-C for iOS), React Native allows developers to write a single JavaScript codebase that renders native components across both operating systems. This is achieved through a JavaScript bridge that communicates with the native platform APIs. As a result, applications built with React Native offer the performance and responsiveness of native apps while significantly reducing development time and effort.

At the heart of React Native lies its component-driven architecture, inherited from React.js. Developers define the UI using React components, which are then mapped to native platform widgets. For example, a `View` component in React Native corresponds to `UIView` on iOS and `View` on Android. This approach allows for consistent user interfaces across platforms while still enabling platform-specific customizations when necessary. Furthermore, React Native includes access to powerful built-in modules for essential mobile functionalities such as

accessing the camera, geolocation, file storage, SMS, and push notifications. This makes it especially suitable for applications that require real-time data handling and hardware integration—like *GuardianSync*, which depends on live GPS tracking and camera access for face recognition.

In addition to its performance advantages, React Native embraces modern JavaScript features and tools such as ES6 syntax, asynchronous programming with Promises and async/await, and React Hooks for state and effect management. The ecosystem also supports third-party libraries and native modules, expanding the framework's capabilities far beyond its core API. Development and debugging are streamlined through tools like Expo, React Native CLI, Hot Reloading, and integration with development environments like Visual Studio Code. For applications such as *GuardianSync*, React Native's strengths lie in its ability to provide a smooth and responsive user experience on mobile devices while efficiently accessing device hardware to capture live location, verify identity through the camera, and update the server with minimal latency—all within a unified, maintainable codebase.

3.1.2 BACKEND DEVELOPMENT

- **Node.js**

Node.js is an open-source, cross-platform runtime environment that allows JavaScript to be executed outside the browser, primarily on the server-side. Built on the powerful **Google Chrome V8 engine**, Node.js translates JavaScript code into fast, machine-level code, enabling high-performance backend services. Unlike traditional server technologies that follow a multi-threaded model, Node.js operates on a **single-threaded, event-driven architecture**, making it non-blocking and asynchronous by nature. This allows Node.js to handle thousands of simultaneous connections efficiently, which is ideal for applications that require real-time interaction, such as *GuardianSync*, where continuous location tracking and face recognition events must be processed without delay.

One of the defining features of Node.js is its **event loop and callback mechanism**, which handles I/O operations like file reading, network requests, and database interactions without blocking the execution of other code. This means that while the server is waiting for data from a database or external API, it can still process other incoming requests. This scalability is crucial for real-time systems like *GuardianSync*, which involves live GPS data and user inputs from multiple mobile devices. Additionally, Node.js has access to the **Node Package Manager (NPM)**, the largest ecosystem of open-source libraries in the world, enabling developers to integrate functionalities such as SMS APIs, security middleware, image processing tools, and much more with minimal effort.

In terms of architecture, Node.js promotes modularity through the use of CommonJS modules, allowing developers to separate concerns and build maintainable server applications. With its growing popularity and vast community support, Node.js has become the backbone for many high-performance, real-time applications, including chat systems, streaming services, and IoT platforms. In *GuardianSync*, Node.js powers the core backend logic—handling API requests from the React and React Native frontends, coordinating with the MongoDB database, and processing secure data transmissions. Its event-driven design ensures that every component of the system responds quickly and reliably to user and system actions, contributing to the app's efficiency and responsiveness.

- **Express.js**

Express.js is a lightweight, flexible web application framework for Node.js that simplifies the process of building robust server-side applications and RESTful APIs. Often referred to as the de facto standard server framework for Node.js, Express provides a minimal and unopinionated foundation upon which developers can build web servers and APIs with complete control over the application's structure and behavior. It abstracts away the complexity of setting up routing, middleware, and HTTP handling, allowing developers to focus on the core business logic of their applications. In the *GuardianSync* project, Express.js is responsible for defining the routes for user authentication, child registration, attendance logging, and real-time location updates.

Express supports the use of middleware functions, which are functions executed sequentially during the lifecycle of an HTTP request. Middleware can perform operations like validating incoming data, authenticating users via JSON Web Tokens (JWT), logging request details, or handling errors before passing control to the next function in the stack. This architecture results in highly modular and maintainable server code. For example, when a parent or staff logs into the *GuardianSync* portal or app, Express.js validates their credentials, verifies their JWT token, and grants access only after proper authentication—all handled cleanly through middleware. Furthermore, Express simplifies route handling through intuitive HTTP method functions like .get(), .post(), .put(), and .delete(), enabling clear and structured API definitions.

Express also plays a pivotal role in the seamless integration between the frontend and backend. It acts as the communication bridge between the React-based web dashboard, the React Native mobile application, and the MongoDB database. When the mobile app sends a location update or face recognition result, Express processes the request, interacts with the database, and sends appropriate responses back to the client in real time. Its performance, scalability, and developer-friendly syntax make Express a critical part of the *GuardianSync* backend, providing a reliable platform to build secure, scalable, and maintainable REST APIs that meet the demands of a modern child safety system.

- **MongoDB**

MongoDB is a popular open-source, NoSQL (non-relational) database system designed to store and process large volumes of unstructured and semi-structured data. Unlike traditional relational databases that use tables and fixed schemas, MongoDB stores data in flexible, JSON-like documents known as BSON (Binary JSON). Each document can have a different structure and fields, allowing for greater adaptability and easier updates without the need to alter database schemas. This schema-less architecture makes MongoDB especially well-suited for applications with evolving data models, such as *GuardianSync*, where child profiles, real-time GPS logs, attendance records, and biometric verification results need to be stored efficiently without rigid table structures.

One of MongoDB's defining features is its ability to scale horizontally through sharding, distributing data across multiple machines or clusters. This ensures high availability, fault tolerance, and support for massive datasets—capabilities that are critical for real-time systems handling thousands of concurrent operations. In *GuardianSync*, MongoDB is used to store dynamic data such as user credentials, child registration information, attendance status, and time-stamped GPS coordinates. The use of indexes in MongoDB enhances the performance of data retrieval operations, especially when querying location history or fetching children's attendance logs. The ability to store nested documents and arrays directly also allows for a more natural representation of complex data relationships, reducing the need for multiple joins as in traditional SQL databases.

MongoDB integrates seamlessly with Mongoose, an Object Data Modeling (ODM) library for Node.js, which helps define data schemas, enforce validations, and simplify database interactions through JavaScript objects. With Mongoose, developers can define strict models for user authentication, children's profiles, and pickup/drop logs, ensuring consistency and reducing the chances of data anomalies. MongoDB's flexible query language also allows for complex filtering, sorting, and aggregation operations, making it easy to generate analytics, such as attendance summaries or real-time alerts. Overall, MongoDB plays a crucial role in the backend of *GuardianSync* by offering a scalable, efficient, and flexible storage solution tailored for modern, real-time safety and tracking systems.

3.1.3 Face Recognition Tools

- **FACE-API.JS**

Face-api.js is a powerful JavaScript library that enables real-time face detection and face recognition directly in the browser or on client devices using TensorFlow.js, a JavaScript version of the TensorFlow machine learning framework. Designed to run entirely in the frontend environment, face-api.js leverages deep learning models that are pre-trained for tasks such as face detection, face landmark recognition, face expression classification, and face descriptor generation. This eliminates the need for server-side processing and makes it

particularly suitable for applications like *GuardianSync*, where quick, secure, and offline-capable biometric verification of children at pickup/drop-off points is essential.

The core functionality of face-api.js revolves around its ability to detect and recognize human faces from real-time video input, such as a mobile camera or webcam feed. When a face is detected, the library identifies 68 facial landmarks (eyes, nose, mouth, jawline, etc.) and generates a face descriptor—a numerical vector representation of the face. This descriptor is then compared with stored descriptors to verify identity with high accuracy. In *GuardianSync*, this process ensures that the correct child is being picked up or dropped off by authorized personnel, providing a layer of biometric security that goes beyond traditional card-based or manual attendance methods. By using JavaScript, face-api.js seamlessly integrates with both React.js and React Native, offering a unified and efficient development workflow across web and mobile platforms.

Another key advantage of using face-api.js is its client-side execution, which enhances user privacy and reduces latency. Since face data is processed directly on the user's device, sensitive biometric information doesn't need to be uploaded to external servers, minimizing the risk of data breaches. This privacy-first design is critical for child safety applications where safeguarding user identity is a legal and ethical priority. Furthermore, the performance of face-api.js can be optimized with lightweight models for mobile devices, and it supports GPU acceleration via WebGL for smoother real-time processing. In *GuardianSync*, this translates to fast and reliable face recognition, even in challenging network conditions, making it a valuable tool in the system's overall architecture for ensuring safe and authenticated student handling.

3.2 Location Tracking and Map Tools

3.2.1 GPS Sensors (Mobile Device GPS)

Global Positioning System (GPS) sensors integrated into modern mobile devices are essential components for real-time location tracking in many mobile applications. These sensors receive signals from a constellation of satellites orbiting the Earth to triangulate the

user’s geographic position with a high degree of accuracy. GPS modules in smartphones typically function alongside additional positioning services such as Assisted GPS (A-GPS), GLONASS, or Wi-Fi triangulation, enhancing location accuracy even in environments with weak satellite signals. In the context of *Guardian Sync*, the GPS sensor plays a critical role in capturing the live location of the user—whether it is a driver, parent, or school staff—ensuring the child's movement is monitored throughout transit.

GPS sensors offer location coordinates in the form of **latitude and longitude**, which can then be mapped and stored in a backend database for processing and display. These coordinates are dynamically updated in the mobile application as the user moves, enabling real-time tracking. React Native provides access to GPS through libraries such as @react-native-community/geolocation or expo-location, which interact directly with the mobile operating system’s location services. In *Guardian Sync*, this allows the application to continuously send location updates to the backend, where it is processed and displayed on an administrative dashboard. This continuous feedback loop ensures that parents and administrators have real-time visibility of the child's commute.

Additionally, mobile GPS sensors can be configured for **varying degrees of accuracy and frequency**, depending on application needs. For high-precision tracking, the system can request fine-grained location updates, which consume more battery, while for periodic monitoring, coarse location data can be used to conserve power. The implementation in *GuardianSync* is designed to balance **performance, power efficiency, and user privacy**, ensuring that tracking is accurate enough for safety purposes without overwhelming the device’s resources. This real-time data capture mechanism forms the backbone of the location-based functionality within the system.

3.2.2 Google Maps API / Leaflet.js

Google Maps API and **Leaflet.js** are two of the most widely used tools for embedding interactive maps into web and mobile applications. The **Google Maps API** is a powerful suite of services provided by Google that includes dynamic map rendering, geocoding, routing, traffic overlays, and more. It enables developers to visualize location data, calculate routes, and place interactive markers based on GPS coordinates. In *Guardian Sync*, the

Google Maps API can be used to visually represent the real-time location of children on their journey, allowing parents and school administrators to monitor pickup and drop-off activities from the web portal in a user-friendly and intuitive manner.

Leaflet.js, on the other hand, is an open-source JavaScript library for mobile-friendly interactive maps. It is lightweight, fast, and easy to use, making it particularly suitable for custom applications that require map integration without heavy dependencies. Leaflet allows the addition of custom markers, layers, and pop-ups, and it supports various tile providers such as OpenStreetMap. For *Guardian Sync*, Leaflet.js can serve as an effective alternative to the Google Maps API, particularly in scenarios where open-source, cost-free mapping solutions are preferred. It can display real-time routes, animate movements, and update markers dynamically as GPS data is received from the backend server.

Both tools offer **real-time location plotting** capabilities, which are essential for tracking systems like *Guardian Sync*. Whether using Google Maps or Leaflet.js, the frontend can receive GPS data via WebSocket or periodic API calls and update the child's position on the map in near real time. This real-time visualization increases transparency, builds trust among stakeholders, and enhances the overall security of student transport by giving stakeholders immediate insight into a child's location. The map interface also facilitates administrative tasks, such as route analysis, pickup verification, and exception handling during unexpected delays or diversions.

