Sri Lanka Intelligent Bus Navigation and Passenger Information System

24-25J-237

Project Proposal Report

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B.Sc. (Hons) Degree in Information Technology Specialized in Information Technology

Faculty of Computing

Sri Lanka Institute of Information Technology

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DECLARATION

Declaration

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Date

8/03/2024

ABSTRACT

In Sri Lanka, public transportation is vital to the daily lives of most citizens, with buses—both from the Ceylon Transport Board (CTB) and private operators—serving as the primary means of travel. The bus transportation sector has become a significant business opportunity, leading to intense competition among operators. While this competition can be economically beneficial for some, it has also brought about numerous challenges, particularly concerning safety. The fierce rivalry between buses often results in reckless driving, contributing to a high number of bus accidents each year. These accidents not only lead to the tragic loss of life but also impose substantial financial costs on the country.

Our primary objective is to address and reduce the occurrence of road accidents involving buses in Sri Lanka. By focusing on safety measures and optimizing bus operations, we aim to mitigate the risks associated with competitive driving behaviors. Additionally, this research takes into account the comfort and convenience of passengers. Providing passengers with real-time information about seat availability is crucial, as it can greatly enhance their travel experience. With knowledge of the available seats on a bus, passengers can make informed decisions, reducing the chances of missing their intended bus and, as a result, saving valuable time.

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
CTB	Ceylon Transport Board
IOT	Internet of things
LCD	Liquid Crystal Display
ETA	Estimate time arrival
GPS	Global Positioning System
MQTT	Message Queuing Telemetry Transport
SSL	Secure Sockets Layer
TLS	Transport Layer Security

1. INTRODUCTION

1.1 Background & Literature survey

Public transportation in Sri Lanka, particularly the bus services operated by both state-owned CTB and privately operated entities, is a crucial part of daily life for millions of people across the country. These buses are the backbone of the nation's transportation network, moving people across urban, suburban, and rural areas, and providing a vital service for those who depend on public transit to commute to work, school, and other daily destinations. However, despite its importance, the public transportation system in Sri Lanka faces significant challenges that severely affect the safety, comfort, and overall efficiency of the services provided.

One of the most critical issues is the intense competition between bus operators, which has far-reaching consequences for both passengers and the broader community. This competition arises from the fragmented structure of the industry, where numerous bus operators, both public and private, run services on the same routes, competing for the same pool of passengers. While the intention behind this competition is to enhance service quality by offering more choices to passengers, in practice, it has often led to negative outcomes that undermine the very goals of safety, reliability, and comfort in public transportation.

One of the most alarming consequences of this competition is the prevalence of reckless driving among bus operators. Driven by the need to attract as many passengers as possible, bus drivers frequently engage in dangerous driving practices, such as excessive speeding, sudden and aggressive lane changes, and risky overtaking maneuvers. These behaviors not only put the lives of passengers at risk but also endanger other road users, including pedestrians, cyclists, and drivers of other vehicles. The pressure to reach bus stops ahead of competitors often leads to violations of traffic regulations, significantly increasing the likelihood of accidents. The consequences of such reckless driving can be severe, resulting in injuries, fatalities, and a general erosion of public confidence in the safety of the bus system.

Moreover, this competitive environment exacerbates the problem of overcrowding on buses. In their quest to maximize passenger numbers, drivers and conductors often allow buses to become dangerously overcrowded, far exceeding their intended capacity. This overcrowding not only causes significant discomfort for passengers but also poses serious safety risks. Overloaded buses are more prone to accidents, and in the event of a sudden stop or collision, the likelihood of injuries among passengers is greatly increased. Additionally, the lack of regulation and enforcement regarding passenger limits allows this issue to persist, contributing to an overall decline in the quality of the public transportation experience.

Another critical challenge stemming from the competitive nature of the bus industry is the unpredictability of bus schedules. The absence of a coordinated scheduling system means that buses often operate according to the whims of individual drivers and operators, rather than adhering to a standardized timetable. This lack of predictability is further exacerbated by the aggressive pursuit of passengers at bus stops. Drivers frequently delay departures in an attempt to attract more passengers, leading to inconsistent and unreliable service. For passengers, this translates into longer wait times, missed connections, and a general sense of uncertainty about their journeys. The unpredictability of bus schedules is particularly problematic during peak travel times when the demand for buses is highest, and passengers are often in a hurry to reach their destinations. This erratic service not only frustrates passengers but also reduces the overall efficiency of the public transportation system.

The challenges posed by reckless Driving', overcrowding, and unpredictable schedules highlight the need for a comprehensive approach to improving the public transportation system in Sri Lanka. To address these issues and enhance passenger comfort, safety, and reliability, it is essential to implement solutions that leverage modern technology and promote better coordination among bus operators. One promising approach to solving these challenges is the integration of Internet of Things (IoT) technology into the public transportation system. IoT can play a crucial role in providing real-time information to both passengers and drivers, enabling safer and more efficient bus operations. For instance, equipping buses with IoT-enabled devices can allow for real-time monitoring of bus locations, speeds, and passenger loads. This data can be used to inform passengers about the estimated arrival times of buses, the availability of seats, and the current crowding conditions on board. By providing passengers with this information through a mobile app at bus stops, they can make more informed decisions.

Below is the information obtained from an analysis report on bus accidents in Sri Lanka 2022 [1].

MINISTRY OF TRANSPORT AND HIGHWAYS

SLTB Buses	Fatal	59	29	37	63
	Minor	272	168	86	157
	Critical	175	126	72	123
	Damages	187	68	65	101

MINISTRY OF TRANSPORT AND HIGHWAYS

Private Buses	Fatal	201	133	129	172
	Minor	632	367	247	397
	Critical	479	432	203	319
	Damages	789	265	285	359

Figure 1.1: survey report on 2022 Bus accidents

Accidents like these often occur when a bus traveling at high speed tries to overtake another bus on the same route. This dangerous situation can lead to collisions, putting both passengers and drivers at risk. To address this issue, we have implemented a solution that provides the driver of the bus following behind with real-time information about the distance to the bus ahead. This information is displayed on a small LCD screen[2] installed in the driver's cabin.

The LCD display continuously shows the distance between the two buses, allowing the driver of the trailing bus to make informed decisions about their speed and driving behavior. By knowing the exact distance to the bus in front, the driver can adjust their speed accordingly, reducing the need for risky overtaking maneuvers. This helps to prevent potential accidents and ensures that passengers are transported safely and efficiently. The system ultimately promotes safer driving practices by encouraging bus drivers to maintain a safe distance from the vehicle ahead, minimizing the risk of accidents caused by sudden braking or overtaking on crowded roads.

Ensuring passenger comfort is a key aspect of our system, especially in the context of public transportation, where overcrowding can greatly impact the travel experience. To address this, we have integrated an ESP32 camera module[5], a compact and efficient device known for its low power consumption and high performance. The ESP32 camera module is strategically placed inside the bus to capture real-time images of the interior at regular intervals. These images provide valuable insights into the current crowd conditions, including the number of passengers, availability of seating, and overall comfort level.

The images captured by the ESP32 module are processed and analyzed to determine the number of empty seats[4] available on the bus. This data is then sent to a mobile application, which is specifically designed for passengers to access real-time information about the buses they plan to board. By checking the app before boarding, passengers can make informed decisions based on the bus's crowd condition, ensuring they choose a bus that offers a comfortable travel experience. This feature is especially useful during peak hours when buses are usually crowded, as it helps passengers avoid overly congested vehicles.

The mobile app, designed with an Intuitive and user-friendly interface, displays real-time information on crowd conditions and seat availability. Passengers can easily access this information, along with additional details such as the bus's estimated time of arrival (ETA) and its current location. By offering a comprehensive overview of the bus's condition, the app enables passengers to plan their journeys more effectively, reducing the stress and discomfort often associated with overcrowded public transportation. Ultimately, this system not only improves the overall passenger experience but also contributes to a more efficient and user-friendly public transport system.

