V2I COMMUNICATION

For emergency vehicle prioritisation.

RAGHUL.G - 21BEC1662

Introduction

Coordinating traffic within the city for purposes of allowing access to some sensitive services like the emergency services, particularly the ambulance, is a major challenge since there is always a lot of traffic hold up. In our project, we present a Vehicle-to-Infrastructure (V2I) communication system that aims at enhancing traffic signal control for ambulances. This system consists of hardware as well as software parts so that the emergency vehicles can pass through quickly and efficiently thereby decreasing response time in emergencies. The project uses the Google Maps API to determine the closest hospital to the accident scene, which the driver of the ambulance key into the On-Board Unit (OBU).

The driver also chooses the desired direction – left, right or straight – and this is transmitted to the Road Side Unit (RSU) mounted at junctions. The hardware design has an OBU in the ambulance with ESP8266 microcontroller and NRF24L01 transmitter, and an RSU has traffic signal module, ESP8266 microcontroller and NRF24L01 receiver. In case of an emergency, the RSU identifies ambulances within a certain radius of the road and adapts traffic signal timings based on the direction of travel. To enhance clarity of the signal, the RSU has different LEDs for left and right turn indications but the straight signal is always on until new directions are received. The system works in the listening mode all the time so that it can respond to new information from the OBU as the ambulance moves on its route.

Introduction

This particular project means that traffic light changes are controlled automatically and hence, this means that ambulances can pass through the intersections without much hindrance as compared to the time that traffic control was done manually. This V2I communication system provides an effective and scalable approach to enhancing emergency vehicle priority. Combining the best of the current hardware and software solutions, it meets a critical requirement of traffic control in large cities, allowing for faster and safer movement of emergency vehicles to the scene.

Problem Statement

Ample research reveals that responding vehicles like ambulances need to cut through thick traffic, especially in urban centers. Public road congestion during rush hour or at poorly controlled intersection may significantly reduce response time and contribute to loss of lives during an emergency. Modern traffic systems do not have dynamic means of providing way for emergency vehicles, therefore drivers need to use their efforts or hope for staking, which is not effective. Though, there are cities where emergency lanes are provided, these are very often clogged or unavailable; secondly, emergency prioritization infrastructure in rural areas is often nonexistent. Nevertheless, services such as Google Maps help with directions but cannot be relied upon to compute for the amount of time lost at a red light. The lack of real time control on traffic lights also slowdown the movement of the ambulance even more. To overcome these challenges, this project is intended to provide a solution to incorporate V2I communication system for controlling the traffic signals, for clearing the routes in dynamic manner, and for achieving faster.

Research Objective

The primary objective of this project is to design and implement a Vehicle-to-Infrastructure (V2I) communication system to prioritize emergency vehicles, particularly ambulances, at traffic signals. The system aims to ensure real-time dynamic control of traffic lights to provide uninterrupted passage for ambulances, thereby reducing delays and enhancing response times during critical emergencies. By leveraging modern APIs such as Google Maps for route optimization and integrating advanced hardware units like On-Board Units (OBUs) and Road-Side Units (RSUs), the project ensures seamless communication between the ambulance and the traffic signal system.

This objective is justified by the growing challenges faced by emergency services in congested urban areas, where fixed traffic cycles hinder the swift movement of ambulances. The project addresses this gap by automating signal adjustments based on directional inputs from the ambulance. This innovation is expected to save lives by facilitating faster transit to hospitals, making it a critical step toward smarter, safer urban transportation systems.

Proposed Methodology

1. Hospital Search and Direction Calculation

The code uses Google Maps API to find the nearest hospitals to an accident location entered by the user. It calculates the driving distance from the accident location to each hospital listed in the `hospitals` array. For each hospital, the program checks if the distance is within a 5-kilometer radius. If so, it updates the nearest hospital based on the shortest route. The directions to the hospital, including route distance and waypoints, are stored and used to generate a Google Maps URL for navigation.

2. Route Waypoint Processing and Output

Once the nearest hospital is found, the code extracts the waypoints along the route from the directions API. It generates a series of maneuvers, such as left (L), right (R), or straight (S), based on the steps of the directions and formats them into a string. The program then prints the hospital's name, route distance, and the maneuvers at each waypoint. Additionally, a Google Maps URL is created, allowing the user to follow the route for navigation, and it would theoretically send each direction to an ESP8266 device via a socket connection (though the related code is commented out).

Proposed Methodology

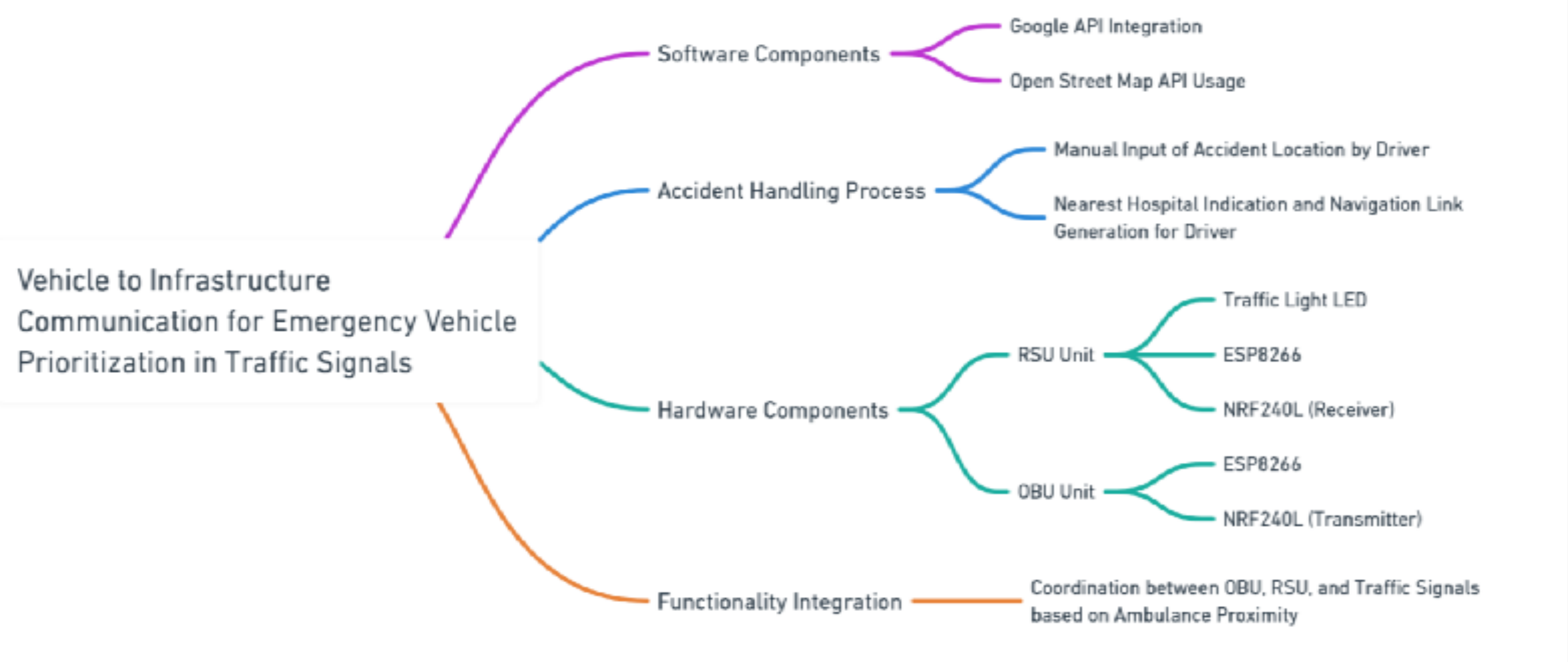
ON-BOARD UNIT (OBU) DESIGN :