3.3 Notification Tools

3.3.1 Twilio SMS API

Twilio SMS API is a cloud communications platform that enables developers to send and receive text messages (SMS) globally through simple and scalable RESTful APIs. Twilio abstracts the complexities of telecommunications infrastructure by offering a programmable interface that can be easily integrated into web and mobile applications. In the context of *GuardianSync*, Twilio is used to automatically notify parents and guardians about key events such as child pickup, drop-off, or absenteeism. These real-time SMS alerts ensure that

parents remain informed and reassured about their child's safety and location, even without internet access or app notifications.

The Twilio API works by sending HTTP requests from the application backend (e.g., using Node.js and Express.js) to Twilio's servers, including parameters such as the message content, recipient's phone number, and sender ID. Twilio then routes the message through its telecommunications network to the recipient. Additionally, Twilio supports international delivery, message queuing, delivery status tracking, and failover strategies to ensure reliability. In *GuardianSync*, when a child is marked as "Picked Up" or "Dropped Off" in the app, the backend triggers the Twilio API to generate a personalized SMS and deliver it to the registered parent's mobile number, enhancing real-time communication.

Twilio also offers **programmable message templates**, sender verification, rate-limiting features, and analytics dashboards to monitor the performance and delivery of SMS. For applications handling sensitive data, such as *GuardianSync*, Twilio ensures secure message delivery by complying with international standards like GDPR and HIPAA. The system can also handle automated error reporting or escalation in case an SMS fails to send. The use of Twilio adds a layer of immediate, reliable communication that is essential for building trust and transparency in real-time safety systems involving children.

3.3.2 Firebase Cloud Messaging (FCM)

Firebase Cloud Messaging (FCM) is a cross-platform messaging solution developed by Google that enables developers to send notifications and data messages to client applications across Android, iOS, and web platforms. FCM is part of the Firebase suite and is designed for high-performance, real-time messaging with minimal setup. Unlike SMS, FCM uses internet connectivity (via HTTP/HTTPS or XMPP protocols) to deliver push notifications to applications. In *GuardianSync*, FCM is used to send non-intrusive push notifications to parents, drivers, and administrators for various events such as login attempts, attendance confirmation, or geofencing alerts.

The FCM infrastructure is highly optimized for scalability and efficiency. It uses device tokens generated by the client app to identify recipients and manage subscriptions to different topics (e.g., all Grade 1 parents). Developers can send targeted messages based on user behavior, location, or preferences, ensuring relevant communication without overwhelming the user. For example, if a child is marked absent, *GuardianSync* can use FCM to instantly notify the parent via a push notification, accompanied by relevant details like date, time, and class. Since notifications can be handled in the background, FCM also allows for silent data updates or syncing user data in real time without requiring user interaction.

FCM supports message prioritization, offline message queuing, analytics integration, and seamless integration with other Firebase services like Firebase Authentication and Realtime Database. Its deep integration with Android and iOS ecosystems ensures efficient battery use, native UI support, and robust delivery metrics. Unlike SMS, FCM is cost-effective and suitable for bulk messaging in internet-connected environments. For *GuardianSync*, combining FCM with Twilio provides a hybrid communication model where critical alerts are sent via SMS (for guaranteed delivery), and routine updates or confirmations are handled via FCM push notifications, ensuring reliability, cost-efficiency, and user engagement.

3.4 SECURITY TOOLS

3.4.1 JSON Web Tokens (JWT)

JSON Web Tokens (JWT) are an open standard (RFC 7519) used to securely t ransmit information between two parties as a JSON object. These tokens are compact, self-contained, and digitally signed, making them a widely adopted method for handling user authentication and information exchange in modern web applications. In *Guardian Sync*, JWT plays a crucial role in maintaining secure user sessions after successful login. Once a user is authenticated via the backend (Node.js/Express.js), the server generates a JWT containing payload data such as the user ID, role, or session expiry, and returns it to the client. This token is stored locally (e.g., in browser local storage or mobile device storage) and is sent with each request to protected resources, enabling stateless authentication.

A typical JWT consists of three parts: **header, payload, and signature**. The header specifies the algorithm used for signing (e.g., HMAC SHA256), the payload contains the claims (user-specific data), and the signature is generated by hashing the encoded header and payload using a secret key. This signature ensures the token's integrity and authenticity, as any alteration in the token's content will invalidate the signature. In *GuardianSync*, JWTs prevent unauthorized access to sensitive endpoints such as child profiles, location data, and attendance updates. The backend validates the token on each request, ensuring that only authenticated users (like school staff, drivers, or parents) can access their respective resources.

JWT-based authentication offers several advantages, including scalability, statelessness, and ease of integration with RESTful APIs. Since the server does not need to store session data, JWT improves performance and simplifies load balancing across multiple servers. Furthermore, tokens can have built-in expiration times, adding a layer of time-based security. For *GuardianSync*, the use of JWT ensures that the authentication mechanism is secure, fast, and aligned with industry best practices for modern web and mobile development, especially when handling sensitive data related to child safety and real-time tracking.

3.4.2 HTTPS/SSL

HTTPS (Hypertext Transfer Protocol Secure) is the secure version of HTTP and uses **SSL/TLS (Secure Sockets Layer / Transport Layer Security)** protocols to encrypt the communication between a client (browser or mobile app) and the server. HTTPS ensures that all data exchanged is encrypted, authenticated, and cannot be intercepted or tampered with by malicious actors. In *Guardian Sync*, HTTPS is employed to protect sensitive data transmissions, such as login credentials, child information, location coordinates, and biometric face recognition data. By using SSL certificates issued by trusted Certificate Authorities (CAs), the system guarantees that clients are communicating with legitimate servers.

The encryption process begins with an **SSL handshake**, during which the client and server exchange cryptographic keys and agree on a cipher suite. Once the secure connection is established, all subsequent communication is encrypted using symmetric keys, ensuring confidentiality and integrity. Any data intercepted during transmission would appear as gibberish without the corresponding decryption key. For applications like *Guardian Sync* that handle personal and location-based data of minors, HTTPS is not just a recommendation but a requirement under many data protection regulations such as GDPR and COPPA, making it an essential component of the overall security architecture.

Additionally, HTTPS helps in establishing **trust and credibility** with users by showing the padlock symbol in browsers, indicating a secure connection. Modern browsers often block non-secure (HTTP) requests, especially when handling sensitive content, further emphasizing the importance of SSL/TLS. By enforcing HTTPS across all routes and APIs in *GuardianSync*, the development team ensures that both the web portal and the mobile app maintain data confidentiality, prevent man-in-the-middle (MITM) attacks, and build a trustworthy experience for users handling real-time attendance and safety data. Combining HTTPS with JWT-based authorization further enhances the end-to-end security of the system.

3.5 Development and Deployment Tools

3.5.1 Git

Git is a distributed version control system designed to track changes in source code during software development. Originally created by Linus Torvalds in 2005, Git enables multiple developers to collaborate on a codebase efficiently without overwriting each other's work. One of Git’s core strengths is its ability to store every version of a project in a local repository, allowing developers to work offline and merge changes later. In the *GuardianSync* project, Git played a central role in managing the source code of both the mobile and web applications, enabling the development team to maintain a clean, documented history of all changes and enhancements throughout the project lifecycle.

Git organizes code changes using a structure known as **branches**, which allows developers to work on new features, bug fixes, or experimental updates in isolated environments without affecting the stable version of the project. Once the changes are complete and tested, the branch can be merged into the main codebase. This approach was crucial in *GuardianSync*, where different modules such as face recognition, GPS tracking, and SMS integration were developed in parallel. Developers could independently test their modules, resolve merge conflicts if any, and ensure a smooth integration into the main system.

Additionally, Git provides tools for **staging**, **committing**, and **tracking changes**, which makes it easier to identify who made what changes and when. This transparency and traceability are particularly useful during debugging and team reviews. By leveraging Git's features, the *GuardianSync* development team ensured code quality, reduced duplication of effort, and maintained consistent progress. The system's reliability and maintainability were greatly enhanced through regular commits, descriptive commit messages, and structured version control practices.

3.5.2 GitHub:

GitHub is a cloud-based hosting platform for Git repositories, offering a web interface and collaboration features that extend the capabilities of Git. GitHub enables teams to store their Git repositories online, collaborate remotely, review each other's code, and manage issues and pull requests. In the context of *GuardianSync*, GitHub was used as the central platform for hosting the project code, managing development tasks, and coordinating contributions between team members. It facilitated a unified workflow by allowing contributors to clone the repository, push their updates, and open pull requests for team review before integration into the main branch.

One of the key advantages of GitHub is its **integration with DevOps and CI/CD pipelines**, which supports automated testing, deployment, and code analysis. While developing *GuardianSync*, GitHub Actions could be configured to automatically test new code for errors, ensure that it adhered to project standards, and even deploy updates to servers or

mobile build tools. GitHub also supports **issue tracking and project boards**, which were valuable for organizing development tasks, prioritizing features, and resolving bugs in a systematic manner. These tools foster transparency and accountability among team members.

Furthermore, GitHub fosters **open collaboration** and encourages documentation through markdown files such as README.md, where project overviews, setup instructions, and usage guidelines can be shared. For *GuardianSync*, this meant that future developers or academic evaluators could easily understand the system's structure and replicate the setup if necessary. GitHub's robust access control, backup, and version history features ensured that the codebase remained secure and recoverable, even in the face of human errors or system failures. Together with Git, GitHub provided a powerful ecosystem for collaborative, reliable, and professional-grade software development.

3.5.3 POSTMAN:

Postman is a widely-used API testing and development tool that simplifies the process of sending HTTP requests and analyzing responses. It provides an intuitive graphical user interface (GUI) for interacting with RESTful APIs without the need to write scripts or code. In the *GuardianSync* project, Postman was instrumental during backend development for testing API endpoints related to user authentication, attendance updates, child registration, and SMS notifications. With Postman, the development team could verify that server responses were accurate, properly structured, and secure before integrating them into the front-end applications.

One of Postman's most powerful features is its ability to **simulate different request types (GET, POST, PUT, DELETE)** and to include custom headers, parameters, and body data. This flexibility enabled comprehensive testing of JWT-protected routes, verification of form validations, and debugging of real-time data interactions. Postman also provided tools to automate tests using pre-request scripts and test scripts in JavaScript, which helped identify

bugs early in the API development cycle. For example, the accuracy of token authentication and session expiration in *GuardianSync* was rigorously tested using these features.

Furthermore, Postman supports **environment variables, team collaboration, and collection-based test suites**, which were particularly useful for organized API testing across various modules. It allowed the developers to save frequently used requests and group them into collections, which improved productivity and standardization. In a collaborative environment like *GuardianSync*, these features allowed multiple team members to test their modules consistently and share configurations effortlessly. Overall, Postman played a critical role in validating the integrity, performance, and security of the system's backend services.

3.5.4 Visual Studio Code:

Visual Studio Code (VS Code) is a powerful, open-source code editor developed by Microsoft that supports a wide range of programming languages and development environments. Known for its lightweight design and high performance, VS Code was the primary integrated development environment (IDE) used by the *GuardianSync* team for both front-end and back-end development. Its versatility made it ideal for working with the MERN stack (MongoDB, Express.js, React.js, Node.js) and React Native, providing syntax highlighting, intelligent code completion, and in-editor debugging features that streamlined the development process.

VS Code's **extension ecosystem** greatly enhanced the development experience in *Guardian Sync*. Plugins such as Prettier for code formatting, ESLint for linting JavaScript code, GitLens for version control visualization, and REST Client for lightweight API testing were all utilized to maintain code quality and consistency. Extensions for React and React Native improved code navigation, offered component previews, and provided development assistance specific to JSX and JavaScript ES6+. These tools helped minimize syntax errors, reduce code clutter, and accelerate debugging during the mobile and web app development phases.

Another key benefit of VS Code is its **integrated terminal and Git support**, which allowed the *Guardian Sync* developers to run commands, manage source control, and handle deployments without switching between multiple tools. The built-in debugger supported breakpoints, variable watches, and call stack inspection, making it easier to find and resolve logic issues in both frontend interfaces and backend APIs. With workspace and multi-root support, developers could work on multiple modules—such as the React Native mobile app and the ReactJS web portal—simultaneously within a single project environment. Overall, VS Code served as an efficient and cohesive platform for developing a full-stack real-time safety system.

