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# Smart Tracks: Navigating Urban Transit with IoT-enabled Bus Networks

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***Abstract***

*Public transportation is a lifeline for countless individuals globally, providing essential connectivity for daily commutes to work and school. However, numerous challenges such as bus delays and inefficient space on the buses often hinder the travel experience. It's crucial to resolve these issues to achieve an efficient public transport system. A promising solution lies in the adoption of an IoT-based application. With this technology, one can track the real-time location of buses, provide accurate arrival time estimates, monitor the number of available seats, and enable advanced seat reservations. Implementing such a system could revolutionize public transportation by significantly improving its efficiency and reliability. Commuters would enjoy a seamless and comfortable travel experience with access to real-time information. Additionally, this innovation could help lessen congestion at bus stops, streamline boarding processes, and enhance overall passenger satisfaction. By integrating IoT solutions, we can create an enjoyable travel experience for everyone, thereby encouraging more people to opt for public transport and contribute to the reduction of traffic congestion and environmental impact. This technological advancement holds great promise for transforming the daily commute, making it a smoother, more predictable, and stress-free part of everyday life.*

**Keywords:** Internet of things (IoT), radio-frequency identification (RFID), data analysis, bus tracking, paperless ticketing

## INTRODUCTION

The proposed application introduces a revolutionary approach to urban transportation by leveraging advanced technology to enhance passenger experience and optimize service efficiency. By utilizing touch sensors, Arduino UNO boards, and camera modules, the application enables the tracking of daily bus ridership and facilitates advanced ticket booking with reserved seating options. This innovative solution not only provides commuters with greater convenience and flexibility but also empowers transit agencies with valuable data insights to improve service planning and operational efficiency. Smart buses, characterized by their integration of cutting-edge technology, represent a significant step forward in modernizing public transportation networks. These vehicles serve as hubs of connectivity, facilitating real-time data analysis and seamless communication with traffic infrastructure and other transit modes. By integrating advanced communication systems and environmentally conscious designs, smart buses enhance the sustainability and efficiency of urban mobility.

The implementation of smart bus technology heralds a new era of urban transit, where passengers

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can expect enhanced reliability and accessibility in their daily commutes. By harnessing the capabilities of touch sensors, Arduino UNO boards, and camera modules, smart buses not only enable precise tracking of passenger numbers but also empower commuters to plan their journeys with greater accuracy. Furthermore, the data generated by these sensors facilitates informed decision-making for transit authorities, leading to optimized service routes and improved overall transit experiences. As cities continue to grapple with the challenges of urban mobility, the integration of smart bus technology offers a promising solution to alleviate congestion, reduce emissions, and enhance the quality of life for residents.

## LITERATURE SURVEY

Numerous studies focus on the development of automated bus ticketing systems utilizing radio-frequency identification (RFID) technology. Additionally, several tracking systems for public bus transportation have been deployed employing similar technologies.

Dalip and Kumar [1] proposed a passenger tracking system utilizing global positioning system (GPS) and Global System for Mobile Communication (GSM) technologies. This system tracks passengers using ticket numbers and displays their location on Google Maps. Additionally, Nath et al. [2] describe RFID as a wireless communication technology enabling computers to read inexpensive electronic tags' identities from a distance without requiring a battery in the tags. They highlight transportation as a significant industry that could benefit from a network of static RFID readers. For instance, in ticket booking systems, rental cars equipped with RFID tags on their windshields could store vehicle identification numbers, among other data.

Lotlikar et al. [3], in their paper, provide a comprehensive explanation demonstrating that RFID technology offers faster scanning times compared to barcode and QR (quick response) code scanning. They highlight this as one of RFID's numerous advantages, as tags can be scanned without requiring direct line of sight. RFID tags automatically capture the radio frequency emitted by the reader from a distance and respond accordingly. This immediate responsiveness makes RFID technology preferable over both barcode and QR code technologies. In their paper, Patel et al. [4] propose a system where passengers utilize RFID cards to scan at RFID scanners, each assigned a unique ID for all traveling passengers. Passenger validation occurs through the system's website hosted on a server, and after validation, passengers select their journey's source and destination, with fare deducted accordingly from their account [5].