OBU is an integral equipment fixed in the ambulance to interact with RSUs met along the route. It consists of a microcontroller from ESP8266 and an nRF24L01 transmitter module. ESP8266 performs all those operations which are related to data processing and communications and the nRF24L01 sends signals in the wireless mode. These signals include important information on the whereabouts of the ambulance and also its direction of travel (straight, left or right respectively). The OBU constantly transmits this information to the other neighboring RSUs within the range so that there is real time update on the movement of the ambulance. This allows the RSUs to optimize timing of the traffic light to allow the ambulance to cross the roads uninterrupted.

ROAD-SIDE UNIT (RSU) DESIGN:

The Road-Side Unit (RSU) is placed in traffic signals in order to get connected to the OBU. The RSU has an ESP8266 microcontroller device, an nRF24L01 receiver module, and a traffic light LED module. The ESP8266 analyses signals arriving from OBUs while the nRF24L01 receiver module is designed to receive signals in a distance of up to certain distance. Upon receipt of signal, the RSU demodulates the data to identify the location of the ambulance and its desired direction either forward, left or right. According to this data, the RSU changes the traffic light signal in such a way that the ambulance can cross the junction as fast as possible. These grants enable the real-time coordination and, therefore, reduce the traffic flow while enhancing the ambulance’s performance in case of emergency.

Proposed System Flowchart



Basic Hardware Setup for Prototype Testing

The On-Board Unit (OBU) is placed in the ambulance, and the Road-Side Unit (RSU) is placed at the signalized intersection. The OBU is required to transmit the real time location and direction information to the RSU through the nRF24L01 transmission module. The RSU incorporates an nRF24L01 receiver module to capture the signal and determine the traffic signal control in accordance with the ambulance's intended path. This configuration allows the RSU to alter traffic light state (for example, changing green to the direction of the approaching ambulance). The setup also provides a basis for the evaluation of the general system and checking whether or not the connection between OBUs and RSUs meets the required criteria for the target traffic control automation

OBU (On-Board Unit) Hardware Components

ESP8266 (Wi-Fi Module) - The ESP8266 Wi-Fi module facilitates wireless communication between the On-Board Unit (OBU) and the Road-Side Unit (RSU), enabling the real-time transmission of directional and signal-control data in the project. It plays a vital role in ensuring seamless connectivity and automation of traffic signals for emergency vehicle prioritization

nRF24L01 (Transmitter Module) - This is used for wireless communication between the OBU and RSU. The OBU sends the intended route (left, right, or straight) to the RSU via Wi-Fi using a secure communication protocol

Manual Input Interface - The ambulance driver manually inputs the direction (left, right, or straight) into the OBU when starting from the accident location. This could be via buttons or a simple touchscreen interface

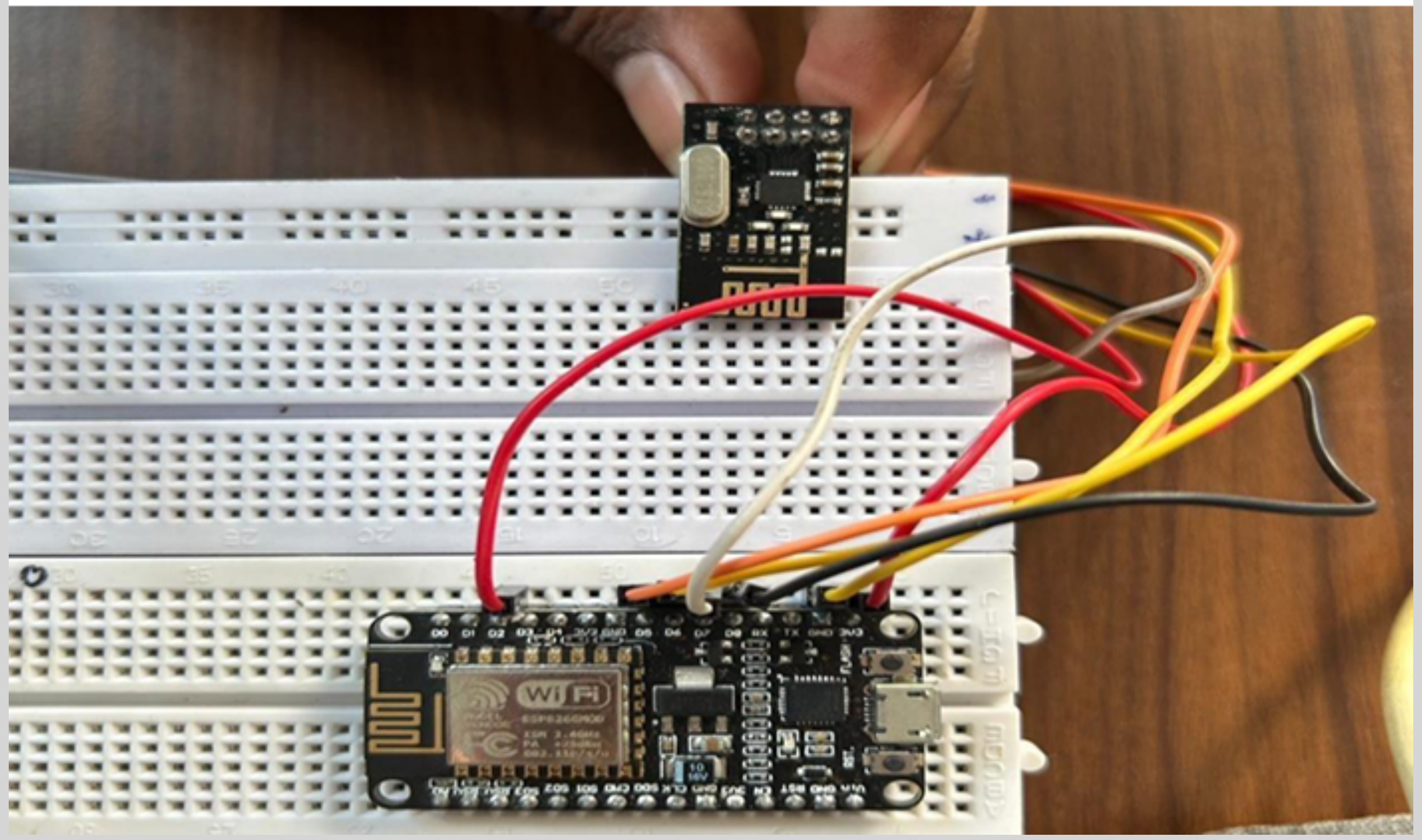
RSU (Road-Side Unit) Hardware Components