When a passenger is waiting for a public transport bus at a bus stop, the presence of another bus already parked there can create confusion and cause the passenger to miss their intended bus. This situation happens when the passenger mistakenly thinks the parked bus isn't the one they need and, as a result, walks past it, missing their ride. Consequently, the passenger ends up wasting a lot of time waiting for the next bus, which can be especially inconvenient during busy times or when buses are less frequent.

This issue underscores the importance of clear communication and effective signage at bus stops, ensuring passengers can easily identify the correct bus even when another vehicle is parked at the stop. This helps save time and reduce frustration.

The mobile app introduces a feature designed to enhance the efficiency and reliability of public transportation by reducing the chances of passengers missing their bus at a stop. When a person or a group is waiting at a bus stop, they can use the app to notify the bus driver of their presence. By simply clicking the “wait” button in the app, passengers can signal their intent to board the next bus. This action immediately updates the bus driver with the number of passengers waiting at that specific stop, which is displayed on their onboard system. This real-time communication between passengers and the driver ensures that the driver is aware of how many people are waiting to board at the next stop. As a result, the driver can plan accordingly, making sure the bus stops to pick up these passengers without bypassing the stop or missing anyone who intends to board

This feature greatly reduces the chances of passengers missing the bus due to confusion or miscommunication at the bus stop. By giving the driver a clear understanding of how many people are waiting at each stop, the app enables more accurate and considerate driving, resulting in a smoother and more predictable bus service. Passengers no longer have to worry about the bus leaving without them, as the driver is fully aware of their presence in advance. This also helps avoid unnecessary delays, as the driver can anticipate the need to stop, leading to a more efficient flow of traffic and better adherence to the schedule. Overall, this feature not only enhances passenger comfort and reduces anxiety at bus stops but also contributes to a more streamlined and reliable public transportation system.

Given these challenges, it is crucial to explore solutions that can mitigate the risks associated with bus competition while also enhancing the overall passenger experience. One promising approach is the application of IoT technology, which provides a range of tools and capabilities that could revolutionize how bus services are managed and experienced. IoT technology enables the real-time collection and analysis of data, offering insights that can be used to optimize bus operations and improve safety.

By equipping buses with IoT devices like GPS trackers and communication modules, it’s possible to monitor the location and status of each bus in real time. This data can be fed into a centralized system that coordinates bus movements, ensuring that buses stick to their designated schedules and reducing the chances of dangerous overtaking at bus stops. For instance, if a bus is detected to be too close to the one ahead, the system could automatically adjust the timing of the next stop or send an alert to the driver to prevent unnecessary competition.

In addition to boosting operational efficiency, IoT technology can greatly enhance the passenger experience by providing real-time updates on bus locations, seat availability, and estimated arrival times. This information can be made accessible to passengers through mobile apps at bus stops, helping them plan their journeys more effectively and reducing the stress of waiting for a bus. Passengers would no longer need to worry about missing a bus or enduring long waits in uncertainty. Instead, they could make informed decisions about which bus to take, whether to wait for the next one, or consider alternative routes.

1.2 Research Gap

In Sri Lanka, a major issue in public bus transportation is the lack of communication between bus drivers and passengers regarding the number of people waiting at the next bus stop. Currently, bus drivers have no way of knowing how many passengers will board at the upcoming stop. This lack of information often results in buses passing by stops without picking up waiting passengers, or passengers missing their desired bus because the driver is unaware of their presence.[6]

The lack of a system that informs drivers about the number of passengers waiting at the next stop leads to inefficiencies and inconvenience. Passengers who are ready to board may go unnoticed by the driver, causing them to miss the bus. This issue is especially common during peak hours when buses are crowded, and drivers are focused on managing the passengers already on board. The uncertainty about how many passengers are waiting at the next stop can result in overcrowded buses, delays, and overall passenger dissatisfaction.

Despite the widespread use of technology in public transportation systems around the world, this specific issue has not been addressed in any of the research papers I have reviewed. While some studies and implementations focus on enhancing the passenger experience through various means, such as small LCD screens displaying information[7] these technologies have not been applied to address the problem of predicting or informing drivers about the number of passengers waiting at the next stop. Current research does not provide a solution that equips drivers with real-time data on the number of passengers intending to board at the next stop.

Implementing a system that allows drivers to see the number of passengers waiting at the next stop could significantly enhance the public transportation experience in Sri Lanka. This system could be fairly simple, using existing technologies like GPS and mobile applications. For instance, passengers could use a mobile app to indicate that they are waiting at a specific stop, and this information could be relayed to the bus driver via a small screen installed in the bus[8]. Such a system would not only reduce the chances of passengers missing their bus but also help drivers manage their routes more efficiently by anticipating the number of passengers they need to accommodate.

The absence of such a system in current research and practice represents a missed opportunity to improve public transportation in Sri Lanka. By addressing this issue, the overall efficiency, reliability, and passenger satisfaction of the bus system could see significant improvements. Future research and development should focus on this gap and explore the potential of integrating real-time passenger data into the bus driver's decision-making process. This would be a valuable addition to the existing body of knowledge and could lead to practical solutions that benefit both drivers and passengers.

In Sri Lanka, a significant number of bus accidents occur each year, prompting the allocation of grants to address this issue. A common and dangerous practice contributing to these accidents is buses overtaking each other by closely following and then passing the bus in front. Despite the seriousness of this problem, it has not been thoroughly examined in the research papers reviewed so far. One potential solution involves installing small LCD displays in buses. These displays could show the distance between the bus and the vehicle ahead, providing the driver with real-time information. This system could help drivers maintain a safe following distance and reduce the likelihood of accidents caused by overtaking maneuvers. However, this approach has not yet been explored in the existing literature, highlighting a gap in current research efforts to improve bus safety in Sri Lanka[9]. Addressing this issue could lead to significant improvements in road safety and reduce the frequency of bus-related accidents.

We are using a GPS/GPRS module that allows for the insertion of a SIM card into the IoT device to establish an internet connection[10]. In many research papers, the WiFi capability of the ESP32 board [11]has been widely utilized. Previous implementations have mainly relied on 3G connections, but by integrating 4G technology, we expect improved data transmission speeds and a more reliable connection, particularly in areas with better 4G coverage. This shift from WiFi to cellular connectivity represents a step forward in IoT device networking, providing greater flexibility and wider reach.

We are using the MQTT protocol[11]which is well-known for its reliability in transferring data to Firebase. The MQTT protocol has been widely employed in various research papers due to its lightweight nature and efficiency, especially in scenarios where network reliability is a concern. By using MQTT, we ensure that data can be transmitted effectively even at very low signal levels, which is crucial for maintaining consistent and accurate data transfer in environments with fluctuating network conditions. This protocol's ability to handle intermittent connectivity makes it an ideal choice for IoT applications, where stable and continuous data flow is essential.

In our implementation, we harness MQTT's strengths to enhance the robustness of our system. While the use of MQTT with Firebase has been explored in some previous studies, our approach reinforces its effectiveness, especially in scenarios that demand reliable data transmission under challenging network conditions. This choice not only aligns with existing research but also ensures that our system remains dependable in real-world applications, where network stability cannot always be guaranteed.

We are committed to providing passengers with the necessary amenities to ensure a comfortable journey to their destination. To achieve this, we are using a camera module[12] to monitor the crowd situation inside the bus at regular intervals. The camera module we've selected is highly cost-effective, making it an ideal choice for widespread use in public transportation systems. By periodically capturing images of the bus interior, we can assess the level of crowding and take the necessary steps to maintain passenger comfort.

The captured images are sent to Firebase Storage, where they are securely stored and processed. This real-time monitoring enables better management of passenger loads, ensuring that buses do not become overly crowded, which can lead to discomfort and potential safety issues. The use of a cost-effective camera module helps keep the overall system affordable while still providing valuable insights into passenger density[13]. This approach is designed to enhance the overall travel experience by enabling timely interventions based on crowding data, thereby ensuring that passengers can reach their destinations comfortably and safely.

The table below, Table 1.1, presents a summary of the above explanation, focusing on the real-time monitoring and management of passenger loads using cost-effective camera modules and Firebase Storage. This approach is aimed at enhancing the overall travel experience by ensuring that buses do not become overly crowded, thereby improving passenger comfort and safety.

