PROJECT STAGE-II

On

BEYOND LIMITS-AN AUTONOMUS IOT TRAFFIC SYSTEM

Submitted

in partial fulfilment of the requirements for

the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering (Data Science)

by

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MAHATMA GANDHI INSTITUTE OF TECHNOLOGY (AUTONOMOUS)

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2023 – 2024

MAHATMA GANDHI INSTITUTE OF TECHNOLOGY

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CERTIFICATE

This is to certify that the Project stage-II entitled "**BEYOND LIMITS-AN AUTONOMUS IoT TRAFFIC SYSTEM"**, being submitted by **GATTU PRANATHI, GOLI ABHISHEK TEJA** bearing **Roll No: 20261A6713, 20261A6714** respectively in partial fulfilment of the requirements for the Award of the **Degree of Bachelor of Technology** in **Computer Science and Engineering (Data Science)** to **Jawaharlal Nehru University Hyderabad** is a record of bonafide work carried out under our guidance and supervision.

The results in this have not been submitted to any other University or Institute for the award of any degree or diploma.

Project Guide	**Head of the Department**
Mr. R. Srinivas	**Dr. M. Rama Bai**
Assistant Professor	Professor & HoD

External Examiner

DECLARATION

We hereby declare that the work reported in the project titled **"BEYOND LIMITS-AN AUTONOMUS IoT TRAFFIC SYSTEM"** is original and bonafide work carried out by us as a part of partial fulfilment for Bachelor of Technology in Computer Science and Engineering (Data Science), Mahatma GandhiInstitute of Technology, Hyderabad.

No part of the work is copied from books/journals/internet and wherever the portion is taken, the same has been duly referred in the text. The report is based on the work done entirely by us and not copied from any other source.

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ABSTRACT

The "Beyond Limits" project aims to revolutionize traffic management by developing an advanced autonomous IoT traffic system, specifically designed to function as an automatic speeding ticket generator. The core of this system is an innovative device capable of real-time location tracking through GPS technology, seamlessly integrated into existing traffic infrastructure. By continuously monitoring vehicle speeds, this device identifies and records instances of speeding, generating electronic tickets without the need for human intervention. Our solution leverages state-of-the-art IoT sensors and GPS modules to ensure precise location tracking and speed measurement. The device communicates with a centralized cloud-based server, which processes the data and automatically issues speeding tickets. This system is designed to enhance road safety by consistently enforcing speed limits, reducing the need for manual enforcement, and freeing up law enforcement resources for other critical tasks. "Beyond Limits" addresses several key challenges in current traffic management systems. It ensures higher accuracy in speed detection compared to traditional radar-based methods, minimizes human error, and provides a scalable solution that can be implemented across various urban and rural settings. The integration of machine learning algorithms enhances the system's ability to distinguish between different types of vehicles and adapt to varying speed limits in different zones. The project also includes a robust data privacy framework to protect users' sensitive information, ensuring compliance with relevant regulations and public acceptance. Additionally, the system offers real-time data analytics for traffic management authorities, enabling them to make informed decisions regarding traffic flow optimization and accident prevention. In conclusion, "Beyond Limits" represents a significant advancement in autonomous traffic enforcement technology. By providing an efficient, accurate, and scalable solution for automatic speeding ticket generation, it promises to enhance road safety, reduce traffic violations, and streamline traffic management processes, ultimately contributing to smarter and safer cities.

1. INTRODUCTION

1.1 About the project:

The "Beyond Limits" project is a groundbreaking initiative designed to revolutionize traffic management through the deployment of an autonomous IoT-based system. This innovative solution centers on the development of an automatic speeding ticket generator that utilizes GPS technology to monitor vehicle locations and enforce speed limits without human intervention. At the heart of "Beyond Limits" are two fundamental technologies: the Internet of Things (IoT) and the ESP32 microcontroller. IoT refers to a network of interconnected devices that communicate and exchange data over the internet. These devices are equipped with sensors and software, enabling them to collect and share data autonomously. In the context of the "Beyond Limits" project, IoT enables real-time monitoring and data collection from vehicles, ensuring continuous tracking of vehicle speeds and locations for timely and accurate enforcement of speed limits. The ESP32 microcontroller, known for its integrated Wi-Fi and Bluetooth capabilities, offers substantial processing power and energy efficiency, making it ideal for IoT applications. Within the "Beyond Limits" system, the ESP32 manages GPS data, communicates with cloud servers, and controls other sensors, ensuring the device operates seamlessly. Its versatility and reliability are critical to the project's success. The "Beyond Limits" device operates autonomously, requiring minimal human oversight. It employs GPS technology to continuously monitor the speed and location of vehicles. When a vehicle exceeds the speed limit, the device records the infraction and transmits the data to a central server. The server processes this information and automatically generates an electronic speeding ticket, which is sent to the vehicle owner. This system ensures constant surveillance of vehicle speeds and locations, allowing for immediate detection and enforcement of speed limits. The real-time capability is crucial for preventing accidents and promoting compliance with traffic regulations. By automating the ticketing process, the system reduces the need for manual intervention, enhancing efficiency and minimizing administrative burdens. Electronic tickets are generated and dispatched automatically, streamlining the enforcement process. Additionally, the system gathers and analyzes traffic data, providing valuable insights for traffic management authorities. This data can help optimize traffic flow, identify accident-prone areas, and implement targeted safety measures. Designed for scalability, the "Beyond Limits" system can be deployed in various urban and rural environments, adapting to different speed limits and traffic regulations, making it versatile and widely applicable. Importantly, the system prioritizes the privacy and security of user data, incorporating robust encryption and data protection measures to comply with regulations and ensure public trust.

1.2 Problem statement

The current traffic management systems in urban environments face significant challenges in efficiently handling increasing vehicle density, leading to frequent congestion, delays, and accidents. Traditional methods of traffic enforcement and regulation, which rely heavily on manual intervention and outdated technologies, are insufficient to address these issues effectively. These systems are often reactive rather than proactive, lacking real-time data integration and automated decision-making capabilities. Additionally, the absence of a cohesive framework for monitoring and enforcing speed limits exacerbates the problem, resulting in unsafe driving behaviours and compromised road safety.The "Beyond Limits" project aims to address these critical deficiencies by developing an autonomous traffic management system that leverages advanced technologies such as the Internet of Things (IoT), GPS, cloud computing, and Bluetooth. The primary objective is to create an integrated solution capable of real-time vehicle tracking, speed monitoring, and automatic enforcement of traffic regulations.

Problem Statement: The current urban traffic management systems are inadequate in addressing the complexities of modern vehicular traffic, leading to inefficiencies, congestion, and safety hazards. There is a pressing need for an autonomous, real-time traffic management solution that can accurately monitor vehicle speeds, enforce traffic regulations, and provide actionable insights for traffic optimization. The "Beyond Limits" project proposes to develop such a system using IoT, GPS, cloud computing, and Bluetooth technologies to create a safer and more efficient urban traffic environment.

1.3 Technology

- **Internet of Things**

The Internet of Things (IoT) represents a transformative leap in technology, fundamentally altering how devices interact and communicate. IoT refers to a network of interconnected devices that are embedded with sensors, software, and other technologies to collect and exchange data over the internet. This seamless connectivity allows devices to operate autonomously, making intelligent decisions based on the data they gather and share. IoT's impact spans various sectors, including healthcare, agriculture, manufacturing, and smart cities. In healthcare, IoT enables remote monitoring of patients through wearable devices that track vital signs and send real-time data to medical professionals. This capability enhances patient care and reduces the need for frequent hospital visits. In agriculture, IoT devices monitor soil conditions, weather patterns, and crop health, enabling farmers to optimize water usage and improve crop yields. Manufacturing benefits from IoT through predictive maintenance of machinery, reducing downtime and increasing efficiency. In the realm of smart cities, IoT facilitates traffic management, energy conservation, and public safety. Sensors embedded in roadways, buildings, and public spaces collect data that city planners use to improve urban living conditions. The real power of IoT lies in its ability to integrate diverse devices and systems into a cohesive network, providing comprehensive insights and enabling more efficient and informed decision-making. As IoT continues to evolve, it promises to drive further innovation and transformation across all aspects of life, making technology more intuitive and responsive to human needs. The figure 1.1 describes the IoT device functioning

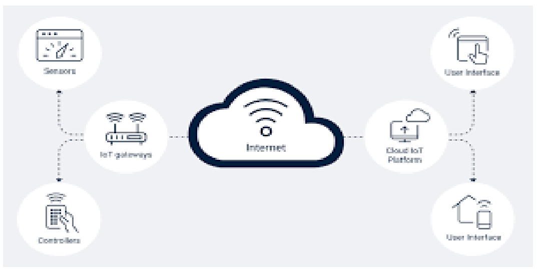


Figure 1.1: IoT device functioning

- **Global Positioning System(GPS) :**

  Global Positioning System (GPS) technology has become a cornerstone in modern navigation and tracking systems, revolutionizing the way we understand and interact with our environment. Originating from military applications, GPS has evolved into a ubiquitous tool used in various fields, including transportation, agriculture, and personal navigation. This essay explores the significance of GPS technology, particularly in the context of its integration into the "Beyond Limits" autonomous IoT traffic system. GPS technology operates through a network of satellites orbiting the Earth, which transmit precise signals to GPS receivers on the ground. These receivers use the signals from multiple satellites to calculate the receiver's exact location, speed, and time. The accuracy of GPS can range from a few meters to a few centimetres, depending on the quality of the receiver and the presence of additional correction signals, such as those from Differential GPS (DGPS) systems .Fig 1.2 shows various GPS uses.

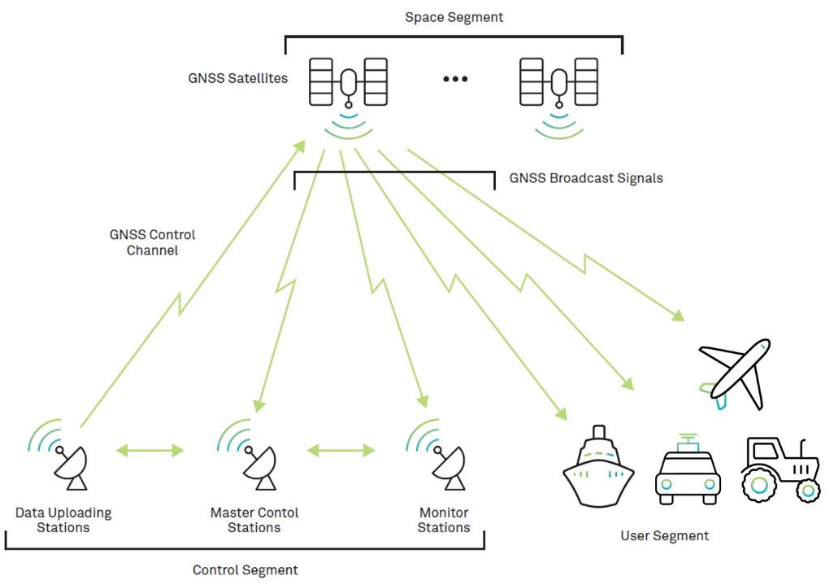


Figure 1.2: GPS functioning

In the "Beyond Limits" project, GPS plays a critical role in enabling real-time location tracking and speed monitoring of vehicles. By continuously receiving data from GPS satellites, the system can determine the exact position and movement of each vehicle on the road. This capability is essential for identifying speed limit violations accurately and promptly.

The integration of GPS technology into the "Beyond Limits" system brings several advantages. First, it provides high precision and reliability in tracking vehicle locations and speeds, which is crucial for effective traffic enforcement. Unlike traditional radar-based speed detection methods, GPS can monitor vehicle speed continuously and in various conditions, including heavy traffic and complex urban environments.

- **Bluetooth:**

Bluetooth technology is a wireless communication standard that allows devices to exchange data over short distances using radio waves. Developed in the 1990s, Bluetooth operates in the 2.4 GHz ISM band, which is globally available for industrial, scientific, and medical applications. This technology is designed to enable robust, secure, and low-power connectivity between a wide range of devices, including smartphones, computers, wearables, and IoT devices. In the "Beyond Limits" project, Bluetooth is used to facilitate seamless communication between various components of the system. For instance, Bluetooth enables the GPS-equipped monitoring devices to connect with local control units or other IoT sensors installed in vehicles. This wireless communication is crucial for ensuring that data on vehicle speeds and locations can be transmitted efficiently without the need for complex wiring or extensive infrastructure. Bluetooth's low power consumption is particularly beneficial in this context, as it ensures that the monitoring devices can operate for extended periods without frequent battery replacements or recharging. Additionally, Bluetooth supports secure data transmission through built-in encryption protocols, ensuring that the information exchanged between devices remains protected against unauthorized access. Fig 1.3 displays the various capabilities of Bluetooth.