ESP8266 (Wi-Fi Module) - This is used for wireless communication between the OBU and RSU. The OBU sends the intended route (left, right, or straight) to the RSU via Wi-Fi using a secure communication protocol

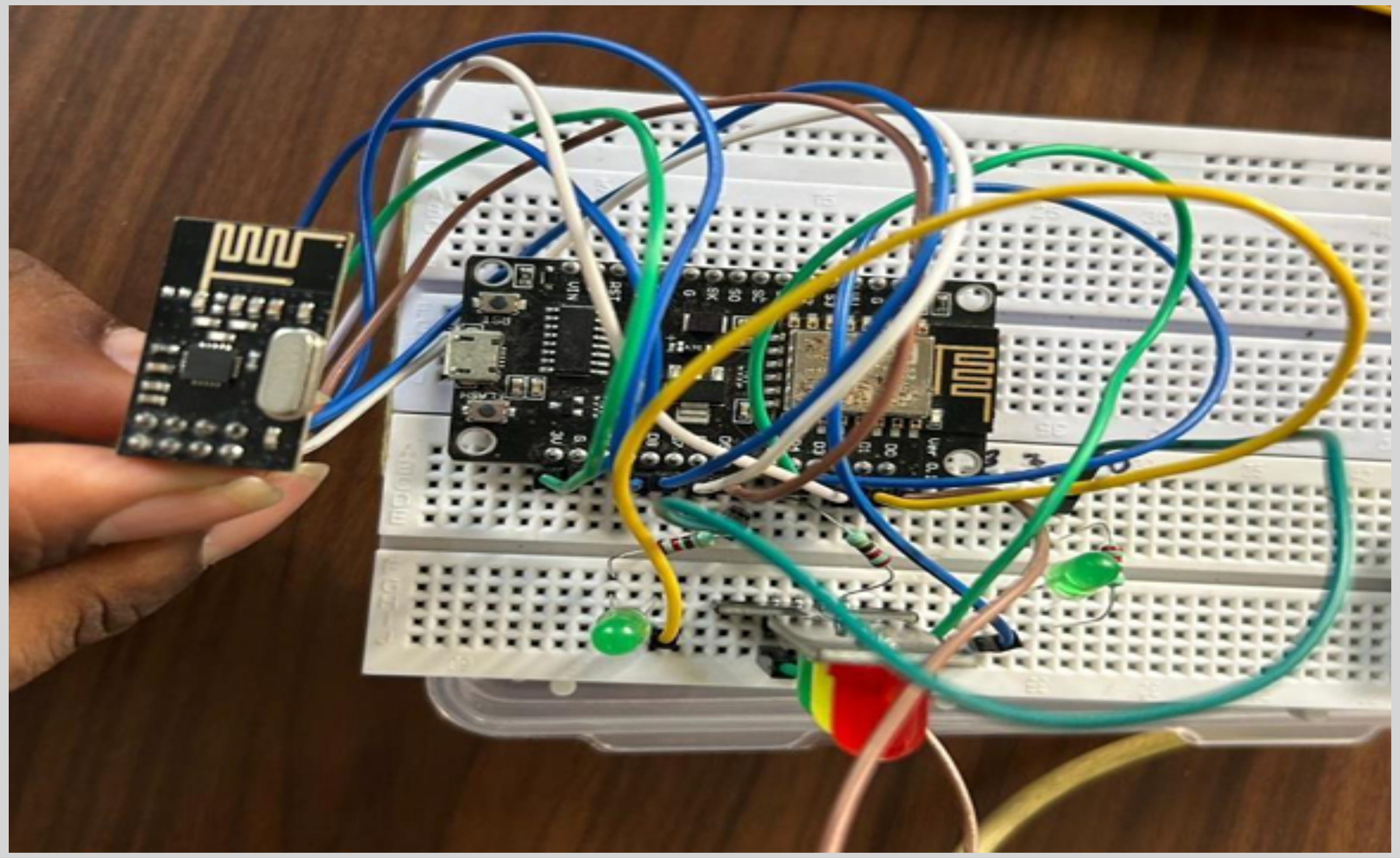
nRF24L01 (Receiver Module) - The nRF24L01 receiver receives the direction signal transmitted by the OBU. Upon receiving the data, it processes the input (left, right, or straight) and sends control signals to the traffic light system

Traffic Light LED Module (Green, Yellow, Red) - The RSU controls the traffic light at the junction. Initially, the straight light will remain on, and the system will adjust the direction based on the input received from the OBU. The system will dynamically switch traffic lights (green, yellow, red) based on the ambulance's intended direction.

