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Intelligent 3-Way Priority-Driven Traffic Light Control System for Emergency Vehicles

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Abstract

The problem of traffic congestion is a significant phenomenon that has had a substantial impact on the transportation system within the country. This phenomenon has given rise to numerous intricacies, particularly in instances where emergency situations occur at traffic light intersections that are consistently congested with a high volume of vehicles. This implementation of a traffic light controller system is designed with the intention of addressing this problem. The purpose of the system was to facilitate the operation of a 3-way traffic control light and provide priority to emergency vehicles using a Radio Frequency Identification (RFID) sensor and Reduced Instruction Set Computing (RISC) Architecture Based Microcontroller. This research work involved designing a system to mitigate the occurrence of accidents commonly observed at traffic light intersections, where vehicles often need to maneuver in order to make way for emergency vehicles following a designated route. The research effectively achieved the analysis, simulation and implementation of wireless communication devices for traffic light control. The implemented prototype utilizes RFID transmission, operates in conjunction with the sequential mode of traffic lights to alter the traffic light sequence accordingly and reverts the traffic lights back to their normal sequence after the emergency vehicle has passed the traffic lights.

Keywords

RFID Sensors, Microcontroller, Traffic Light Control System, RISC Architecture, Intelligent Systems

1. Introduction

The RFID Sensor-Based Priority-Driven Traffic Light Control System for Emergency Vehicles is a specialized traffic management system designed to provide priority access for emergency vehicles at intersections. This system utilizes RFID (Radio Frequency Identification) sensors to detect and identify emergency vehicles equipped with RFID tags, allowing them to preemptively and safely navigate through traffic. Without an RFID Sensor-Based Priority-Driven Traffic Light Control System for Emergency Vehicles, several challenges can arise in effectively managing traffic for emergency vehicles [1]. Some of these challenges include traffic congestion, safety risks, and lack of coordination and public safety concerns: In the absence of a priority-driven system, emergency vehicles may face significant delays and congestion at intersections. They would need to navigate through regular traffic, which can hinder their response times and potentially jeopardize lives and property. Without a dedicated system, emergency vehicles may need to maneuver aggressively through traffic, increasing the risk of accidents, collisions, and harm to pedestrians, drivers, and emergency personnel. Traffic lights operate based on predefined timing patterns, and without a priority-driven system, there is limited coordination with emergency vehicles. This lack of synchronization can lead to delays and inefficiencies in emergency response [2]. In the absence of a priority-driven system, emergency vehicles may experience longer response times due to traffic congestion and delays at intersections. This can impact the ability to reach critical situations promptly. In situations where emergency vehicles are unable to navigate through traffic efficiently, public safety may be compromised. Delays in reaching emergencies, such as fires, accidents, or medical emergencies, can have severe consequences for individuals in need of immediate assistance. Consequently, addressing these challenges requires the implementation of effective traffic control measures, such as the adoption of advanced technology systems, improved driver education and awareness, and the development of alternative routing strategies for emergency vehicles. The use of priority-driven systems like RFID Sensor-Based Traffic Light Control can significantly mitigate these challenges by facilitating smoother traffic flow, reducing response times, and enhancing the overall efficiency of emergency services.

Several countries encounter the predicament of accidents occurring at traffic light intersections, specifically involving emergency vehicles and other vehicles in the public domain. Many traffic control systems lack appropriate protocols for handling emergency situations [2]. The presence of traffic congestion poses a challenge for emergency vehicles, such as ambulances, in reaching their intended destination within the desired timeframe. Furthermore, the predicament exacerbates as emergency vehicles are compelled to endure delays at intersections equipped with traffic lights due to other vehicles failing to yield the right of way. This phenomenon results in a temporal delay and has the potential to impact the urgency of the situation. Moreover, instances of vehicular collisions may arise at intersections when emergency vehicles disregard red traffic lights. The traffic light control system, proposed in this work using RISC Architecture Microcontroller and Mobile RFID Sensor-Based Intelligent Priority-Driven Traffic Light

Control System offers a potential solution to circumvent the challenges encountered by emergency vehicles at traffic intersections.