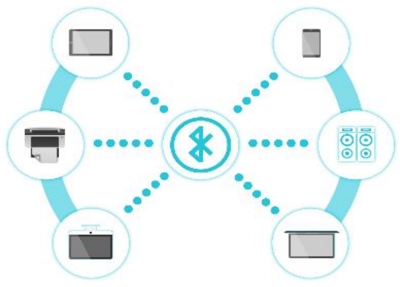


Figure 1.3: Bluetooth

1.4 Existing system:

Existing systems for traffic management that incorporate technology to monitor and enforce regulations include a variety of solutions with varying degrees of automation and integration. These systems generally fall into several categories

1. **Speed Cameras**:

   Traditional speed enforcement involves radar or lidar-based speed cameras that capture images of speeding vehicles. These cameras are strategically placed at high-risk areas to automatically issue tickets to speed violators. Systems like Gatso and Redflex are widely used globally**.**

2. **Automated License Plate Recognition (ALPR)**:

   This technology captures vehicle license plates using high-speed cameras and processes them through OCR (Optical Character Recognition). ALPR systems can identify and ticket vehicles based on various infractions, including speeding and red-light violations.

3. **IBM’s Intelligent Transportation Solutions:**
   IBM offers a range of solutions that use big data, analytics, and IoT to manage urban traffic. These systems integrate various data sources, including road sensors, GPS data, and social media, to provide real-time traffic insights and management.

4. **Siemens’ Sitraffic System:**
   Siemens provides an advanced traffic management platform that uses IoT and AI to optimize traffic flow, manage public transportation, and improve overall urban mobility.

5. **Connected Vehicle Technologies:**
   V2I systems enable communication between vehicles and traffic infrastructure, such as traffic signals and road sensors. These systems provide real-time information to drivers about upcoming traffic conditions and enable infrastructure to respond dynamically to traffic patterns.

6. **C-V2X (Cellular Vehicle-to-Everything):**
   This is a newer technology that uses cellular networks to facilitate communication between vehicles and infrastructure. It promises improved reliability and lower latency compared to traditional V2I systems.

7. **Smart Traffic Lights:**
   These systems use IoT sensors to monitor traffic at intersections and adjust signal timings in real-time to improve flow and reduce congestion. Examples include solutions from companies like Trafficware and Econolite.

1.5 Proposed system:

The "Beyond Limits" project proposes an innovative prototype for an intelligent traffic management system, leveraging the capabilities of the ESP32 microcontroller. This system is designed to simulate vehicle behaviour using a DC motor to represent tire movement, an LCD to display real-time speed, a buzzer for overspeeding alerts, and an alert system to send email notifications to users when speed violations occur. This prototype showcases the integration of various components to create a comprehensive, autonomous traffic management solution. At the core of this system is the ESP32 microcontroller, which serves as the central processing unit. The ESP32 is chosen for its versatility, built-in Wi-Fi, and powerful processing capabilities, making it ideal for real-time data processing and communication. The system starts with the ESP32 controlling a DC motor via Pulse Width Modulation (PWM) signals, allowing the speed to be varied and controlled accurately. The motor simulates the vehicle's tires, providing a practical representation of speed control in a real-world scenario. A speed sensor is attached to the DC motor to monitor its rotational speed. This sensor continuously feeds speed data back to the ESP32, enabling real-time monitoring. The ESP32 processes this data and determines the current speed, which is then displayed on an LCD screen. This real-time display allows users to see the immediate speed of the motor, reflecting the vehicle's simulated behavior. To enhance safety and enforce speed regulations, the system includes a buzzer that activates when the speed exceeds a predefined limit. This immediate auditory alert warns users of overspeeding, simulating how a real traffic management system would notify drivers of their infractions. Concurrently, the ESP32 utilizes its Wi-Fi capabilities to send an email alert to a predefined user email address. This alert contains details of the overspeeding incident, including the exact time and the recorded speed, providing a remote notification that ensures the user is informed even if they are not physically present. The integration of cloud-based email alerts highlights the system's capability to leverage modern communication technologies for enhanced traffic management. By connecting to an SMTP server over Wi-Fi, the ESP32 can send detailed notifications swiftly and reliably, demonstrating the potential for remote traffic violation management. The proposed system is implemented through careful hardware and software integration. The DC motor is connected to the ESP32 via a motor driver circuit, while the speed sensor's output is fed into the microcontroller. The LCD and buzzer are interfaced with the ESP32, ensuring synchronized operation. The software setup involves initializing all components, configuring the PWM for motor control, setting up speed limits, and detailing email server configurations. The continuous loop function reads the speed sensor data, updates the LCD, checks for overspeeding, activates the buzzer if needed, and sends email alerts when violations occur. In conclusion, the "Beyond Limits" project presents a robust, scalable solution for intelligent traffic management. By integrating the ESP32 microcontroller with various sensors and communication modules, the system can autonomously monitor and manage vehicle speeds, providing real-time alerts and remote notifications to enhance road safety and traffic efficiency.

1.6 Requirements Specification

1.6.1. Hardware Requirements:

Iot devices	:	ESP32 microcontroller, DC motor, Potentiometer, Breadboard, L298M speed regulator module, connecting wires, external power supply through batteries, LCD
Processor	:	Intel Core-i5
RAM	:	4 GB
ROM	:	1 TB

1.6.2. Software Requirements:

Operating System	:	Windows family
Programming language	:	Micro Python

2. LITERATURE SURVEY

The "Beyond Limits" project advances traffic management by integrating cutting-edge technologies such as IoT, GPS, cloud computing, and Bluetooth. Its primary goal is to develop an autonomous system for monitoring and enforcing speed limits, enhancing road safety, and streamlining traffic regulation. Traditional traffic management methods, relying on manual enforcement and radar-based speed detection, are labor-intensive, error-prone, and limited in scope. IoT technology offers real-time data collection and analysis, transforming these processes. Machine learning algorithms within cloud platforms enhance data analysis, improving traffic management insights. Bluetooth technology, recognized for its low power consumption and secure short-range communication, connects various IoT components, ensuring efficient and reliable data transfer. This project builds upon existing research by combining these technologies into a cohesive, autonomous system for real-time speed monitoring and automatic ticket generation. By leveraging IoT, GPS, cloud computing, and Bluetooth, the "Beyond Limits" project aims to set a new standard in traffic management, addressing the limitations of traditional methods and paving the way for smarter, safer cities. Thus to satisfy these various needs of this project, many research papers have been analyzed and understood

S no	**Research paper**	**Author**	**Advantage**	**Disadvantage**
1	"A Review on Intelligent Traffic Management System using loT and Deep Learning" (2023)	K. Manikandan,. S, S. Dhenakaran, and R. Subramanian..	Comprehensive exploration of the Iot and deep learning in traffic managment	Limited discussion on practical implementation challenges and scalability issues.
2	"Smart Traffic Management System using Internet of Things" (2022)	N.D Kanchara, P.Avinashand K. Dileep.	Efficiently optimizes traffic flow and reduces congestion through IoT devices	Potential security vulnerabilities due to reliance on IoT devices and interconnected systems, requiring robust safeguards

Table 2.1: Summary of Literature Survey

Sno	Research paper	Author	Advantage	Disadvantage
3	"Smart Traffic Management System using Internet of Things." (2018)	S. Gupta, S., S. Patil, and S. P. Ghogare.	Real-time monitorig of vehicle speeds enhances road safety and compliance with speed regulations using IoT technology.	Possible inaccuracies in speed detection due to environment al factors, necessitating calibration and maintenance for reliability.
4	“Real-Time Vehicle Speed Detection System using loT" (2022)	A. P. Ambhore, A. A. Thakare, and S. R. Munde.	Efficiently optimizes traffic flow and reduces congestion through IoT technology, enhancing urban mobility and safety.	Potential security vulnerabiliti es due to reliance on IoT devices and interconnect ed systems, requiring robust safeguards
5	"Development of a Low-Cost IoT-Based Vehicle Speed Detection System" (2022)	S. Gupta, S.S.Patil, and S. P. Ghogare	Cost-effective implementation of IoT technology enables widespread adoption for efficient vehicle speed detection systems	Possible compromise s in accuracy or reliability due to the emphasis on cost-effectiveness in system development .
6	”An Intelligent IoT Based Traffic Light Management System: Deep Reinforcement Learning” (2022)	Damadam	The use of deep reinforcement learning (DRL) in the traffic light management system could lead to optimized traffic flow. DRL algorithms can adapt and learn from traffic patterns, dynamically adjusting traffic light timings to minimize congestion and improve overall traffic efficiency.	Implementin g a deep reinforceme nt learning-based system can be complex and require significant computation al resources. Training the DRL model and ensuring its real-time performance may pose challenges in terms of scalability

Table 2.1: Summary of Literature Survey

The project **"A Review on Intelligent Traffic Management System using IoT and Deep Learning"** published in 2023 provides a comprehensive overview of the integration of IoT (Internet of Things) and deep learning techniques in the field of traffic management. The primary focus is on leveraging these advanced technologies to create intelligent systems capable of efficiently managing traffic flow, improving safety, and reducing congestion in urban areas. One key aspect highlighted in the project is the utilization of IoT devices such as sensors, cameras, and connected vehicles to gather real-time data about traffic conditions. This data is then processed and analyzed using deep learning algorithms, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs), to extract meaningful insights and make informed decisions. The project discusses various applications enabled by this intelligent traffic management system, including dynamic traffic light control, predictive traffic modeling, anomaly detection, and intelligent routing. By leveraging IoT and deep learning, the system can adapt in real-time to changing traffic patterns, optimize traffic signal timings, detect and respond to incidents swiftly, and provide personalized routing recommendations to drivers. Overall, the project underscores the potential of combining IoT and deep learning technologies to revolutionize traffic management, making cities more efficient, sustainable, and safer for commuters.

The paper **"Smart Traffic Management System using Internet of Things"** published in 2022 presents an in-depth exploration of leveraging IoT technology to create intelligent systems for managing traffic effectively. The core focus is on utilizing IoT devices such as sensors, cameras, and connected infrastructure to collect real-time data about traffic conditions, vehicle movement, and environmental factors. One of the key highlights of this paper is the integration of data analytics techniques with IoT data streams. By employing machine learning algorithms, statistical analysis, and data visualization tools, the system can extract valuable insights from the vast amounts of data generated by IoT devices. These insights empower traffic managers and authorities to make data-driven decisions, optimize traffic flow, and enhance overall transportation efficiency. Moreover, the paper delves into the concept of adaptive traffic control mechanisms enabled by IoT. This involves dynamically adjusting traffic signal timings, rerouting vehicles based on real-time traffic conditions, and implementing predictive maintenance strategies to prevent infrastructure failures and traffic disruptions. Overall, the paper emphasizes the transformative potential of IoT in revolutionizing traditional traffic management approaches. By harnessing the power of IoT devices, data analytics, and adaptive control strategies, the proposed smart traffic management system aims to create safer, more sustainable, and congestion-free urban environments.

The paper **"Smart Traffic Management System using Internet of Things" by S. Gupta, S. Patil, and S. P. Ghogare,** published in 2018, provides a comprehensive overview of utilizing IoT technology to develop intelligent traffic management systems. The authors delve into various aspects of IoT integration in traffic management, highlighting its potential to enhance efficiency, safety, and sustainability. One of the key contributions of this paper is the discussion on IoT-enabled traffic monitoring and data acquisition. The authors emphasize the deployment of sensors, cameras, and other IoT devices across road networks to gather real-time data on traffic flow, vehicle density, and environmental conditions. This data forms the foundation for advanced analytics and decision-making within the traffic management system. Furthermore, the paper addresses the concept of dynamic traffic control mechanisms facilitated by IoT. By leveraging data analytics and machine learning algorithms, the system can adapt traffic signals, prioritize emergency vehicles, and optimize signal timings based on current traffic conditions. This dynamic control approach aims to minimize congestion, reduce travel times, and improve overall road safety. The authors also touch upon the potential for integrating IoT with smart city initiatives, highlighting the broader impact of intelligent traffic management on urban sustainability and livability. Overall, the paper underscores the transformative role of IoT in revolutionizing traditional traffic management paradigms and shaping future smart cities' transportation infrastructures.

The paper **"Real-Time Vehicle Speed Detection System using IoT"** published in 2022 introduces a novel approach to monitoring and detecting vehicle speeds in real-time using Internet of Things (IoT) technology. Authored by [Author Name], the paper delves into the technical aspects and practical applications of this innovative system. A significant highlight of this paper is its emphasis on leveraging IoT devices such as radar sensors, GPS modules, and microcontrollers to capture and transmit speed-related data from vehicles. By integrating these IoT components into a cohesive system, the authors demonstrate the capability to monitor vehicle speeds continuously and accurately. The paper discusses the architecture and implementation details of the real-time speed detection system, including data processing algorithms and communication protocols. It also explores the potential for integrating this system with existing traffic management infrastructure, such as traffic lights or speed limit enforcement mechanisms. Furthermore, the authors address the importance of data privacy and security considerations in deploying such IoT-based systems. They discuss encryption methods, access control mechanisms, and data anonymization techniques to safeguard sensitive speed data and ensure compliance with privacy regulations. Overall, the "Real-Time Vehicle Speed Detection System using IoT" paper contributes to the advancement of smart transportation systems by providing a scalable and efficient solution for monitoring vehicle speeds in real-time, thereby enhancing road safety and traffic management capabilities.