Right and Left Turn LEDs - In addition to the standard traffic light module (green, yellow, and red), the RSU includes two separate LEDs to indicate right and left turns. These LEDs will light up based on the intended direction transmitted from the OBU, ensuring clear visual cues for turn prioritization



OBU (On-Board Unit) Hardware Setup



RSU (Road-Side Unit) Hardware Setup

Working Mechanism of the System

The system works by allowing the ambulance On Board Unit (OBU) to communicate without any problem with the Road Side Unit (RSU) at the traffic junctions. This interaction guarantees real time prioritization of emergency vehicles. The mechanism involves the following steps

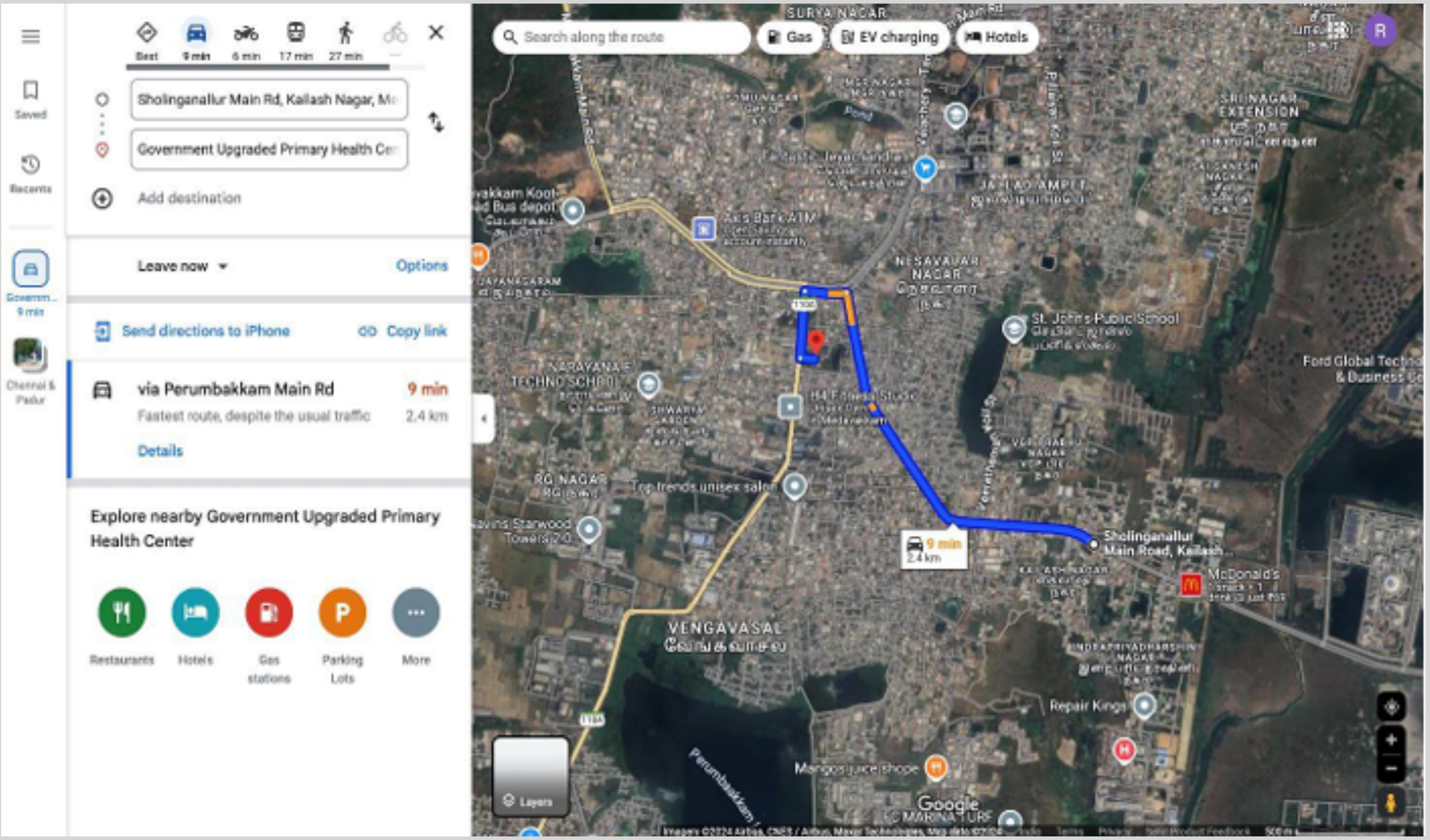
Listening Mode - The OBU signals are received by the RSU in a continuous listening mode. This keeps the system always active and responding to ambulance inputs. The OBU in the ambulance sends signals consisting of the intended route direction, i.e. left, right or straight. In this case the RSU takes all these inputs and adjusts the traffic signals accordingly. The importance of uninterrupted communication and reduced delays due to manual interventions at junctions necessitates this continuous listening mode.