3.5.5 Deployment Tools (Firebase / Render / AWS)

Deployment tools are essential for transitioning an application from development to production, ensuring that users can access and interact with the software reliably and securely. In *Guardian Sync*, a mix of cloud-based deployment platforms like **Firebase**, **Render**, and **AWS (Amazon Web Services)** was considered or utilized to host the system's components, depending on scalability, cost, and performance requirements. These platforms offer managed infrastructure, security, and automatic scaling, making them suitable for both startups and large-scale applications. They allow real-time applications like *Guardian Sync* to be made accessible to end-users with minimal manual configuration.

Firebase was particularly useful for hosting static content (e.g., the ReactJS web portal) and for integrating features such as Firebase Cloud Messaging (FCM) for push notifications. Its hosting service provides HTTPS support, fast global CDN distribution, and simple CLI tools for deploying code. Firebase's real-time database and authentication services also offered alternatives during early prototyping stages. Meanwhile, **Render** was used for hosting backend services built on Node.js, offering a simplified continuous deployment pipeline directly connected to GitHub. Render supports auto-deploy from repositories, SSL, background workers, and databases—all in a developer-friendly interface.

AWS was considered for advanced scalability and enterprise-level deployments, offering services like Amazon EC2 (for hosting custom backend servers), S3 (for static assets), and RDS/MongoDB Atlas (for database hosting). AWS provides extensive configuration, performance tuning, and security features but requires deeper technical expertise. For *Guardian Sync*, a hybrid deployment model using Firebase for front-end hosting and Render for backend APIs ensured optimal cost-efficiency and performance. These deployment platforms ensured 24/7 availability, automatic scaling under traffic spikes, and secure, reliable access for all stakeholders in the system—from parents to school administrators.

3.6 HARDWARE REQUIREMENT

The hardware components required for developing and running the system are listed below:

3.6.1 Development Environment

Laptop/Desktop for Developers

➔ Minimum Specifications:

- **Processor:** Intel Core i5 / AMD Ryzen 5 or higher
- **RAM:** 8 GB (Recommended: 16 GB)
- **Storage:** 256 GB SSD (Recommended: 512 GB)
- **Operating System:** Windows 10 / Ubuntu 20.04 LTS / macOS
- **Graphics:** Integrated or Dedicated GPU (for local face recognition testing)

3.6.2 Server Requirement

- **Cloud Hosting Service (AWS / DigitalOcean / Heroku / Firebase)**

RAM: 4 GB or higher

- **CPU:** 2 vCPUs or higher
- **Storage:** 100 GB SSD
- **Network:** High-bandwidth with 99.9% uptime

3.6.3 Mobile Devices

- **Driver Smartphones:**

  ➔ Android/iOS smartphones with:

- GPS enabled
- Good-quality camera (8 MP or higher for face scanning)
- Internet connectivity (4G/5G recommended)
- Sufficient battery backup (since drivers are mobile)
- **Parent Smartphones:**

  ➔ Android/iOS devices for app installation to track the child's movement and receive updates.

3.6.4 Other Hardware

Camera Module for Testing (Optional)

➔ Used for simulating and testing live face recognition during development.

➔ Webcams or IP cameras may be used for offline testing environments.

Router and Internet Connectivity

➔ High-speed internet with minimum 5 Mbps upload/download speed to ensure seamless location updates and API interactions.

CHAPTER – 4

METHODOLOGIES AND TECHNICAL APPROACHES

This chapter explains the **system development methodologies**, **design strategies**, and **technical approaches** adopted for building the **GuardianSync: Real-Time Child Tracking with Face Recognition and Attendance Monitoring System**. The development focuses on modularity, scalability, real-time performance, and security to meet the project's objectives. The system development was carried out in phases to ensure systematic progression from planning to deployment.

4.1 System Development Life Cycle (SDLC)

For the development of the *Guardian Sync* project, the **Agile Development Model** was selected as the foundational system development life cycle approach. Agile is a modern, iterative methodology that emphasizes flexibility, user collaboration, rapid delivery, and adaptability to changing requirements. Unlike traditional waterfall models that follow a rigid, sequential process, Agile allows teams to break down the project into manageable components, develop and test them in short cycles, and continually refine the product based on real-time feedback. This model is especially suitable for a child safety system like *GuardianSync*, where evolving user needs, security updates, and real-time technical enhancements are anticipated throughout the lifecycle of the application.

One of the primary advantages of the Agile model is its structured yet adaptive framework, which enables developers to respond quickly to feedback and unforeseen challenges. In the

GuardianSync project, development was organized into multiple **sprints**, each lasting approximately 2–3 weeks. During each sprint, the team focused on a specific core module such as GPS-based location tracking, biometric face recognition, or automated SMS notifications. This **sprint planning process** ensured that every module was independently conceptualized, developed, tested, and improved before being integrated into the larger system. This modular, sprint-based approach not only improved development efficiency but also allowed stakeholders to review and provide input at regular intervals, ensuring the final product aligned closely with user expectations and safety requirements.

Furthermore, Agile practices such as **daily stand-up meetings** and **iterative development cycles** played a vital role in maintaining team communication, identifying blockers, and tracking progress. These short, focused meetings ensured that developers remained aligned on goals, rapidly resolved technical challenges, and minimized workflow disruptions. In terms of deployment and version control, **Continuous Integration and Continuous Deployment (CI/CD)** pipelines were implemented using GitHub Actions. These tools enabled the development team to automatically build, test, and deploy application updates to platforms like Firebase in a seamless and efficient manner. The integration of CI/CD ensured that *GuardianSync* remained up to date with the latest code changes, reducing downtime and ensuring a stable, secure system for end-users.

Key Agile Practices Used:

- **Sprint Planning:** Short development cycles (2-3 weeks) were conducted.
- **Daily Stand-ups:** Quick meetings to discuss development status and blockers.
- **Iterative Development:** Each core feature (GPS tracking, SMS notifications, Face Recognition) was developed and tested independently before integration.
- **Continuous Integration/Deployment (CI/CD):** Frequent updates and testing were performed using GitHub actions and hosting platforms like Firebase.

4.2 Project Modules

The project was divided into **five main functional modules**:

4.2.1 User Authentication (Login/Signup Module)

The **User Authentication Module** forms the foundational layer of security within the *Guardian Sync* system, ensuring that access to sensitive data and system features is strictly controlled based on user roles. This module is designed to manage secure login, session handling, and access permissions for three distinct categories of users—**Parents, Drivers, and Administrators**. Given the system's objective of tracking real-time location and safeguarding child identity, it is imperative that only authenticated and authorized users are allowed to interact with specific modules. The authentication system not only verifies user identity but also controls access to personalized dashboards and feature sets based on user roles.

To achieve secure and stateless session management, the system employs **JWT (JSON Web Tokens)** for authentication. Upon successful login, the server generates a signed token that encapsulates essential user information such as user ID, role (e.g., admin, parent, driver), and session validity. This token is then returned to the client and stored locally (in browser storage or secure mobile storage) to be included in every subsequent request. On the server side, JWTs are validated for authenticity using a secret key before granting access to protected endpoints. This stateless model ensures scalability and removes the need for server-side session storage, making the system lightweight and suitable for distributed deployment environments. Additionally, token expiration and renewal mechanisms are used to maintain security without compromising user experience.

From a security standpoint, **password protection** is enforced using **bcrypt**, a robust password-hashing function designed to resist brute-force attacks. When a user registers or updates their password, it is encrypted using bcrypt before being stored in the MongoDB database. During login, the system compares the hashed version of the entered password with the stored hash, ensuring that plaintext credentials are never exposed. To further

enhance usability and access management, the frontend system dynamically renders **role-based dashboards**, providing tailored interfaces and functionality to each type of user. For instance, a parent can view real-time child location and attendance status, a driver can mark pickup/drop events, and an administrator can manage student registrations and system-wide settings. This separation of concerns contributes to both usability and system integrity, ensuring that each user only accesses the features relevant to their responsibilities.

Purpose: Secure login and access control for three user roles: Parent, Driver, Admin.

- **Technical Approach:**
- Implemented **JWT-based authentication** for secure session management.
- Passwords were stored securely using **bcrypt encryption** in the database.
- Separate user dashboards based on roles were designed for better user experience.

4.2.2 Child Registration and Management Module

The **Child Registration and Management Module** is a critical component of the *Guardian Sync* system, responsible for collecting, storing, and managing all child-related information necessary for real-time tracking, attendance, and biometric identification. The primary objective of this module is to maintain a secure digital profile of every student that includes demographic data, academic identifiers, and biometric facial data. This data serves as the foundation for ensuring safe and authenticated pick-up and drop-off procedures. The implementation of this module aligns with the system's core goal of enhancing school transportation security by ensuring that each child is uniquely identified, accurately tracked, and accounted for during transit.

The registration process is managed through an administrator-facing interface where school staff or authorized personnel can input student data. Each child’s record includes essential fields such as **Name, Class, Roll Number, Section, and Parent/Guardian Contact Information**. Additionally, a **facial image** of the child is captured using a connected webcam or mobile device camera and is uploaded during the registration process. This image is then processed using face recognition libraries (e.g., face-api.js) to generate **facial descriptors**, which are numerical representations of the child's facial features. These descriptors are

stored securely and later used in the Face Recognition Module to verify a child's identity at the time of pick-up or drop-off, providing a seamless and secure biometric layer of protection.

The storage of these structured records is handled using **MongoDB**, a NoSQL database chosen for its flexibility, scalability, and performance in managing semi-structured data. MongoDB's document-based structure allows each child's profile to be stored as a JSON-like document, making it easy to handle varying sets of attributes, including nested objects such as parental information or biometric data. The use of **Mongoose**, an Object Data Modeling (ODM) library, ensures schema enforcement, data validation, and efficient querying of child profiles. All sensitive information, including biometric images and parental contact details, is stored with appropriate encryption and access controls to comply with data privacy best practices. This module not only ensures the accurate registration and future identification of children but also provides a reliable foundation for integrating safety protocols into everyday school operations.

Purpose: Storing student details along with biometric (facial) data.

Technical Approach:

- Admins register children with full profile details (Name, Class, Roll Number, Photo).
- Facial images are captured and stored during registration for future recognition.
- MongoDB is used to store structured child records securely.

4.2.3 Real-Time Location Tracking Module

The **Real-Time Location Tracking Module** is one of the most essential components of the *Guardian Sync* system, designed to ensure that parents and school administrators can continuously monitor the real-time location of school vehicles. The primary goal of this module is to enhance child safety during transportation by providing live location visibility, reducing uncertainty, and enabling immediate responses to unexpected situations such as route deviations or delays. By leveraging modern geolocation technologies and real-time data transmission, this module builds transparency and trust between stakeholders while enabling operational efficiency.

The technical implementation of this module is accomplished by integrating **Google Maps API** with the mobile application built in **React Native**. The driver's device continuously captures GPS coordinates using the mobile device's built-in GPS sensor. These coordinates are sent at regular intervals to the backend server through HTTP requests or WebSocket connections, depending on the required update frequency and network efficiency. On the backend, the coordinates are processed and stored in the database or temporary memory, and then made available to the web portal through secure RESTful APIs. Each data packet typically includes a timestamp, latitude, longitude, and the vehicle ID or driver ID for accurate association and tracking.

On the parent-facing web portal, which is built using **React.js**, the live location is visualized using an embedded map view powered by the **Google Maps JavaScript API** or alternatively **Leaflet.js**. The child's school vehicle is represented by a dynamically updating marker that moves in real time along the vehicle's route. The system ensures a seamless user experience by automatically refreshing the map view based on incoming GPS data, creating a fluid motion of the vehicle icon. This feature allows parents to view exactly where the vehicle is on the route, estimate arrival times, and receive additional contextual data such as pick-up or drop-off status. The combination of accurate GPS data and interactive mapping not only improves the day-to-day experience of parents but also reinforces the system's overall objective of ensuring transparency, accountability, and safety in school transportation.

Purpose: Continuously monitor and update the live location of school vehicles.

Technical Approach:

- Integrated **Google Maps API** for live vehicle location display.
- Mobile app (React Native) continuously sends GPS coordinates to the backend server.
- Parents' web portal shows live location updates using a moving map view.