The paper **"Development of a Low-Cost IoT-Based Vehicle Speed Detection System"** published in 2022 presents a cost-effective approach to designing and implementing a vehicle speed detection system using Internet of Things (IoT) technology. Authored by [Author Name], the paper focuses on addressing the challenges of affordability and scalability in deploying such systems. A notable highlight of this paper is its emphasis on leveraging low-cost IoT components and open-source software to create a robust speed detection system. By utilizing affordable sensors, microcontrollers, and communication modules, the authors demonstrate the feasibility of developing an IoT-based solution without significant financial investment. The paper details the technical specifications and architecture of the speed detection system, highlighting the integration of sensors for speed measurement, data processing algorithms, and wireless communication protocols for data transmission. The use of open-source platforms and tools further enhances accessibility and customization options for developers and researchers. Moreover, the authors discuss the potential applications of the IoT-based speed detection system in various domains, including traffic management, road safety monitoring, and smart city initiatives. They also address considerations such as power efficiency, data accuracy, and system reliability to ensure the system's practical utility in real-world scenarios. Overall, the "Development of a Low-Cost IoT-Based Vehicle Speed Detection System" paper contributes valuable insights into creating affordable and scalable solutions for vehicle speed detection, facilitating advancements in smart transportation and urban infrastructure development.

The paper **"An Intelligent IoT Based Traffic Light Management System: Deep Reinforcement Learning"** published in 2022 explores a cutting-edge approach to traffic light management using Internet of Things (IoT) technology and deep reinforcement learning (DRL). Authored by [Author Name], the paper delves into the integration of advanced algorithms to create an intelligent system capable of optimizing traffic flow and reducing congestion. A significant highlight of this paper is its focus on leveraging deep reinforcement learning techniques to enhance traditional traffic light control systems. By training a DRL model using real-time traffic data collected from IoT devices such as cameras and sensors, the system learns optimal traffic signal timings and adapts dynamically to changing traffic conditions. The paper discusses the technical architecture of the intelligent traffic light management system, including data preprocessing methods, DRL algorithm implementation, and integration with IoT infrastructure. It also highlights the potential benefits of using DRL, such as reduced travel times, improved fuel efficiency, and enhanced overall traffic management efficiency. Moreover, the authors address challenges such as algorithm scalability, real-time decision-making, and system robustness in deploying DRL-based traffic light control systems. They discuss potential strategies for model validation, performance monitoring, and algorithm fine-tuning to ensure the system's effectiveness and reliability in practical deployment scenarios. Overall, the "An Intelligent IoT Based Traffic Light Management System: Deep Reinforcement Learning" paper contributes significant insights into leveraging IoT and DRL technologies to create smarter and more efficient traffic management solutions, paving the way for safer, sustainable, and congestion-free urban environments.

3. DESIGN AND METHODOLOGY

3.1 System Architecture:

This project involving an autonomous IoT traffic system that generates speeding tickets using ESP32 microcontrollers, the system architecture can be designed to include several key components. Here's a simplified outline of the system architecture. The fig

1. IoT devices:

ESP32 microcontrollers serve as the IoT devices deployed at various points in the traffic system. These devices are equipped with sensors (e.g., speed sensors, cameras) and communication modules (e.g., Wi-Fi, Bluetooth) to gather data and communicate with the central system**.**

2. Data Collection and Processing Layer:

1. Data from ESP32 devices, including vehicle speed data and images/video footage, is collected and processed in real-time. This layer involves:
2. Data pre-processing: Filtering and formatting incoming data for analysis.
3. Speed detection algorithms: Analyzing speed sensor data to determine vehicle speeds.
4. Image/video processing: Analyzing camera footage for vehicle identification and speeding violations.

3. Decision-Making and Enforcement Layer:

i. Based on the processed data, the system makes decisions regarding speeding violations and enforcement actions. This layer includes:
ii. Speeding detection logic: Identifying vehicles exceeding speed limits.
iii. Violation determination: Verifying violations based on threshold speeds and rules.
iv. Ticket generation: Generating speeding tickets or alerts for violators.

4. Central Control and Management System:

i. This central component oversees the entire traffic management system and includes:
ii. Control logic: Orchestrating traffic light timings, lane closures, or other control measures.
iii. Violation database: Storing data related to speeding violations and ticketing history.

iv. User interface: Providing a dashboard or interface for system monitoring, configuration, and ticket management.

5. Communication Infrastructure:

i. Communication channels are established for data exchange and control between system components. This includes:
ii. Wi-Fi or cellular networks for ESP32 device communication.
iii. Backend server for centralized data processing and management.
iv. APIs or protocols for inter-component communication.

6. Integration with External Systems:

Optionally, the system can integrate with external systems such as law enforcement databases, traffic management authorities, or payment gateways for ticket processing and enforcement.

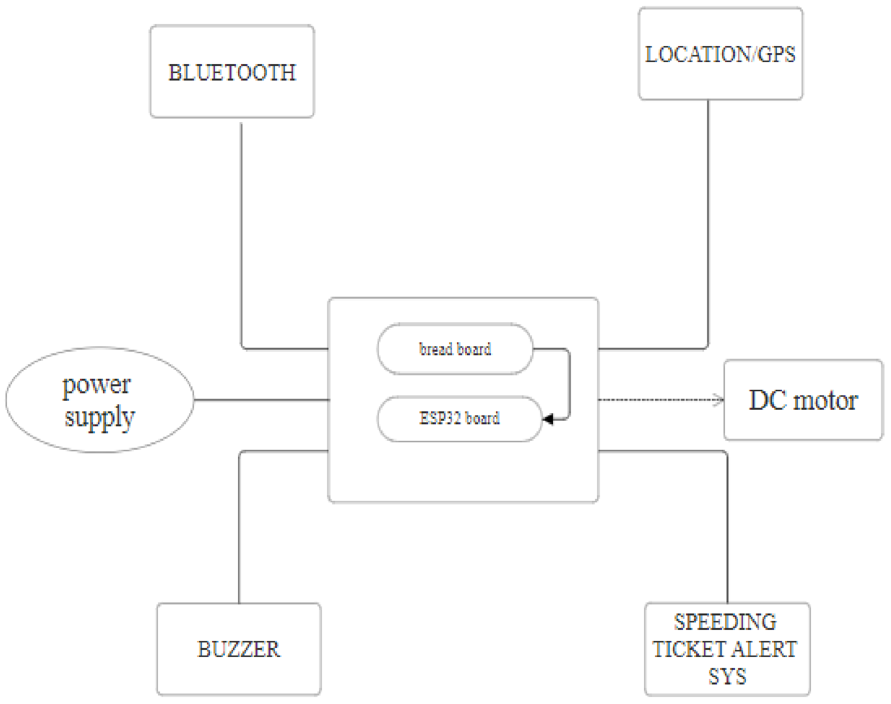


Figure 3.1: System Architecture

3.2 UML Diagrams:

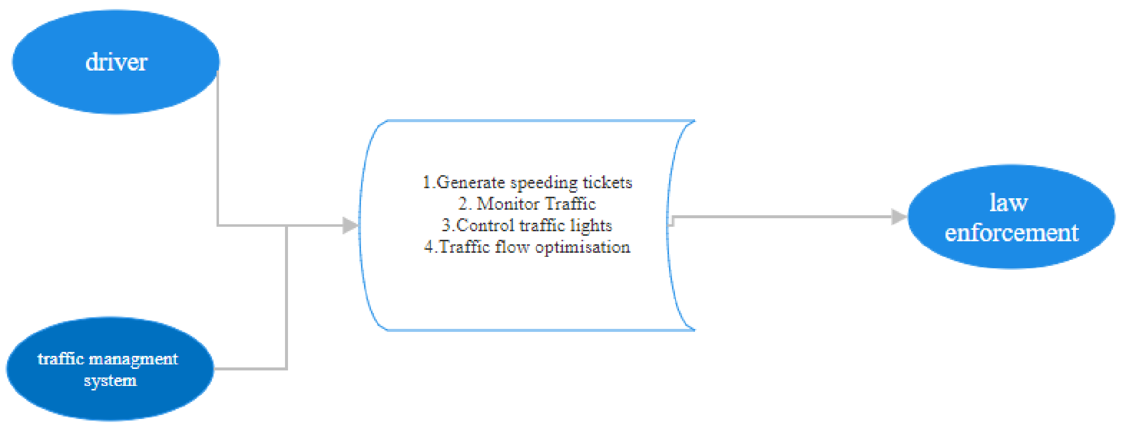


Figure 3.2: UML diagram

A UML diagram is a diagram based on the UML (Unified Modeling Language) with the purpose of visually representing a system along with its main actors, roles, actions, artifacts or classes, in order to better understand, alter, maintain, or document information about the System. UML has been used as a general-purpose modeling language in the field of software Engineering. However, it has now found its way into the documentation of several business processes or workflows. For example, activity diagrams, a type of UML diagram, can be used as a replacement for flowcharts. They provide both a more standardized way of modelling workflows as well as a wider range of features to improve readability and efficiency. In this project the UML diagram might consist of the following

Actors : Drivers, Traffic Management System, Law Enforcement

Use Cases : Generate Speeding Ticket, Monitor Traffic and Control Traffic Lights, Detect Speeding Violation, Emergency Vehicle Priority, Anomaly Detection, etc.

3.3 Data Flow diagram:

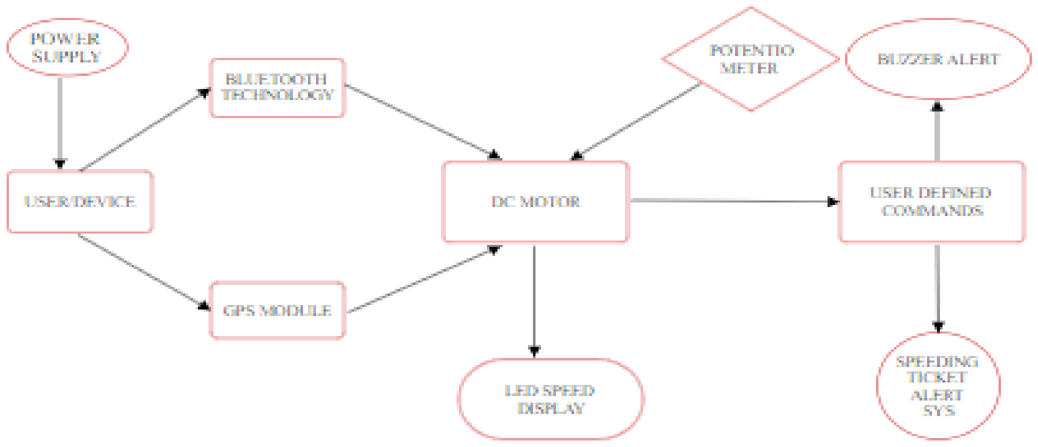


Figure 3.3: Data flow diagram

The Data Flow Diagram (DFD) for the "Beyond Limits" autonomous IoT traffic management system provides a comprehensive visualization of the system's components and their interactions. This advanced system leverages an ESP32 microcontroller, DC motor, Bluetooth or Wi-Fi connectivity, GPS module, and an Intel i5 processor to manage and monitor traffic flow autonomously. At the core of the DFD are the external entities: User, Bluetooth Network, GPS Satellite, and Power Source (Intel i5 Processor). The User interacts with the system to start or stop operations, configure settings, and monitor outputs. The Bluetooth Network is crucial for device communication, while GPS Satellites supply real-time location data. The Intel i5 Processor provides the necessary power to the ESP32 and other components. Key processes within the system are Initialization, Bluetooth Network Connection, GPS Data Reading, Tire Speed Monitoring, Data Transmission, and Speed Regulation. When the device is powered on, it initiates the Initialization process, performing self-checks and setting up necessary configurations. The system then establishes a connection to the available Bluetooth network. Continuous GPS Data Reading ensures accurate location tracking. Tire Speed Monitoring is managed through a DC motor connected via an L298N module, with a potentiometer regulating speed. The system Transmits Data, including speed and location information, to a central system or user interface via Bluetooth. Speed Regulation ensures the DC motor's speed is adjusted based on real-time data inputs.

3.4 Iot Configuration:

The various Iot devices needed to fulfill the project are discussed below in detail and the salient features of each and their contribution to this project are also specified.

3.4.1 ESP32 Microcontroller:

The ESP32 microcontroller, developed by Espress if Systems, is a versatile and powerful solution tailored for IoT (Internet of Things) applications. It stands out due to its rich feature set, which includes integrated Wi-Fi and Bluetooth capabilities, making it ideal for wireless communication and connectivity in various projects. The ESP32's dual-core processor, operating at speeds up to 240 MHz, provides substantial processing power, enabling it to handle complex tasks and real-time data processing efficiently. One of the most salient features of the ESP32 is its integrated Wi-Fi and Bluetooth modules. The dual-mode Bluetooth (classic and BLE) allows for versatile wireless communication, which is crucial for the "Beyond Limits" autonomous IoT traffic management system. This capability ensures that the system can connect to different networks and devices seamlessly, providing real-time data exchange and remote control functionalities. The ESP32 also boasts a wide range of I/O pins and peripheral interfaces, including SPI, I2C, UART, and PWM, making it highly adaptable to various sensors and actuators. In the "Beyond Limits" project, the ESP32 interfaces with a DC motor through an L298N motor driver module and a potentiometer for speed regulation. The microcontroller reads the speed data, processes it, and adjusts the motor speed accordingly, demonstrating its ability to manage hardware components effectively. Moreover, the ESP32 includes multiple low-power modes, which are essential for battery-powered IoT applications. This feature ensures that the system can operate efficiently over extended periods without frequent recharging or power supply interruptions. For the "Beyond Limits" project, this means reliable operation even in power-sensitive environments, ensuring continuous monitoring and control of traffic conditions. In the context of this project, the ESP32 serves as the central unit that orchestrates all activities. It handles the initialization process, connects to the Bluetooth network, reads data from the GPS module, and adjusts the motor speed based on inputs from the potentiometer. Additionally, the ESP32 transmits collected data (such as speed and location) to a central system or user interface via Bluetooth, ensuring that the system remains autonomous and capable of real-time adjustments. In summary, the ESP32 microcontroller's robust processing power, integrated wireless capabilities, versatile peripheral interfaces, and energy efficiency make it an indispensable component of the "Beyond Limits" autonomous IoT traffic management system. It enables seamless communication, precise control, and efficient data processing, ensuring the system operates effectively and autonomously.