In many developing countries, the exponential growth in the number of automobiles and the construction of new roads has not been accompanied by corresponding advancements in traffic control and management infrastructure [3]. Despite the implementation of various measures such as the construction of flyovers and bypass roads, the establishment of ring systems, and the rehabilitation of existing roads, it is important to acknowledge that there are additional factors associated with the issue of traffic congestion that contribute to its inherent complexity. The flow of traffic is contingent upon various factors, including the time of day, with peak hours typically occurring in the morning and evening, as well as the time of year, such as during holidays and the summer season. Additionally, it is worth noting that the majority of traffic light systems in developing countries are characterized by the utilization of hard-coded delays [3]. In this context, the transition time slots of the lights are predetermined and remain constant, irrespective of the actual traffic conditions at any given moment. The third aspect pertains to the condition of a single traffic signal at an intersection, which has an impact on the movement of vehicles at nearby intersections. Moreover, the traditional traffic system fails to account for the occurrence of accidents, road works, and disabled vehicles, all of which contribute to the exacerbation of traffic congestion. Furthermore, a critical concern pertains to the unimpeded traversal of intersections by emergency vehicles with higher priority, including ambulances, rescue vehicles, fire brigades, and police units, which may encounter difficulties navigating through congested areas. Moreover, the event of pedestrians crossing the lanes has a significant impact on the overall functioning of the traffic system. There is a pressing need to enhance the existing traffic system in order to address the significant issue of traffic congestion, mitigate transportation challenges, decrease traffic volume and waiting times, minimize overall travel duration, optimize vehicle safety and efficiency, and extend the advantages in the realms of health, economy, and the environment.

This study presents a novel approach to a traffic light control system that is characterized by its simplicity, affordability, and real-time capabilities. The proposed system is designed to address various limitations in existing traffic management systems, with the ultimate goal of enhancing overall traffic management efficiency. This research aims to design and implement of an intelligent 3-Way Priority-Driven Traffic Light Control System for Emergency Vehicles using RFID. An overview of the solution and process involved RFID Technology Integration. The proposed system incorporates Radio Frequency Identification technology to uniquely identify and track emergency vehicles. Each emergency vehicle is equipped with an RFID tag that transmits a unique identifier. It provides the capability for priority detection when an emergency vehicle approaches an intersection. The RFID reader at the traffic light detects the RFID tag and identifies the vehicle as an emergency vehicle requiring priority access and assigns priority to the emergency vehicle based on its detection, ensuring that the vehicle receives a green signal at the traffic light, allowing it to pass through the intersection without delay. The implementation of the system improves response times for emergency vehicles, enhances traffic flow management, and increases overall safety on the road. By utilizing RFID technology and intelligent control algorithms, the system effectively prioritizes emergency vehicles and ensures their swift movement through intersections, ultimately contributing to better emergency response services in urban areas.

2. Related Work

Accidents involving emergency vehicles are a global issue that is gaining concern. The majority of incidents involving emergency vehicles occur at intersections because these vehicles travel at higher speeds during emergency situations, which can result in severe injuries or fatalities. Researchers have proposed a number of traffic management schemes [2] to prioritize the passage of emergency vehicles and organize traffic flows at intersections. Intelligent traffic control systems to prioritize emergency vehicles were proposed in [4]. In this approach, cameras were installed at intersections to measure traffic conditions, which were then utilized to estimate traffic signal sequences.

Shang *et al.*, [5] proposed a traffic light system that alerted drivers of the approach of an emergency vehicle, allowing them to avoid traffic congestion and guide the vehicle to its destination. In this disposition, the emergency vehicle controlled the traffic signal at the intersection through a transmitter installed on the emergency vehicle to transmit a signal to the traffic light receivers whenever the vehicle is in emergency mode. The signal is then processed by a master controller, which preempts the sequence of the traffic light to regulate the flow of traffic at the intersection where the emergency vehicle is located. The master controller also provides an output that displays signals indicating the presence of an emergency vehicle to drivers approaching the intersection from the opposite direction. However, the display system did not indicate whether or not the emergency vehicle has traversed the intersection. To address this limitation a joint adaptive routing and traffic signal control algorithm for improving traffic operations in a vehicular ad hoc network environment was proposed in [3]. Through a vehicle-to-vehicle infrastructure, drivers could access real-time traffic data to make route decisions at each intersection based on a hyper-path trees model. Two traffic signal control strategies (phase selection control and modified max pressure control) were proposed in order to examine the impacts of incoming traffic and existing delays on traffic signal operation. To complete this effort, Pudu *et al.*, [6] designed a traffic light control system that solved the problem of traffic congestion and provided an emergency route for the emergency vehicle by placing the radio transmitter and antenna on the vehicle. The radio transmitted a signal to an adjacent vehicle. The radio receivers installed at four intersection traffic lights received the emergency signal from passing emergency vehicles. The first signal code includes a frequency for an emergency vehicle, whereas the second signal code includes a frequency for another vehicle. The transmitted signals provide various traffic light pole information in normal or emergency conditions. When the receiver receives the signal from the emergency vehicle transmitter, the emergency vehicle's traffic light system will be activated. This approach proved to be ineffective and complex as a sound signal-producing unit has to be mounted on an emergency vehicle, a sound signal detection unit mounted on a non-emergency vehicle, and a display unit remotely located on the non-emergency. The approach did not actually control the traffic lights but adopted an apparatus that produces sound signals to generate and transmit sound signals. In conjunction with a siren, a switch is used to regulate the operation manually so as to control the traffic.