The Android application based smart bus transportation system is a pioneering solution developed to mitigate the risks associated with bus travel during the ongoing pandemic. Each bus in the system is equipped with a Raspberry Pi processor, infrared (IR) sensors, and GPS unit to facilitate real-time monitoring and passenger safety. The IR sensors, strategically positioned at entry and exit points, accurately track the occupancy of seats by detecting passenger boarding and alighting. This data, alongside the bus's precise location obtained from the GPS unit, is transmitted to a cloud server via a Wi-Fi module, ensuring continuous updates on a dedicated website. Passengers can conveniently book available seats through the Android app, with the option for online payment and ticket generation. Upon booking, passengers receive SMS notifications with their ticket details and can monitor the bus's location in real-time via the app.

To further ensure passenger safety, an IR temperature sensor monitors passengers' health by detecting temperature anomalies. If the temperature exceeds a predetermined threshold, the Raspberry Pi alerts the bus attendant with an alarm, prompting necessary action. Additionally, passengers receive SMS reminders 10 minutes before their scheduled pick-up time, providing updates on the bus's location and essential safety precautions to adhere to during travel. Ticket booking is streamlined through a user-friendly interface, requiring a unique user ID and password, selection of starting and destination points, passenger count, and choice of preferred bus. Payment is facilitated through a wallet, enhancing

 

convenience and efficiency for passengers. Overall, the integration of advanced technology and proactive safety measures ensures a seamless and secure travel experience for passengers utilizing the smart bus transportation system [6].

A novel approach for efficiently tracking city buses by leveraging rapid information retrieval techniques. The suggested system involves creating an Android application specifically designed for tracking buses. Departing from the conventional general packet radio service (GPRS)-based tracking, the system integrates GPS technology to precisely determine the buses' locations and coordinates in real-time. A microcontroller, specifically Arduino UNO, equipped with GSM/GPRS connectivity, serves as the central processing unit within each bus. Additionally, the buses are equipped with four IR sensors positioned at the front and rear doors.

These sensors accurately count passengers boarding and alighting from the bus, with data transmitted to the Arduino UNO via Bluetooth connectivity. The collected information, encompassing location data and passenger counts, is seamlessly updated on a cloud server. Moreover, a user-friendly Android application is developed to provide the public with comprehensive access to this information [7].

An innovative adaptive interactive bus transportation system designed to address the shortcomings of existing geographic information system (GIS) services, particularly in regions lacking comprehensive coverage. Unlike conventional approaches reliant on mainstream services like Google Maps, our system utilizes customized shapefiles containing only pertinent data on bus routes and stations. This tailored solution offers affordability, customization, flexibility, and scalability, catering to diverse transportation needs. Crucially, the system eliminates the time latency associated with traditional GIS services, as shapefiles can be updated promptly and directly, ensuring real-time accuracy. Central to our system's functionality is its predictive capability in anticipating traffic congestion, allowing for proactive passenger management. By notifying waiting passengers in advance and enabling drivers to select alternative routes, when necessary, the system optimizes efficiency and minimizes delays.

At the heart of the technology lies the internet of things (IoT) bus unit, comprising an Arduino microcontroller equipped with a GPS module and a 3G/GPRS/GSM shield. This unit transmits GPS data and a unique unit ID to an application server, which hosts a MySQL and PHP infrastructure. Upon receipt of this data, the server initiates reverse geocoding requests to a designated Geo Server containing geospatial data and functions. Subsequently, the Geo Server responds with a JSON object containing the closest route IDs and attributes of nearby stations. The database schema employed by our system encompasses essential information such as bus ID, MAC address of the IoT unit within the bus, route ID, timestamp ID, latitude, longitude, and other pertinent bus-related data. This comprehensive database facilitates seamless operation and efficient data management, ensuring the smooth functioning of the transportation system. The adaptive interactive bus transportation system represents a pioneering approach to modernizing public transportation infrastructure. By leveraging IoT technology, predictive analytics, and customized geospatial data, our system offers a robust solution tailored to the needs of regions lacking comprehensive GIS services, promising enhanced efficiency, reliability, and passenger satisfaction [8, 9].