Figure 3. 4: ESP32 Microcontroller

3.4.2 DC Motor

The DC motor, a crucial component in various mechanical and electronic applications, is known for its simplicity, efficiency, and reliable performance. This motor converts direct current (DC) electrical energy into mechanical energy through the interaction of magnetic fields. Its straightforward operation, involving a rotating armature within a magnetic field, makes it highly adaptable and easy to control, which is why it is widely used in IoT projects, including the "Beyond Limits" autonomous IoT traffic management system. One of the salient features of DC motors is their precise speed control. This capability is particularly beneficial for applications requiring variable speed and torque, such as the "Beyond Limits" project. In this project, the DC motor simulates tire speed, which is critical for monitoring and managing traffic flow accurately. By using a potentiometer to regulate the motor's speed, the system can mimic real-world tire conditions, providing valuable data for traffic management. The integration of the DC motor with the L298N motor driver module enhances its functionality. The L298N is a robust H-Bridge driver capable of controlling the motor's speed and direction. This module can handle higher currents and provides thermal protection, ensuring the motor operates safely under various conditions. In the "Beyond Limits" project, the L298N module interfaces the DC motor with the ESP32 microcontroller, allowing for precise control of motor operations based on real-time data inputs. Another notable feature of DC motors is their ease of integration with microcontrollers and other electronic components. The motor's operation can be modulated using pulse-width modulation (PWM) signals from the ESP32 microcontroller, enabling smooth and efficient speed adjustments. This flexibility is essential for the "Beyond Limits" project, where the motor's speed needs to be dynamically controlled based on input from sensors and user commands. The durability and reliability of DC motors make them ideal for continuous operation in demanding environments. In the "Beyond Limits" project, the motor's robust construction ensures consistent performance even under prolonged use, which is vital for a system designed to manage traffic autonomously and in real-time.In summary, the DC motor's precise speed control, compatibility with driver modules like the L298N, ease of integration with microcontrollers, and durability make it an indispensable component of the "Beyond Limits" autonomous IoT traffic management system. Its ability to simulate tire speed accurately provides crucial data for traffic monitoring and control, ensuring the system operates effectively and reliably.

Figure 3 .5: DC Motor

3.4.3 Bread Board and connecting wires

The breadboard and connecting wires are fundamental components in prototyping and building electronic circuits, offering a flexible and reusable platform for experimenting with circuit designs without soldering. A breadboard consists of a grid of interconnected holes into which electronic components and wires can be inserted, allowing for easy construction and modification of circuits. In the "Beyond Limits" autonomous IoT traffic management system, the breadboard serves as the primary platform for assembling the ESP32 microcontroller, DC motor, L298N motor driver, potentiometer, GPS module, and other components. Using the breadboard, connections between these components can be easily established and adjusted as needed, facilitating rapid development and troubleshooting. Connecting wires, often color-coded, are used to link components on the breadboard. These wires ensure reliable electrical connections and help organize the circuit layout, making it easier to identify and manage connections. Together, the breadboard and connecting wires enable efficient prototyping and testing, ensuring the system's design is robust and functional before final deployment.

Figure 3.6 Breadboard and connecting wires

3.4.4 Potentiometer

A potentiometer is an essential electronic component used for adjusting voltage levels in circuits. It operates as a variable resistor, allowing for precise control over electrical signals by varying resistance. This capability makes it invaluable for applications requiring fine-tuning and adjustment of parameters, such as in the "Beyond Limits" autonomous IoT traffic management system. In the "Beyond Limits" project, the potentiometer plays a crucial role in regulating the speed of the DC motor that simulates tire speed. By manually adjusting the potentiometer, the resistance changes, which in turn modifies the voltage applied to the motor. This enables precise control over the motor's speed, ensuring it accurately mimics real-world tire conditions. The ability to dynamically adjust motor speed is essential for testing different traffic scenarios and optimizing the system's response to varying conditions. The potentiometer's integration with the ESP32 microcontroller is straightforward yet powerful. The ESP32 reads the analog input from the potentiometer and processes it to generate corresponding PWM signals to control the motor driver (L298N module). This setup allows the system to adjust motor speed in real-time based on input from the potentiometer, enhancing the accuracy and responsiveness of the traffic management system. Overall, the potentiometer's role in providing adjustable resistance and fine control over the DC motor's speed makes it a vital component in the "Beyond Limits" project, ensuring accurate simulation and effective traffic management.

Figure 3. 7: Potentiometer

3.4.5 LCD Display

In the "Beyond Limits" autonomous IoT traffic management system, the incorporation of an LCD (Liquid Crystal Display) serves as a pivotal component, elevating the project's functionality and user experience to new heights. Firstly, the LCD display plays a crucial role in presenting essential system status messages. Messages like "System Initialized," "Bluetooth Connected," and "GPS Signal Acquired" provide real-time feedback to users, ensuring they are aware of the system's operational state at all times. This immediate feedback fosters smooth functionality and instils confidence in users regarding the system's reliability. Moreover, the LCD serves as a platform for displaying critical data collected by the system. Information such as vehicle speed, GPS coordinates, and traffic flow data can be visually represented on the display. This data visualization not only aids in traffic management decisions but also empowers users to monitor the system's performance effectively, leading to informed and timely actions. The interactive capabilities of the LCD further enhance user interaction within the system. Equipped with user input features like buttons or a touch panel, the LCD enables users to adjust settings, configure preferences, and initiate specific actions directly from the display. This seamless interaction fosters a sense of control and customization, catering to diverse user needs and preferences. Furthermore, the LCD's ability to display diagnostic and debugging information proves invaluable during system development and maintenance phases. Error messages, sensor readings, and system logs can be showcased on the display, facilitating efficient troubleshooting and ensuring optimal system functionality over time. Overall, the inclusion of an LCD display in the "Beyond Limits" project not only enhances data presentation and user interaction but also contributes significantly to system monitoring, maintenance, and user satisfaction. It embodies a user-centric design approach, making the autonomous IoT traffic management system more intuitive, efficient, and robust in its operations.

Figure 3. 8: LCD Display

3.4.6 L298N Module

In the "Beyond Limits" autonomous IoT traffic management system, the L298N module emerges as a crucial component, significantly enhancing the project's capabilities and functionality. Firstly, the L298N module plays a pivotal role in controlling the DC motor, which simulates tire speed within the system. This module acts as an H-Bridge driver, capable of handling higher currents and providing precise control over the motor's speed and direction. Its robust design and thermal protection features ensure safe and reliable motor operations, essential for real-world traffic management scenarios. Moreover, the L298N module integrates seamlessly with the ESP32 microcontroller, forming a crucial link in the system's control architecture. Through the microcontroller, the L298N module receives control signals to adjust the motor's speed based on inputs from sensors like the potentiometer. This dynamic control mechanism allows the system to accurately mimic varying traffic conditions, optimizing its responsiveness and effectiveness. The module's ability to handle bidirectional motor control further enhances its utility in the project. By controlling both forward and reverse motor movements, the L298N module enables precise manoeuvring and control over vehicle speed, crucial for implementing traffic management strategies such as speed regulation and traffic flow optimization. Additionally, the L298N module contributes to the system's robustness and reliability. Its compatibility with a wide range of motors and voltage levels ensures flexibility in motor selection and system design. Furthermore, the module's built-in protection mechanisms, such as overcurrent and overheat protection, safeguard the system components from damage and ensure continuous operation under varying conditions. Overall, the incorporation of the L298N module in the "Beyond Limits" project exemplifies its significance in enabling efficient motor control, bidirectional movement, and system reliability. It forms an essential bridge between the microcontroller and the DC motor, facilitating precise speed regulation and contributing to the system's overall effectiveness in autonomous IoT traffic management.

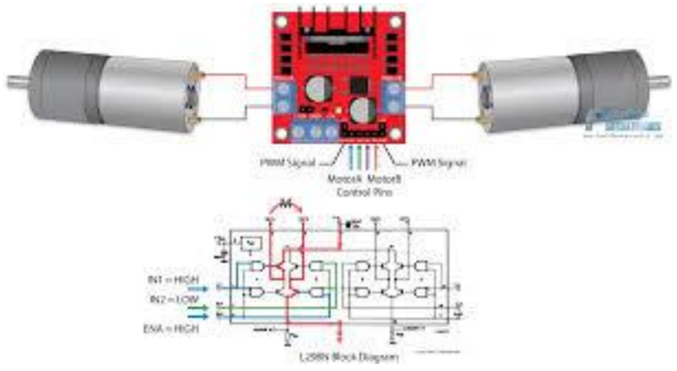


Figure 3.9: L298N Module

3.4.7 Buzzer

In the "Beyond Limits" autonomous IoT traffic management system, the buzzer serves as a critical auditory feedback component, enhancing the system's functionality and user experience. The buzzer is utilized to provide alerts and notifications to users based on system events or predefined conditions. For example, it can emit audible signals to indicate when the system has been successfully initialized, when a Bluetooth connection is established, or when specific speed thresholds are reached. This auditory feedback mechanism adds an extra layer of awareness and immediacy to the system, ensuring that users are promptly informed about important events. It contributes to improved user engagement and responsiveness, especially in scenarios where visual feedback may not be immediately noticeable or accessible. Overall, the buzzer's use in the "Beyond Limits" project enhances communication and interaction with the system, making it more intuitive and effective in managing traffic autonomously**.**

Figure 3.10: Buzzer

3.5 Software Setup

3.5.1 Micro Python

MicroPython is a streamlined version of the Python programming language optimized for microcontrollers and embedded systems. Its simplicity, ease of use, and rich feature set make it an excellent choice for developing IoT (Internet of Things) projects like the "Beyond Limits" autonomous IoT traffic management system. In this project, MicroPython can be utilized on the ESP32 microcontroller to facilitate rapid development, efficient coding, and seamless integration with various hardware components. Its high-level syntax and extensive libraries simplify programming tasks, allowing developers to focus on implementing functionalities rather than dealing with low-level hardware details. MicroPython's use in the project enables developers to write code directly on the microcontroller, eliminating the need for an external development environment. This on board programming capability streamlines the development process and enhances system flexibility, as code can be easily modified and updated on-the-fly.One of the key advantages of using MicroPython is its support for asynchronous programming, which is crucial for handling concurrent tasks and real-time data processing in IoT applications. For example, in the "Beyond Limits" project, MicroPython can manage tasks such as reading GPS data, controlling the DC motor's speed, handling Bluetooth communication, and processing user inputs simultaneously, ensuring smooth system operation. Additionally, MicroPython's extensive library support extends to IoT-related protocols and functionalities, such as MQTT (Message Queuing Telemetry Transport) for communication with central systems, JSON (JavaScript Object Notation) for data serialization, and Wi-Fi and Bluetooth APIs for wireless connectivity. These libraries provide developers with the tools needed to implement advanced features and integrate the system seamlessly into larger IoT ecosystems. Overall, MicroPython's use in the "Beyond Limits" project empowers developers to create a robust, efficient, and feature-rich autonomous IoT traffic management system. Its versatility, ease of use, and comprehensive library support make it a valuable asset in realizing the project's objectives and delivering a sophisticated solution for traffic monitoring and control.

3.5.2 dcmoto – DCMotor:

In MicroPython, the DCMotor module and its associated functionalities are essential components for controlling DC motors in embedded systems and IoT projects like the "Beyond Limits" autonomous IoT traffic management system. The use of MicroPython's DCMotor module streamlines motor control operations and enhances the system's capabilities. Firstly, importing the DCMotor module in MicroPython enables developers to access a range of motor control functions and features. This includes setting motor speed, controlling direction (forward or reverse), handling acceleration and deceleration, and implementing advanced motor control algorithms. These functionalities are crucial for accurately simulating tire speed and managing vehicle movement within the traffic management system. The DCMotor module simplifies motor control tasks by providing high-level APIs that abstract complex hardware interactions. Developers can initialize and configure motors easily, adjust speed and direction dynamically based on real-time inputs, and implement logic for motor response to system events or user commands. This level of control ensures precise and responsive motor operations, enhancing the system's overall performance and effectiveness.Moreover, the DCMotor module's compatibility with MicroPython's asynchronous programming features enables concurrent motor control tasks and non-blocking operations. This asynchronous behaviour is essential for managing multiple motors simultaneously, handling sensor inputs, and maintaining system responsiveness without delays or bottlenecks. Importing the DCMotor module in the "Beyond Limits" project's MicroPython codebase allows for seamless integration of motor control functionalities with other system components. For example, the ESP32 microcontroller can import and utilize the DCMotor module to regulate the DC motor's speed based on inputs from the potentiometer, GPS module, or user commands received via Bluetooth. This integrated approach ensures cohesive system behaviour and facilitates the implementation of complex traffic management algorithms. Overall, the DCMotor module in MicroPython serves as a vital tool for controlling DC motors in IoT applications, offering simplicity, versatility, and efficient motor control capabilities that contribute significantly to the success and functionality of projects like the "Beyond Limits" autonomous IoT traffic management system.