A more proactive technique is proposed [5]. The author utilized cutting-edge technologies, including infrared cameras and GPS, to detect the presence of emergency vehicles and compute the real-time traffic density using RFID identifiers to detect the presence of emergency vehicles, while the inductive loop method [7] was used to enumerate the vehicles. Recent technologies, such as RFID, Bluetooth, ZigBee, and the global system for mobile communication have been found to be efficient in the design of intelligent traffic control systems. Utilizing localization algorithms to determine the locations of vehicles containing wireless sensor network nodes and sensor networks has been argued to provide promising solutions for traffic management [4]. A variant of this approach consisted of two-way communication between emergency vehicles approaching a congested intersection with one or more traffic signals [7]. The system temporarily overrides the traffic signal sequence and provides the most efficient route for the vehicle through the intersection while redirecting general traffic. As part of the invention, the traffic light control system notifies the emergency vehicle that the transmitted signal has been received. In one representation, the stored predetermined traffic pattern is configured to be responsive to manual intervention from a dispatching center or to time-of-day conditions. The traffic light control apparatus is operated by voice or data transmitted from the emergency vehicle's standard two-way voice communications system to a central control station which controls the traffic. In comparison, a simpler approach is proposed [8]. The authors proposed a technique for emergency vehicle preemption with sensors installed at each intersection to detect the presence of emergency vehicles. The traffic light controller provided an emergency vehicle with a green light until it exited the intersection. A protocol for the automatic clearance of ambulance lanes using RFID and GPS was also proposed in [9]. This protocol aimed to reduce ambulance travel delays by removing lanes prior to an ambulance's arrival at an intersection. Similarly, Naik *et al.*, [10] proposed a system that also grants clearance to any emergency vehicle by illuminating the emergency vehicle's path with green lights. A vehicle travelling through the lane will continue to receive green signals in this manner. However, due to a lack of synchronization, the wave disturbances in this system caused severe traffic problems. A system in which traffic estimation cameras are installed at red signals has been proposed [11]. The vehicles in that channel were allowed to pass by modifying the timer for efficient traffic flow based on the need for density increases. The authors implemented a density-based traffic light control system by employing an obstruction gate and GSM technology. In their system, the traffic density is used to automatically vary the signal timing, and a microcontroller provides the delay. However, this system does not solve the emergency vehicle problem. A methodology that involves the utilization of a PIC microcontroller within a traffic control system, embedded with (IR) sensors to assess the level of traffic density has been proposed [12]. The approach facilitates the implementation of dynamic time periods for varying levels of traffic and used a control device to monitor emergency vehicles. This system has the disadvantage that the portable device must be transported with the emergency vehicle.

A framework for determining the signal control parameters that minimize total travel durations at intersections has also been proposed for traffic signal control [11]. To capture queue spillbacks, the proposed architecture incorporates the double-queue traffic flow model into a signal-controlled traffic network. Using Wardrop's first principal model [11], motorist route choices in response to changes in traffic signal control were also captured. To address the proposed nonlinear programming problem with time-varying delay terms, a solution based on a heuristic genetic algorithm was implemented. The system deployed a co-simulation-based optimization strategy to give vehicles priority at traffic lights. This system presupposes that vehicles and intersection controllers are in constant communication. When a vehicle approaches a signalized intersection, it sends its real-time information (velocity, location, size, etc.) to the intersection controller. The intersection controller then allocates the highest passing priority to the vehicle based on its estimated arrival time at the intersection. Other implementations simply adopted a self-organizing paradigm where green signal periods are extended to accommodate traffic on the lane that emergency vehicle is expected to arrive [12]. In order to reduce transit delays, a dynamic coordination mechanism was implemented in which small groups of closely spaced traffic signals communicate with one another to cycle synchronously at critical intersections.

