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Live Bus Tracking System

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Abstract: *Public transport is essential to urban mobility, but its effectiveness is compromised by the absence of real-time monitoring, risky driving habits, unreliable arrival times that can be due to various reasons in major metropolitans such as Delhi and Mumbai. These issues affect passenger experience severely, resulting in lower ridership and higher use of personal vehicles, thus increasing traffic jams and air pollution in already congested urban areas. This study is an examination into the building of a low-cost, cost-effective accessible real-time bus location system without costly capital expenditures or significant changes in fleets. The solution in question utilizes off- the- shelf technologies to achieve a rich, end-to- end networked tracking setup. Using conventional GPS capabilities built into smartphones carried by the bus driver and transit staff, our system avoids the need for any dedicated hardware installations yet provides efficient tracking functionality. The gathered location information is sent via a well-optimized protocol that manages update frequency versus resource use, providing accurate tracking without wasting battery or network load. The architecture of the system utilizes cloud computing for backend processing, which adds scalability to handle increasing ridership and maintain stable deployment with less downtime even at times of high usage. The cloud-based solution allows for swift data processing of key features like arrival times. The system has various features to enhance the quality of the public transit experience, such as an overall alert system that informs passengers of delays, route alterations or emergency conditions. By solving these underlying problems in public transport our system seeks to promote higher ridership by improving passenger convenience and service dependability. This transition towards more public transport use contributes to environmental pursuits on a larger level by minimizing the introduction of new personal vehicles into the road network, thus lowering carbon emission with growing climate change and global warming issues..*

Keywords: Real-Time Bus Tracking, Android Application, Firebase, A* Algorithm, ETA Prediction

I. INTRODUCTION

Urban mobility is maintained through public transport facilities, and public transport facilities serve millions of passengers on a daily basis. Unpredictability in the arrival timings of buses angers the passengers and discourages ridership notwithstanding. The Delhi Transport Corporation's Live Bus Tracking System aims to bridge this crucial gap through the provision of real-time bus location data as well as arrival time to public transport users. This system presents a complete solution for real-time bus tracking in existing fleet of buses and easily available technologies. With the help of mobile devices and their inbuilt GPS sensors, which does not need upfront investment of installing new devices and specialized hardware. This reduces the cost of implementation significantly while maintaining good tracking functionality

The mobile app consists of two core modules, i.e., driver module and passenger module. Whereas the driver module captures and reports the locations, the passenger module assists one in viewing locations of buses and tracking their path along those bus routes. The system also offers route optimizing algorithms, and passengers are provided with a most efficient path between two points in the network.

For accurate bus location tracing at minimal cost, the project uses Google Maps API and on-board smartphone-based GPS modules transported by drivers and marshals. Redundancy through the two-source approach enables perpetual tracking in adverse environments. Location data is routed to a Firebase server, where it is updated periodically,

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compromising real-time data requirements to battery usage and system load requirements. The passenger-side mobile app displays this location data on a map-based interactive interface so that passengers can see bus movements in near real-time. The app provides route data, estimated time of arrival, and interchange suggestion where there are no direct routes.

With the use of this system, public transit agencies can enhance quality of service and customer satisfaction at minimal capital investment. The system is designed to be expandable, rollout incrementally over time on large fleets of buses, and scalable to meet multiple operating needs.

II. METHODOLOGY

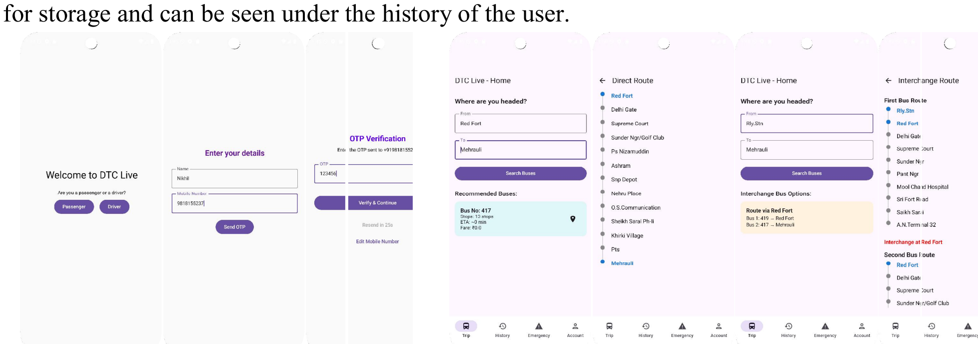
Our system consists of two components the frontend and the backend. The frontend consists of the mobile app which is for the passenger and the driver. The backend is for data storage and other processing tasks

Frontend:

The frontend of the system is divided into two components:

The Passenger Module:

When the passenger first opens the app and chooses the passenger role on his screen. He is taken to the next screen where he has to input his name and mobile phone number. The phone number provided will be used for the OTP verification. After the verification is complete on the home screen of the app, the passenger can select his “From” and “To” destination upon his selection the app is going to use An shortest distance searching algorithm to search for the bus route with the least distance. After finding the route if it is a direct route a result card is displayed to the user. On clicking which the user can see the entire timeline of his journey. If the route is not direct and needs some interchanges there is accommodation for that scenario as well, user is displayed with a result card on clicking he can see the entire timeline of the buses he needs to interchange and the stops at which he needs to interchange the buses. On the timeline screen the user also has an option to see the live location of the bus on the google maps which will be displayed on a separate screen of the app and the ETA. After clicking on the result card, the history of these journeys is sent to the firebase for storage and can be seen under the history of the user.