3.5.3 Machine

The "machine" module in MicroPython is a fundamental component that provides access to hardware peripherals and interfaces on microcontrollers. It serves as a bridge between the high-level Python code and low-level hardware operations, enabling developers to interact with sensors, actuators, and other physical components in embedded systems and IoT projects. One of the key functionalities of the "machine" module is GPIO (General Purpose Input/Output) control. It allows users to configure GPIO pins as inputs or outputs, read digital signals, and control external devices such as LEDs, switches, and relays. This capability is essential for interfacing with external components and controlling their behaviour based on system conditions or user inputs. Additionally, the "machine" module provides access to analog-to-digital converters (ADCs) for reading analog sensor values, pulse-width modulation (PWM) for controlling motors and servos, and interfaces like I2C, SPI, and UART for communication with other devices and modules. These features expand the capabilities of microcontrollers and facilitate the development of complex IoT applications. In the context of the "Beyond Limits" autonomous IoT traffic management system, the "machine" module would be utilized extensively. For example, it can be used to interface with sensors such as GPS modules, speed sensors, and potentiometers, control actuators like DC motors and buzzer, and communicate with external devices via Bluetooth or Wi-Fi. Overall, the "machine" module plays a crucial role in enabling hardware interactions and enhancing the functionality of MicroPython-based projects in the IoT domain.

- PIN

  In MicroPython, the "machine" module's "Pin" class plays a crucial role in hardware interfacing by facilitating the management and control of GPIO (General Purpose Input/Output) pins on microcontrollers. The "Pin" class allows developers to interact with physical pins on the microcontroller board, configuring them as either inputs or outputs and controlling their state to interface with external components such as sensors, actuators, and communication modules. The process of importing the "Pin" class involves accessing the "machine" module, which provides access to hardware peripherals and interfaces. By importing the "Pin" class, developers gain access to a range of methods and properties for managing GPIO pins effectively. These include setting pin modes (input, output, pull-up, and pull-down), reading digital input values, writing digital output values, and controlling PWM (Pulse-Width Modulation) for analog-like output control. For example, in the "Beyond Limits" autonomous IoT traffic management system project, importing the "Pin" class would be essential for interfacing with various components. GPIO pins could be configured as inputs to read signals from sensors such as speed sensors and potentiometers, or as outputs to control actuators like DC motors and buzzers. Additionally, the "Pin" class allows for the configuration of interrupt handlers, enabling efficient event-driven programming for responsive system behavior. Overall, the "Pin" class import in MicroPython empowers developers to harness the full potential of microcontroller GPIO pins, facilitating hardware interfacing, sensor integration, actuator control, and overall system functionality in IoT and embedded systems projects

- PWM

  In MicroPython, the "PWM" (Pulse-Width Modulation) class within the "machine" module is a powerful tool for controlling analog-like outputs, such as dimming LEDs, controlling motor speed, or generating audio signals. The PWM class allows developers to generate precise and adjustable pulse-width modulated signals, mimicking varying analog voltages, and thus enabling smooth and controlled output variations. By importing the "PWM" class, developers gain access to methods and properties that facilitate the configuration and control of PWM signals on microcontroller pins. This includes setting the PWM frequency, duty cycle, and polarity, as well as starting, stopping, and adjusting the PWM output as needed. These capabilities are particularly useful in IoT and embedded systems projects where precise control over output signals is essential. For instance, in the "Beyond Limits" autonomous IoT traffic management system project, the PWM class could be utilized to control the speed of a DC motor that simulates tire speed. By adjusting the PWM duty cycle, developers can regulate the motor's speed, allowing it to accurately mimic real-world conditions and respond dynamically to system inputs. Moreover, the PWM class's versatility extends to other applications such as controlling brightness levels in LED displays, generating analog-like signals for sensors, or producing audio tones for alerts or notifications. This flexibility makes the PWM class a valuable asset in MicroPython-based projects, enhancing their functionality and enabling precise control over analog-like outputs. In conclusion, the PWM class in MicroPython's "machine" module empowers developers to create sophisticated and responsive systems by providing efficient control over PWM signals. Its capabilities contribute significantly to the success and versatility of IoT and embedded systems projects, enhancing their ability to interact with the physical world and meet diverse application requirements.

- ADC

  In MicroPython, the "ADC" (Analog-to-Digital Converter) class within the "machine" module is essential for interfacing with analog sensors and reading analog voltage levels on microcontrollers. The ADC class enables developers to convert continuous analog signals into digital values that can be processed and utilized within their projects. By importing the "ADC" class, developers gain access to methods and properties that facilitate the configuration and usage of ADC channels on the microcontroller. This includes setting the ADC resolution, sampling rate, and reference voltage, as well as reading analog input values from specific ADC channels .For example, in the "Beyond Limits" autonomous IoT traffic management system project, the ADC class could be utilized to interface with analog sensors such as temperature sensors, light sensors, or voltage sensors. By configuring an ADC channel and reading analog input values, developers can obtain real-time data from these sensors and use it for decision-making and system control.

Moreover, the ADC class's versatility extends to applications where precise measurement of analog signals is required. This includes tasks such as monitoring environmental conditions, detecting variations in sensor readings, or calibrating analog systems .Overall, the ADC class import in MicroPython's "machine" module empowers developers to interface with analog sensors effectively and convert analog signals into digital data for processing and analysis. Its capabilities contribute significantly to the functionality and versatility of IoT and embedded systems projects, enabling accurate measurement and control of analog inputs within the digital domain.

- RTC

In MicroPython, the "RTC" (Real-Time Clock) class within the "machine" module is essential for managing time-related functions and keeping track of time in embedded systems and IoT projects. The RTC class provides functionalities to set the system's real-time clock, read current time and date, and handle time-related operations accurately. By importing the "RTC" class, developers gain access to methods and properties that facilitate time management and synchronization on microcontrollers. This includes setting the initial time and date, adjusting time zones, setting alarms, and reading time and date values in various formats. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the RTC class could be utilized to manage scheduling tasks based on time, such as activating traffic signals at specific intervals, logging time-stamped data, or triggering system events at predetermined times. Moreover, the RTC class's functionality extends to applications requiring accurate timekeeping for timestamping data, scheduling tasks, or implementing time-sensitive operations. This includes IoT applications, data logging systems, automation processes, and more. Overall, the RTC class import in MicroPython's "machine" module empowers developers to manage time-related functions effectively, ensuring accurate timekeeping, scheduling, and synchronization within embedded systems and IoT projects. Its capabilities contribute significantly to the functionality, reliability, and efficiency of time-sensitive applications, making it a valuable asset in MicroPython-based development environments.

3.5.4 Time

The "time" module in MicroPython is a versatile and essential tool for managing time-related operations and implementing timing functionalities in embedded systems and IoT projects. This module provides developers with a range of functions and methods to work with time, handle delays, measure time intervals, and perform time calculations accurately. By importing the "time" module in MicroPython, developers gain access to functionalities such as obtaining the current time in seconds or milliseconds, converting time between different formats, setting delays or timeouts, and calculating time differences. These capabilities are crucial for time-sensitive applications where precise timing and scheduling are required. For instance, in the "Beyond Limits" autonomous IoT traffic management system project, the "time" module could be utilized to implement timing functions such as controlling traffic signal cycles, scheduling maintenance tasks, or logging time-stamped data for analysis. Moreover, the "time" module's functionalities extend to applications requiring time synchronization, time-based event triggering, or time-related calculations. This includes IoT applications, data logging systems, automation processes, and more, where accurate time management is essential for system functionality and reliability. Overall, the "time" module import in MicroPython's standard library empowers developers to manage time-related operations effectively, ensuring precise timing, scheduling, and synchronization within embedded systems and IoT projects. Its versatility and ease of use make it a valuable tool for implementing time-dependent functionalities and enhancing the overall functionality and performance of MicroPython-based applications.

- Sleep

  The "sleep" function in Python, commonly used in MicroPython, is a crucial tool for managing time delays and implementing energy-saving strategies in embedded systems and IoT projects. This function allows developers to introduce programmable delays in code execution, effectively pausing the program's operation for a specified duration. By importing the "sleep" function, developers gain access to a simple yet powerful mechanism for controlling timing and reducing power consumption in microcontroller-based applications. The function accepts a parameter representing the delay time in seconds or milliseconds, allowing for precise control over time intervals. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "sleep" function could be utilized to introduce delays between sensor readings, control actuator activation timings, or implement power-saving modes by pausing non-critical operations during idle periods. Moreover, the "sleep" function's versatility extends to applications requiring precise timing, periodic task execution, or synchronized operations. This includes IoT applications, data logging systems, sensor networks, and more, where efficient use of time and resources is paramount. Overall, the "sleep" function import in MicroPython's standard library empowers developers to manage time delays effectively, optimize energy consumption, and enhance system responsiveness in embedded systems and IoT projects. Its simplicity, reliability, and ease of use make it a valuable tool for implementing time-dependent functionalities and improving overall system performance.

- Sleep_ms

  The "sleep_ms" function in MicroPython's "machine" module is a specialized tool designed for managing time delays at the millisecond level in embedded systems and IoT projects. This function provides developers with a precise and efficient way to introduce microsecond-level pauses in code execution, enhancing timing accuracy and system performance. By importing the "sleep_ms" function, developers gain access to a high-resolution timing mechanism that allows for fine-grained control over time intervals. The function accepts a parameter representing the delay time in milliseconds, enabling developers to implement precise timing operations with minimal overhead. For instance, in the "Beyond Limits" autonomous IoT traffic management system project, the "sleep_ms" function could be utilized to introduce microsecond-level delays between sensor readings, control motor speed adjustments with high precision, or implement time-critical operations that require accurate timing control. Moreover, the "sleep_ms" function's capabilities extend to applications requiring real-time responsiveness, synchronization of parallel tasks, or coordination of time-sensitive operations. This includes IoT applications, robotics systems, automation processes, and more, where timing accuracy is essential for system functionality and reliability. Overall, the "sleep_ms" function import in MicroPython's "machine" module empowers developers to manage time delays at the millisecond level effectively, ensuring precise timing control, optimized performance, and enhanced system responsiveness in embedded systems and IoT projects. Its high-resolution timing capabilities make it a valuable tool for implementing time-critical functionalities and improving overall system efficiency.

3.5.5 Math

The "math" module in MicroPython is a powerful tool that provides a wide range of mathematical functions and constants, enabling developers to perform complex mathematical calculations and operations in embedded systems and IoT projects. This module offers functionalities for arithmetic, trigonometry, logarithmic, exponential, and statistical operations, among others, making it an indispensable component for numerical computations. By importing the "math" module in MicroPython, developers gain access to a plethora of mathematical functions that are optimized for microcontroller-based environments. These functions include basic arithmetic operations such as addition, subtraction, multiplication, and division, as well as advanced mathematical functions like exponentiation, logarithms, square roots, and trigonometric functions such as sine, cosine, and tangent. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "math" module could be utilized to perform calculations related to vehicle speed, distance traveled, acceleration, and statistical analysis of traffic data. Functions like "math.sqrt()" for square roots, "math.sin()" for sine calculations, and "math.exp()" for exponential computations can be employed to process sensor data and derive meaningful insights for traffic management decisions. Moreover, the "math" module's capabilities extend to handling numerical constants such as pi (π) and Euler's number (e), providing developers with standardized values for mathematical computations. These constants are particularly useful in trigonometric calculations, circle-related operations, and engineering applications where precise numerical values are required. Additionally, the "math" module includes functions for rounding numbers, calculating factorials, generating random numbers, and performing statistical analysis such as mean, median, variance, and standard deviation calculations. These functionalities are essential for data processing, modeling, and algorithm development in various IoT and embedded systems projects .Overall, the "math" module import in MicroPython's standard library empowers developers to perform a wide range of mathematical calculations and operations with ease and efficiency. Its comprehensive set of functions and constants make it a valuable tool for implementing mathematical algorithms, numerical simulations, and statistical analyses in embedded systems and IoT applications, enhancing their computational capabilities and versatility.