Li *et al.*, [12] also proposed using Timed Petri Nets (TPN) for a traffic control system. The proposed system provides emergency vehicles with priority, enabling them to traverse intersections with less delay. Utilizing a reachability graph analysis, the liveness and reversibility of the proposed TPN model were demonstrated. Intersection traffic-light control systems were modeled using Petri nets (PNs). At intersections, cameras were used to detect accidents in order to prevent massive congestion caused by these incidents. To assure safety at an intersection, the proposed model recovers deadlocks, prevents lovelocks, and resolves conflicts. Similarly, a set of algorithms for planning traffic signal timings using deep reinforcement learning has been proposed [11]. A Deep Neural Network (DNN) was designed to learn from the sampled inputs and outputs of the traffic control system. On the basis of the obtained DNN, the optimal traffic signal timing plan for the intersection's complex vehicle dynamics was developed. An abstruse approach is discussed in [13]. Under the assumption that vehicle-to-infrastructure communication is available for various traffic modes, a multi-modal traffic signal priority problem is proposed. In this approach, when approaching a signalized intersection, priority-eligible vehicles, such as emergency vehicles, transit buses, commercial lorries, and pedestrians, could submit requests for priority to a traffic signal controller. One potential issue with the aforementioned approach is the likelihood of receiving numerous requests from both vehicles and pedestrians, resulting in the presence of multiple concurrent active requests. In order to effectively integrate multiple priority requests from different modes of transportation, including vehicles and pedestrians, it is necessary to develop a request-based mixed-integer linear programme for the approach to be effective.

In summary existing approaches either propose techniques to address the problem of prioritizing emergency vehicles at intersections or address the problem of managing the sequences and durations of traffic light signals based on the vehicle densities of particular road segments or approaches. Other works concentrate on adjusting the timing of green traffic signals based on the detected real-time traffic, without taking into account the presence of other emergency vehicles at an intersection. Accordingly, there are few protocols that address both problems (*i.e.*, prioritize emergency vehicles at intersections and estimate the durations of traffic light signals based on vehicle density). Consequently, the most significant contribution of this study is a system that prioritizes emergency vehicles at intersections and manages the sequences and durations of traffic light signals based on the vehicle density on each approach, as measured by force- resistive sensors. In addition, we provide information regarding the algorithms executed by emergency vehicles, intersection control systems. In addition, extensive simulations are conducted to demonstrate how the proposed scheme accommodates the arrival of emergency vehicles in order to decrease emergency vehicle response times at intersections.

3. Method

The process of implementing a RISC architecture microcontroller and mobile RFID sensor-based intelligent priority-driven traffic light control system consists of several key steps. These include system design, microcontroller programming, RFID sensor integration and tagging, sensor data acquisition and programming, traffic light control, real-time communication, and system validation. The system's architecture and components have been clearly defined. The Atmega 324 microcontroller is utilized as the central processing unit in the traffic light system. It is responsible for controlling the system's operations. Additionally, the

RC522 RFID sensors are employed to detect and identify emergency vehicles. The development of firmware for the RISC architecture microcontroller focuses on implementing the necessary logic for controlling traffic lights. The implementation of algorithms for traffic light sequencing, timing, and priority management is crucial. Additionally, the microcontroller's I/O pins are configured to effectively interface with the traffic light hardware. The integration of mobile RFID sensors with a microcontroller allows for the establishment of communication protocols and data formats [7]. This enables the transmission of real-time information between the sensors and the microcontroller. RFID tags are installed on emergency vehicles to facilitate identification. These tags are configured with unique identification codes and the necessary information required for priority access. The mobile RFID sensors are configured to detect the presence and proximity of RFID-tagged emergency vehicles in order to capture important vehicle information, including identification codes and location. The microcontroller processes sensor data and analyses it to determine the priority level of detected emergency vehicles. This analysis is based on predefined rules and criteria. The management of Traffic Light Control involves the utilization of processed data to dynamically adjust the timings and sequences of traffic lights. Priority access is a system that is put in place to recognize emergency vehicles and proactively adjust traffic light signals in their favor. The real-time communication network facilitates data exchange and synchronization between the mobile RFID sensors, microcontrollers, and traffic light controllers. This enables seamless traffic management and response in real-time. In order to ensure the reliability and effectiveness of the system, it is essential to conduct a thorough validation process. This involves creating a detailed model and conducting simulations to assess the design's functionality and performance. By doing so, any potential issues or shortcomings can be identified and addressed before proceeding with the actual construction of the device. Extensive testing is performed in order to guarantee the precise detection of emergency vehicles, appropriate assignment of priority, and efficient control of traffic lights. The proposed method integrates a RISC architecture microcontroller and mobile RFID sensors to create a traffic light control system that is intelligent and responsive. This system prioritizes emergency vehicles. The system utilizes real-time data from sensors to make informed decisions and enhance traffic flow. This leads to improved emergency response times and ensures safer and more efficient traffic management.