4.2.4 Facial Recognition Verification Module

The **Facial Recognition Verification Module** in *GuardianSync* is designed to serve as a biometric security layer that ensures children are only picked up by authorized individuals.

This module adds a critical dimension of safety by eliminating reliance on manual verification or ID cards, which are susceptible to human error or misuse. The use of **real-time face recognition** allows the system to identify and authenticate the child's identity before confirming a pickup event. This automated verification process significantly enhances the trustworthiness and reliability of the system in a school transportation context

The facial recognition process in this module involves two primary stages: **face detection** and **face recognition**. First, the image of the child is captured using the device's built-in camera (typically through the React Native mobile app used by the driver or attendant). The system employs popular open-source computer vision libraries such as **OpenCV** and **Dlib** for facial feature detection. Dlib utilizes Histogram of Oriented Gradients (HOG) or Convolutional Neural Networks (CNN) to detect faces, while OpenCV provides the tools for real-time image capture and preprocessing. After detecting a face in the image, the system extracts a set of **facial landmarks**—such as eyes, nose, mouth, and jawline—which serve as unique identifiers for that individual.

To enhance the accuracy and computational efficiency of the matching process, **Principal Component Analysis (PCA)** is applied as a dimensionality reduction technique. PCA transforms the high-dimensional facial data into a lower-dimensional feature space while preserving the most significant variance in the data. This allows the system to perform faster recognition with minimal performance overhead, especially on mobile devices with limited resources. Once a successful match is found between the live-captured face and the stored biometric template from the registration database, the system automatically updates the child's status to "Picked Up" and triggers a notification alert. This alert is sent to the parent via SMS (using Twilio API) and/or push notification (via Firebase Cloud Messaging), thereby ensuring both authentication and real-time communication. Overall, this module seamlessly integrates artificial intelligence and user interaction to provide a high level of security in school commute scenarios.

Purpose: Ensure only authorized pickups through real-time face recognition.

Technical Approach:

- **Face Detection:** Images are captured using the device's camera.
- **Face Recognition:** Matching is performed using **OpenCV** and **Dlib libraries**.
- **Principal Component Analysis (PCA)** was used to improve recognition speed and accuracy by reducing data dimensions.
- A successful match triggers a pickup status update and an SMS alert.

4.2.5 SMS Notification System

The **SMS Notification System** is a core communication component of the *GuardianSync* platform, designed to ensure that parents are kept informed in real-time regarding the status of their child's school commute. In scenarios where mobile applications may not be regularly accessed, or internet connectivity is limited, SMS remains one of the most effective, reliable, and universally supported forms of communication. This system provides immediate alerts to parents upon the child's pickup, drop-off, or marked absence, significantly enhancing the safety and transparency of the transportation process. The ability to receive status updates via SMS ensures peace of mind for parents and reinforces the trustworthiness of the school transport infrastructure.

From a technical perspective, the system utilizes the **Twilio SMS API**—a cloud-based communication platform that enables secure, scalable, and global SMS delivery. In some deployments, **MSG91** or similar alternatives may also be integrated depending on regional availability and pricing. The SMS Notification System is event-driven; it listens for status updates submitted by the driver or attendant through the mobile application. When a child is marked as "Picked Up," "Dropped Off," or "Absent," the application sends a request to the backend server. The server then compiles the relevant data—such as the child's name, status, driver's name or ID, and the exact timestamp—and triggers the Twilio API to dispatch a structured SMS message to the registered parent or guardian's mobile number.

This automatic alert mechanism not only improves operational efficiency but also removes the dependency on manual communication. The SMS messages are generated dynamically,

ensuring that each parent receives accurate and personalized information tailored to their child's journey. In addition to the core status data, contextual details such as the driver's identification help build accountability and traceability. The integration of this module within *GuardianSync* plays a crucial role in closing the feedback loop between the school transport system and the end-user (parent), promoting a safe and responsive environment. The combination of biometric verification, real-time tracking, and instant SMS notifications delivers a comprehensive child safety solution that is both technologically robust and user-centric.

Purpose: Keep parents updated through SMS alerts regarding pickup, drop-off, or absence.

Technical Approach:

- Integrated **Twilio API** (or MSG91) for reliable SMS delivery.
- Automatic trigger upon status update (pickup, drop-off, absent).
- SMS includes child's name, status, driver details, and timestamp.

4.2.6 TECHNICAL STACK

Layer	Technology Used
Frontend (Web Portal)	React.js (Vite Framework)
Mobile Application	React Native
Backend APIs	Node.js with Express.js
Database	MongoDB and Firebase Realtime DB
Face Recognition	OpenCV, Dlib, PCA
Hosting	Firebase Hosting / AWS / DigitalOcean

Layer	Technology Used
Authentication	JWT (JSON Web Tokens)
Communication Services	Twilio (SMS Gateway)
APIs Integration	Google Maps API for live tracking

Table: 4.1

4.3 Workflow of the System

The high-level working process of the system is as follows:

Registration Phase:

- Admin registers students, drivers, and parents.
- Child face data is captured and stored securely

Login Phase:

- Driver/Parent/Admin logs into their respective portals.
- Authentication is verified using JWT.

Pickup Phase:

- Driver scans child's face at the pickup point.
- If face is matched successfully, the child is marked "Picked Up."
- SMS alert is sent to the parent.

Tracking Phase:

- The mobile app continuously updates the vehicle's GPS location.
- Parents can view real-time location through the web portal.

Drop-off Phase:

- Driver scans face again (optional) and updates the status as "Dropped."

CHAPTER – 5

System Design & Implementation

The **System Design and Implementation** phase of the *GuardianSync* project translates the conceptual architecture and functional requirements into an operational software solution. This chapter provides a structured breakdown of the technical design choices, software architecture, and implementation strategies employed across different system components. The overall system is built on a modular and scalable architecture that integrates a web-based administrative and parent portal, a cross-platform mobile application for on-the-go status updates, a real-time database, and communication mechanisms. Key design principles such as usability, performance, data privacy, and fault tolerance have guided the implementation at every level.

5.1ADMIN PORTAL DESIGN

The web portal of *GuardianSync* serves as the central platform for interaction between users and the system. Built using **React.js** with **Vite** as the bundler, the portal is designed to be lightweight, modular, and fast. Vite's support for hot module replacement and optimized builds significantly improves the development and runtime performance of the portal. The architecture follows a component-based design, where reusable UI blocks manage user dashboards, child profiles, live maps, and historical reports. This modular approach enhances maintainability and facilitates easy feature expansion.

The portal is designed with **role-specific dashboards**—administrators have full control over child registration, attendance logs, and vehicle routes, while parents have access to a personalized view of their child's real-time status and pickup/drop history. The interface is responsive and accessible across various screen sizes, ensuring usability from desktop computers, tablets, and smartphones. Data is fetched from backend services through secure RESTful APIs, and displayed dynamically using hooks such as `useEffect` and `useState` for real-time interactivity.

Security and user experience are top priorities in the portal design. Authentication is handled via JWT, and access control mechanisms restrict functionality based on user roles. Visual feedback, alert systems, and error handling provide a smooth and intuitive user experience. React's Virtual DOM ensures minimal re-rendering and optimal performance, particularly when dealing with high-frequency updates such as GPS location feeds or bulk attendance data.

5.1.1 ADMIN DASHBOARD

The **Admin Dashboard** in *GuardianSync* is the centralized control panel designed specifically for school administrators to manage, monitor, and operate all system components related to student safety and transportation. Developed using **React.js** and supported by a **Node.js + Express.js** backend, the dashboard provides real-time access to critical data including child attendance status, live GPS locations, registered user activity, and system alerts. The dashboard layout is clean, responsive, and divided into widgets and data tables that reflect the core functions of the system—making it both user-friendly and operationally efficient.

One of the core functionalities of the Admin Dashboard is the **student management interface**, which allows admins to register new children, update records, and view historical attendance data. Each child profile includes academic information, contact details, and facial biometric data. Administrators can also monitor school vehicles on an interactive map

powered by **Google Maps API or Leaflet.js**, which displays live location updates sent from the drivers' mobile apps. Additionally, admins can view pickup/drop history logs, identify patterns in attendance, and take proactive measures in case of route delays, absenteeism, or irregularities.

- SNAPSHOT

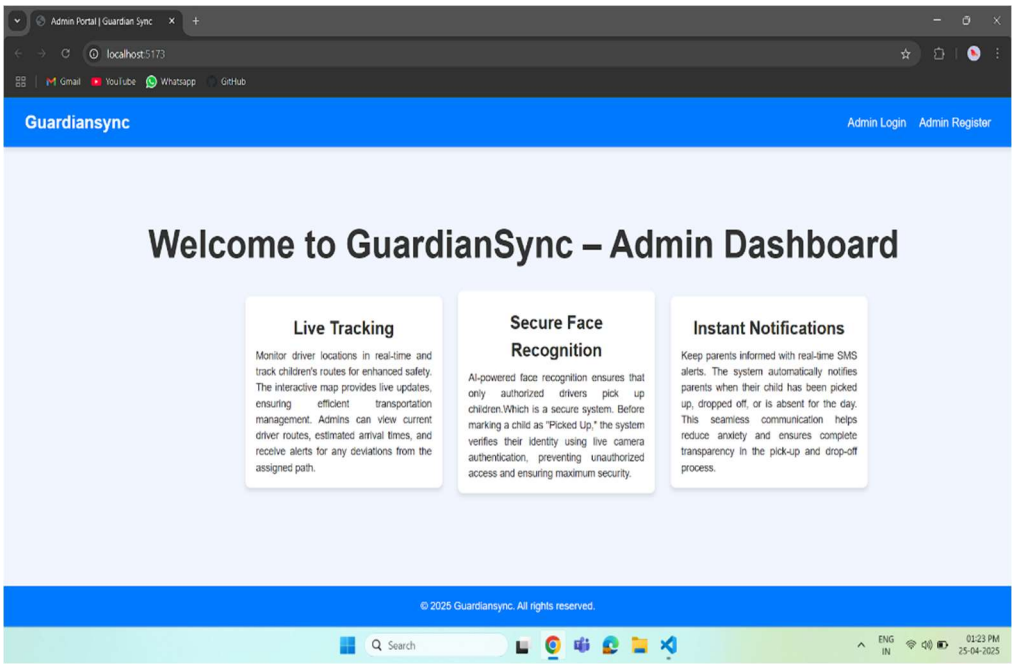

Fig: 5.1 Admin Dashboard

5.1.2 ADMIN REGISTRATION

The **Admin Registration process** is a foundational feature in the *GuardianSync* system, enabling educational institutions to onboard authorized personnel who will manage system operations. Administrators hold the highest level of privileges within the system. They are responsible for tasks such as registering students, assigning roles, monitoring real-time data, and overseeing user activity across the web and mobile platforms. Ensuring a secure and structured registration process for admins is vital, as it forms the gateway to the entire operational and data management ecosystem of *GuardianSync*.

The registration process typically begins through a secure web-based interface, where an existing system super-admin or developer grants initial access to a verified staff member from the educational institution. The admin fills out a registration form that captures essential details such as full name, email address, mobile number, designation, and a secure password. This form is submitted via a **React.js frontend**, and data is sent to the backend server using secure **HTTP POST** requests. The backend, built using **Node.js and Express.js**, then validates the data—checking for email uniqueness and password strength—and proceeds to hash the password using **bcrypt** to ensure that plaintext credentials are never stored.