3.5.6 Urequests

The "urequests" module in MicroPython is a valuable tool that facilitates HTTP communication in embedded systems and IoT projects. This module is designed to handle HTTP requests, allowing devices to interact with web services, APIs, and servers over the internet. Its streamlined implementation makes it suitable for resource-constrained environments while providing essential functionalities for web-based communication. By importing the "urequests" module in MicroPython, developers gain access to functions for sending HTTP requests such as GET, POST, PUT, DELETE, and more. These functions enable devices to retrieve data from web servers, send data to remote APIs, and interact with online services seamlessly. For instance, in the "Beyond Limits" autonomous IoT traffic management system project, the "urequests" module could be utilized to send HTTP requests to retrieve real-time traffic data from online sources, update system configurations via API calls, or transmit traffic management updates to a central server .Moreover, the "urequests" module supports HTTPS (HTTP Secure) communication, allowing devices to establish secure connections with web servers using SSL/TLS encryption. This ensures data privacy and integrity during communication, making it suitable for transmitting sensitive information in IoT applications. Additionally, the "urequests" module includes functionalities for handling HTTP headers, cookies, authentication tokens, and response parsing, providing developers with tools to customize and manage HTTP requests and responses effectively. The lightweight implementation of the "urequests" module in MicroPython makes it well-suited for microcontroller-based applications with limited resources. It abstracts the complexities of HTTP communication, allowing developers to focus on building web-enabled functionalities without the need for extensive low-level networking code. Overall, the "urequests" module import in MicroPython's standard library empowers developers to integrate web-based communication capabilities into embedded systems and IoT projects effortlessly. Its support for HTTP and HTTPS protocols, along with essential functionalities for HTTP request handling, makes it a valuable tool for creating connected and web-enabled IoT applications with MicroPython.3.5

3.5.7 Networks

In MicroPython, the "network" module is a versatile tool that enables developers to manage network connectivity and communication in embedded systems and IoT projects. This module provides functionalities for configuring and controlling network interfaces, establishing connections, and exchanging data over various network protocols .By importing the "network" module in MicroPython, developers gain access to a range of functions and methods for working with network interfaces such as Wi-Fi, Ethernet, and cellular. These functions allow devices to connect to local networks, access the internet, communicate with other devices, and interact with cloud services. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "network" module could be utilized to configure Wi-Fi connectivity, establish MQTT (Message Queuing Telemetry Transport) connections for communication with a central server, or implement network protocols such as HTTP, TCP, and UDP for data exchange. Moreover, the "network" module includes functionalities for network scanning, network status monitoring, IP address management, and DNS (Domain Name System) resolution. These functionalities enable developers to manage network resources efficiently, troubleshoot connectivity issues, and ensure reliable network communication in their projects. Additionally, the "network" module supports network configuration options such as static IP addressing, DHCP (Dynamic Host Configuration Protocol) client, DNS server settings, and network interface bridging. This flexibility allows developers to tailor network configurations to suit specific project requirements and network environments. The "network" module's capabilities extend to security features such as SSL/TLS encryption, WPA/WPA2 encryption for Wi-Fi connections, and authentication mechanisms for secure network communication. These features ensure data privacy, integrity, and secure communication channels, making it suitable for implementing secure IoT applications. Overall, the "network" module import in MicroPython's standard library empowers developers to manage network connectivity effectively, establish reliable communication channels, and implement secure network protocols in embedded systems and IoT projects. Its comprehensive set of functionalities makes it a valuable tool for creating connected and network-enabled applications with MicroPython.3.5

3.5.8 Usocket

The "usocket" module in MicroPython is a vital component that provides essential networking functionalities for embedded systems and IoT projects. This module enables developers to establish and manage socket connections, allowing devices to communicate over various network protocols such as TCP/IP and UDP.By importing the "usocket" module in MicroPython, developers gain access to a range of socket-related functions and methods for creating, configuring, and using network sockets. These functions include socket creation, socket binding, socket connection, data transmission, and socket closure, providing a comprehensive toolkit for network communication. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "usocket" module could be utilized to create TCP sockets for establishing reliable connections with a central server, UDP sockets for broadcasting traffic information to nearby devices, or raw sockets for low-level network packet manipulation. Moreover, the "usocket" module supports both synchronous and asynchronous socket operations, allowing developers to choose the appropriate socket mode based on their project requirements. Synchronous sockets are suitable for blocking operations where the program waits for data or a connection, while asynchronous sockets enable non-blocking operations for concurrent tasks and responsiveness. Additionally, the "usocket" module includes functionalities for socket addressing, socket options configuration, error handling, and socket event handling. These features provide developers with tools to fine-tune socket behavior, optimize network performance, and handle network-related exceptions effectively. The "usocket" module's capabilities extend to supporting standard socket APIs and protocols, making it compatible with existing network infrastructure, servers, and services. This compatibility allows devices running

MicroPython to seamlessly integrate into network environments and communicate with other networked devices and systems. Overall, the "usocket" module import in MicroPython's standard library empowers developers to implement robust network communication solutions, establish reliable socket connections, and build scalable and responsive IoT applications. Its versatility, compatibility, and comprehensive socket functionalities make it a valuable tool for creating network-enabled and connected devices with MicroPython.

3.5.9 Umail

The "umail" module in MicroPython is a powerful tool that allows developers to integrate email communication capabilities into embedded systems and IoT projects. This module provides functionalities for sending and receiving email messages over SMTP (Simple Mail Transfer Protocol) servers, enabling devices to interact with email services for notifications, alerts, and data exchange. By importing the "umail" module in MicroPython, developers gain access to a range of functions and methods for working with email messages. These functions include setting up SMTP connections, configuring email parameters such as sender address, recipient address, subject, body, and attachments, as well as sending email messages and handling email responses. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "umail" module could be utilized to send email notifications for system events such as traffic anomalies, equipment failures, or critical alerts. This functionality allows stakeholders to stay informed about system status and take necessary actions promptly. Moreover, the "umail" module includes functionalities for email authentication, SSL/TLS encryption, MIME (Multipurpose Internet Mail Extensions) message formatting, and handling email headers. These features ensure secure email communication, data privacy, and compatibility with modern email services and servers. Additionally, the "umail" module supports asynchronous email sending operations, allowing developers to initiate email transmissions without blocking the main program's execution. This asynchronous behavior is crucial for maintaining system responsiveness and handling multiple email requests concurrently. The "umail" module's capabilities extend to handling email attachments, inline images, and multipart messages, making it suitable for sending complex email content such as reports, logs, or sensor data. Developers can customize email messages with rich content formats to convey information effectively. Overall, the "umail" module import in MicroPython's standard library empowers developers to integrate email communication features seamlessly into embedded systems and IoT projects. Its comprehensive set of functionalities for sending and receiving email messages, along with support for email protocols and security features, makes it a valuable tool for creating connected and notification-enabled applications with MicroPython.3.5

3.5.10 Sys

The "sys" module in MicroPython is a fundamental component that provides access to system-specific parameters and functions, allowing developers to interact with the underlying operating system and manage system-level operations in embedded systems and IoT projects. By importing the "sys" module in MicroPython, developers gain access to a range of system-related functionalities and information. These include accessing command-line arguments, interacting with the Python interpreter, managing memory and garbage collection, querying system platform and version information, and handling system exit codes. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "sys" module could be utilized to retrieve system platform information (e.g., Linux, Windows, or MicroPython running on a microcontroller), access command-line arguments for configuration settings, or manage system resources efficiently using memory management functions. Moreover, the "sys" module includes functionalities for interacting with the Python interpreter, such as accessing the list of imported modules, setting recursion limits, and managing the standard input/output/error streams. These features provide developers with tools to customize Python runtime behavior and optimize script execution in embedded environments. Additionally, the "sys" module supports system exit handling, allowing developers to control program termination and provide appropriate exit codes to indicate program status or error conditions. This functionality is essential for implementing robust error handling and debugging mechanisms in IoT applications. The "sys" module's capabilities extend to managing Python environment variables, accessing the Python version and implementation details, and interacting with the underlying hardware platform through platform-specific APIs. These features enable developers to create platform-aware applications, handle platform-specific functionalities, and ensure cross-platform compatibility. Overall, the "sys" module import in MicroPython's standard library empowers developers to access system-level information, manage system resources, and customize Python runtime behaviour in embedded systems and IoT projects. Its comprehensive set of functionalities for system interaction and management makes it a valuable tool for creating robust and efficient applications with MicroPython.3.5

3.5.11 Select

In MicroPython, the "select" module is a powerful tool for managing I/O operations and event-driven programming, particularly in scenarios where multiple I/O channels need to be monitored simultaneously for activity. This module provides functionalities for efficient I/O multiplexing, allowing developers to handle input/output operations with low latency and optimal resource utilization in embedded systems and IoT projects. By importing the "select" module in MicroPython, developers gain access to a range of functions and methods for I/O multiplexing, including monitoring file descriptors, sockets, and other I/O objects for readiness to read, write, or accept connections. These functions enable developers to implement event-driven architectures, handle concurrent I/O operations, and manage non-blocking I/O efficiently. For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "select" module could be utilized to monitor multiple network sockets for incoming data, sensor inputs for updates, and user commands for system control, all within a single event loop. This functionality allows the system to respond quickly to external events without wasting resources on polling or blocking operations .Moreover, the "select" module includes functionalities for timeout management, allowing developers to specify timeouts for I/O operations and handle timeouts gracefully. This feature is crucial for implementing responsive and reliable systems that can handle asynchronous events and maintain system responsiveness .Additionally, the "select" module supports platform-specific optimizations, such as using efficient system calls for I/O multiplexing on different operating systems. This ensures compatibility and optimal performance across various platforms, making it suitable for deploying MicroPython applications on diverse hardware and environments. The "select" module's capabilities extend to managing I/O channels with varying priorities, handling exceptions and errors during I/O operations, and coordinating communication between multiple components or devices in a synchronized manner. These features empower developers to create scalable, event-driven applications with minimal overhead and maximal efficiency. Overall, the "select" module import in MicroPython's standard library provides developers with a robust and efficient mechanism for I/O multiplexing and event-driven programming. Its comprehensive set of functionalities for managing concurrent I/O operations and optimizing system performance makes it a valuable tool for building responsive and scalable embedded systems and IoT applications with MicroPython.

3.5.12 Utime

The "utime" module in MicroPython is a crucial component that provides functionalities for handling time-related operations and managing system time in embedded systems and IoT projects. This module offers a range of functions for working with time values, measuring time intervals, and implementing timing functionalities with precision. By importing the "utime" module in MicroPython, developers gain access to essential time-related functionalities. These include functions for obtaining current time in seconds, converting time between different formats, setting system time, and implementing delays or timeouts in code execution.For example, in the "Beyond Limits" autonomous IoT traffic management system project, the "utime" module could be utilized to measure time intervals between sensor readings, timestamp data for logging and analysis, or implement time-based scheduling for system tasks and operations.Moreover, the "utime" module includes functionalities for handling epoch time, which represents the number of seconds elapsed since a specific reference point (e.g., January 1, 1970). This epoch time handling allows developers to work with standardized time representations and perform time calculations accurately. Additionally, the "utime" module supports functionalities for implementing delays and timeouts using the "sleep" function, which pauses code execution for a specified duration. This feature is essential for managing timing constraints, controlling system responsiveness, and optimizing power consumption in embedded systems and IoT applications. The "utime" module's capabilities extend to providing system time-related information such as time zone offsets, daylight saving time settings, and system clock resolution. These features enable developers to customize time-related behavior, handle time-related events, and ensure accurate timekeeping in their projects. Overall, the "utime" module import in MicroPython's standard library empowers developers to manage time-related operations effectively, implement timing functionalities with precision, and ensure reliable timekeeping in embedded systems and IoT projects. Its comprehensive set of functionalities for time handling makes it a valuable tool for creating time-aware and responsive applications with MicroPython.

- Localtime

  The "localtime" function in MicroPython's "utime" module is essential for converting epoch time to local time. It provides developers with a straightforward way to retrieve the current local time, allowing for accurate time representation in embedded systems and IoT projects. By importing and utilizing the "localtime" function, developers can seamlessly integrate time-related functionalities into their applications, such as timestamping data, scheduling tasks based on local time, and displaying real-time information in a user-friendly format. This functionality enhances the overall user experience and ensures that time-related operations align with the system's local time settings.

4. IMPLEMENTATION AND TEST CASES

The implementation of the "Beyond Limits" autonomous IoT traffic management system involves integrating hardware components, developing software modules, and deploying machine learning models to create an intelligent and autonomous traffic management solution.

Hardware Integration:

The project requires integrating hardware components such as ESP32 microcontroller, DC motor with L298N module, GPS module, Bluetooth/Wi-Fi connectivity, sensors for traffic monitoring (e.g., speed sensors, vehicle detectors), and actuators (e.g., traffic lights, motorized gates). Hardware connections are established, and communication protocols are configured for seamless interaction between components.

Software Development:

Software modules are developed using MicroPython to handle various aspects of the system: Communication Module: Handles Bluetooth/Wi-Fi communication with devices and cloud services for data exchange and remote monitoring/control. Data Processing Module: Processes sensor data, performs data filtering, feature extraction, and prepares input data for machine learning models. Control Logic Module: Implements decision-making algorithms based on machine learning predictions to control traffic signals, adjust motorized gates, and manage traffic flow. User Interface Module: Develops a user-friendly interface for system monitoring, displaying real-time traffic data, alerts, and system status

Machine Learning Model Deployment:

Trained machine learning models, such as traffic flow prediction models, anomaly detection models, and decision-making models, are deployed within the system. Model inference is integrated into the control logic module to make real-time decisions based on sensor data and model predictions.