Research A - IoT-based bus monitoring system using a mobile app for real-time tracking of bus location, seat availability, and passenger activities, enhancing service efficiency and management[7].

Research B - IoT-based system improves Sri Lanka's public transport with real-time bus tracking, automated ticketing, and smart card authentication for enhanced service efficiency[10].

Research C- IoT-based GPS vehicle tracking and theft detection system using Google Cloud IoT Core and Firebase for real-time location monitoring and theft alerts via a web interface[11].

Application Reference	Displaying the distance between a bus and the bus ahead of it.	Displaying the passengers boarding from the next stop.	Passengers can get an idea about the seat availability of the bus.	Use MQTT for pass the data	Connect the IoT device to the internet using a GSM/GPRS module.
Research A	✗	✗	✗	✗	✗
Research B	✗	✗	✓	✗	✓
Research C	✗	✗	✗	✓	✓
Proposed System	✓	✓	✓	✓	✓

Table 1- Comparison of former researches

While there are existing mobile applications for public buses, our proposed system introduces powerful new functionalities that greatly enhance the real-time monitoring and management of passenger loads. This mobile application is designed not only to help passengers and bus operators easily monitor bus occupancy levels but also to offer advanced features that set it apart from current solutions. For example, our system includes real-time crowd density analysis using cost-effective camera modules, predictive seat availability notifications, and improved data transmission capabilities through 4G networks. These innovations aim to enhance passenger comfort, safety, and the overall efficiency of the public transportation system, providing a more robust and user-friendly experience than existing applications.

1.3 Research problem

Public transportation systems, especially buses, face several challenges that can significantly impact their efficiency and reliability. Among these, bus overcrowding, intense competition among operators, and the lack of real-time monitoring and management of passenger loads are critical issues that must be addressed to ensure a reliable and safe public transportation system. Tackling these challenges is crucial for maintaining the efficiency and profitability of public transit operations, while also ensuring passenger satisfaction and safety.

One of the main issues affecting bus transportation is overcrowding, which diminishes both the productivity and comfort of the system. Overcrowding can lead to delays, safety concerns, and an overall unpleasant experience for passengers. This problem is especially common in large-scale public transportation networks, where buses operate continuously throughout the day to meet the demands of a growing population. When buses become overcrowded, it not only inconveniences passengers but also adds extra strain on bus operators and the transportation infrastructure as a whole.

Another significant issue is the intense competition among bus operators. In many public transportation systems, particularly in Sri Lanka, there is fierce competition among buses to pick up as many passengers as possible, often leading to reckless driving behavior. Buses frequently try to overtake one another to get ahead and maximize their profits by picking up more passengers. This competitive behavior can create dangerous driving conditions, resulting in a higher incidence of accidents. These accidents not only pose a significant risk to passengers and other road users but also contribute to delays and disruptions in the transportation system.

Additionally, the lack of real-time monitoring and management of passenger loads is a major challenge in public bus transportation. Without the ability to monitor how many passengers are waiting at the next stop, bus drivers often operate without crucial information that could help them manage their routes more effectively. This can lead to buses passing by stops without picking up passengers or becoming overcrowded because drivers are unaware of the number of passengers they need to accommodate. This issue is particularly problematic during peak hours when the demand for public transportation is highest, leading to passengers missing their desired bus and experiencing significant delays in their commute.

Moreover, the lack of awareness among bus operators and passengers about the availability of advanced tools and technologies that can monitor bus occupancy levels and predict crowding exacerbates these issues. Many existing public transportation systems have not yet adopted such technologies, which could help mitigate the problems of overcrowding and unsafe driving practices. This gap in technology usage means that buses often become overcrowded, and drivers are left to make decisions without sufficient information, leading to inefficiencies and increased safety risks.

To address these challenges, it is essential to implement advanced monitoring systems that enable real-time data collection and analysis of passenger loads. These systems could utilize technologies such as GPS, GPRS modules, and camera modules to track the number of passengers boarding at each stop and provide this information to bus drivers in real-time. By equipping buses with small LCD screens that display the distance to the vehicle ahead, as well as the number of passengers waiting at upcoming stops, drivers can make informed decisions that enhance the efficiency and safety of their routes. This real-time monitoring system would help reduce the likelihood of buses becoming overcrowded and minimize the competition among bus operators, which often leads to dangerous driving practices.

Furthermore, educating both passengers and bus operators on the use of these advanced monitoring tools is crucial for improving the overall efficiency and safety of public transportation. By raising awareness about the benefits of these technologies, transportation authorities can encourage their adoption and ensure that both drivers and passengers are better prepared to handle the challenges of public transit. This education could include training programs for bus operators on effectively using the monitoring systems and public awareness campaigns to inform passengers about how these systems work and the benefits they offer.

In addition to implementing monitoring systems, addressing the issue of competition among bus operators is also important. Regulatory measures could be introduced to limit competition and ensure that buses operate according to safety guidelines rather than focusing solely on maximizing profits. These regulations could include strict penalties for reckless driving and overtaking, as well as incentives for bus operators who prioritize passenger safety and comfort over profit margins. By reducing the pressure on bus operators to compete for passengers, these measures would contribute to a safer and more reliable public transportation system.

In conclusion, public transportation systems, particularly buses, face several challenges that can significantly impact their efficiency and reliability. Overcrowding, intense competition among bus operators, and the lack of real-time monitoring and management of passenger loads are critical issues that must be addressed to improve the overall performance of the public transportation system. By implementing advanced monitoring systems, educating passengers and bus operators, and introducing regulatory measures to reduce competition, transportation authorities can enhance the safety, efficiency, and reliability of public bus transportation. These improvements will ensure that the public transportation system meets the needs of daily commuters and contributes to a more sustainable and profitable transportation infrastructure.

2. OBJECTIVE

2.1 Main Objective

The main objective of this study is to enhance passenger comfort and safety by optimizing bus operations through real-time IoT technology. This study focuses on implementing systems that provide real-time data on passenger loads, bus positioning, and crowd levels. By utilizing this data, the study aims to enable more efficient and safer bus operations, ultimately improving the overall public transportation experience.

2.2 Specific Objectives

There are four specific objectives that must be reached in order to achieve the overall objective described above.

1. Enhance Driver Awareness

The objective of enhancing driver awareness centers on providing bus drivers with real-time information about traffic conditions, passenger loads, and the proximity of other vehicles. By equipping drivers with up-to-date data through IoT-enabled systems, they can make informed decisions, reducing the risk of accidents and improving route efficiency. This real-time awareness allows drivers to anticipate potential hazards, manage bus capacity more effectively, and ensure a smoother, safer journey for passengers, leading to better driving practices and a more positive public transportation experience.

2. Reduce Bus Competition

Reducing bus competition focuses on curbing the aggressive behavior often observed among bus drivers competing to pick up more passengers. This objective involves implementing systems that discourage reckless driving and overtaking, which are common contributors to bus-related accidents. By providing drivers with real-time data on passenger counts and bus positions, along with introducing regulatory measures, the pressure to compete for passengers can be lessened. This approach encourages safer driving practices, decreases the risk of accidents, and promotes a more orderly and efficient public transportation system.

3. Monitor Seat Availability

Monitoring seat availability is essential for enhancing passenger comfort and managing bus capacity. This objective leverages IoT technology to provide real-time data on the number of available seats on each bus. By conveying this information to both drivers and passengers, the system helps prevent overcrowding and keeps passengers informed about seating options before they board. This real-time monitoring optimizes bus capacity, reduces overcrowding, and improves the overall travel experience by allowing passengers to plan their journey with accurate seating information.

4. Facilitate Real-Time Data Sharing

Facilitating real-time data sharing involves implementing IoT systems that allow continuous exchange of crucial information between buses, central control systems, and passengers. This goal ensures that all stakeholders have access to up-to-date information on bus locations, passenger loads, seat availability, and traffic conditions. By enabling seamless communication and data sharing, the system enhances the coordination of bus operations, improves decision-making for both drivers and passengers, and ultimately contributes to a more efficient and responsive public transportation network.