The Driver Module:

When the driver opens the app and selects the role of the driver, he is prompted to enter his name and the number plate of the bus he is driving today After that a facial recognition opens which scans the face of the driver. After the verification is completed successfully the driver is taken to the home screen where he can see the entire route of the bus he is driving, the bus number plate, the route number and the upcoming stop. When the driver starts his trip and clicks on “Start Trip” the app asks for location access.

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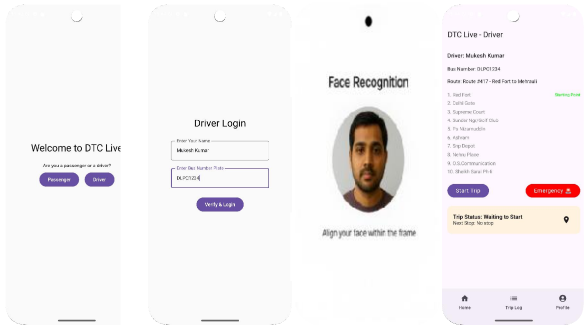
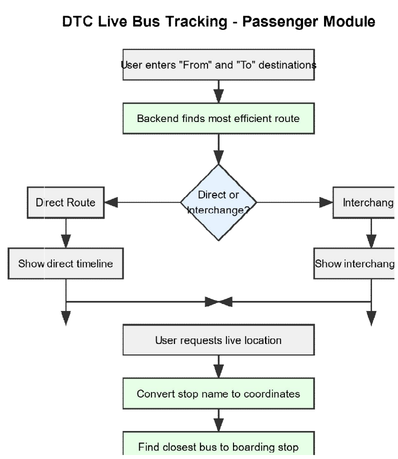


Backend:
Just like the frontend our backend is also divided into component the driver's module and the passenger module. Since we are using Firestore, a lot of the server-side logic is abstracted away. But we need a separate server to handle the ETA, live location requests from the user along with a server to run our algorithm which finds the most efficient route to the destination.

The Passenger Module:
When the passenger enters his "From" and "To" destination in the search box. The app makes a request to the backend server for an efficient between the two stops. The backend server runs an algorithm to check the distance between each bus stop and selects the route with the least amount of total distance. If the algorithm finds the most efficient route is a direct route a "Direct Route" result card is displayed to the user upon clicking which the user can see entire timeline of the bus. If the algorithm finds that the most efficient route needs the user to interchange buses it shows "Interchange Route" result card with the bus stop where the passenger needs to change his/her bus.
When the user requests for the live location of the bus, the passenger is taken to a different screen with Google Maps embedded in it. The app then makes a request to the backend server with name of the boarding stop of the passenger. The server uses Google Maps Geocoding API to convert the stop name into latitude and longitude. Once it is done the server compares the location of all the buses relative to the user entered boarding stop. The bus which is the closest to the user is selected, after the bus is selected the backend makes a query to the Firebase database to fetch the location details of the bus to the Google Maps API to render the live location of the bus based on the proximity of the boarding stop to the closest bus



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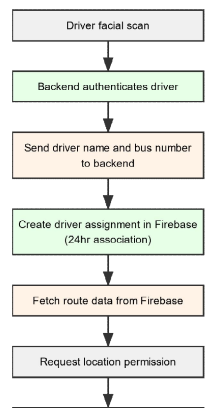
The Driver Module:

After the facial scan of the driver is completed, the facial data is sent to the backend server to check whether the name and facial data are present in the database under one association. When the authentication is done the app sends out the Name of the Driver, Bus Number Plate to the backend server. Firebase then creates a document under "Driver Assignments" collection with today's date + bus number plate under which the driver's name, the timestamp of his login, the bus he is driving on that date is stored. This dynamically assigns the bus to the driver for 24hrs after 24hrs the assignment of the driver to the bus is terminated. After successfully assigning the bus to the driver, the backend sends back the route data from the firebase. Finally, the app asks driver for the location permission from the driver. Upon granting the permission the app sends out location data to the backend to be stored in the firebase database every 10secs.