## METHODOLOGY

The proposed application aims to revolutionize the commuting experience by facilitating advance bus seat bookings and real-time bus tracking, all geared towards enhancing the overall travel convenience for commuters. The application operates through a user-friendly process, starting with authentication via login credentials for user verification. Once authenticated, users input their boarding and destination stops, along with the number of passengers in their group [10].

Following this, the application generates a comprehensive list of available buses, complete with estimated arrival times, empowering users to make informed decisions based on their convenience.

 

Users can then proceed to book their desired bus with ease, with the application displaying the corresponding fare for transparency. After receiving user confirmation, the application smoothly guides users to a secure payment gateway for completing the transaction.

Upon successful payment, users receive a unique QR code, serving as a digital ticket for their booked bus journey. This QR code is essential for subsequent processing and boarding. Upon reaching the designated bus stop, users simply scan their QR code at the designated kiosk scanner, triggering the generation of a one-time password (OTP) for additional security verification.

This meticulously designed process ensures a seamless and hassle-free journey for commuters, eliminating the need for physical ticketing and reducing wait times at bus stops. By leveraging technology to streamline the booking and boarding process, the application significantly enhances the overall travel experience for commuters, fostering greater efficiency and convenience in urban transportation systems (Figure 1).

## UTILIZATION OF QR CODE IN THE APPLICATION

As the prevalence of smartphones and wireless network infrastructure continues to grow, passengers increasingly rely on mobile devices to access information regarding timetables, bus arrival times, and more. Originating in 1994 from Denso Wave, a subsidiary of Toyota, the QR code emerged as a two-dimensional information container capable of encoding data in an optically readable format, easily decipherable by smartphones. Unlike conventional barcodes limited to storing 20 digits, QR codes boast a significantly higher information storage capacity, making them a versatile tool for various applications.