3. Methodology

The proposed smart system is designed to improve the efficiency and safety of bus operations by providing real-time data to both drivers and passengers. Central to this system is an LCD display mounted in front of the bus driver, which acts as the primary interface for delivering essential information. The display shows the distance to the bus ahead, helping the driver maintain a safe following distance and reducing the risk of accidents caused by sudden braking or close proximity.

In addition to displaying the distance to the bus in front, the LCD also provides the driver with real-time information about the number of passengers waiting at the next stop. This feature allows the driver to anticipate how many people will board the bus, facilitating better route management and minimizing the chances of overcrowding. With this information, the driver can make informed decisions about adjusting speed or making additional stops, ensuring a smoother and more efficient journey.

The system benefits not only drivers but also passengers. Through a mobile application, passengers can check the crowd status of the bus they plan to board. This real-time information allows them to make informed decisions about whether to wait for the next bus or board the current one based on available seating. The system also displays the number of available seats on the bus, helping passengers avoid overcrowded conditions and improving their overall travel experience.

3.1 System Architecture

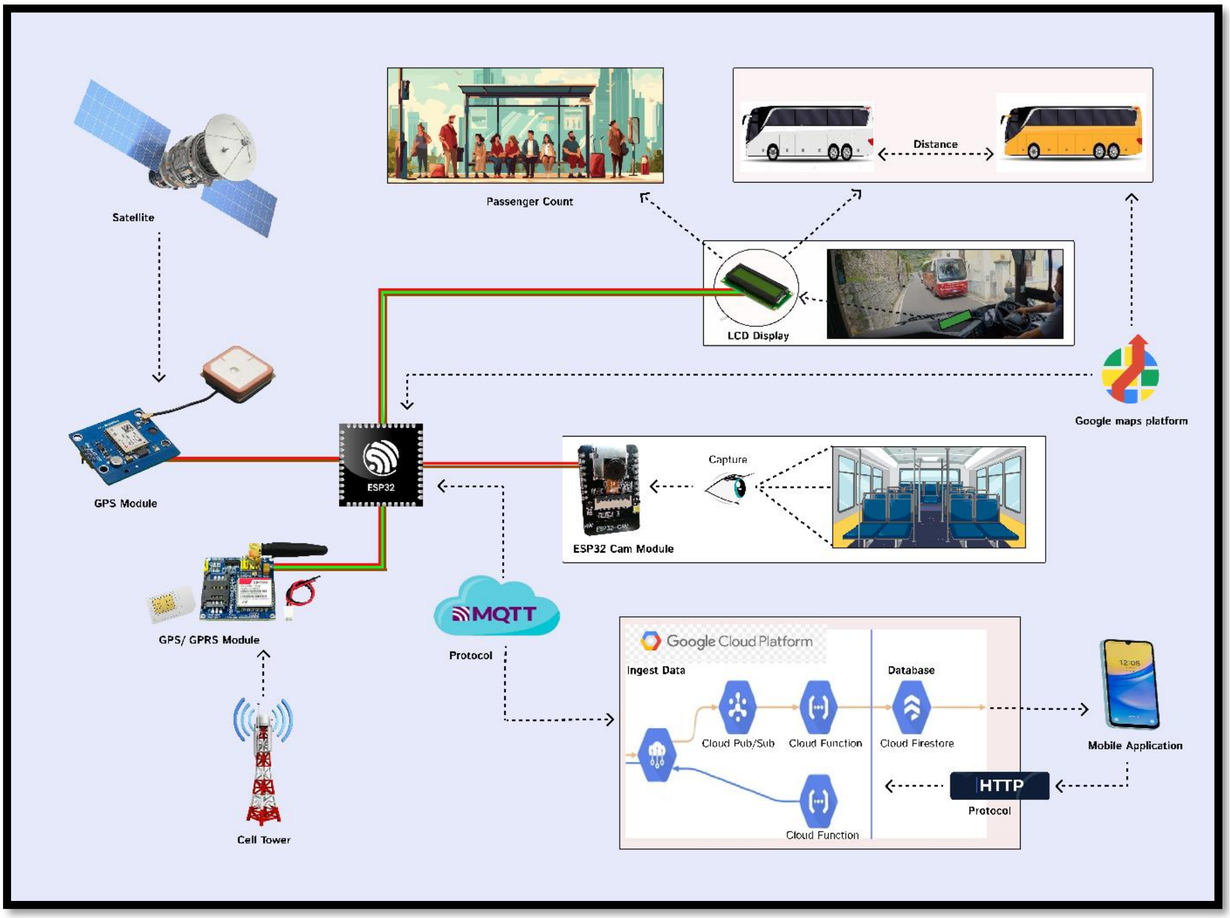

Figure 3. 1: System diagram of the IOT device

In the proposed system, a GPS module is crucial for acquiring the bus's current location. This location data is vital for various functions, such as tracking the bus's position, providing real-time updates to passengers, and enabling effective route management. The GPS module continuously transmits the bus's location data to the central system, where it is processed to enhance the overall efficiency and safety of bus operations.

To establish an internet connection, the system uses a GPS/GPRS module that can house a SIM card. This module is essential for creating a reliable connection to the internet, necessary for real-time data transmission. By inserting a SIM card into the GPS/GPRS module, the system can connect to a 3G or 4G network, depending on the available signal strength in the area. This cellular connection is key to maintaining continuous communication between the IoT device on the bus and the central system.

The use of a 3G or 4G signal ensures that the IoT device maintains a stable and robust internet connection, which is crucial for the real-time data processing and communication required by the system. This connectivity enables the IoT device to send and receive data on the bus's location, passenger load, and other critical parameters. Choosing 3G or 4G technology ensures that the system can operate effectively in various environments, whether in urban areas with strong network coverage or in more remote locations where connectivity may be weaker.

All modules within the system are connected through this internet-enabled network, allowing for seamless integration and communication between different components. The data collected by the GPS module, along with other sensors and modules on the bus, is transmitted to the central system via the internet connection provided by the GPS/GPRS module. This setup ensures that all parts of the system work together cohesively, delivering real-time updates and enabling efficient management of bus operations.

At the core of this system is the ESP32 board, which manages the operations of all connected modules. The ESP32 is a highly versatile microcontroller known for its powerful processing capabilities and cost-effectiveness. In this system, the ESP32 is responsible for coordinating data collection from the GPS module, managing the internet connection via the GPS/GPRS module, and processing the data before transmitting it to the central system.

The use of the ESP32 board ensures that the system remains efficient and reliable, even when handling large volumes of data from various modules. Its low power consumption and high processing speed make it an ideal choice for the continuous, real-time operation required by this smart bus system. Furthermore, the ESP32's affordability makes it a cost-effective solution for large-scale deployment across multiple buses, allowing the system to be widely implemented without incurring excessive costs.

In this system, we use Firebase as a real-time database because of its strong cloud-based storage capabilities. Firebase allows us to efficiently store and manage data, providing seamless access to real-time information across all connected devices. This cloud-based approach ensures that the system can easily scale and handle large volumes of data without sacrificing performance or reliability.

To transfer data from the IoT device to Firebase, we use the MQTT protocol. MQTT is well-known for its reliability, particularly in situations where network stability may be an issue. This lightweight messaging protocol is designed to enable efficient communication between devices, even in low-bandwidth environments. By using MQTT, we ensure that the data collected by the IoT device is securely and reliably transferred to Firebase, maintaining the integrity of the information being processed. The combination of Firebase and MQTT allows us to create a system that is both scalable and dependable, ensuring real-time data availability and consistent performance under a variety of conditions.

We use the OV5640 camera module to capture images at regular intervals, which are then sent to Firebase for storage and processing. This method allows us to monitor the bus's interior, offering real-time insights into the number of empty seats and the overall crowd situation. By analyzing these images, both bus operators and passengers can clearly understand the bus's occupancy level, enabling better decision-making regarding boarding and seating availability.