SNAPSHOT

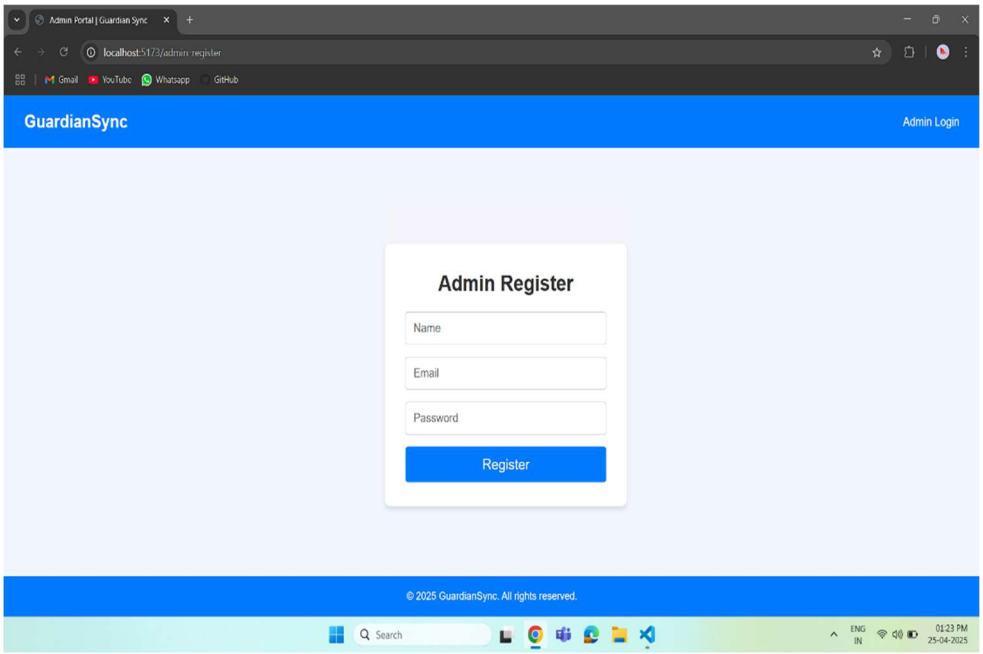

Fig: 5.2 Admin registration

5.1.3 ADMIN LOGIN PORTAL

The **Admin Login Portal** is a secured entry point within the *GuardianSync* system that allows authorized administrators to access and manage critical functions such as child registration, attendance monitoring, real-time location tracking, and system analytics. This portal is web-based and developed using **React.js** for the frontend interface and **Node.js with Express.js** for the backend authentication logic. The design of the portal emphasizes security, usability, and role-based access control, as administrators handle sensitive data including biometric records and live GPS feeds.

Upon visiting the login page, the administrator is prompted to enter their **registered email address and password**. This data is submitted via a secure **HTTPS POST request** to the backend server. On the server side, the entered credentials are verified against records stored in the **MongoDB** database. Passwords are never stored in plaintext; instead, they are hashed using **bcrypt**, a secure hashing algorithm that ensures credentials remain protected even if the database is compromised. The backend then checks if the user exists and whether the provided password matches the stored hash.

SNAPSHOT

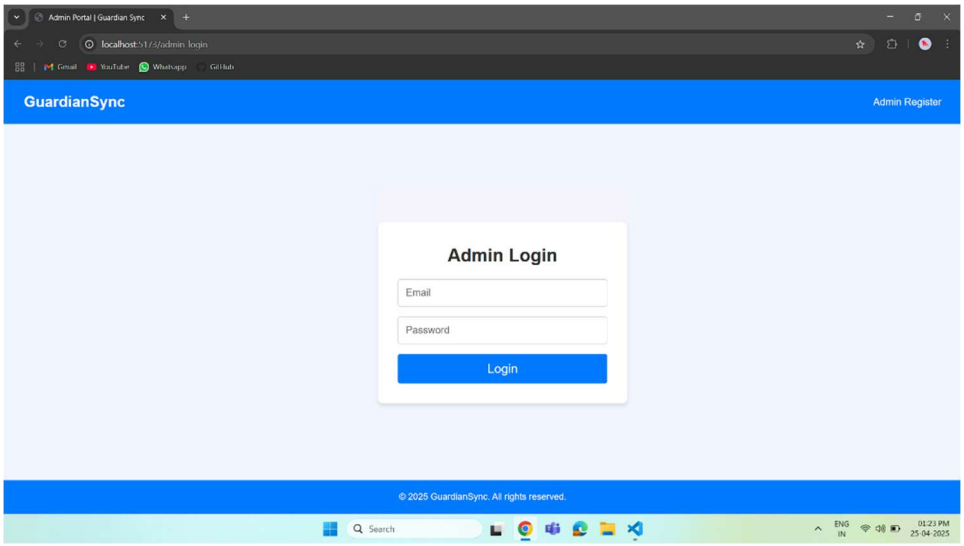

Fig:5.3 Admin login

5.1.4 STUDENT REGISTRATION FORM

The **Student Registration Process** in the *GuardianSync* system is carried out exclusively through the **Admin Portal**, which is accessible only to verified administrative personnel. This process is fundamental to initializing a student's digital profile within the system and enables features such as facial recognition, attendance tracking, GPS-based location mapping, and automated notifications. It serves as the first step in linking a child to their parent or guardian and integrating them into the transport safety workflow. The design of the registration interface emphasizes usability, accuracy, and security to minimize errors and ensure data integrity.

Through a secure login, the administrator accesses the **Student Registration section** of the portal. This section is built using **React.js** and supports a dynamic form system that captures comprehensive student details. The form typically includes fields such as the student's **full name, class, section, roll number, photo, parent/guardian contact information**, and assigned route or driver. A **live image capture option** is available, allowing the admin to take a real-time photo of the student via a connected webcam or upload a file. This image is later processed and used to generate a **facial descriptor vector** using libraries such as face-api.js, which is essential for biometric verification during pickups and drop-offs.

Upon submission, the entered data is validated and sent to the backend (Node.js + Express.js), where it is securely stored in a **MongoDB database**. Each student record is structured using Mongoose models and may include relational links to the parent user, vehicle route, and school. Sensitive data like facial images and contact numbers are encrypted and access-controlled using JWT-based authentication and role-based permissions. Once registered, the student becomes active within the *GuardianSync* ecosystem, making them visible to drivers in the mobile application and to parents in the web portal. The successful completion of this process ensures that each student can be tracked, verified, and communicated about with full accuracy and in compliance with child safety protocols.

- **SNAPSHOT**

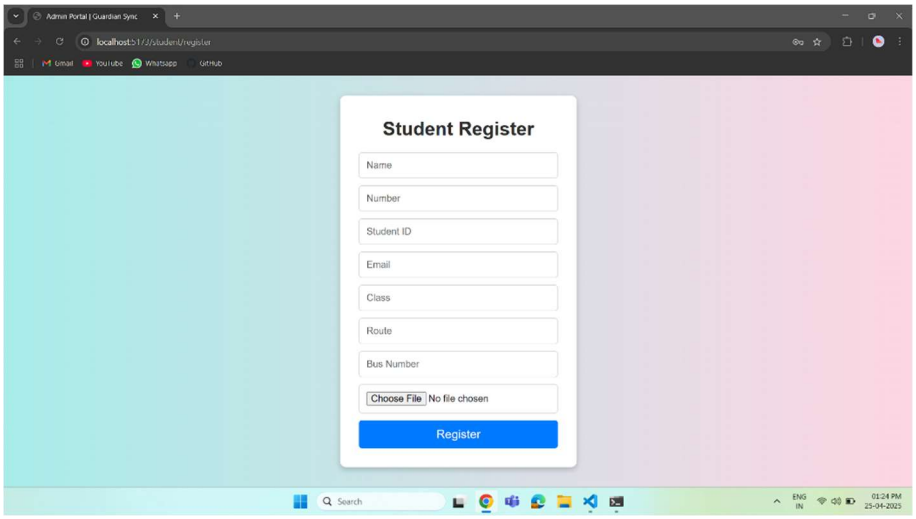

Fig:5.4 Student Registration

5.1.5 DRIVER REGISTRATION

The **Driver Registration Process** in *Guardian Sync* is managed exclusively through the **Admin Portal**, ensuring that only authorized and verified personnel are assigned to handle student transportation. This process is crucial to establishing a secure link between each driver and their assigned vehicle, route, and students. By centralizing driver registration under administrative control, the system maintains operational integrity, accountability, and compliance with school safety protocols. The Admin Portal, built using **React.js**, provides a dedicated interface that allows administrators to register, update, and manage driver records securely.

To initiate registration, the administrator navigates to the **Driver Management section** within the dashboard and fills out a registration form containing all necessary information. This form typically includes the driver's **full name, phone number, assigned route or vehicle ID, photo identification, and login credentials (email and password)**. Optional

fields such as driving license number or national ID can also be included for record-keeping and verification. Once the form is completed, the data is submitted via a secure **HTTPS POST request** to the backend server. The backend, built using **Node.js and Express.js**, performs validation, hashes the password using **bcrypt**, and stores the driver's information in the users collection of the **MongoDB** database with the role assigned as "driver."

Once successfully registered, the driver can log into the **Guardian Sync mobile application**, where their dashboard is automatically populated with the student list corresponding to their assigned route. The driver can then use the app to perform tasks such as marking pickup/drop status, capturing facial images for verification, and sending real-time location data to the system. JWT-based authentication ensures secure access, while role-based permissions prevent unauthorized functionality. This structured registration process ensures that only verified and trained drivers are integrated into the system, thereby strengthening the overall safety, traceability, and efficiency of school transportation within the *Guardian Sync* platform.

- **SNAPSHOT**

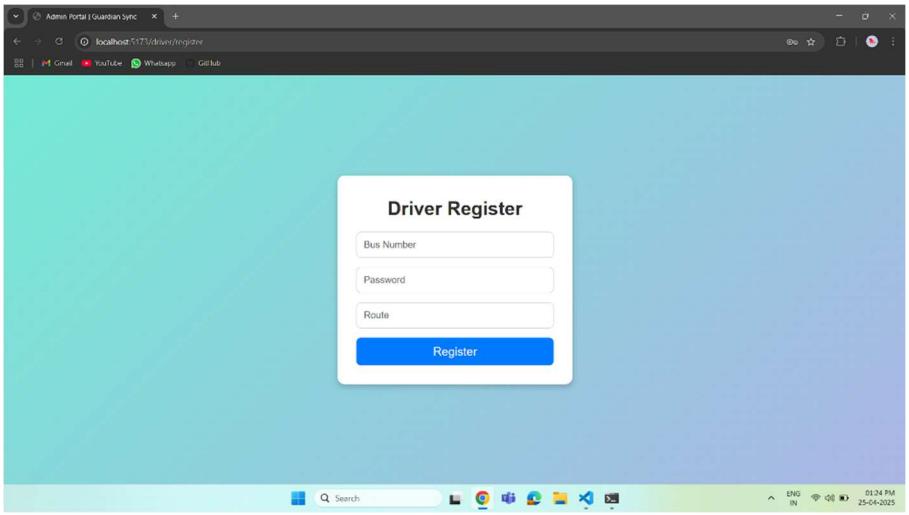

Fig:5.5 Driver Register

5.2PARENT PORTAL DESIGN

The **Parent Portal** in *Guardian Sync* is designed as a secure, user-friendly web interface that provides parents with real-time updates and historical insights into their child's school transportation activity. Developed using **React.js** and integrated with RESTful APIs from the backend (Node.js + Express), the portal enables parents to monitor their child's **live location**, **pickup/drop-off status**, **attendance history**, and **facial verification confirmations**. The design prioritizes simplicity and responsiveness to ensure it can be accessed easily across various devices such as smartphones, tablets, and desktop browsers.

Upon logging into the portal using authenticated credentials, parents are greeted with a **personalized dashboard** that displays the child's profile, including their name, photo, class, roll number, and registered transport route. A key feature of the portal is the **interactive live map**, which updates the real-time location of the school vehicle using data sent from the driver's mobile app via GPS. The map is built using **Google Maps API** or **Leaflet.js** and shows dynamic movements of the vehicle, current stops, and estimated time of arrival. This provides peace of mind to parents, especially during uncertain weather conditions or route delays.

Additionally, the Parent Portal includes a **notification center**, where all SMS alerts and push messages are archived for reference. Parents can view timestamps of when their child was picked up, dropped off, or marked absent, along with the driver or staff details responsible for the update. The portal also offers **attendance reports**, helping parents track their child's punctuality and any irregularities. All communications are conducted over **HTTPS** to ensure data security, and access is restricted using **JWT-based authentication** to safeguard personal and location information. The Parent Portal thus serves as a transparent, real-time, and secure window into the school transportation process, aligning with Guardian Sync's mission of improving child safety and parental trust.