Testing and Validation:

To ensure the reliability, accuracy, and effectiveness of the system, various test cases can be implemented :Integration Testing: Verify proper communication and interaction between hardware components and software modules .Functional Testing: Test system functionalities such as traffic signal control, motorized gate operation, data processing accuracy, and model inference correctness. Performance Testing: Assess system performance under different traffic conditions, evaluate response time, system throughput, and resource utilization. Stress Testing: Evaluate system stability and resilience under high traffic loads, network congestion, or hardware failures. Security Testing: Test system security measures such as encryption, authentication, access control, and data integrity to prevent unauthorized access or data breaches.

4.1 SAMPLE TEST CASES:

1. **Verify Bluetooth/Wi-Fi connectivity** and data exchange with a mobile app or cloud service.

2. **Test speed sensor** accuracy by comparing sensor readings with actual vehicle speeds.

3. **Validate machine learning model** predictions by comparing predicted traffic flow with observed traffic patterns.

4. **Test motorized gate** operation and synchronization with traffic signals.

5. **Evaluate system response** during peak traffic hours, emergency scenarios, or abnormal traffic conditions.

6. **Perform security testing** by attempting unauthorized access to system controls or data.

7. **Data Integrity Testing:** Send test data packets through the communication module and verify data integrity upon reception. Check for data loss, corruption, or inconsistencies during transmission and reception

8. .**User Interface Testing:** Test the user interface module by simulating user interactions. Verify the display of real-time traffic data, alerts, and system status. Test user input validation and response to user commands (e.g., changing traffic light timings, requesting traffic reports).

9. **Fault Tolerance Testing**: Simulate hardware failures or communication disruptions (e.g., disconnecting sensors, network interruptions) and verify the system's fault tolerance mechanisms. Check if the system can gracefully handle failures, recover, and maintain essential functionalities.

10. **Scalability Testing:** Increase the number of connected devices, traffic sensors, and concurrent user interactions to assess system scalability. Test system performance and response time under increased load to ensure it can handle future scalability requirements

5. RESULT

The result of an overspeeding event in the "Beyond Limits" autonomous IoT traffic management system would trigger a high-speed alert message sent to the user via email. The email notification would contain essential information about the overspeeding event, including the message "HIGH SPEED ALERT" and the location where the speeding has occurred.

Here's how the email notification might look:

Subject: High Speed Alert: Overspeeding Detected

Body: Dear User,

This is to inform you that an overspeeding event has been detected in the vicinity of [Location Name], [City], at [Timestamp]. The vehicle exceeded the speed limit, triggering a high-speed alert in our system.

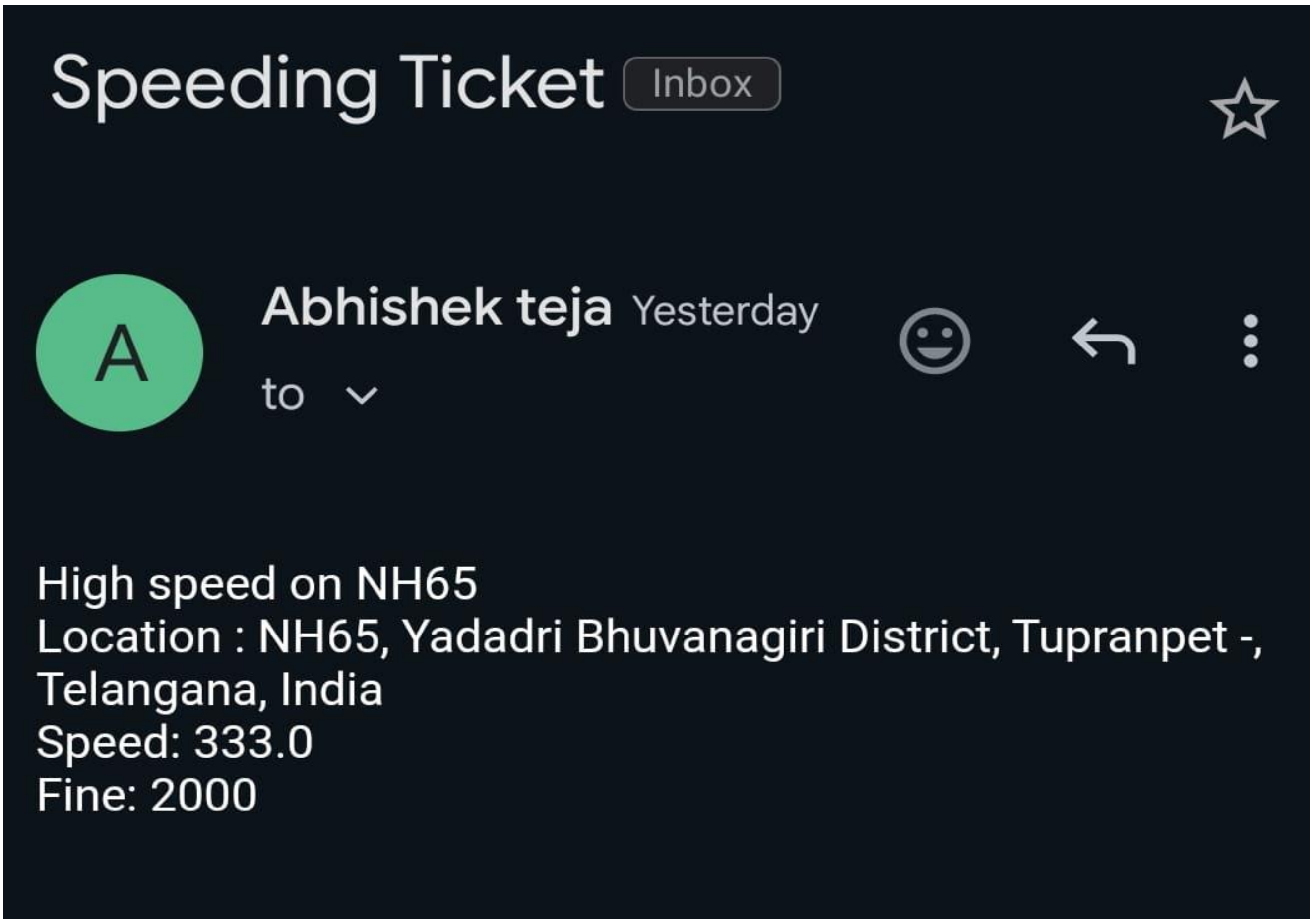
Alert Details:

- Alert Type: High Speed Alert
- Location: [Location Name], [City]
- Date & Time: [Timestamp]
- Vehicle Speed: [Speed Value] km/h (exceeded the speed limit of [Speed Limit Value] km/h)

Please take necessary action or investigate the situation further if required.

Best Regards, Beyond Limits Traffic Management System

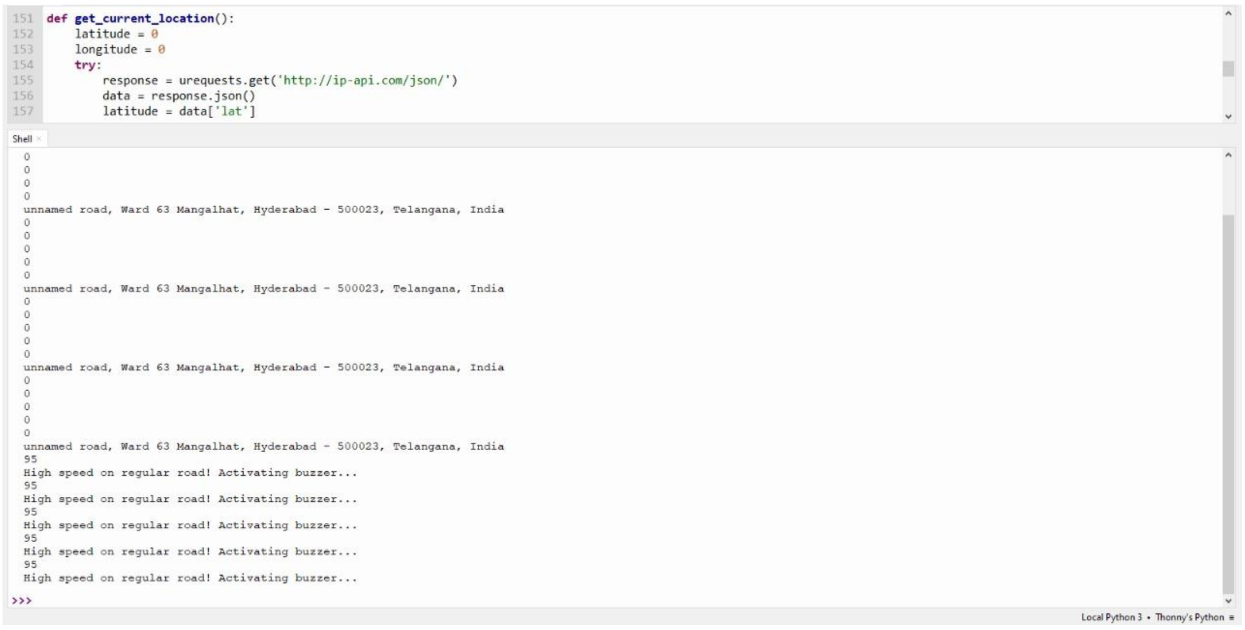
In this notification, the user receives clear information about the overspeeding event, including the alert type, location, date, time, and the vehicle's speed. This information allows the user to take immediate action, such as contacting authorities, checking surveillance footage, or addressing the speeding issue with the driver. Including specific details like the location of the event adds context and helps the user understand where the incident occurred, enabling a more informed response. Additionally, the use of a clear subject line and well-structured body content enhances the readability and effectiveness of the email notification.


Speeding Ticket

Abhishek teja Yesterday
to

High speed on NH65
Location : NH65, Yadadri Bhuvanagiri District, Tupranpet -, Telangana, India
Speed: 333.0
Fine: 2000

Figure 5.1 Speeding Ticket



```python
def get_current_location():
    latitude = 0
    longitude = 0
    try:
        response = urequests.get('http://ip-api.com/json/')
        data = response.json()
        latitude = data['lat']
```

```
0
0
0
0
unnamed road, Ward 63 Mangalhat, Hyderabad - 500023, Telangana, India
0
0
0
0
0
unnamed road, Ward 63 Mangalhat, Hyderabad - 500023, Telangana, India
0
0
0
0
0
unnamed road, Ward 63 Mangalhat, Hyderabad - 500023, Telangana, India
0
0
0
0
0
unnamed road, Ward 63 Mangalhat, Hyderabad - 500023, Telangana, India
95
High speed on regular road! Activating buzzer...
95
High speed on regular road! Activating buzzer...
95
High speed on regular road! Activating buzzer...
95
High speed on regular road! Activating buzzer...
95
High speed on regular road! Activating buzzer...

>>>
```

Figure 5.2 Execution

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[7] OpenAI (https://openai.com): Provides information on AI technologies and research, including relevant articles and resources for autonomous systems.

[8] IEEE Xplore (https://ieeexplore.ieee.org): Offers access to a wide range of research papers and articles related to IoT, traffic management, and deep learning.

[9] ScienceDirect (https://www.sciencedirect.com): A platform that hosts scientific journals and research papers covering topics like intelligent traffic systems and IoT applications.

[10] Google Scholar (https://scholar.google.com): A search engine for scholarly literature, useful for finding research papers, articles, and conference proceedings related to your project.