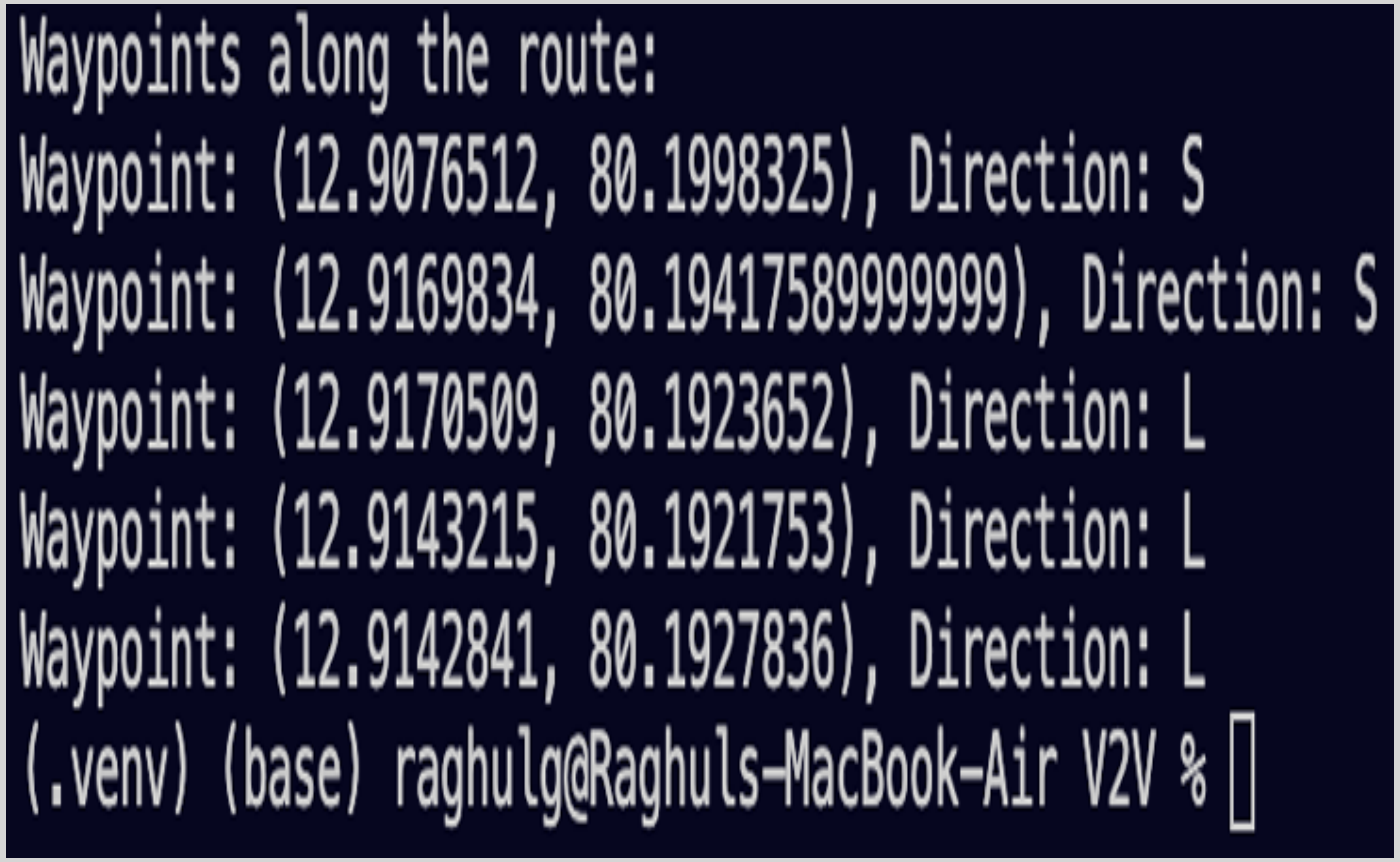
Direction Control - After the ambulance driver enters the direction to which the OBU should be directed, it sends the signal to the RSU through the nRF24L01 transmitter. This data is interpreted by the RSU with a corresponding receiver to calculate the necessary traffic signal adjustments. For example, if the ambulance needs to turn left, the RSU will send a message to the left turn LED and stop conflicting traffic flows. This directional control guarantees the ambulance's path is clear before its arrival, cutting waiting times and improving ambulance transit efficiency.

Continuous Response - The RSU is designed to be real time adaptable with the RSU continuously monitoring and updating its signal control based on new inputs from the OBU. The OBU sends updated directional signals as the ambulance processes through its route, which are processed by the RSU to transform the traffic lights as those signals change. This continuous response mechanism makes sure that the system is able to follow the ambulance around multiple junctions without breaks.

Initial State of Traffic Lights - By default, the RSU illuminates the straight traffic light in order to let all vehicles including the ambulance pass smoothly without any direction indication. The setup minimizes disruption at intersections. If the OBU sends a directional signal, the RSU will adjust the lights, turning on the left or right LED, as appropriate, while keeping the ambulance's priority. This default state reduces response time by having a baseline configuration ready