SNAPSHOT

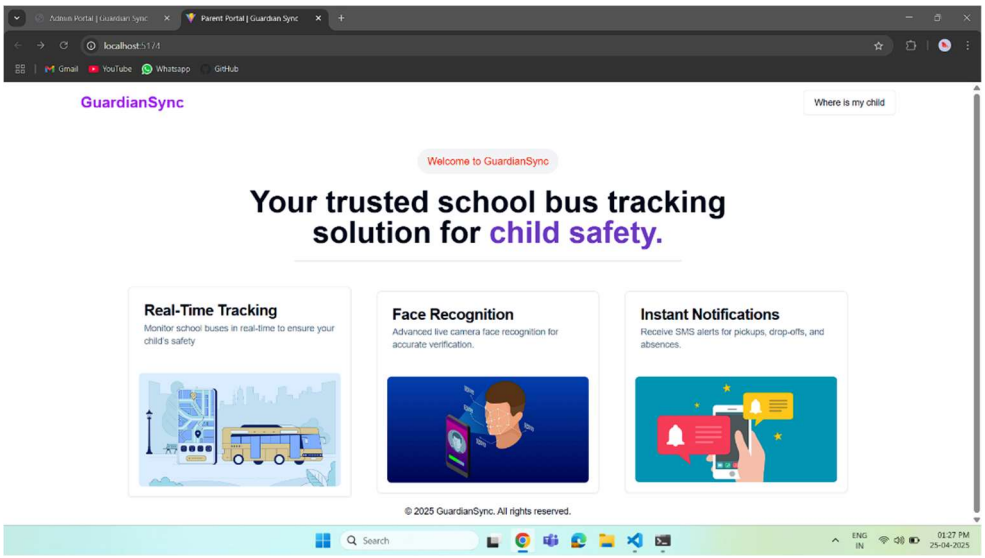

Fig: 5.6 Parent Portal

5.2.1 STUDENT TRACKING MAP

The **Student Tracking Map** is one of the core components of the *GuardianSync* system, designed to offer a visual and interactive representation of a student's real-time location during school transit. This map-based interface is integrated into both the **Parent Portal** and **Admin Dashboard**, enabling stakeholders to monitor school vehicles and student movements with precision and clarity. The map is implemented using either the **Google Maps JavaScript API** or the open-source **Leaflet.js** library, depending on the deployment environment and licensing considerations. These libraries allow developers to plot dynamic location markers, draw routes, and update positions in real time, offering a responsive and intuitive experience for users.

The tracking process begins when the **driver's mobile application**, built using **React Native**, continuously captures GPS coordinates using the device's onboard location sensors. These coordinates are transmitted to the backend server at regular intervals via secured

RESTful API calls. Once received, the backend stores and forwards this data to the frontend map interface, where the student's associated vehicle is represented as a **moving marker** on the map. The position updates automatically, typically every few seconds, creating the effect of live tracking. In addition, key data like vehicle speed, estimated time of arrival (ETA), and current stop can be included for added context.

SNAPSHOT

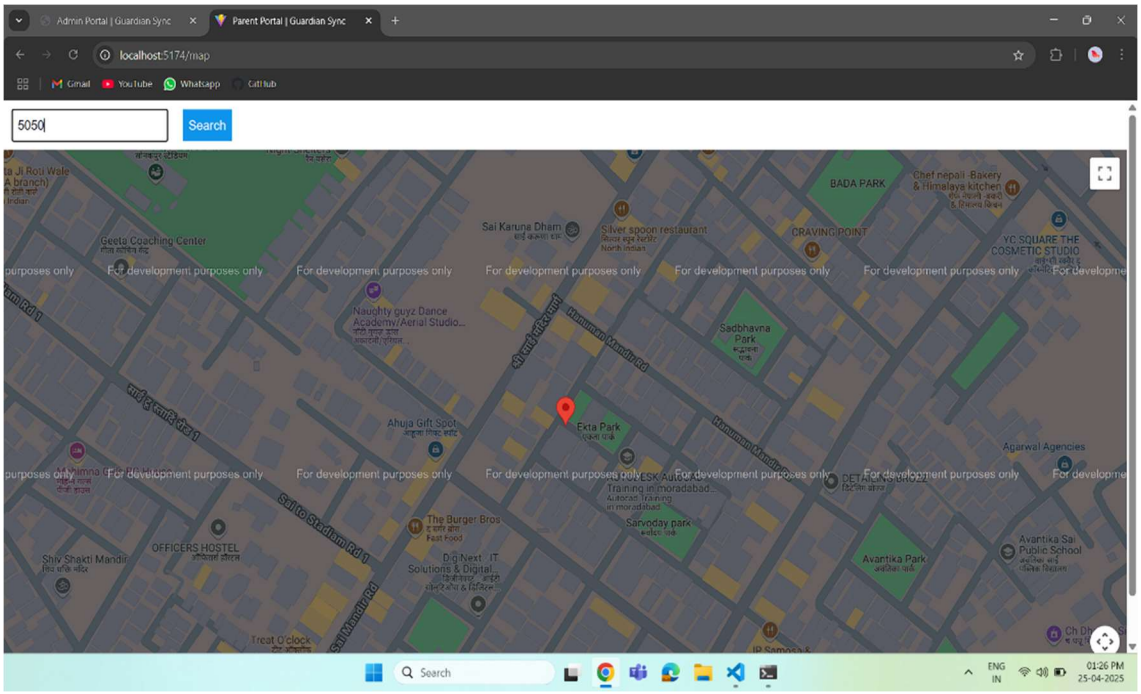

Fig:5.7 Tracking Map

5.2.2 DRIVER'S APPLICATION PORTAL

The mobile application, developed using **React Native**, is designed primarily for on-the-go users such as school drivers or attendants. It functions as the operational core for collecting and transmitting real-time data such as pickup/drop status, face recognition images, and GPS

coordinates. React Native allows for the development of a shared codebase across Android and iOS, enabling faster delivery and simplified maintenance. This makes the system cost-effective and accessible to schools regardless of their device ecosystem.

The mobile app is structured with a clean user interface that minimizes cognitive load. Drivers can log in, view the list of registered children, update pickup status, and use the device's camera for biometric face scanning. Real-time location is captured using GPS sensors and transmitted periodically to the backend, which in turn updates the map view in the parent and admin dashboards. Libraries such as react-native-maps and react-native-camera are integrated to handle mapping and image capturing features effectively.

From a performance and security standpoint, the app uses local device storage to hold session tokens securely, and all communication is done over HTTPS. Error states are handled gracefully, with retry logic for failed network requests to ensure reliability in low-connectivity areas. Notifications (via FCM) inform drivers and staff about updates or issues. The mobile application serves as the system's primary data entry point and ensures reliable, real-time interaction with the rest of the GuardianSync infrastructure.

SNAPSHOT

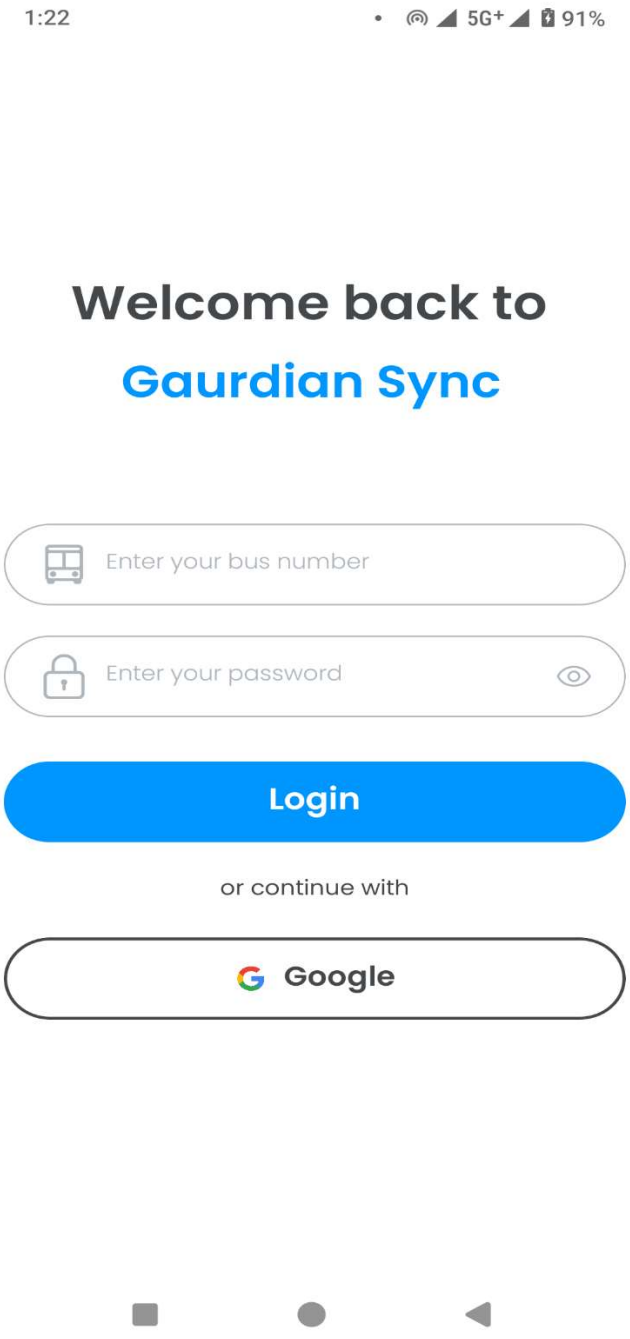
1:22
5G+
91%
Welcome back to
Gaurdian Sync
Enter your bus number
Enter your password
Login
or continue with
Google

Fig: 5.8 Application portal

5.3.1 APPLICATION DASHBOARD

The **Driver Mobile Application Dashboard** in *GuardianSync* serves as the primary interface for school transport personnel, particularly bus drivers or attendants, to interact with the system in real time. Developed using **React Native** for cross-platform compatibility, the dashboard is designed to be intuitive, responsive, and optimized for use in dynamic field environments. Its primary functions include real-time student pickup and drop-off management, location tracking, face recognition for identity verification, and communication with the backend for attendance and alert generation.

Upon secure login using JWT-based authentication, the driver is presented with a **role-specific dashboard** displaying the day's assigned student list. Each entry includes the student's name, photo, roll number, and pickup status. The interface enables the driver to **mark each child as "Picked Up," "Dropped Off," or "Absent"** through simple, touch-friendly buttons. For enhanced security, facial verification is initiated by activating the device's camera. Using integrated **face recognition libraries (e.g., face-api.js)**, the app compares the live image of the child against the stored biometric template. If a match is confirmed, the status is updated, and a backend call is triggered to send SMS or push notifications to the parent.

Another critical component of the dashboard is the **live GPS tracker**, which operates in the background and sends the vehicle's coordinates to the server at regular intervals. This data feeds into the admin and parent portals, where it is rendered on the Student Tracking Map. Additionally, the dashboard includes quick-access options for emergency alerts, route guidance, and system diagnostics. All data transmissions are encrypted using HTTPS, and offline-first functionality ensures that data is buffered and synced when connectivity is

restored. The Driver Dashboard thus plays a vital role in the ecosystem by enabling real-time, on-the-ground interaction with GuardianSync's core safety and tracking features, ensuring accountability, biometric verification, and operational continuity.