3.1. System Block Diagram and Description of Components

The block diagram for an RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System consists of several key components that work together to facilitate efficient traffic management and prioritize the movement of emergency vehicles. **Figure 1** depicts a description of the various blocks in the system.

The control signal configuration of the system is illustrated in **Figure 1**, which

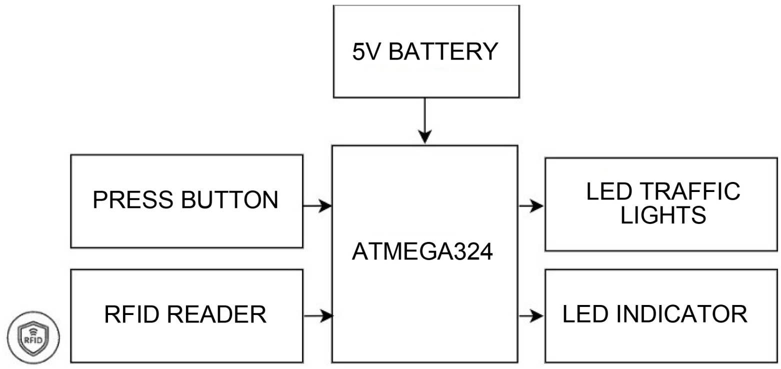

Figure 1. Proposed system block diagram.

offers a comprehensive overview of the flow of these signals. RFID sensors are strategically deployed in proximity to the intersection with the purpose of detecting the presence of approaching vehicles. The sensors consist of transponders mounted on emergency vehicles and RFID readers integrated into traffic lights. When an automobile equipped with an RFID tag nears an intersection, the RFID reader identifies and sends the distinct identifier of the tag to the traffic signal control system. The control system is responsible for receiving the identifier of the RFID tag and subsequently analyzing the data in order to determine the priority level of the incoming vehicle. The control system is responsible for generating control signals for the traffic lighting at the intersection, taking into consideration the priority level of the approaching vehicle. The duration and sequence of traffic lights are determined by these signals with the aim of optimizing traffic flow and granting priority to vehicles with higher priority. The RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System effectively utilizes RFID technology and intelligent control algorithms to optimize traffic flow, alleviate congestion, and assign priority to vehicles based on their individual requirements or level of urgency. The sensors are tasked with the detection and identification of RFID tags that have been installed on emergency vehicles. Radio frequency signals are emitted by the devices and subsequently receive responses from the RFID tags, thereby facilitating the acquisition of proximity and identification data. The RFID reader module is responsible for receiving and interpreting the data that is transmitted by the RFID sensors. It performs the task of extracting pertinent information, such as vehicle identification codes and the corresponding location data. The ATMEGA324 Microcontroller is selected for this implementation due to its low power consumption and utilization of the AVR-enhanced RISC architecture. The microcontroller block functions as the primary processing unit within the system, receiving data from the RFID reader in order to execute essential processing and decision-making functions. The microcontroller is responsible for regulating the timing and sequencing of traffic lights, taking into consideration the priority assigned to emergency vehicles that have been detected. The Traffic Light Control Unit encompasses both the hardware and software components that are responsible for the regulation and management of the traffic lights located at an intersection. The system is responsive to commands issued by the microcontroller, enabling it to modify signal timings in order to facilitate the prioritized movement of emergency vehicles. The power supply unit is responsible for delivering the requisite electrical power required for the functioning of the system's components. The prototype utilizes a 5 V battery as the designated voltage source necessary for this particular implementation. The power supply is responsible for converting 120 volts of alternating current (AC) into a 5-volt Direct Current (DC) suitable for battery utilization.

3.2. ATMEGA324 Microcontroller Port Configuration

Port A (*PA* [7:0]): This port is configured to provide analogue inputs to the Analog-to-digital Converter. The described component is an 8-bit I/O port that supports bidirectional communication. It includes internal pull-up resistors that can be individually enabled or disabled for each bit. The output buffers exhibit symmetrical drive characteristics, meaning they have equal capabilities for both sinking and sourcing current. When pull-up resistors are activated, the port pins that are externally pulled low will source current as inputs. When a reset condition becomes active, the port pins are tri-stated, regardless of whether the clock is running or not.