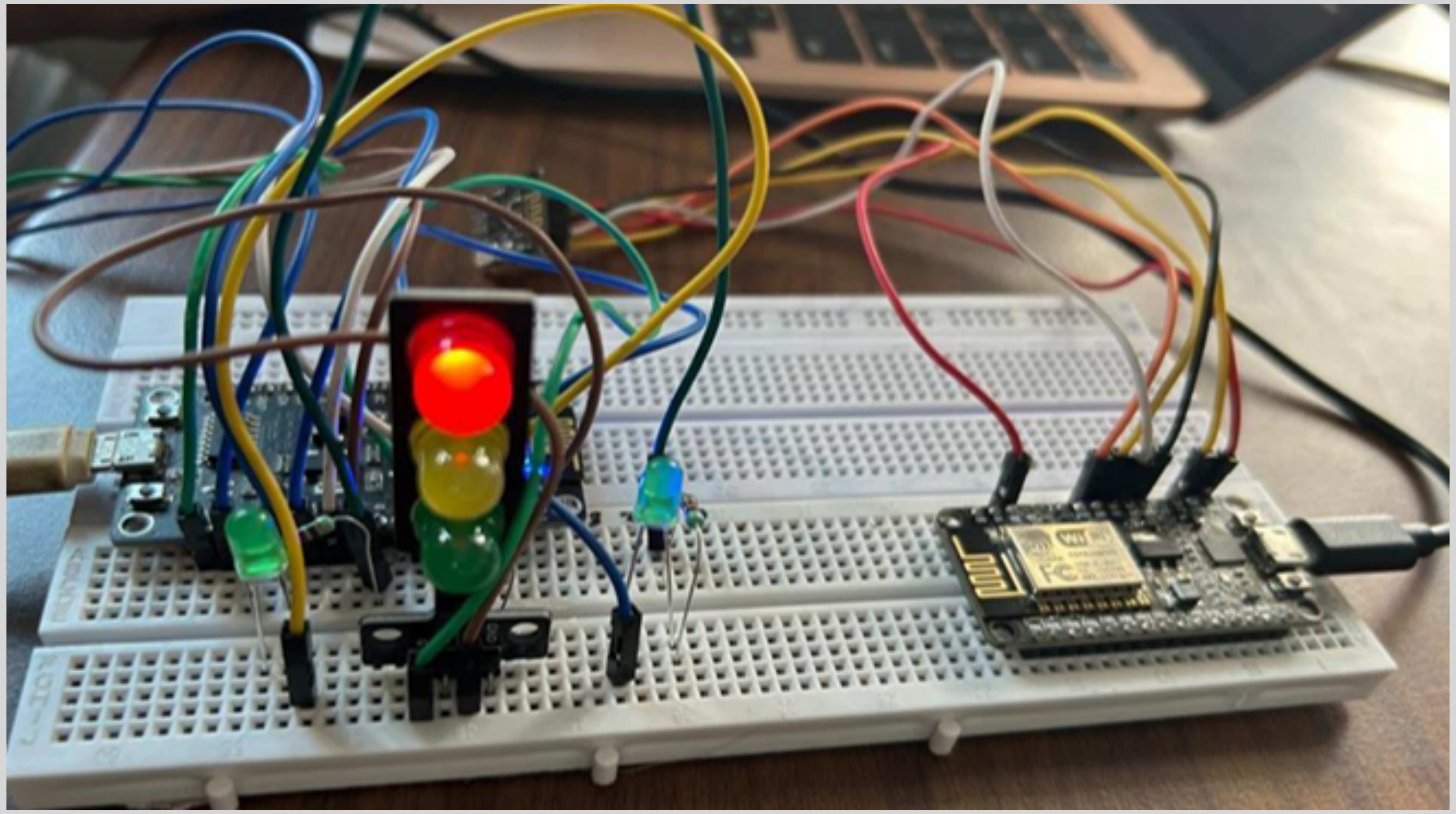
Implementation Result



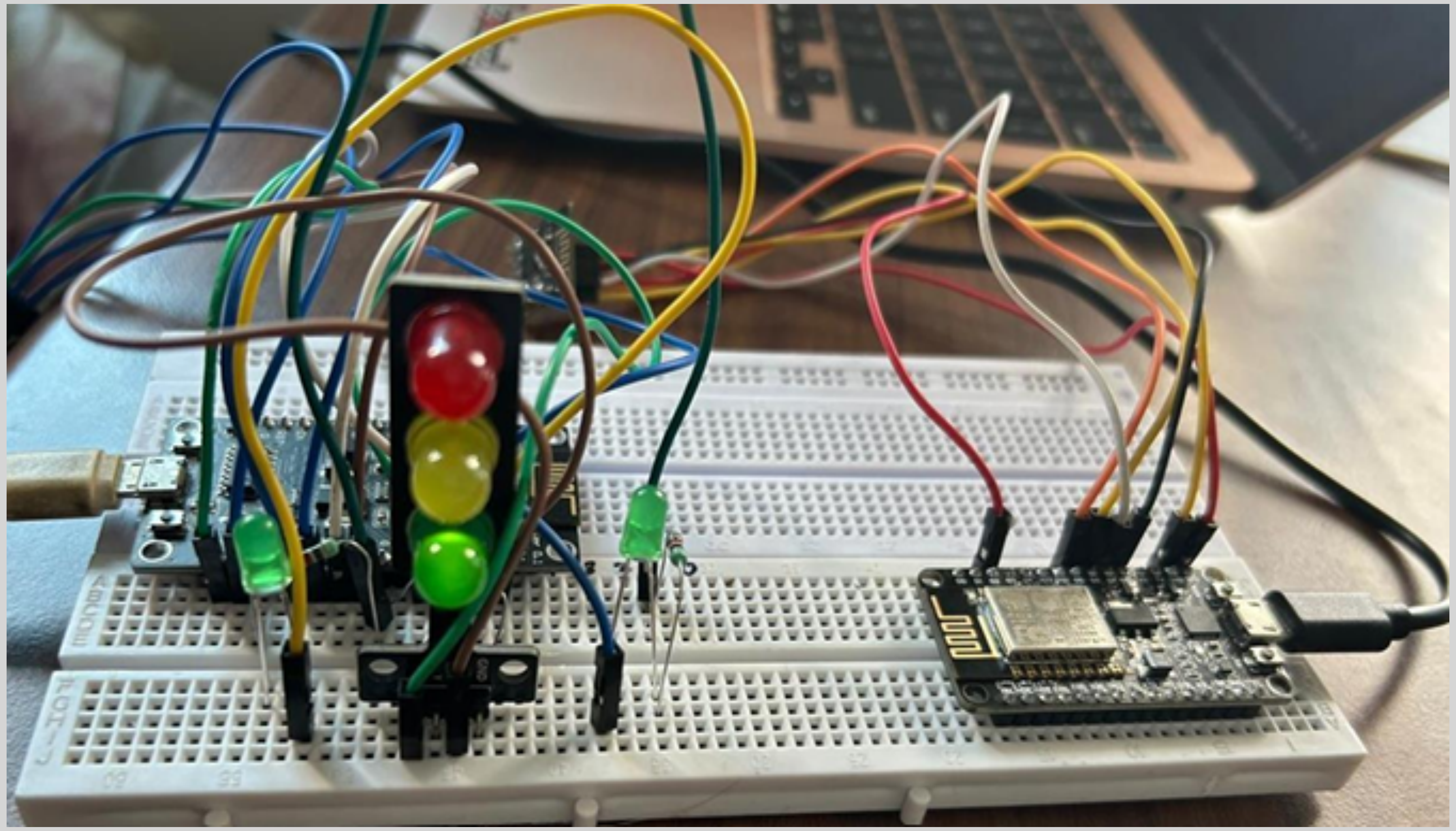


```
Waypoints along the route:
Waypoint: (12.9076512, 80.1998325), Direction: S
Waypoint: (12.9169834, 80.19417589999999), Direction: S
Waypoint: (12.9170509, 80.1923652), Direction: L
Waypoint: (12.9143215, 80.1921753), Direction: L
Waypoint: (12.9142841, 80.1927836), Direction: L
(.venv) (base) raghulg@Raghuls-MacBook-Air V2V % 
```