- **SNAPSHOT**

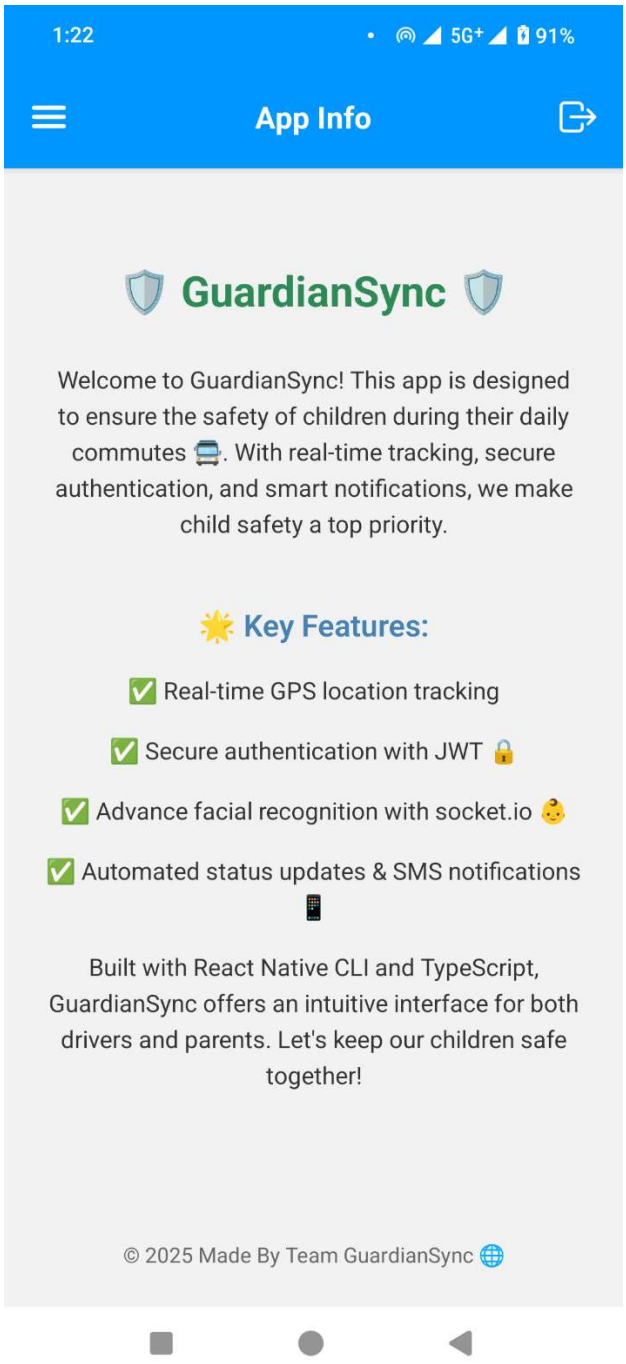

FiG:5.9 Application Dashboard

5.3.2 REGISTERED STUDENT

The **Registered Student Status** feature in the *GuardianSync* Driver Application allows transport personnel—primarily drivers or attendants—to view and update the real-time pickup, drop-off, and attendance status of each student assigned to their route. This functionality is critical to ensuring that only registered children are managed during school transit and that their guardians receive timely and accurate updates. The list of students is dynamically fetched from the backend system, filtered by route or vehicle ID, and displayed within the driver's dashboard interface.

Each student listed in the application includes key identifying information such as **name, roll number, class, photo, and current status** (e.g., *Not Picked Up, Picked Up, Dropped Off, or Absent*). The status of each child can be changed through a **touch-based interface** featuring clearly labeled buttons. When the child is picked up, the driver initiates a **facial verification scan** (where enabled), confirming the student's identity using live camera input and pre-registered biometric data. Upon successful recognition, the child's status is updated to *Picked Up*, and an automated event is triggered to send an **SMS or push notification** to the parent.

All status updates are **timestamped and logged**, and transmitted to the backend using secured RESTful API calls. These updates are immediately reflected in the Parent and Admin dashboards, providing stakeholders with real-time visibility. Furthermore, the application prevents duplicate or unauthorized updates by validating role permissions and route assignments. If a child is marked *Absent*, the system skips biometric verification and still notifies the parent. This real-time, verified status management system ensures transparency, prevents misuse, and forms a digital attendance trail for each student during their daily commute, reinforcing *Guardian Sync*'s commitment to child safety and accountability.

SNAPSHOT

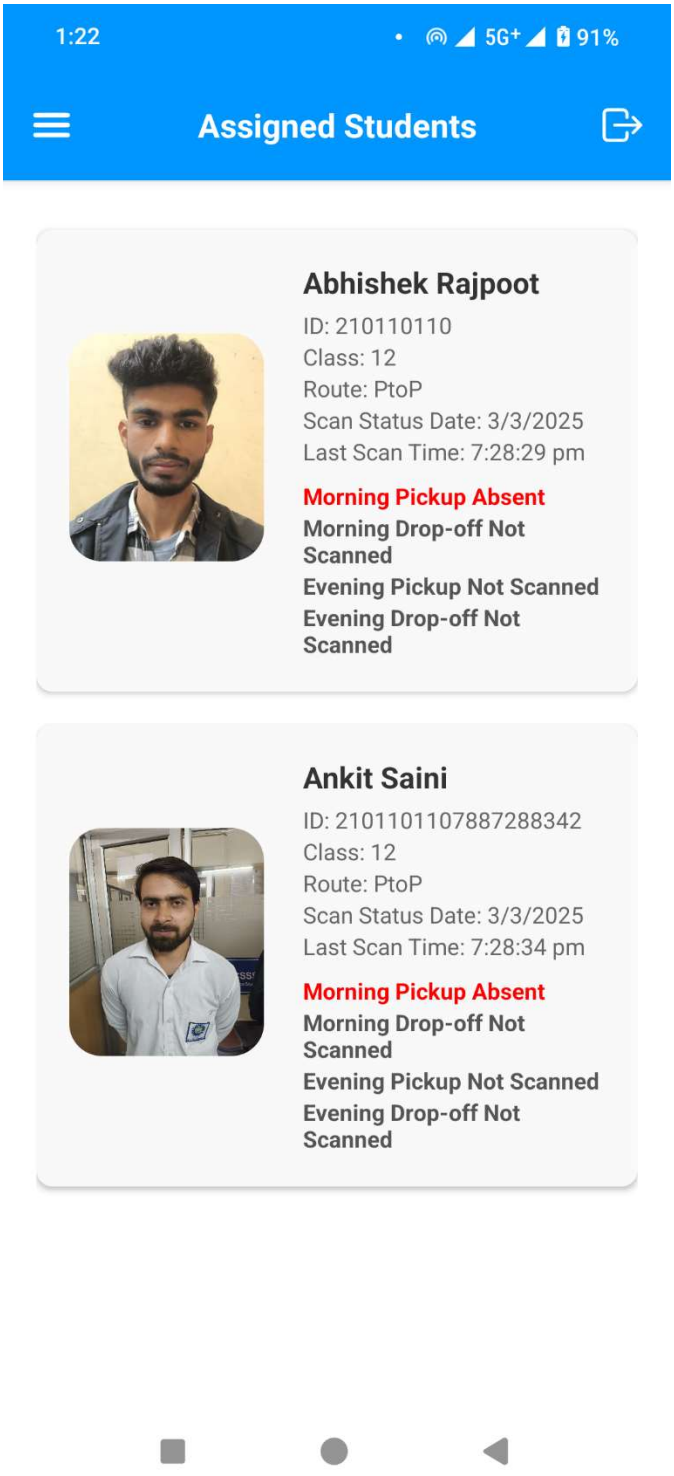

Fig:6.1 Registered Student

5.3DATABASE DESIGN

The database for *GuardianSync* is built using **MongoDB**, a NoSQL, document-oriented database that provides flexibility in storing dynamic and hierarchical data structures. It is particularly suitable for a project like GuardianSync where data models—such as child profiles, attendance logs, and location histories—can vary in complexity. Using **Mongoose** as an Object Data Modeling (ODM) tool, the system enforces schema consistency, handles data validation, and simplifies interactions between the backend and the database.

Each child record is stored as a document within a children collection, containing nested fields for biometric descriptors, parent information, academic details, and status logs. Similarly, the users collection holds credential data, hashed passwords, and role metadata. Location data is stored with time-stamped entries, allowing for historical tracking and route reconstruction if needed. Indexes are used for optimizing read/write operations, particularly for frequently queried fields like student ID, driver ID, and timestamps.

Security and performance are integral to the database design. Sensitive data such as hashed passwords and biometric vectors are encrypted and access to the database is restricted via secure credentials and IP whitelisting. Regular backups are configured, and a replication mechanism can be implemented to support high availability. The structure supports fast querying, flexibility in adding new features, and resilience under scale, making it ideal for real-time, multi-user environments like GuardianSync.

5.5 Security Features

Security is fundamental to the GuardianSync system due to its handling of sensitive data such as student profiles, biometric identifiers, and real-time GPS locations. To ensure robust user authentication, the system employs **JWT (JSON Web Tokens)**, enabling stateless, signed tokens that verify user identity and role with every API request. Tokens are issued upon successful login and include an expiration timestamp to enhance session security and prevent token hijacking.

Passwords are encrypted using **bcrypt**, a one-way hashing function designed to withstand brute-force attacks. These encrypted hashes are stored in MongoDB, ensuring that even if the database is compromised, the plaintext passwords cannot be retrieved. Role-based access control is enforced throughout the application, meaning that each user—whether an admin, driver, or parent—can only access data and features relevant to their role. This principle of least privilege helps minimize the risk of internal misuse or accidental exposure.

To secure data in transit, all communications between the frontend and backend are conducted over **HTTPS**, leveraging SSL/TLS encryption protocols. This prevents man-in-the-middle (MITM) attacks and data sniffing. Biometric data is processed locally on the device when possible, and facial descriptors are securely stored without exposing raw image files. Backend APIs are rate-limited and protected by authentication middleware, ensuring the system remains resilient to denial-of-service (DoS) attacks and unauthorized access attempts.

5.6 SMS Notification Integration

The SMS Notification System is integrated into *Guardian Sync* to provide **real-time communication** between the system and parents, particularly in scenarios where mobile app notifications may be missed or internet connectivity is limited. This system ensures that parents are promptly alerted about key status changes such as their child being picked up,

dropped off, or marked absent. The notification system operates automatically and removes the need for manual updates by school staff.

The SMS module is built using **Twilio SMS API**, which enables secure, programmable SMS dispatch across global networks. In regions where Twilio is limited, **MSG91** can be used as an alternative provider. When a status update is recorded in the mobile app—such as a successful pickup following face recognition—the backend processes this event, generates a structured message including the child's name, current status, driver name or ID, and a timestamp, and sends the message to the parent's registered phone number.

This system is tightly integrated with the backend's event management system and requires minimal overhead once configured. It uses secure API calls and dynamic message formatting, ensuring that each message is accurate, personalized, and immediately actionable. In addition to improving parental awareness, the SMS alerts also serve as an audit trail of child movements, which can be used by school administrators in case of disputes, delays, or safety concerns.

CHAPTER 6

TESTING & EVALUATION

6.1 INTRODUCTION

Software testing is a critical phase in ensuring the stability, reliability, and security of a real-time application like *Guardian Sync*, which deals with sensitive child safety data. The system includes complex modules such as GPS tracking, facial recognition, and role-based dashboards, all of which must function accurately and securely under varying conditions. To affirm system quality, *Guardian Sync* adopted a strategic and layered approach to software testing that covered everything from isolated module validation to full-system user acceptance and security testing. The testing activities were conducted systematically to align with the agile development methodology and ensure both performance and usability in real-world scenarios.

6.2 Strategic Approach to Software Testing

The software testing approach in *Guardian Sync* followed a multi-stage model comprising Unit Testing, Integration Testing, System Testing, User Acceptance Testing (UAT), and Security Testing. Each stage aimed to validate different levels of the application's functionality, from individual components to the system's behavior in a production-like environment. The testing spiral started with backend modules like API endpoints and authentication logic, moved to frontend components, and concluded with complete system evaluation under user conditions.

These tests were executed using tools like Jest, Postman, Firebase emulator, and manual interaction with the mobile and web interfaces. A test-driven approach was used in certain modules (e.g., face recognition and GPS services) to minimize defects early in development. This comprehensive methodology ensured that *GuardianSync* was rigorously tested across various functional layers and user environments.

6.2.1 Unit Testing

Objective: To validate that each individual component or module functions as intended.

Unit testing in *GuardianSync* involved testing individual frontend components (React/React Native), backend APIs (Node.js/Express), and utility services (face recognition, GPS fetchers) in isolation.

API endpoints were tested using Postman to simulate HTTP requests for user login, registration, location updates, and status changes. All routes were validated for successful responses, correct status codes, and error handling.