Port B (*PB* [7:0]): The port is an 8-bit I/O port that supports bi-directional communication. It includes internal pull-up resistors that can be individually enabled or disabled for each bit. The output buffers exhibit symmetrical drive characteristics, meaning they have equal capabilities for both sinking and sourcing current. When pull-up resistors are activated, the port pins that are externally pulled low will source current as inputs. When a reset condition becomes active, the port pins are put into a tri-state mode, regardless of whether the clock is running or not. In addition to its primary purpose, this port also fulfills various specialized functions.

Port C (*PC* [7:0]): The component is an 8-bit I/O port that supports bi- directional communication. It includes internal pull-up resistors that can be individually enabled or disabled for each bit [6]. The output buffers exhibit symmetrical drive characteristics, meaning they have equal capabilities for both sinking and sourcing current. When pull-up resistors are activated, the port pins that are externally pulled low will source current as inputs.

3.3. System Description and Operation

The operation of the RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System follows a sequential approach in order to prioritize the passage of emergency vehicles at intersections. The system initiates its operation by employing RFID sensors strategically positioned at intersections to identify the presence of emergency vehicles equipped with RFID tags. The sensors emit radio frequency signals and receive responses from the RFID tags that are installed on the vehicles, thereby providing information regarding proximity and identification. The data from the RFID sensor is transmitted to an RFID reader, which retrieves pertinent information, such as the identification code and location of the detected vehicles. The data that has been extracted is subsequently subjected to processing by a microcontroller. This microcontroller undertakes the task of assessing the priority level assigned to the emergency vehicles that have been detected. This assessment is based on a set of predetermined rules and criteria [2]. The microcontroller utilizes an emergency vehicle database in order to verify the legitimacy and priority level of the identified vehicles. The microcontroller utilizes the designated priority levels to ascertain the necessary modifications needed for the traffic light signals. The communication occurs between the traffic light control unit and the intersection's traffic lights, wherein the former comprises both hardware and software elements that are accountable for the regulation of the traffic lights.

The traffic light control unit modifies the signal timings and sequences in accordance with the priority-driven determinations made by the microcontroller. The system grants priority access to identified emergency vehicles by proactively altering the traffic light signals in their favor. During the course of operation, the microcontroller and the traffic light control unit establish and uphold a real-time communication interface. This facilitates the smooth exchange and synchronization of data to guarantee precise and effective traffic management. The system perpetually monitors the intersection to detect the presence of emergency vehicles. The system employs real-time adjustments to traffic light signals in order to optimize traffic flow and minimize congestion, thereby facilitating the efficient movement of vehicles and enabling emergency vehicles to reach their destinations in a timely manner. The model in **Figure 2** is used to simulate and test these operations. The enhancement of traffic management is achieved through the prioritization of emergency vehicle movement by the RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System, which combines RFID sensor technology, intelligent data processing, and real-time communication. The implementation of this system can lead to a decrease in response times, an enhancement in the overall flow of traffic, and an improvement in safety at intersections. Consequently, it contributes to the optimization of emergency services and the creation of a safer road environment.

4. Results and Discussion

The materials and components required for the construction of this device were carefully selected and designated. Prior to establishing the necessary connections with the components, resistance checks were conducted on all the required components using an ohmmeter. The initial iteration of the schematic diagram (**Figure 2**) was conducted in order to determine the optimal arrangement of materials and components. Subsequently, the completed system underwent testing to evaluate the functionality of the design. The physical realization of the