Implementation Result

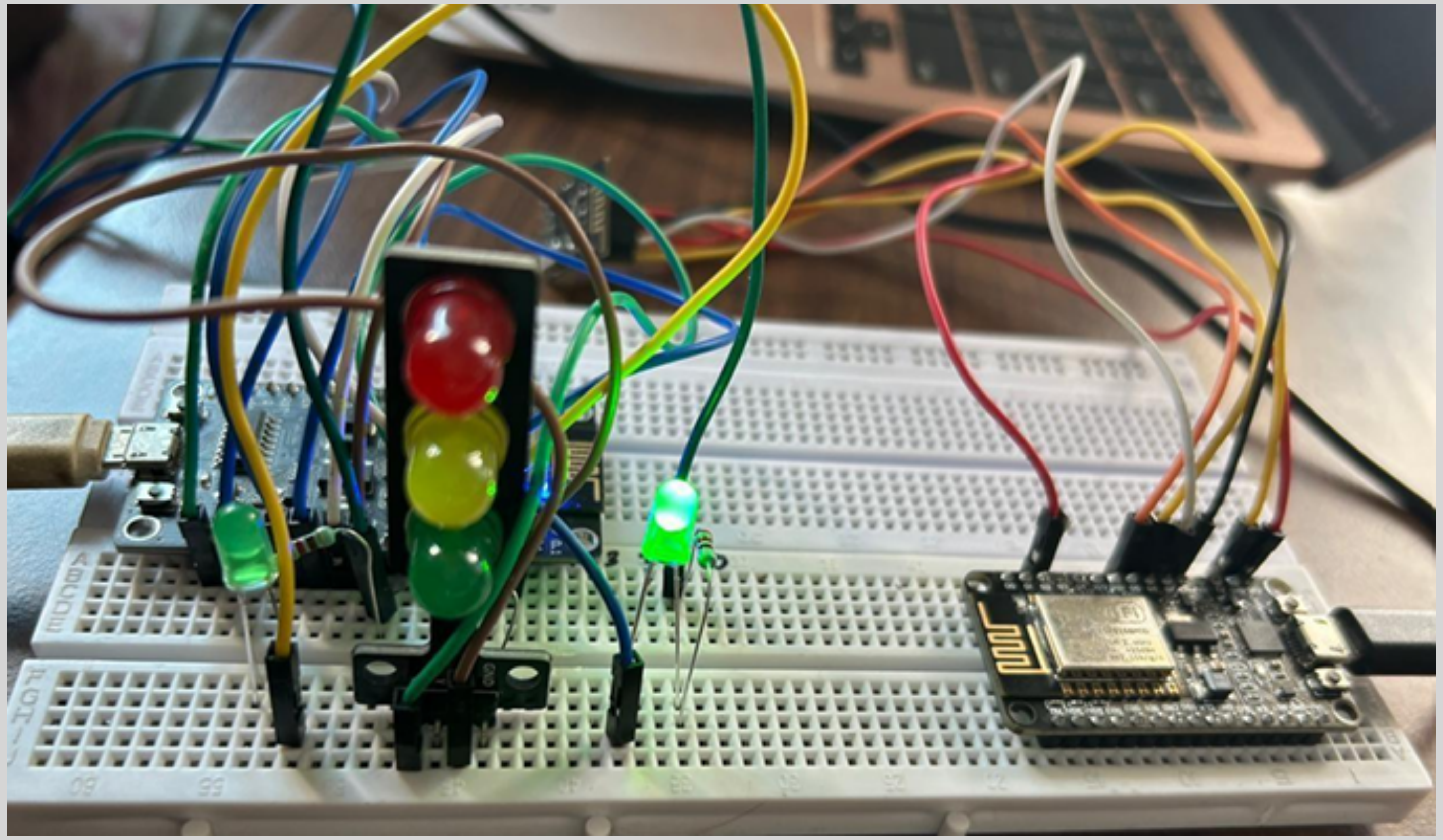


Default RED LED Glowing

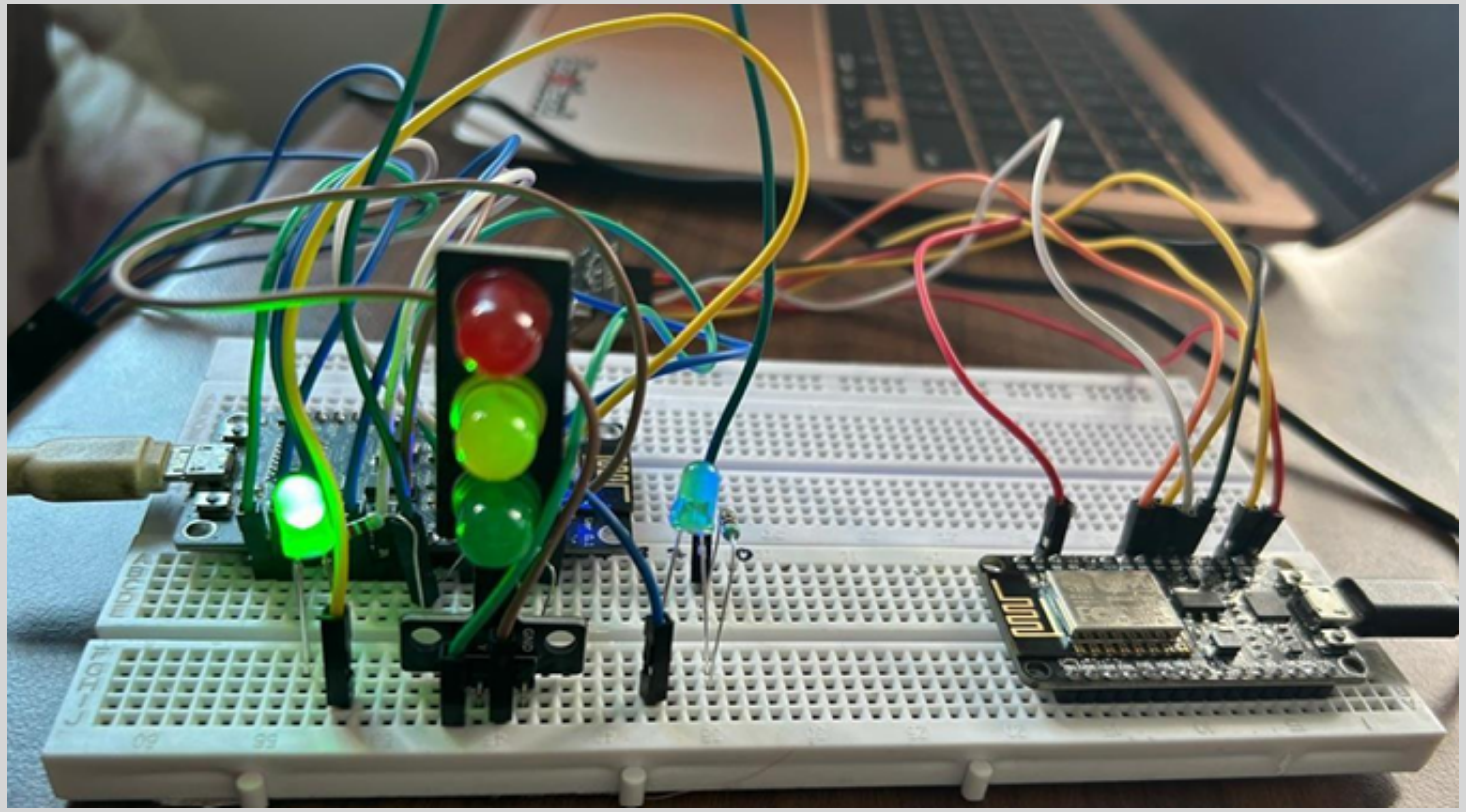


Straight LED Glowing when ‘S’ is Received

Implementation Result



Right LED Glowing when ‘R’ is Received



Left LED Glowing when ‘L’ is Received

Result

1) **Response Time Efficiency** - Ambulance delays at intersections are dramatically reduced over fixed cycle traffic lights. Manual intervention or pre-defined cycles that do not consider emergency situations are required by conventional systems. On the other hand, the proposed model allows ambulances to have uninterrupted passage, automating signal changes. Preemptively clearing the intended route is critical in life saving situations, and this automation decreases response times by doing so. Furthermore, the OBU to RSU real time data exchange is very effective because the adjustments are made immediately, especially in high traffic scenarios.

2) **Accuracy of Signal Control** - The prototype shows great signal control accuracy, with LEDs and traffic lights responding to the ambulance's directional inputs with great precision. Separate directional LEDs for left and right turns are included to provide clarity for other road users and to help smooth ambulance movement. It achieves this level of accuracy to minimize confusion at junctions and to eliminate errors with manual traffic control. Precise adjustments of the system improve its suitability to complex urban environments with multiple lanes and directional splits.

3)**Reliability in Continuous Inputs** - The reliability of continuous inputs is one of the key strengths of the system. In listening mode, the RSU processes dynamic inputs from the OBU without delay or error. Unlike traditional systems, which rely on operator intervention, this real time adaptive system is able to navigate through multiple junctions with no operator intervention. In scenarios with frequent directional changes, there is robust communication between the OBU and RSU, and the performance is uninterrupted.

4) **Comparison with Traditional Systems** - The V2I based model is more efficient, reliable and response time than traditional traffic systems. Manual systems tend to run unattended but are heavy on delays and inconsistencies, especially during peak hours. Ambulances in fixed cycle systems cannot dynamically prioritize. However, the proposed system guarantees real time input adjustments, which makes it much faster and more accurate than conventional models. This practicality is an indication of its suitability for large scale implementation in urban traffic management, and can be used as a solution to ambulance transit delays

DISCUSSIONS

This project signifies a crucial advancement in traffic management systems by prioritizing emergency vehicles through Vehicle-to-Infrastructure (V2I) communication. The integration of hardware components like the On-Board Unit (OBU) and Road-Side Unit (RSU) ensures seamless real-time communication, allowing traffic signals to dynamically adapt based on the ambulance's intended route. By leveraging APIs like Google Maps, the system identifies the nearest hospital, optimizes the route, and minimizes delays, thereby enhancing emergency response efficiency.

The continuous listening mode of the RSU ensures immediate signal adjustments to clear the path for ambulances, making it significantly faster and more reliable than conventional traffic systems. The prototype's accuracy in adjusting LEDs and traffic lights based on directional inputs validates its practical application for real-time scenarios. This approach eliminates dependency on manual interventions, reducing human error and ensuring uninterrupted transit for emergency vehicles.