The OV5640 camera module Is selected for its ability to capture high-quality images while remaining cost-effective, making it ideal for continuous monitoring without significantly impacting system resources. The images captured by the camera are automatically uploaded to Firebase, where they can be accessed and analyzed in real-time. This approach provides a dependable way to monitor seat availability and crowd density, enhancing passenger comfort and optimizing bus operations by preventing overcrowding and ensuring effective seat management. The integration of the OV5640 camera module into the system is essential for maintaining the efficiency and safety of public transportation.

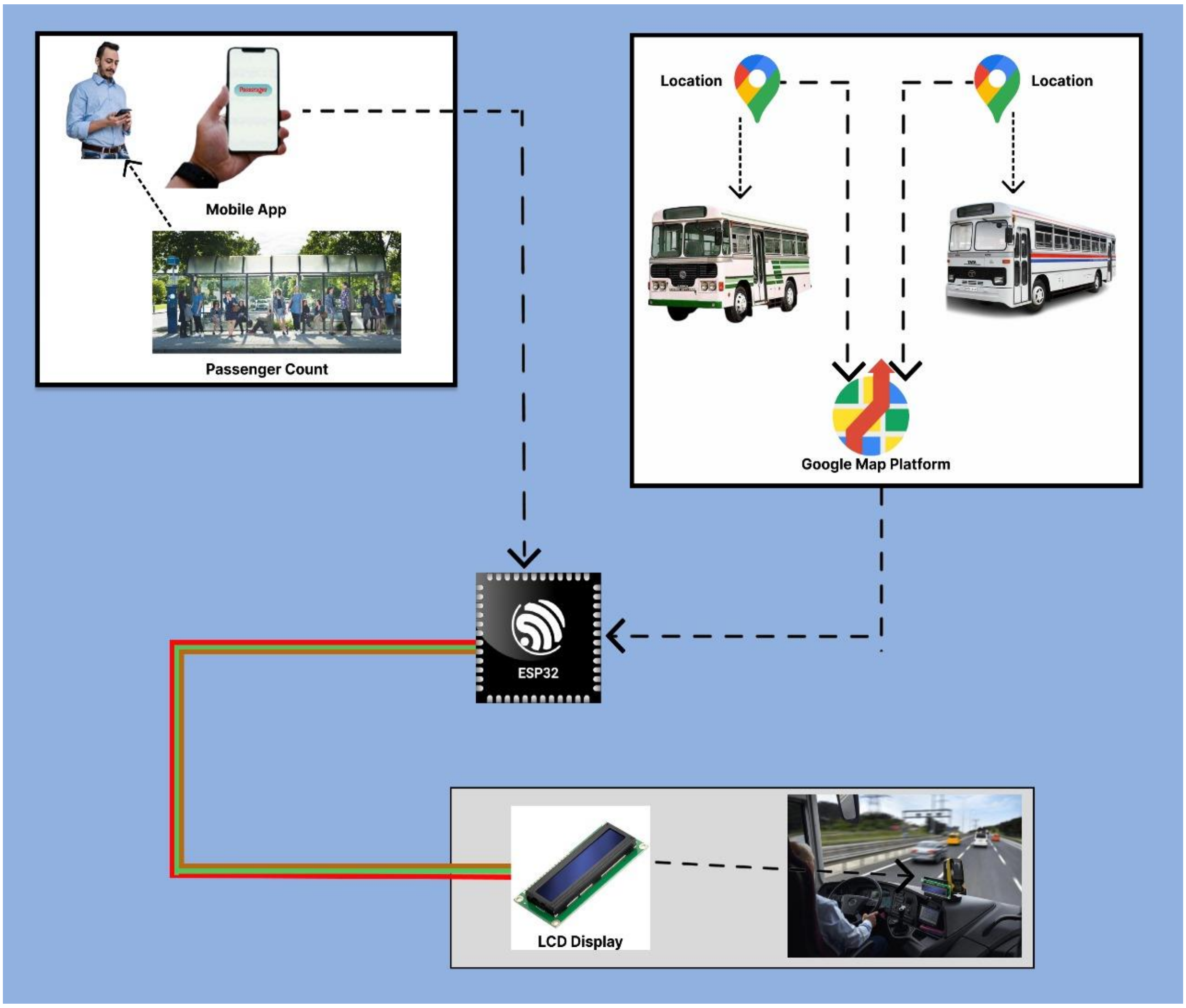

Figure 3. 2: System diagram Distance calculating and the Passenger count

Figure 3.2 illustrates a system that enables a person standing at a bus stop and waiting for a bus to press a button via a mobile phone app. When the passenger at the bus stop clicks the button, the total number of passengers who have indicated their presence at that location is displayed on the LCD screen in front of the bus driver. This feature provides the bus driver with real-time information about the number of passengers waiting to board at the next stop.

By displaying this count on the driver's LCD screen, the system enables the driver to manage the boarding process more effectively. The driver can anticipate the number of passengers who will be boarding, helping to optimize bus operations and reduce the chances of overcrowding. This feature not only enhances the efficiency of bus operations but also improves the overall passenger experience by ensuring that buses stop when needed and do not bypass waiting passengers. This simple yet effective feature plays a crucial role in improving communication between passengers and bus drivers, ultimately contributing to a smoother and more reliable public transportation system.

In the same way, our system installs an IoT device in every bus. This device plays a crucial role in enhancing safety by using the current location data obtained from the IoT device to determine the distance between the bus and the one in front of it. This distance is then displayed on the LCD screen of the bus following behind. By providing the driver with real-time information about the proximity of the bus ahead, the system helps the driver maintain a safe following distance.

This feature is particularly important in reducing the risk of accidents, as it enables drivers to make informed decisions and adjust their speed accordingly to avoid collisions. The continuous monitoring of the distance between buses ensures that drivers are always aware of their surroundings, even in heavy traffic or low-visibility conditions. By integrating this functionality into every bus, the system not only improves individual bus safety but also contributes to the overall safety and efficiency of the public transportation network. This proactive approach to accident prevention is a key component of our system, aimed at making bus travel safer for both drivers and passengers.

A summary of the technologies, techniques, and architectures used for the IoT device is presented in Table 3.1 below, highlighting key components for efficient, real-time data processing and communication.

Technologies	Microcontrollers(ESP32), GPS/GPRS modules,GPS Module, Data Storage(Firebase Realtime Database), Sensors(Camera modules (e.g., OV5640))
Techniques	MQTT, SSL/TLS
Architectures	Client-Server Architecture, Edge Computing

Table 2 - Technologies, techniques and architectures used.

3.1.1 Software solution

The Software Development Life Cycle (SDLC) is a structured approach to software development that ensures code accuracy and consistency [23]. In the traditional approach, when requirements change, developers cannot return to previous steps, forcing them to follow all steps in sequence. However, with the agile methodology in SDLC, developers are not bound by this rigid structure. Agile focuses on adapting to changes. Among the various agile frameworks, Scrum stands out as the most effective. It is a lightweight agile project management framework used to manage and solve complex adaptive problems [14]. Figure 3.1.1 shows the six core processes of the agile methodology.