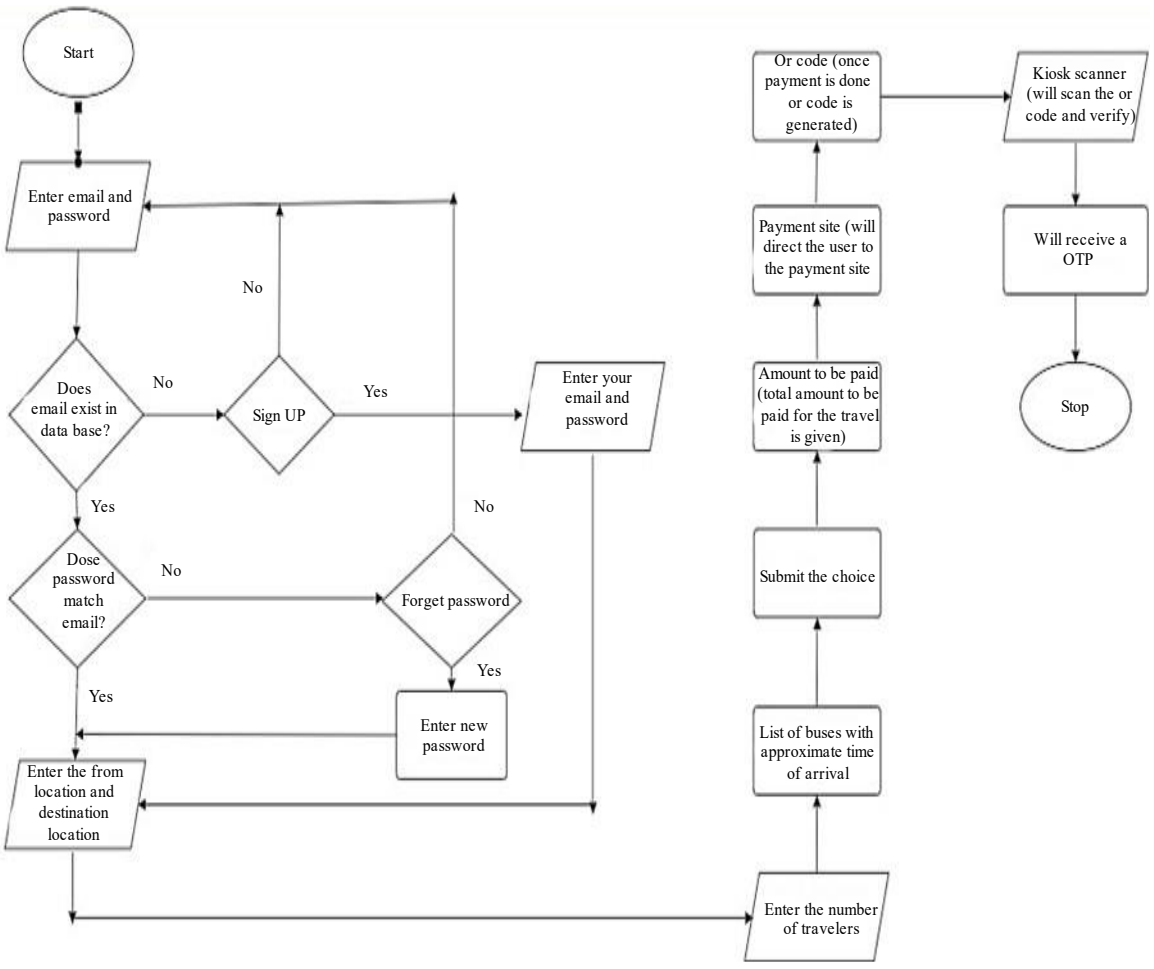


**Figure 1.** Flowchart.

 

With distinct versions offering differing storage capacities, QR codes have become the preferred choice for information dissemination due to their low-cost transfer and compatibility with ubiquitous smartphone technology. Their adaptability extends to diverse printed materials and locations, including posters, books, magazines, and public spaces like bus stops and store windows.

Originally conceived as an alternative to universal product code (UPC) barcodes, QR codes have found utility across a spectrum of functions, including product tracking, item identification, time tracking, document management, and marketing initiatives. Notably, researchers have explored innovative applications such as cost-effective 3D smartphone solutions for indoor navigation and efficient tools like QR-Maps for precise indoor user location retrieval (Figure 2).

In our official capacity, we utilize QR codes to enhance the passenger experience by providing vital information at bus stops. By scanning QR codes strategically placed at these locations, passengers gain access to real-time updates on bus arrival times, current bus locations, and route maps. This integration enhances convenience and efficiency for travelers, facilitating informed decision-making and smoother transit experiences.

## RESULTS

The introduction of this application represents a noteworthy advancement in improving the efficiency and convenience of urban bus transportation systems. The user-friendly interface offers a seamless ticket booking process, effectively minimizing waiting times and ensuring a hassle-free travel experience. The process begins on the home page, where users are prompted to enter their credentials if they have already registered. Alternatively, new users can register by providing their details.

Once successfully logged in, users proceed to book their ticket by entering their starting point (From) and destination. After entering the required information, users simply press 'Book', and the ticket is reserved (Figures 3–6).

**Figure 2.** A quick response (QR) code.


**Figure 3.** Sign up page.

 