The project also highlights the importance of scalability. While the current implementation is limited to a single junction, expanding it to cover multiple intersections will enhance its utility in urban areas. Furthermore, integrating AI and IoT technologies could optimize traffic signal timings by analyzing real-time traffic patterns. Incorporating 5G networks could improve communication reliability, making the system even more robust.

In essence, this project not only addresses a critical urban challenge but also lays the groundwork for future smart city infrastructure, aiming to save lives by reducing emergency response times. It underscores the transformative potential of technology in creating safer and more efficient urban mobility solutions.

Conclusion and Future Scope

The problem of traffic congestion for emergency vehicles in urban environments has been long standing, and this project offers a practical solution to that problem. The system addresses the critical need for real time ambulance prioritization at traffic signals by leveraging Vehicle to Infrastructure (V2I) communication. Modern APIs like Google Maps, as well as advanced hardware units like On-Board Units (OBUs) and Road-Side Units (RSUs) can be integrated with system to dynamically adjust traffic lights depending on the route ambulance intended to take. That way, the emergency vehicle has a clean path for getting through, to keep down how long it takes to arrive at the scene, and how efficient emergency services are, particularly in heavy traffic city roads. The system offers great potential for improving emergency vehicle transit and saving lives in critical situations by its ability to continuously process real time inputs and adjust traffic signals accordingly. The scope of this project can be expanded greatly looking ahead. An initial enhancement could scale the system to include multiple junctions across larger urban areas. If it scales, the system can be integrated with increasingly sophisticated technologies like Artificial Intelligence (AI) and the Internet of Things (IoT) leading to further improvement in the way the system can predict traffic movements and optimize signal settings. The system further could also learn to identify peak traffic periods and subsequently adapt its strategy for prioritizing emergency vehicles based on that.

In addition, the system could be further automated by having GPS tracking on ambulances so that drivers wouldn't have to manually input accident locations and intended routes. If such advancements existed, the system would be less dependent on human error and a lot of the work would be streamlined. In addition to automating the system, there is a large opportunity to expand the project to support multiple emergency vehicles at the same time. To achieve that, more sophisticated algorithms for conflict resolution would need to be developed, so that multiple ambulances can be prioritized efficiently without compromising service of other emergency vehicles. This could be adapted to manage other critical services such as fire truck and police vehicles many others, increasing the added value of the system. Integrating the system with existing smart city infrastructure, in particular with centralized traffic management systems, might be a critical step toward large scale deployment. If the system did this, it could be a component of something much more holistic, a larger ecosystem of connected urban tech and could improve coordination and scalability. Future instantiations may employ a set of emerging technologies that enhance the real time responsiveness of the system based on 5G networks, 5G networks would help reduce latency and provide faster more reliable communication between the OBU and RSUs.