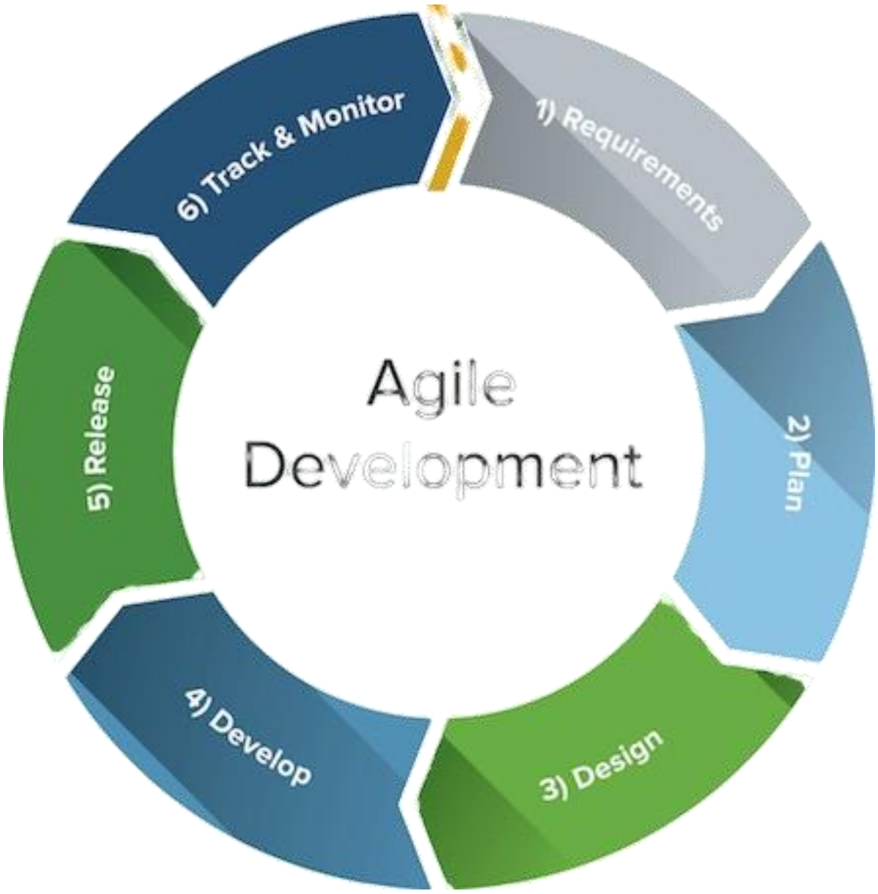

Figure 3. 3: Agile Methodology [14]

- ### Requirement gathering

To gather requirements for the IoT-based smart bus monitoring system, online meetings were held with public transportation authorities, bus operators, and technology experts. During these discussions, stakeholders highlighted key challenges, including overcrowding, unsafe driving practices due to competition between buses, and the lack of real-time information for both drivers and passengers. It was agreed that a system providing real-time updates on passenger count, seat availability, and bus positioning would greatly enhance safety and efficiency. As a result, developing a smart IoT-based system was recognized as essential for improving public transportation.

Feasibility study (Planning)

- **Economic Feasibility**

The economic feasibility of the IoT-based smart bus monitoring system involves evaluating the development costs against the expected benefits. This assessment is vital to ensure the project remains cost-effective while delivering meaningful improvements to public transportation. The IoT system is designed to be both affordable and efficient, making it feasible for widespread implementation across multiple buses without imposing high costs on operators or authorities. The system uses cost-effective components, like the ESP32 microcontroller and OV5640 camera module, which offer robust functionality at a relatively low cost. Additionally, leveraging cloud services like Firebase ensures scalable data storage without requiring extensive on-premises infrastructure. By keeping both development and operational costs low, the system is economically feasible, providing a high return on investment through enhanced safety, fewer accidents, and increased passenger satisfaction, ultimately making public transportation more reliable and efficient.

- **Scheduled feasibility**

Schedule feasibility for the IoT-based smart bus monitoring system involves evaluating whether the project timeline is realistic and if each task can be completed within the allotted time. The success of the project depends on meeting these deadlines, as delays could undermine the system's intended benefits. The project timeline is designed to ensure that all phases, from initial design and prototyping to testing and deployment, are completed on schedule. Each task is meticulously planned and aligned with the overall project milestones, as outlined in the project timeline. This includes the timely acquisition of hardware components, integration of IoT modules, and the testing phases. By sticking to the established timeline, the project ensures the system will be ready for implementation without delays, allowing for timely deployment in public transportation systems and delivering the expected improvements in safety and efficiency.

- **Technical Feasibility**

Technical feasibility for the IoT-based smart bus monitoring system involves determining whether the necessary skills, expertise, and technologies are available to successfully develop and implement the system. This includes assessing the team's ability to work with IoT hardware like microcontrollers (e.g., ESP32) and sensors, as well as their proficiency in integrating these components with cloud services such as Firebase. Understanding and implementing software architectures, like client-server or edge computing models, is also critical to ensure the system's efficiency and scalability. Moreover, strong communication skills are vital for effectively gathering requirements and feedback from stakeholders, including transportation authorities and bus operators, ensuring that the system is tailored to meet users' specific needs. In summary, technical feasibility planning ensures that the development team has the necessary expertise to manage the complexities of IoT device integration, real-time data processing, and cloud communication, paving the way for the successful deployment of the smart bus monitoring system.

- **Design (system and software design documents)**

  After the planning phase, system and software design documents are created which contributes to the overall system diagram.