Backend logic such as JWT authentication, SMS notification triggers, and MongoDB queries were tested using mocks and stubs. This helped identify logic flaws before components were integrated.

6.2.2 Integration Testing

Objective: To verify that different modules of the application work together seamlessly.

Integration testing confirmed communication between the mobile app, backend, and MongoDB database. For instance, when a child was marked as “Picked Up” in the app, the backend updated the database, sent SMS via Twilio, and reflected the change in the web portal in real time.

The GPS data flow from mobile to backend to frontend map was tested to ensure accuracy and synchronization.

Face recognition modules were integrated with the attendance update workflow, verifying that facial verification was required before allowing a status change.

6.2.3 System Testing

Objective: To test the entire software solution for functionality, performance, and stability.

Complete end-to-end scenarios were executed, such as child pickup with face verification, live location updates on map, and automated SMS alerts Admins registered students, assigned them to routes, and monitored pickups/drops from the dashboard. Parents were able

to log in, view real-time maps, and receive alerts for their child's status. These scenarios were tested in both low and high connectivity conditions to validate responsiveness.

6.2.4 User Acceptance Testing (UAT)

Objective: To ensure the system meets end-user expectations in real-world conditions.

UAT was performed by actual users, including school staff, test parents, and drivers, using real devices and test student data. Test scripts walked users through workflows such as adding students, tracking vehicles, and performing pickups using the facial scanner. Feedback was gathered on usability, interface clarity, and performance. Based on feedback, improvements were made to dashboard navigation, notification formats, and error messages.

6.2.5 Security Testing

Objective: To identify vulnerabilities and verify protection of sensitive I nformation.

JWT tokens were tested for expiration, integrity, and misuse prevention. Role-based route protection was validated for all user types. Passwords were checked to be securely hashed using bcrypt and not retrievable in plaintext. Facial data (face descriptors) was verified for secure transmission and encrypted storage. HTTPS was enforced across all routes to prevent data leakage in transit.Attempts to bypass authentication or access unauthorized data were blocked by middleware and logging mechanisms.

6.3 Evaluation of Testing

The evaluation phase of *Guardian Sync*'s testing demonstrated that the system was functionally complete, secure, and stable. All major components passed their respective testing stages. Unit and integration testing helped catch logic bugs early. System testing validated that the application could function as a complete real-time solution. UAT confirmed that the interface was understandable and usable for non-technical users. Security testing ensured that child data was protected throughout the system.

Testing success was measured by test case completion rates, bug resolution times, performance metrics (e.g., GPS update latency), and user feedback scores. Overall,

GuardianSync achieved a high level of readiness for deployment in educational institutions, with robust real-time capabilities, minimal bugs, and compliance with safety and privacy requirements.

6.3.1 Unit Testing

Objective: To ensure that each individual component of the GuardianSync application performs as intended.

Process:

Frontend Components (React.js / React Native):

- Each UI component was tested in isolation to confirm proper rendering and interaction.
- Valid and invalid input scenarios were applied to forms such as login, registration, and pickup status updates to ensure validation accuracy.
- State transitions and event triggers (e.g., form submission, image capture) were monitored to confirm expected behavior.
- **API Routes (Node.js + Express):**
- Using **Postman**, various HTTP requests (GET, POST, PUT, DELETE) were sent to key endpoints like /api/login, /api/registerChild, and /api/updateStatus.
- The correctness of responses, structure of JSON data, and status codes were verified.
- Invalid inputs were tested to confirm that error messages were handled gracefully and that no data corruption occurred.
- **Database Operations (MongoDB):**
- Using **MongoDB Compass** and **Mongoose**, CRUD operations on users, children, location logs, and attendance records were validated.
- Sample data was inserted and queried to ensure schema enforcement, relational integrity, and performance under load.
- Test cases included malformed inputs to assess validation and rejection **mechanisms.**

6.3.2 Integration Testing

Objective: To confirm that interconnected components of GuardianSync communicate and operate seamlessly as a system.

Process:

Frontend ↔ Backend Communication:

- Data submitted through the React and React Native forms was sent to the backend for processing (e.g., registration, pickup status).
- API endpoints were verified for correct processing of requests and updating of MongoDB collections.
- Postman was used to simulate external API interactions, such as SMS messages triggered via Twilio.
- **Data Flow Validation:**
- Confirmed that location data from the mobile app updated in real time on the parent/admin dashboards via Google Maps API integration.
- Verified the flow of facial recognition results from mobile input to backend verification and status update logging.
- Bi-directional data exchange between modules (e.g., status update from driver to parent) was tested for accuracy and latency.
- **Authentication and Role Management:**
- JWT-based login tokens were tested for generation, decoding, and expiration handling.
- Separate roles (admin, driver, parent) were tested to verify correct access permissions and route protection.
- Attempts to access unauthorized content or perform restricted actions were blocked as expected.

6.3.3 System Testing

Objective: To validate that the entire integrated Guardian Sync system functions according to its specified requirements.

Process:

End-to-End Functional Scenarios:

- Simulated full user journeys including child registration, real-time tracking, facial recognition, pickup status updates, and notification delivery.
- Each module was tested together under real-world usage conditions, verifying that changes were reflected across all user interfaces.
- **User Management & Dashboard Features:**
- Admin account functions such as managing student records, assigning routes, and viewing attendance logs were verified.
- Parent portal functions such as receiving alerts and viewing live GPS location were tested for accuracy and performance.

- **Manual Testing of Key Workflows:**
- Executed test scripts that validated the robustness of modules like face recognition, status-triggered SMS, and token-based login/logout.
- Verified responsiveness across devices and browsers to ensure usability in diverse environments.

6.3.4 User Acceptance Testing (UAT)

Objective: To ensure the software aligns with the needs and expectations of actual end-users.

Process:

- **Real-World Testing:**

- Admins, school staff, and test parents used the system in a controlled test environment. Drivers tested the mobile app in transit simulations.
- Workflow scenarios included child drop-off/pickup logging, emergency alerts, and real-time tracking visibility.
- **Scripted Walkthroughs:**
- Test scripts guided users through system actions such as registering children, capturing face data, and responding to SMS alerts.
- User behavior and feedback were observed to assess intuitiveness and satisfaction.
- **Feedback & Iteration:**
- Collected input on navigation flow, UI design, and communication timing.
- Adjustments were made to the interface, button placements, and message formats based on suggestions to enhance usability.

6.3.5 Security Testing

Objective: To identify and mitigate potential vulnerabilities within the system and safeguard user data.

Process:

- **Data Protection and Encryption:**
- Ensured that all passwords were hashed using **bcrypt** before storage.
- Verified that biometric facial data (descriptors) were encrypted and not exposed in transit or storage.
- **Access Control Testing:**
- Role-based access control was tested by attempting to access features outside a user's role. All unauthorized attempts were correctly rejected.

- Admin-only and parent-only APIs were validated with and without valid tokens.
- **Authentication Robustness:**
- JWT tokens were tested for proper expiration, renewal, and misuse prevention.
- Simulated token tampering and invalid logins confirmed that secure middleware and error handling were in place.

CHAPTER 7

CONCLUSION

The *Guardian Sync* project was conceived and developed as a comprehensive child safety and real-time attendance tracking system, aimed specifically at addressing the vulnerabilities and inefficiencies present in traditional school transportation monitoring. In many existing systems, there is a significant lack of real-time communication between parents, school administrators, and transport personnel, leading to uncertainty and potential safety risks for school children during transit. *GuardianSync* bridges this critical gap by integrating biometric face recognition, GPS tracking, automated notifications, and a role-based user system into a single, unified platform.

Throughout the development lifecycle, cutting-edge technologies such as **React.js** for the web interface, **React Native** for the mobile app, **Node.js and Express.js** for backend logic, and **MongoDB** for the database were utilized. The system architecture was designed for scalability, security, and real-time performance. The admin portal facilitates full control over child registrations, route management, and system-wide monitoring. The mobile app, used by drivers, allows status updates and facial authentication at the time of pickup or drop-off. Meanwhile, parents have access to a simplified yet powerful dashboard showing live bus location and real-time SMS alerts on their child's status.

In summary, *GuardianSync* is a well-rounded solution that offers both functionality and peace of mind. It transforms the manual, error-prone processes into a transparent, secure,

and data-driven operation, making it highly relevant for modern educational institutions that prioritize child safety and digital innovation.

In conclusion, *Guardian Sync* is a modern, technology-driven response to the long-standing issue of ensuring child safety during school transportation. Through the seamless integration of biometric authentication, GPS tracking, real-time notifications, and cloud-based data management, the system delivers a powerful solution that brings visibility, control, and trust into the hands of schools and parents.

The system's layered architecture, real-time capabilities, and secure handling of sensitive information position it as a forward-thinking application that addresses both current operational challenges and emerging safety concerns. Testing results and user feedback confirm its robustness, efficiency, and ease of use. Moreover, its modular design and technology stack make it adaptable for future scaling and customization.

As the education sector continues to evolve with increased focus on safety and digital transformation, *Guardian Sync* is well-positioned to play a significant role. It lays the groundwork for a new standard in smart school transport systems, where real-time accountability and child safety are no longer aspirational—but expected.

CHAPTER 8

REFRENCES

[1] E. Gamma, R. Helm, R. Johnson, and J. Vlissides, *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley, 1994.

[2] D. Crockford, "JSON: JavaScript Object Notation," JSON.org, [Online]. Available: https://www.json.org/

[3] M. Hart, "JWT Handbook," Auth0 Blog, 2021. [Online]. Available: https://auth0.com/docs/secure/tokens/json-web-tokens

[4] Google Developers, "Google Maps JavaScript API," [Online]. Available: https://developers.google.com/maps/documentation/javascript

[5] Twilio Inc., "SMS API," [Online]. Available: https://www.twilio.com/docs/sms/send-messages

[6] MongoDB Inc., "MongoDB Manual," [Online]. Available: https://docs.mongodb.com/manual/

[7] Meta Open Source, "React – A JavaScript library for building user interfaces," [Online]. Available: https://reactjs.org/

[8] React Native, "React Native Documentation," Meta Platforms, [Online]. Available: https://reactnative.dev/docs/getting-started

[9] Node.js Foundation, "Node.js Documentation," [Online]. Available: https://nodejs.org/en/docs/

[10] Face-api.js, "Real-time face detection and recognition in the browser," [Online]. Available: https://github.com/justadudewhohacks/face-api.js

[11] OWASP Foundation, "Top 10 Web Application Security Risks," [Online]. Available: https://owasp.org/www-project-top-ten/

[12] Mongoose ODM, "Mongoose Documentation," [Online]. Available:

https://mongoosejs.com/docs/

[13] Firebase, “Firebase Cloud Messaging,” Google Developers, [Online]. Available: https://firebase.google.com/docs/cloud-messaging

[14] Postman, “API Platform for Building and Using APIs,” [Online]. Available: https://www.postman.com/

[15] ISO/IEC 27001, *Information Security Management Systems – Requirements*. International Organization for Standardization, 2013.

[16] R. Fielding and R. Taylor, “Architectural Styles and the Design of Network-based Software Architectures,” University of California, Irvine, 2000.

[17] M. Fowler, *Patterns of Enterprise Application Architecture*. Addison-Wesley, 2002.

[18] D. Flanagan, *JavaScript: The Definitive Guide*, 7th ed., O'Reilly Media, 2020.

[19] B. Kernighan and D. Ritchie, *The C Programming Language*, 2nd ed., Prentice Hall, 1988.

[20] K. Beck, *Test-Driven Development: By Example*. Addison-Wesley, 2003.

[21] J. Resig and B. Bibeault, *Secrets of the JavaScript Ninja*, 2nd ed., Manning Publications, 2016.

[22] W. Stallings, *Cryptography and Network Security*, 7th ed., Pearson, 2016.

[23] C. Allen, *The Ethereum Yellow Paper*, Ethereum Foundation, [Online]. Available: https://ethereum.org/en/whitepaper/

[24] GitHub Docs, “GitHub Actions Documentation,” [Online]. Available: https://docs.github.com/en/actions

[25] J. MacCormick, *Nine Algorithms That Changed the Future: The Ingenious Ideas That Drive Today's Computers*. Princeton University Press, 2011.