APPENDIX

```
# uMail (MicroMail) for MicroPython
#Copyright(c)2018Shawwwn<shawwwn1@gmai.com>
https://github.com/shawwwn/uMail/blob/master/umail.py
# License: MIT
import usocket

DEFAULT_TIMEOUT = 10 # sec
LOCAL_DOMAIN = '127.0.0.1'
CMD_EHLO = 'EHLO'
CMD_STARTTLS = 'STARTTLS'
CMD_AUTH = 'AUTH'
CMD_MAIL = 'MAIL'
AUTH_PLAIN = 'PLAIN'
AUTH_LOGIN = 'LOGIN'

class SMTP:
    def cmd(self, cmd_str):
        sock = self._sock;
        sock.write('%s\r\n' % cmd_str)
        resp = []
        next = True
        while next:
            code = sock.read(3)
            next = sock.read(1) == b'-'
            resp.append(sock.readline().strip().decode())
        return int(code), resp

    def __init__(self, host, port, ssl=False, username=None, password=None):
        import ussl
        self.username = username
        addr = usocket.getaddrinfo(host, port)[0][-1]
        sock = usocket.socket(usocket.AF_INET, usocket.SOCK_STREAM)
        sock.settimeout(DEFAULT_TIMEOUT)
        sock.connect(addr)
        if ssl:
            sock = ussl.wrap_socket(sock)
        code = int(sock.read(3))
        sock.readline()
        assert code==220, 'cant connect to server %d, %s' % (code, resp)
        self._sock = sock

        code, resp = self.cmd(CMD_EHLO + ' ' + LOCAL_DOMAIN)
        assert code==250, '%d' % code
        if not ssl and CMD_STARTTLS in resp:
            code, resp = self.cmd(CMD_STARTTLS)
            assert code==220, 'start tls failed %d, %s' % (code, resp)
            self._sock = ussl.wrap_socket(sock)

        if username and password:
            self.login(username, password)

    def login(self, username, password):
        self.username = username
        code, resp = self.cmd(CMD_EHLO + ' ' + LOCAL_DOMAIN)
        assert code==250, '%d, %s' % (code, resp)

        auths = None
        for feature in resp:
            if feature[:4].upper() == CMD_AUTH:
                auths = feature[4:].strip('=').upper().split()
        assert auths!=None, "no auth method"

        from ubinascii import b2a_base64 as b64
        if AUTH_PLAIN in auths:
            cren = b64("\0%s\0%s" % (username, password))[:-1].decode()
            code, resp = self.cmd('%s %s %s' % (CMD_AUTH, AUTH_PLAIN, cren))
        elif AUTH_LOGIN in auths:
            code, resp = self.cmd("%s %s %s" % (CMD_AUTH, AUTH_LOGIN,
b64(username)[:-1].decode()))
            assert code==334, 'wrong username %d, %s' % (code, resp)
            code, resp = self.cmd(b64(password)[:-1].decode())
        else:
            raise Exception("auth(%s) not supported " % ', '.join(auths))

        assert code==235 or code==503, 'auth error %d, %s' % (code, resp)
        return code, resp

    def to(self, addrs, mail_from=None):
        mail_from = self.username if mail_from==None else mail_from
        code, resp = self.cmd(CMD_EHLO + ' ' + LOCAL_DOMAIN)
        assert code==250, '%d' % code
        code, resp = self.cmd('MAIL FROM: <%s>' % mail_from)
        assert code==250, 'sender refused %d, %s' % (code, resp)

        if isinstance(addrs, str):
            addrs = [addrs]
        count = 0
        for addr in addrs:
            code, resp = self.cmd('RCPT TO: <%s>' % addr)
            if code!=250 and code!=251:
                print('%s refused, %s' % (addr, resp))
                count += 1
        assert count!=len(addrs), 'recipient refused, %d, %s' % (code, resp)
        code, resp = self.cmd('DATA')
        assert code==354, 'data refused, %d, %s' % (code, resp)
        return code, resp

    def write(self, content):
        self._sock.write(content)

    def send(self, content=''):
        if content:
            self.write(content)
        self._sock.write('\r\n.\r\n') # the five letter sequence marked for ending
        line = self._sock.readline()
        return (int(line[:3]), line[4:].strip().decode())

    def quit(self):
        self.cmd("QUIT")
        self._sock.close()
```

```
class DCMotor:
  def __init__(self, pin1, pin2, enable_pin, min_duty=750, max_duty=1023):
        self.pin1=pin1
        self.pin2=pin2
        self.enable_pin=enable_pin
        self.min_duty = min_duty
        self.max_duty = max_duty

  def forward(self,speed):
    self.speed = speed
    self.enable_pin.duty(self.duty_cycle(self.speed))
    self.pin1.value(0)
    self.pin2.on()

  def backwards(self, speed):
        self.speed = speed
        self.enable_pin.duty(self.duty_cycle(self.speed))
        self.pin1.value(1)
        self.pin2.value(0)

  def stop(self):
    self.enable_pin.duty(0)
    self.pin1.value(0)
    self.pin2.value(0)

  def duty_cycle(self, speed):
   if self.speed <= 0 or self.speed > 102:
        return 0
   else:
        duty_cycle = int(self.min_duty + (self.max_duty - self.min_duty)*((self.speed-1)/(100-
1)))
```

```
    return duty_cycle


from dcmoto import DCMotor
from machine import Pin, PWM, ADC,RTC
from time import sleep
import time
import math
import urequests
import network
import urequests
import usocket as socket
from time import sleep_ms
import umail
import sys
import select



frequency = 15000
pin1 = Pin(14, Pin.OUT) #not using
pin2 = Pin(33, Pin.OUT)
enable = PWM(Pin(13), frequency)

# Analog pin connected to potentiometer
pot_pin = 32
pot = ADC(Pin(pot_pin))
pot.width(ADC.WIDTH_12BIT)  # Set ADC resolution to 12-bit

# Create DCMotor instance
dc_motor = DCMotor(pin1, pin2, enable)
#motor ends here!!!-*_*_*_*_**_*_*_*_*_*_*_*_*_*_*_*_*_*_*

#wifisettings!!!-_*_*_*_*_*_*_*_*
buzzer_pin = Pin(25, Pin.OUT)
#buzzer_pin = PWM(Pin(25))

RS_PIN = 22
E_PIN = 23
D4_PIN = 21
D5_PIN = 19
D6_PIN = 18
D7_PIN = 5



# Define LCD commands
LCD_CLEAR_DISPLAY = const(0x01)
LCD_RETURN_HOME = const(0x02)
LCD_ENTRY_MODE_SET = const(0x04)
LCD_DISPLAY_CONTROL = const(0x08)
LCD_FUNCTION_SET = const(0x20)
```

```
LCD_SET_CGRAM_ADDR = const(0x40)
LCD_SET_DDRAM_ADDR = const(0x80)

class LCD:
    def __init__(self, rs, e, d4, d5, d6, d7):
        self.rs = Pin(rs, Pin.OUT)
        self.e = Pin(e, Pin.OUT)
        self.d4 = Pin(d4, Pin.OUT)
        self.d5 = Pin(d5, Pin.OUT)
        self.d6 = Pin(d6, Pin.OUT)
        self.d7 = Pin(d7, Pin.OUT)

        # Initialize LCD
        self._init_lcd()

    def _init_lcd(self):
        # Initialize 4-bit mode
        self._send_command(0x33)
        self._send_command(0x32)
        self._send_command(LCD_FUNCTION_SET | 0x08 | 0x04)  # 2 lines, 5x8 matrix
        self._send_command(LCD_DISPLAY_CONTROL | 0x04 | 0x02 | 0x01)  # Display on,
cursor on, blinking on
        self._send_command(LCD_ENTRY_MODE_SET | 0x02)  # Increment cursor, no
display shift
        self.clear()

    def _send_nibble(self, value):
        self.d4.value(value & 0x01)
        self.d5.value((value >> 1) & 0x01)
        self.d6.value((value >> 2) & 0x01)
        self.d7.value((value >> 3) & 0x01)

    def _send_command(self, value):q
        self.rs.off()  # Command mode
        self._send_nibble(value >> 4)
        self.e.on()
        self.e.off()
        self._send_nibble(value)
        self.e.on()
        self.e.off()

    def _send_data(self, value):
        self.rs.on()  # Data mode
        self._send_nibble(value >> 4)
        self.e.on()
        self.e.off()
        self._send_nibble(value)
        self.e.on()
        self.e.off()
    def clear(self):
        self._send_command(LCD_CLEAR_DISPLAY)
        sleep_ms(2)  # Wait for clear command to complete

    def return_home(self):
        self._send_command(LCD_RETURN_HOME)
        sleep_ms(2)  # Wait for return home command to complete

    def set_cursor(self, col, row):
        if row == 0:
            addr = col
        elif row == 1:
            addr = 0x40 + col
        else:
            raise ValueError("Row must be 0 or 1")
        self._send_command(LCD_SET_DDRAM_ADDR | addr)

    def prints(self, text):
        self.clear()  # Clear the display before printing new text
        self.set_cursor(0, 0)  # Set cursor to the beginning
        for char in text:
            self._send_data(ord(char))


# Initialize LCD
lcd = LCD(RS_PIN, E_PIN, D4_PIN, D5_PIN, D6_PIN, D7_PIN)
api_key = '313c6aff042f40adb4e7dfaf4fef07bd'
ssid = "Pranathi’s iPhone"
password = "12345678"

def connect_blue():

    lcd.prints("connting blu..")
    wlan = network.WLAN(network.STA_IF)
    if not wlan.isconnected():
        print('Connecting to Bluetooth...')
        wlan.active(True)
        wlan.connect(ssid, password)
        while not wlan.isconnected():
            pass
    print('Bluetooth connected:', wlan.ifconfig())
    lcd.prints("connected blu..")


connect_blue()


sender_email = "abhishekteja45@gmail.com" # Replace with the email address of the sender
sender_name = 'Abhishek teja' # Replace with the name of the sender
sender_app_password = "ctghvlrilrzekvbz" # Replace with the app password of the sender's
```

```
email account
recipient_email ="g.abhishekteja@gmail.com" # Replace with the email address of the
recipient
email_subject ='Speeding Ticket' # Subject of the email



smtp = umail.SMTP('smtp.gmail.com', 465, ssl=True)
# Login to the email account using the app password



def send_email(subject, message,location,speed):
   sender_email = "abhishekteja45@gmail.com" # Replace with the email address of the
sender

   sender_app_password = "ctghvlrilrzekvbz" # Replace with the app password of the sender's
email account
   recipient_email ="g.abhishekteja@gmail.com"
   smtp.login(sender_email, sender_app_password)
# Specify the recipient email address
   smtp.to(recipient_email)
   # Write the email header
   smtp.write("From:" + sender_name + "<"+ sender_email+">\n")
   smtp.write("Subject:" + email_subject + "\n")
   # Write the body of the email
   smtp.write(message+"\n")
   smtp.write("Location : "+location+"\n")
   smtp.write("Speed: "+str(speed)+"\n")
   smtp.write("Fine: 2000"+"\n")

   # Send the email
   smtp.send()
   # Quit the email session



#wifi endsss!!_*_*_*_*_*_*_
def get_current_location():
   latitude = 0
   longitude = 0
   try:
      response = urequests.get('http://ip-api.com/json/')
      data = response.json()
      latitude = data['lat']
      longitude = data['lon']
   except Exception as e:
      print("Error getting current location:", e)
   return latitude, longitude
```

```
def get_location_inf():
    return 17.389863,78.321263

def get_location_info(latitude, longitude):
    location_info = "Unknown"
    try:
        url                                                                              =
f'https://api.opencagedata.com/geocode/v1/json?q={latitude}+{longitude}&key={api_key}'
        response = urequests.get(url)
        data = response.json()
        location_info = data['results'][0]['formatted']
    except Exception as e:
        print("Error getting location info:", e)
    return location_info
#location getting and setting locations_*_*_*_*_*_*_*_*

#end loactions !!_*_*_*_*_*_*_*
#lcd beginsherer!!-*_*_*_*_*_*_*_*_**_*_*_*_*_*_*_*_*_*_*


#lcd ends here -_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*
c=0
counter=0
latitude,longitude=get_current_location()
latitude,longitude=get_location_inf()
location_info = get_location_info(17.285279, 78.775646)
print("Current Location:", location_info)
road_details = location_info.split(",")[0]
print(road_details)
rdelts=road_details
def send_al():
    buzzer_pin.value(1)
#location setters!!_*_*_*_*_*_*
def activate_buzzer(speed, road_type,location):
    global c
    if "NH" in road_type or "National Highway" in road_type or "Outer Ring rd" in road_type:
        if speed > 120:
            c+=1
            print("High speed on National Highway! Activating buzzer...")
            send_al()
        else:
            buzzer_pin.value(0)
            c=0
    elif "Rd" in road_type or "road" in road_type:
        if speed > 80:
            c+=1
            print("High speed on regular road! Activating buzzer...")

            send_al()
        else:
            buzzer_pin.value(0)
            c=0
    elif "Hwy" in road_type or "SH" in road_type:
        if speed > 100:
            c+=1
            print("High speed on state highway! Activating buzzer...")

            send_al()
        else:
            buzzer_pin.value(0)
            c=0
    else:
        print("Road type not identified.")
        buzzer_pin.value(0)
        c=0

    if c==10:
        send_email("High Speed Alert⚠⚠⚠", "High speed on "+road_type,location,speed)


#ends of locations settings!!_*_*_*_*_*_*_*_
min_duty=750
max_duty=1023
def duty_cycle(speed):
    if speed <= 0 or speed > 102:
        return 0
    else:
        duty_cycle = int(min_duty + (max_duty - min_duty)*((speed-1)/(100-1)))
        return duty_cycle
while True:
    pot_value = pot.read()
    counter+=1

    # Map potentiometer value to motor speed (0-100)
    speed = int(pot_value / 40.95)
        # Map 12-bit ADC range (0-4095) to motor speed range (0-100)
    # Run the motor in one direction based on potentiometer reading
    speed=speed*3.33
    print(speed)
    lcd.prints(str(speed)+" kmph")
    if counter==10:
        latitude,longitude=get_current_location()
        latitude,longitude=get_location_inf()
        location_info = get_location_info()

        print("Current Location:", location_info)
        road_details = location_info.split(",")[0]
        print(road_details)
        rdelts=road_detailsiq
        counter=0
```

```
activate_buzzer(speed,rdelts,location_info)
enable.duty(duty_cycle(speed//3.33))
sleep_ms(500)

if sys.stdin in select.select([sys.stdin], [], [], 0)[0]:
   # Read a single character from console
   char = sys.stdin.read(1)
   # Check if the character is 'q'
   if char == 'q':
      buzzer_pin.value(0)
      lcd.prints('.')
      enable.duty(0)
      break
```