- **Sequence Diagram**

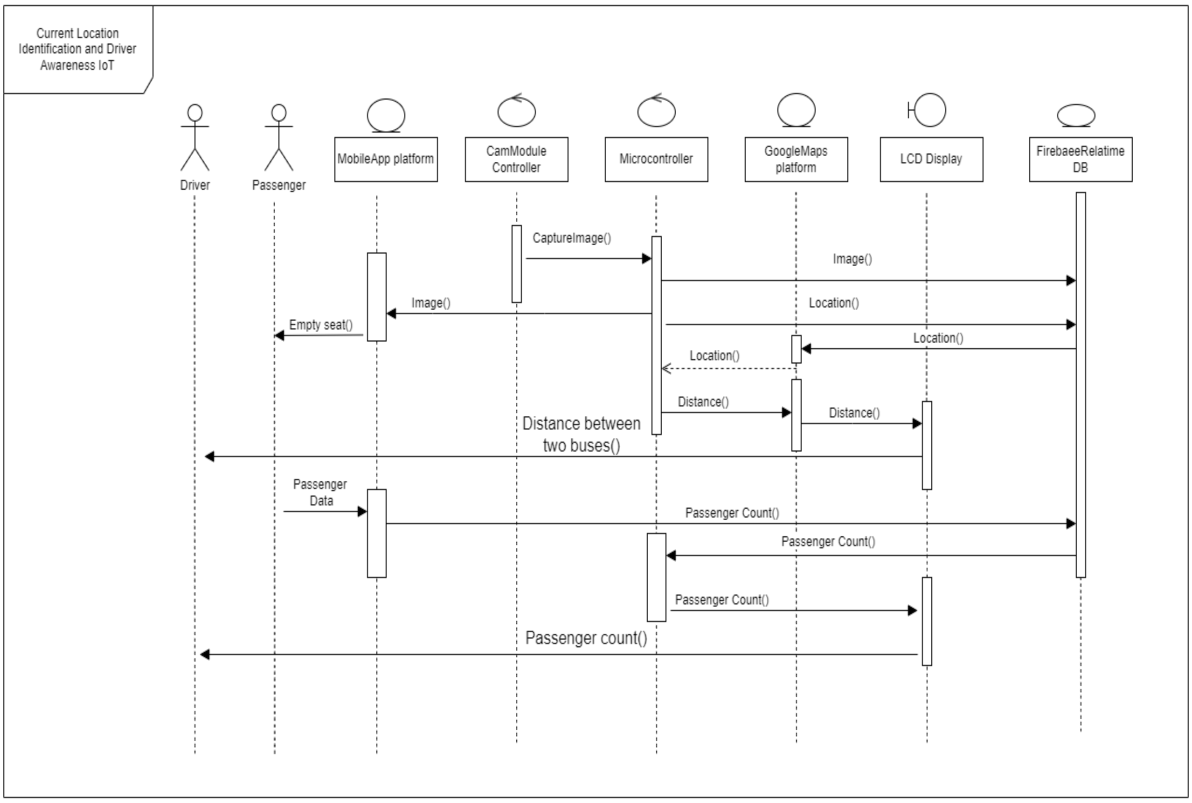

Figure 3. 4: Sequence Diagram of IOT Device

- **Use case Diagram**

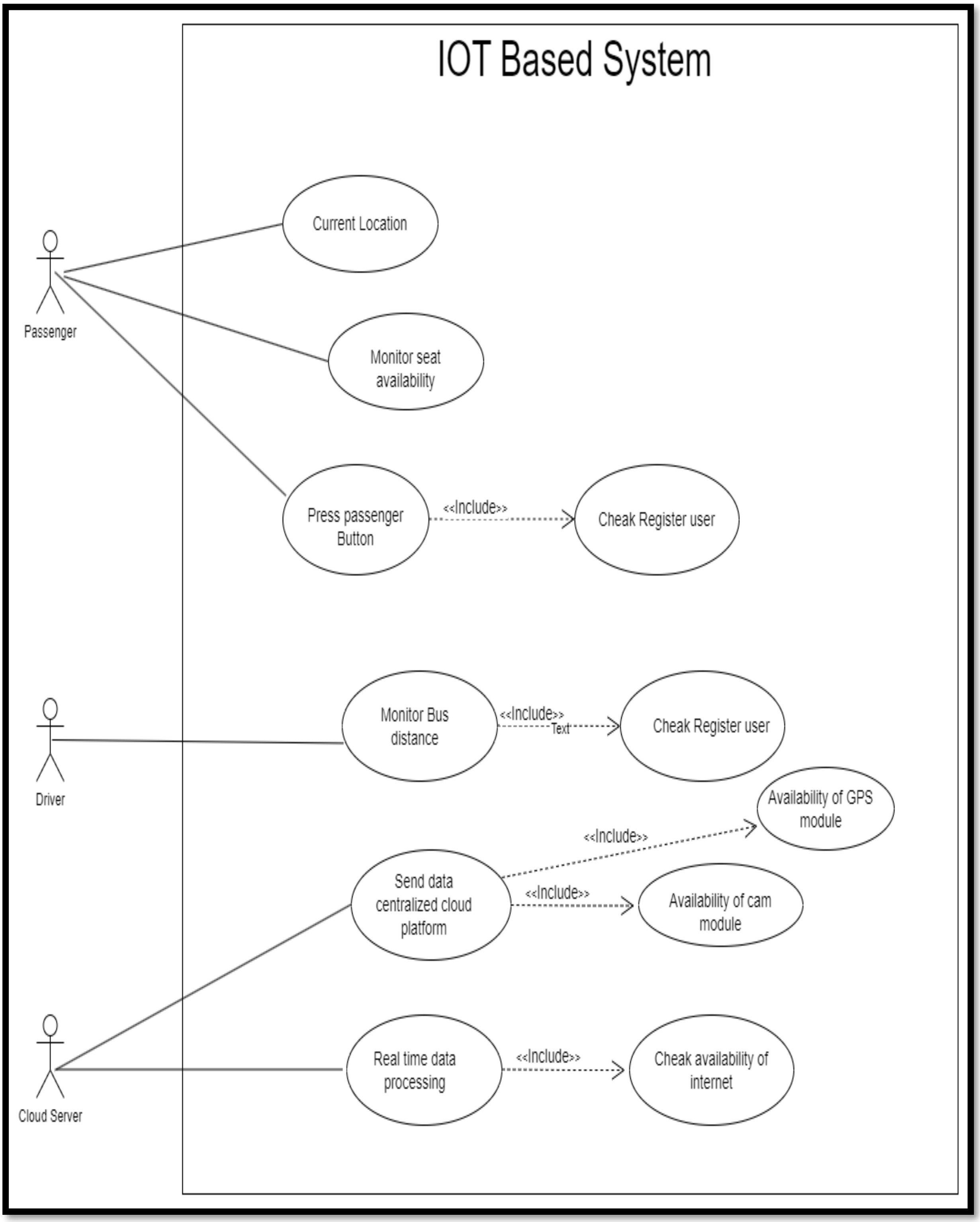

Figure 3. 5: Usecase diagram of IOT Device

- ## Implementation (Development)

- The implementation process outlined in the methodology involves developing the following functionalities to meet user requirements, providing a reliable and accurate solution for the IoT-based smart bus monitoring system.

- Integration of IoT Devices with Buses: Integrating IoT devices such as ESP32 microcontrollers, GPS/GPRS modules, and OV5640 camera modules into the buses to gather real-time data on bus location, passenger count, and seat availability.

- Real-Time Data Transmission Using MQTT Protocol: Using the MQTT protocol for reliable and efficient data transmission from IoT devices to the cloud-based Firebase platform, the system ensures that real-time information is consistently available for both drivers and passengers.

- Development of a Driver Interface with LCD Display: A user-friendly interface is implemented on an LCD display for bus drivers, presenting crucial information like the distance to the bus ahead, the number of passengers waiting at the next stop, and current crowd levels inside the bus.

- Crowd Monitoring and Seat Availability Tracking: Using the OV5640 camera module and image processing techniques, the system monitors the crowd situation inside the bus and tracks seat availability, offering real-time updates to both the driver and passengers through connected systems.

- ## Testing (Track and Monitor)

In this phase of the IoT-based smart bus monitoring system, rigorous testing is conducted to identify and address any gaps, missing requirements, errors, or bugs, ensuring the system's overall quality and reliability. The testing process begins with unit testing, where individual components like the ESP32 microcontroller, GPS/GPRS modules, and camera modules are tested for functionality. Next, component testing ensures that each module functions correctly within the system.

Integration testing follows, verifying that the interconnected components, including data transmission via MQTT to Firebase, work together seamlessly. System testing then evaluates the entire IoT system's performance under real-world conditions, such as tracking bus locations, monitoring passenger counts, and displaying data on the driver's LCD interface. Finally, user acceptance testing (UAT) is performed with bus operators and passengers to ensure the system meets their needs and expectations. Feedback from UAT is used to make final adjustments, ensuring the system is fully functional, user-friendly, and ready for deployment in public transportation.

3.1.2 Commercialization

This research offers a smart solution to tackle key challenges in public transportation, particularly bus overcrowding, safety, and efficiency. The IoT-based smart bus monitoring system will be presented to public transportation authorities, bus operators, and passengers as part of a larger initiative to improve the overall effectiveness of the transportation network.

The system will be available In two versions. The first version includes essential features like real-time monitoring of bus occupancy, seat availability, and the distance between buses. It provides accurate and timely information to both drivers and passengers, enhancing decision-making and improving the overall travel experience.

The second version, a premium offering, includes advanced features such as detailed crowd analytics, predictive seat availability, and enhanced safety alerts for drivers. This version is designed for transportation authorities and bus operators who want to maximize operational efficiency and passenger safety. By offering a tiered approach, the system remains accessible to all users while providing additional value through premium features for those seeking more comprehensive transportation management solutions.

3.1.2.1 Future scope

The IoT-based smart bus monitoring system could be upgraded with features like predictive maintenance alerts, helping bus operators identify potential mechanical issues before they cause breakdowns. It could also connect with smart city infrastructure to better coordinate with traffic signals and other vehicles, optimizing routes and reducing delays. Moreover, the system could monitor the bus's internal environment, managing factors like temperature, humidity, and air quality to ensure a more comfortable and healthier experience for passengers. These enhancements would not only boost the system's functionality but also contribute to a smarter, more efficient public transportation network.

4. PROJECT REQUIREMENTS

4.1 Functional requirements

1. Stable Internet Connection

The system must maintain a reliable and continuous internet connection to ensure seamless data transmission between IoT devices and the cloud, allowing for real-time monitoring and communication.

2. Data Acquisition

The system must efficiently collect and process data from various sensors and modules, ensuring accurate and timely information is available for analysis and decision-making.

3. Cloud Storage Integration
The system must integrate seamlessly with cloud storage solutions like Firebase, allowing for secure, scalable storage and real-time access to collected data across all connected devices.

4. Real-Time Location Tracking
The system must provide accurate, real-time tracking of the bus's location using GPS data, enabling precise monitoring and updates for both drivers and passengers.

4.2 Non-functional requirements

1. Real-Time Processing

The system must process data instantly, ensuring that all information, such as location and passenger counts, is current and readily available for immediate decision-making and action.

2. Data Transmission Reliability

The system must ensure reliable and consistent data transmission, minimizing data loss or delays to maintain accurate and continuous communication between IoT devices and the cloud.

3. System Availability

The system must be reliably available and operational, minimizing downtime to ensure continuous service and real-time monitoring of public transportation activities.

4. Data Integrity

The system must maintain data accuracy and consistency during transmission, storage, and processing, ensuring that all information remains reliable and unaltered throughout its lifecycle.

4.3 System Requirements

The purpose of the system requirements is to outline the hardware and software resources needed for the IoT-based smart bus monitoring system to operate effectively. The software specifications for this proposed component are as follows.