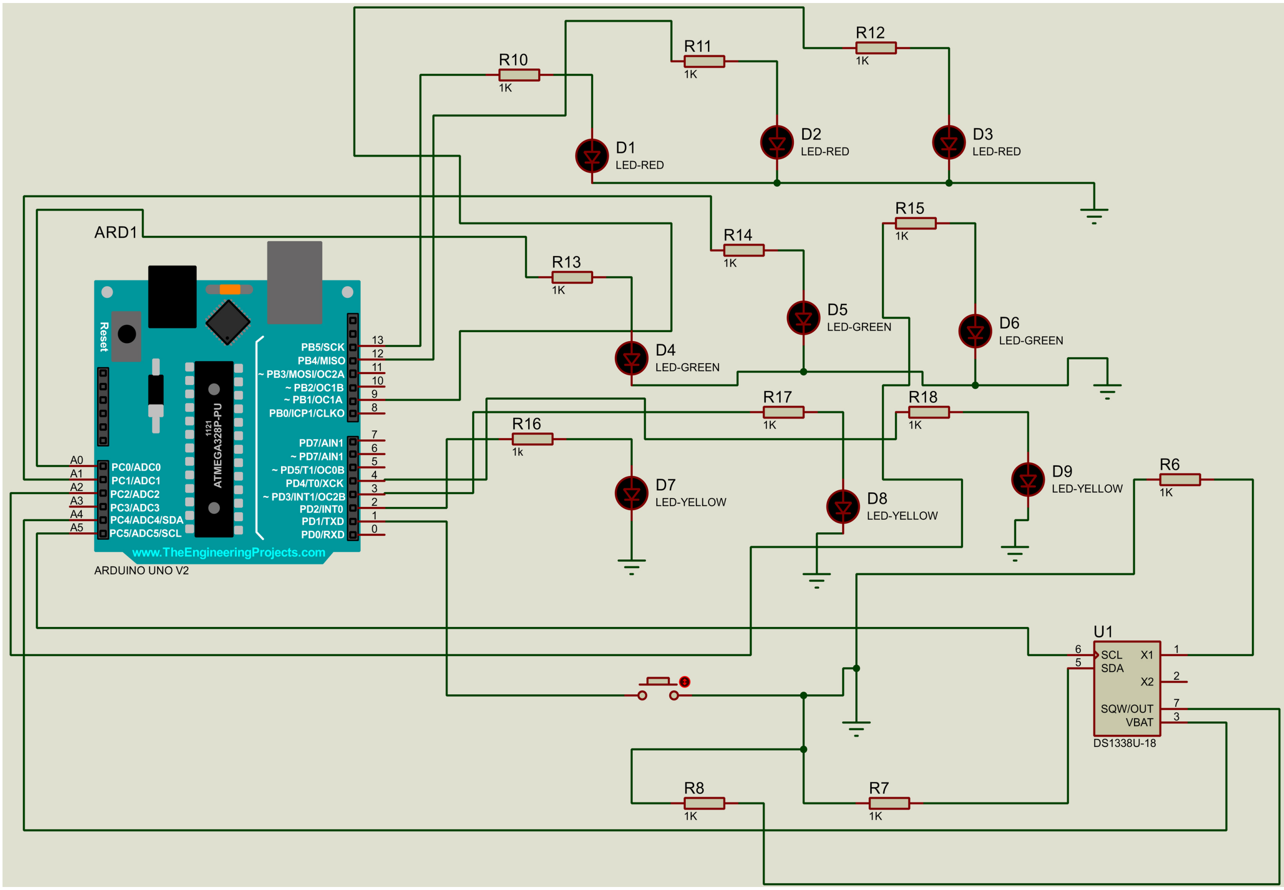

Figure 2. Schematic diagram of circuit design.

device's design involved the arrangement of its components onto the Vero board in preparation for the soldering process. After utilizing a digital multimeter to determine the terminals of the component employed in this design, the prototype was constructed on a worktop board to evaluate its functionality prior to its permanent transfer onto the Vero board. Nevertheless, the simulation of each block was conducted using computer-based Electronics Workbench software in order to validate the output against the anticipated design parameters. The digital logic's input was initially supplied with a clock signal and subjected to testing, as it is the central component responsible for overseeing the operation of the entire circuit.

4.1. Architectural Design and Implementation

The hardware implementation consists of five main hardware/electronic devices namely ATMEGA324 Microcontroller, RFID Reader and RFID Tag, Switch, battery and Light Emitting Diodes. The RFID readers are connected internally through the ATMEGA324 Microcontroller. The RFID reader reads inputs from the tag and turns them into output by turning the LEDs to red. The initiating switch is also connected to the ATMEGA324. Both the ATMEGA324 and the LEDs used for the traffic lightispoweredwith1Ampereregulatedpower supply each. Three LED lights are connected with ATMEGA324 and used for simulating the traffic signal. The RFID reader is a wireless device that uses radio waves to transmit signals that activate the tag used to gather information from an RFID Tag and it is used to track individual objects. The switch component is used for making or breaking the connection in the circuit. It takes control of the flow of electrical current within the battery and other components that makes up the system.

When the switch is turned on, it passes current to other components but once it is turned off, it immediately cuts off the current from the battery. The battery used in the construction of the system is a 5v battery. The power supply converts 120 volts of alternating current (AC) into 5 volts of direct current (DC). Light Emitting Diodes (LED) lights emit light up to 90% more efficiently than incandescent bulbs. An electric current pass through a microchip which illuminates the tiny light sources which we call LED and the result is visible light. The assembled device is depicted in **Figure 3**.

4.2. Phases of Simulation of the 3-Way Priority-Driven Traffic Light Control System

First Phase: Here, the normal system passed the two lanes of traffic to go and holds the other lane (**Figure 4**).