DTC Live Bus Tracking - Driver Module



Route Searching Algorithm:

To efficiently determine the shortest path between two bus stops, we implement the A*(A-Star) algorithm – a widely used informed search algorithm in pathfinding and graph traversal. The A* algorithm combines the advantages of Dijkstra's algorithm and Greedy Best-First Search by incorporating both the cost to reach a node and a heuristic estimate of the cost to reach the destination.

Let $G = (V, E)$ represent the graph, where V is the set of vertices (bus stops), and E is the set of edges (routes between stops). Each edge e € E has an associated cost, which can be a function of distance, time or traffic congestion.

Algorithm Steps:

Initialization:

Let *start* be the source bus stop and *goal* to be the destination.

Initialize an open priority queue with *start*, and a gScore map with $g(start) = 0$.

For each node, compute $f(n) = g(n) + h(n)$, where $h(n)$ is the heuristic function.

Heuristic Function h(n):

We use the Haversine formula to estimate the straight-line (geodesic) distance between a given node and the goal.

$$h(n) = 2R \cdot \arcsin\left(\sqrt{(\sin\ \hat{}2.(\Delta\phi/2) + \cos(\phi\_1) \cdot \cos(\phi\_2) \cdot \sin\ \hat{}2.(\Delta\lambda/2))}\right)$$

where R is the Earth's radius $\varnothing$ is latitude and λ is longitude.

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Main Loop:
Select the node with the lowest $f(n)$ from the open queue.
If it is the goal node, reconstruct the path and return it.
Otherwise, for each neighbor:
Calculate tentative g-score.
If this path to the neighbor is shorter, update the neighbor's score and insert it into the open queue.

Path Reconstruction:
Upon reaching the goal, backtrack using a "cameFrom" map to reconstruct the optimal path from the source to the destination.

Advantages:
A* provides optimal and efficient pathfinding in real-time transit systems.
It supports dynamic edge weights, allowing integrations of real-time data such as traffic and delays.
The use of a geographical heuristic ensures accurate spatial awareness.

Application in the System:
In our system, all bus stops and interconnections are stored as a graph in Firebase, when a user selects a source and destination in the mobile app, a backend server queries this graph and executes the A* algorithm to return the shortest path. The path is then visualized in the app, enhancing the user's journey planning experience

III. LITERATURE SURVEY

Many researchers have proposed different ways to update real-time location of the buses.
In 2021, Akash Singh, Shivam Choudhary and A. Mary Porsonia proposed a system that adds necessary features such as searching for bus routes, live location of the bus and a notification system to alert the passengers about the cause of the day if any. This system also can predict the ETA of the bus. The app has three modules: The Admin Module, The User module and the Driver Module. The system utilizes Android Mobile with GPS capabilities
In 2020, Akshay Sonawane, Kushal Gogri, Ankeet Bhanushali and Milind Khairnar proposed the idea of developing a mobile application to help the daily travelers of bus to track the location of the bus. To show the approximate time taken by the bus to reach the user, this paper utilizes a Google's Matrix algorithm. The application developed in android studio uses Google Maps API at its core. The paper also has diagrams for the proposed system which are easy to understand.
In 2024, Mrs. M. Parveenbanu, Ms. Meiyyammal. M, Ms. Prasannadevi. P and Ms. Sathiyasri. P created a mini project that overviews the development of a bus tracking and ticket booking system that enables passengers easily book tickets online, calculate the fare using self-made algorithm and track the live-location of the buses. This system provides a unique ticket ID making it easier for the passengers to board the bus without any hassle
In 2024, Sanjukta Mohanty, Aditya Aswajeet Nayak, Prassannajeet Pradhan, Subrat Kumar Sahoo and Sonali Beura created a web application that utilizes GPS technology to track college bus locations for students to easily access the live location of the buses with internet connectivity. The live location of the bus is updated regularly in the central controller. Aiming to improve the efficiency of college bus transportation, their solution makes a smoother campus experience.
In 2019, Prithvi Raju Kunder, Neha Maruti Nayak, Disha Santosh Pandey, Reena Somani proposed development of an android based mobile application for its wide user base and its open-source environment. The paper aims to encourage commuters to use the public transportation more frequently by generating fast and accurate results to save time based on previous research that states GPS tracking system enabled transport system tend to be favored by passengers.
In 2024, Ishwar Bagad, Samruddhi Pimpale, Pooja Patil, Jayshree Rane used Google Maps and Next.js to create a web application for tracking the bus whereabouts. To transmit the data from the bus to the web application Raspberry Pi and

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NEO 6 GPS module are used. The data from the hardware is sent via an API to the website. This project makes it easier for the passengers to book their tickets online