- Arduino IDE -for programming and configuring the ESP32 microcontroller.
- Firebase for real-time data storage and cloud integration- providing seamless communication between IoT devices and the cloud.
- MQTT Protocol- for reliable data transmission between the IoT devices and the central system.
- C++ - for programming and configuring the ESP32 microcontroller, enabling efficient management of sensor data, communication protocols, and real-time processing of information within the IoT system.

4.4 User Requirements

This IoT-based smart bus monitoring system is developed for two types of users:

1. Passengers

Passengers will use the mobile application to check real-time information on bus occupancy, seat availability, and crowd levels before boarding. The app allows them to make informed decisions about whether to wait for the next bus or board the current one, ensuring a more comfortable and convenient travel experience. Passengers can also signal their intent to board a bus at a specific stop, which will be communicated to the driver in real time.

2. Drivers

Drivers will use the system to monitor key data such as the distance to the bus ahead, the number of passengers waiting at the next stop, and the current occupancy level inside the bus. This information is displayed on an LCD screen in the bus, allowing the driver to manage the route more efficiently, reduce the risk of overcrowding, and maintain a safe following distance. The system supports drivers in making informed decisions, enhancing both safety and operational efficiency.

5. Gantt Chart

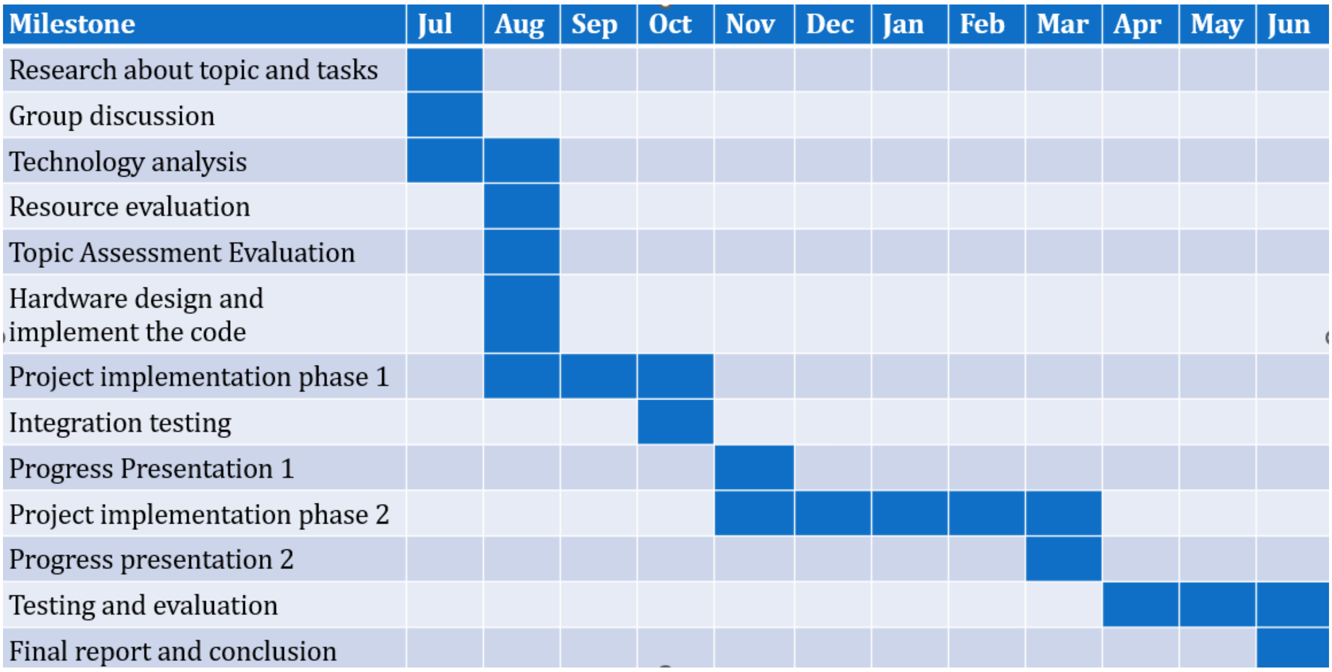

Figure 5. 1: Gantt chart

5.1 Work Breakdown Structure

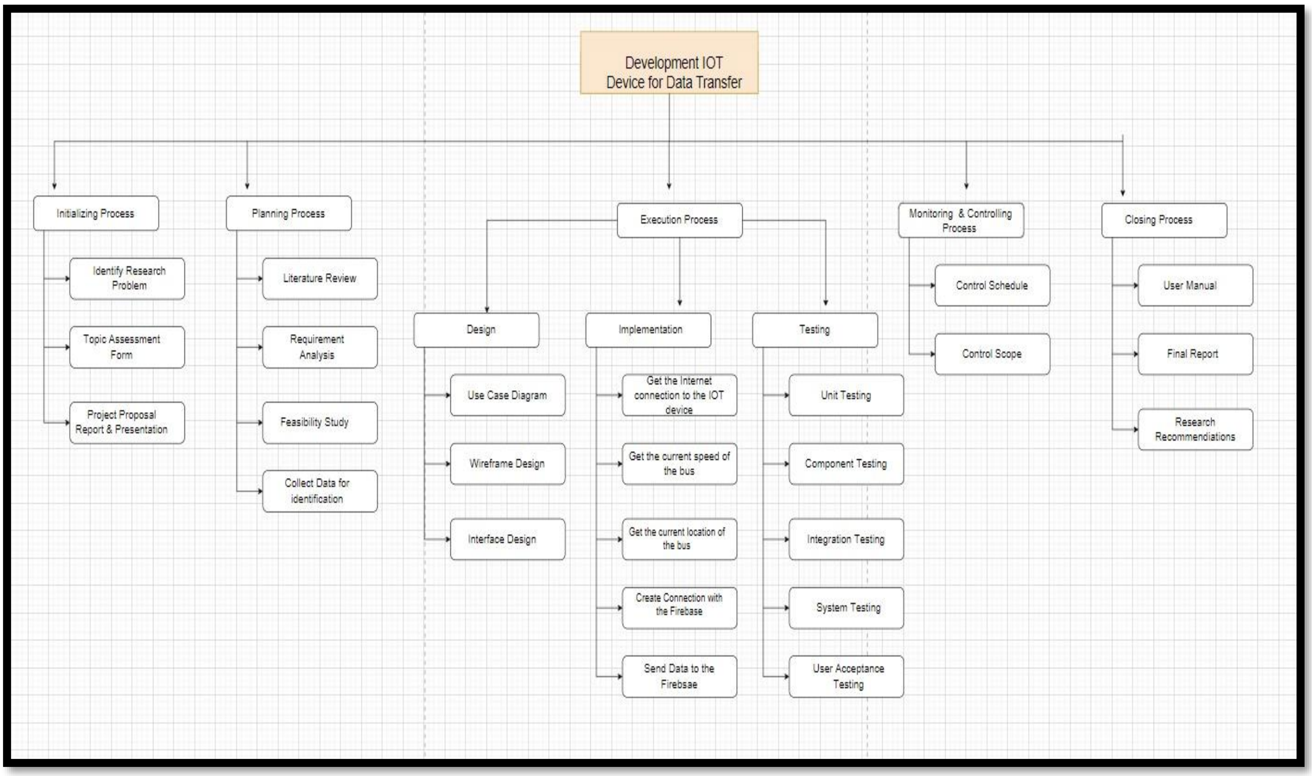

Figure 5. 2: Work Breakdown Chart of IOT device

6. BUDGET AND BUGET JUSTIFICATION

Below table 6.1 depicts the overall budget of the entire proposed system Table 6. 1 : Expenses for the proposed system

Expenses	
Requirement	**Cost(Rs.)**
GPS Module	950.00
GPS/GPRS Module	4950.00
OV5640 Camera Module	3000.00
ESP32 Board	1800.00
LCD Display	1300.00
Connecting wires	200
Bread Board	400
Total Cost	12600.00

Table 3 - Expenses for the proposed system

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APPENDICES

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Appendix 1- Plagiarism report