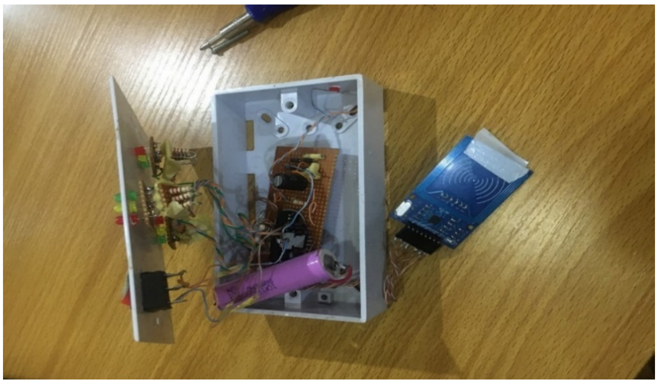

Figure 3. Hardware implementation.

Figure 4. Two traffic lane PASS, one on STOP state.

Second Phase: Here, the normal system passes one lane of traffic to go and holds two of the other lanes at ready state (**Figure 5**).

Third Phase: Here, the traffic light system stopped vehicles moving on one traffic lane and permitted two lanes to move (**Figure 6**).

Fourth Phase: Here, the RFID tag is placed at the front of the RFID reader to be able to change the normal traffic system through the ATMEGA324 microcontroller to an emergency system for a specific time (**Figure 7**).

Fifth Phase: After the RFID tag is placed at the front of the RFID reader, the button is pressed and held to activate the emergency mode.

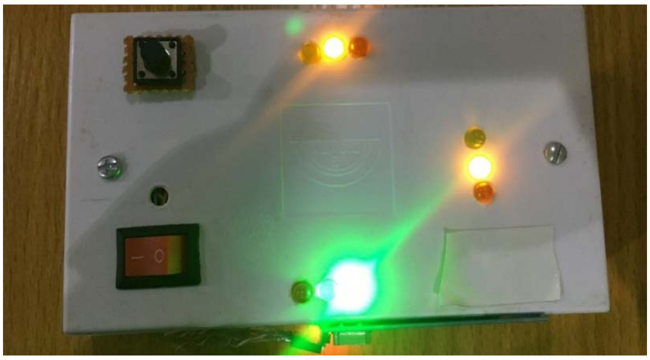

Figure 5. One traffic lane PASS, two on READY state.

Figure 6. Two traffic lane PASS, one traffic lane on STOP state.

Figure 7. RFID tag is placed at the front of the RFID Reader.

Figure 8. Switch pressed and held to activate the emergency mode.

Upon activation and pressing of the button, the LED lights undergo a transition to a red, thereby halting the movement of all vehicles. This measure is implemented to facilitate the unobstructed passage of emergency vehicles, as shown in Figure 8.

5. Conclusion

In conclusion, the implementation of an RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System provides significant benefits for traffic management and the prioritization of emergency vehicle movement. Through the integration of RFID sensors, microcontrollers, and traffic signal control mechanisms, the system contributes to effectively addressing the issues of congested intersections and delayed emergency responses. By providing emergency vehicles with priority access at intersections, the system facilitates quicker and more effective response times. This results in improved emergency services that could potentially save lives. The system enhances the overall traffic flow at intersections by dynamically adjusting traffic light signals based on detected priority vehicles. This aids in reducing traffic, minimizing delays, and improving the effectiveness of the road network. The system prioritizes the movement of emergency vehicles, reducing the risks associated with aggressive driving maneuvers and enhancing the safety of both emergency responders and other road users. Using RFID sensors and microcontrollers, the system executes data processing and decision-making in real-time. This expedites the prioritization of emergency vehicles, assuring expeditious access and reducing response times. The system manages traffic intelligently by adjusting the traffic light signals based on the priority vehicles detected. This optimization improves traffic flow, reduces congestion, and increases the overall effectiveness of the road network. The RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System can be integrated into the existing traffic control infrastructure without extensive alterations. The successful implementation of an RFID sensor-based intelligent priority-driven traffic light control system improves emergency response, traffic flow, and overall road safety significantly. By giving emergency vehicles priority access to intersections, the system optimizes traffic management and contributes to a more resilient transportation network. While the RFID Sensor-Based Intelligent Priority-Driven Traffic Light Control System presents numerous advantages, there are several areas that warrant further research to enhance its capabilities and address potential limitations. One such is the use of advanced vehicle detection techniques. This entails exploring alternative vehicle detection techniques that complement RFID sensors such as video analytics, LiDAR, or ultrasonic sensors to improve the accuracy and reliability of vehicle detection.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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