S. no.	Title	Author(s)	Research Gap	Technologies Used	Publishing Date
1.	Live Bus Tracking System	Akash Singh, Shivam Choudhary, A. Mary Posonia	Lacks OTP verification and route optimization for passengers	Android. NoSQL Database, GPS	2021
2.	Bus Location Tracking System	Ishwar Bagad, Samruddhi Pimpale, Pooja Patil, Jayshree Rane	No android app	Raspberry Pi, NEO6 GPS, Next.js, Node.js	March-April, 2024
3.	Real-Time Bus Tracking System using Mobile Technology	M. Parveenbanu, Meiyyammal. M., Prasannadevi P., Sathiyasri P.	Lacks dynamic driver assignment to the buses	GPS, Google Maps API, Web Application	2024
4.	Live-Bus Tracking using Greedy-Based Approach	Sanjukta Mohanty, Aditya Aswajeet Nayak, Prassannajeet Pradhan, Subrat Kumar Sahoo, Sonali Beura	Use suboptimal greedy algorithm instead of A* algorithm	GPS, Google Maps API, Greedy Algorithm	May, 2024
5.	The Real-Time Bus Tracking System	Prithvi Raju Kunder, Neha Maruti Nayak, Disha Santosh Pandey, Reena Somani	Basic Android UI, Lacks OTP verification	Android Firebase, RFID	March-April, 2019
6.	Real Time Bus Tracking System	Akshay Sonawane, Ankeet Bhanushali, Kushal Gogri, Milind Khairnar	Lacks OTP verification and facial recognition	Android, Google Maps API, Firebase	June, 2020

IV. CONCLUSION

The proposed Live Bus Tracking System offers an easy-to-use public transit system. Through live GPS tracking, dynamic routing, and efficient user and driver verification mechanisms, the system commits to addressing the shortcomings of existing transit systems.

One of the key enhancements is the shortest path calculation through A* algorithm implementation, which supports effective route planning and reduces overall travel tie for commuters. Compared to the traditional GPS position-based tracking system, this system enhances routing intelligence by examining multiple possible routes and automatically selecting the optimum one.

Mobile app is developed in driver and passenger modules with a user-friendly interface as per their use. Facial recognition enables secure verification of drivers based on a facial embedding storage system, bringing the level of safety and responsibility in operations a leap forward. In the passenger module, OTP login authentication ensures the individual data private and isolated from other users, adds an added layer of data security and integrity.

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One of the aspects is dynamic driver assignment. Which makes monitoring and logging driver assignments to the corresponding bus easier. Passenger history is maintained on a per-person level allowing for customized data management, future travel analysis, and improved user experience.

Besides, instead of overwhelming passengers with all the information of buses nearby, the app displays only those buses belonging to the passenger's boarding point by proximity filtering. This improves readability immensely along with instant quick decision making.

The platform lays the foundation to be expanded even more through machine learning-enabled ETA estimation, enhancing bus arrival prediction more with learnings derived from history, traffic trends, and time, offline feature addition, emergency SMS notification, geofencing, and driver behavioral analysis in follow-on releases that will further raise the reliability and dependability of the system even in low-connectivity environments.

V. FUTURE SCOPE

The system is far from perfect the system can be enhanced by:

1. Incorporating payment options through which the passengers can reserve their tickets online at their own convenience:

Future deployments can have an in-app online payment gateway, enabling travelers to book and pay for tickets within the mobile application. A QR code based e-ticketing system with fare charges that are dynamic and depend on distance. The integration with digital wallets and UPI adds ease of use, lowering reliance on cash payments.

2. Incorporating "One Tap" emergency call facility for women

A committed emergency button in the mobile application which can directly alert authorities, send the live location of the women passenger and provide the live camera feed from the bus to the authorities. Connected to nearby police stations and transport authorities will provide quick response and rescue women from harassment.

3. A complaint system for users.

Enabling a customer complaint portal in the app through which customer can note down the route number and the bus number plate to make their complaints such as (driver attitude, seats broken, cleanliness, etc.).

4. A Management Web Portal

A portal for middle-level fleet managers would monitor real-time bus locations, maintenance needs, and passenger counts. Driver allocation, fuel usage analytics would optimize operational efficiency.

5. Employing algorithms to monitor rough driving by drivers:

IoT sensors and telematics can detect harsh braking, speeding or jerky steering, rating drivers on safety metrics. Which in-hand lower accidents and improve passenger comfort

6. Using AI to estimate ETA based on past data, weather, time of day, road type (highways, regular roads), past trip records:

Sophisticated algorithms would learn arrival times from historical traffic data, weather patterns, road condition, and seasonality. Real-time delays would be adjusted through machine learning algorithms like LSTM networks, which would inform travelers using mobile apps and digital signs in terminals.

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I would like to express my heartfelt gratitude to Ms. Raheel Hassan for her invaluable guidance, support, and encouragement throughout the development of this research work. Her expertise and constructive feedback have been instrumental in shaping the direction of this paper. I am deeply thankful for her dedication and mentorship, which inspired me to achieve this milestone.

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