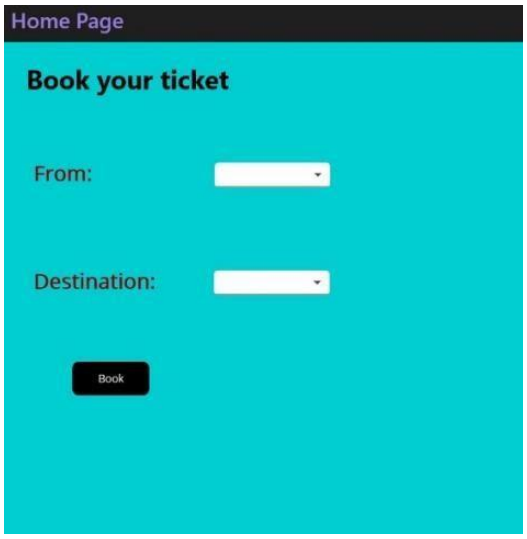


**Figure 4.** Home page

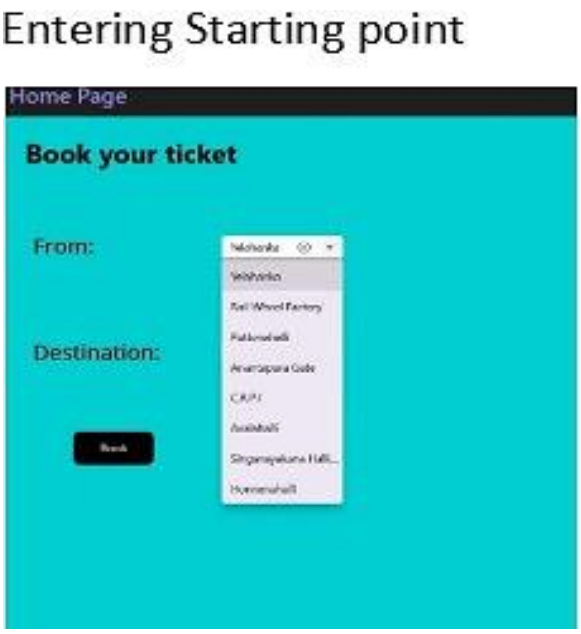


**Figure 5.** Starting point.


**Figure 6.** Destination.


**Figure 7.** Payment.

Payment is then processed, and a QR code is generated and received by the user, acting as their ticket for boarding the bus (Figure 7).

 

## CONCLUSIONS

To conclude, the introduction of this application signifies a noteworthy achievement in improving the effectiveness and convenience of urban bus transportation systems. By empowering passengers to pre-book tickets and providing comprehensive access to real-time information on bus availability and locations, this innovative solution promises to significantly mitigate waiting times and streamline the overall travel experience. Moreover, by enabling passengers to make informed decisions regarding their journeys, such as selecting buses with available seating capacity, the application enhances passenger satisfaction and comfort. In addition to its direct advantages for commuters, the application also supports wider objectives of sustainable urban mobility by encouraging the utilization of public transportation and decreasing dependence on private vehicles. Additionally, the integration of IoT technology not only enhances operational efficiency but also opens avenues for further advancements, such as predictive analytics for optimizing route planning and reducing congestion. As cities continue to evolve towards smarter, more interconnected urban environments, the adoption of such intelligent transportation solutions plays a pivotal role in fostering a seamless and sustainable mobility ecosystem for all residents.

### Future Scope

Smart bus technology is poised for an exciting future, with advancements that can revolutionize public transportation. Here are some key areas of exploration:

- *Enhanced Integration:* Imagine smart buses seamlessly communicating with traffic lights, adjusting timings based on real-time bus location to minimize congestion. This would optimize routes and reduce travel times for everyone.
- *Optimization Enhanced by Artificial Intelligence:* Through artificial intelligence and machine learning, ridership patterns and traffic data can be analyzed. This allows for dynamic route adjustments, deploying buses based on demand and rerouting to avoid delays.
- *Connected City Ecosystems:* Smart buses can become part of a larger smart city network, sharing data with other systems. This could improve urban planning, optimize parking availability, and even integrate with ride-sharing services for a seamless multi-modal travel experience.
- *Advanced Passenger Convenience:* Imagine boarding at a bus stop with digital displays showing real-time arrival times, potential delays, and even alternative routes. Integrated fare systems with contactless payments would further enhance convenience.
- *Electric and Autonomous Future:* As electric vehicle technology matures, expect to see a shift towards zero-emission smart buses. Additionally, autonomous driving holds promise for the future, though significant safety and regulatory hurdles need to be addressed.

These are just some glimpses into the future of smart bus technology. By leveraging innovation and data, smart buses have the potential to make public transportation the preferred choice for a cleaner, more efficient, and more rider-friendly urban experience.

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