

Smart Traffic Management System for Smart Cities with Emergency Prioritization

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ABSTRACT

As urban populations continue to grow, the demand for efficient traffic management in smart cities becomes increasingly pressing. Traditional traffic lights, with fixed timing sequences, often lead to unnecessary delays for motorists and fail to accommodate vehicle priorities. This paper proposes a Smart Traffic Management System (STMS) tailored for smart cities, focusing on emergency prioritization. The system integrates a microcontroller, Radio Frequency Identification (RFID), and infrared (IR) sensors, and responds dynamically based on the nature of the vehicle and lane congestion. Emergency Vehicles (EVs) such as Ambulances and Fire trucks are given priority through the RFID setup while sensors track the number of vehicles on each lane. Leveraging sensor networks and intelligent algorithms, the STMS dynamically adjusts traffic signals and communicates with emergency services to ensure swift response times during critical situations. Through simulation studies and real-world implementation, the effectiveness and scalability of the proposed STMS are evaluated, demonstrating its potential to enhance urban mobility, reduce congestion, and improve emergency response capabilities in smart cities.

Keywords: *Congestion, emergency, priority, RFID, sensors, traffic.*

1. INTRODUCTION

Traffic congestion is a global issue that is responsible for accidents and delays of vehicles (Chaudhari, 2021). This delay is attributed to the loss of lives and property and cannot be afforded by emergency vehicles because time is of the essence. Failure of an Ambulance to transport patients in a critical state, medical equipment, accident victims, or medicines on time could be fatal for the victims (Sumia and Ranga, 2018).

The duties carried out by the fire service, police, trucks conveying perishables, and top government officials cannot be underrated. The world's population growth rate has skyrocketed in the last two centuries. Growing from 1 billion in 1800 to 6 billion in 1999 (Sadigov, 2022). In China, private cars went from 70 million in 2010 to 320 million in 2018 (Guo et al., 2020).

The rapid increase in population has put a lot of strain on city infrastructures and service deliveries. Many cities are enhancing the quality and performance of urban services by incorporating digital and smart systems (Kumar et al., 2020). One of the smart city solutions is a Smart Traffic Management System (STMS).

STMS is an intelligent solution to traffic congestion in urban areas. A system is said to be smart if it can make decisions on its own. A smart traffic signal framework detects the presence or nonappearance of vehicles and responds accordingly with little or no human involvement. Effective traffic control is needed in highly populated areas as traffic congestion is a threat to the ecosystem; causing more emission of carbon dioxide (Hilmani et al., 2020).

A system for controlling traffic lights using an Arduino Mega 2560 microcontroller, IR sensors, and RFID readers and tags to coordinate the green light duration and sequence on a four-lane intersection is proposed in this paper. It functions based on vehicle density and the presence of RFID tags possessed by emergency vehicles.

2. METHODOLOGY

A 5V power supply turns on the microcontroller which supplies 3.3V to the RFID readers and IR sensors. The sensors are placed on the side of the road to monitor the presence of vehicles. The number of active sensors represents the number of vehicles, and the microcontroller uses this to determine the lane to be given the ‘go’ signal. The sensors do not span the entire length of the road due to reason of cost, fair timing distribution, and accuracy of the system. Three sensors are placed on the lanes to be equidistant from the intersection.

The system swaps from one congested lane to another based on the activity of the sensors but if the time reaches

a set threshold (for this project we use ten seconds), it swaps to the next congested lane. In essence, if ten seconds elapse or sensors are inactive, the lane changes.

RFID readers are placed very close to the edge of the road. RFID tags of emergency vehicles are first registered in the system. Once within the scanning

area of the RFID reader, the emergency vehicle is detected and the green light is given to that lane for a certain threshold (for this project we use thirty seconds).

The system possesses indicating elements in the form of a buzzer at the center of the intersection and 2 LEDs (green and red) on each lane. These elements give information to other motorists about the presence of the emergency vehicles. When a registered EV is present, the buzzer is triggered, and the green LED flashes. If the RFID tag possessed by the EV is unregistered, the buzzer is not triggered, and the red light flashes. Figure 1 below is a block diagram and Figure 2 is the algorithm of the system.

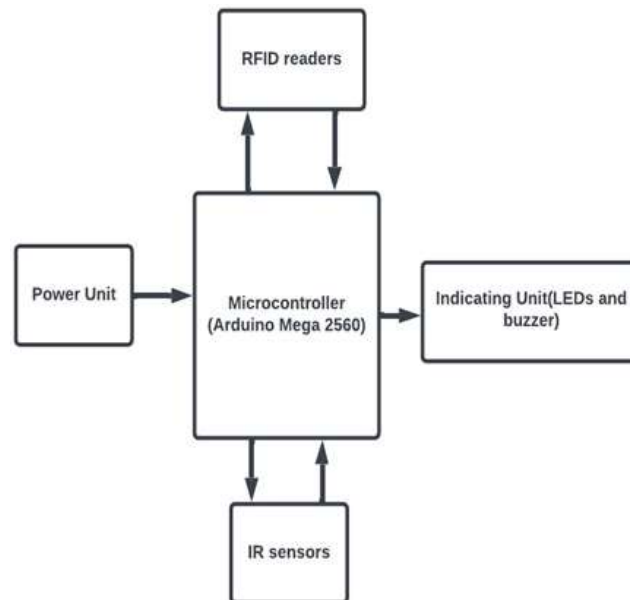


Figure 1: Block diagram of the proposed system

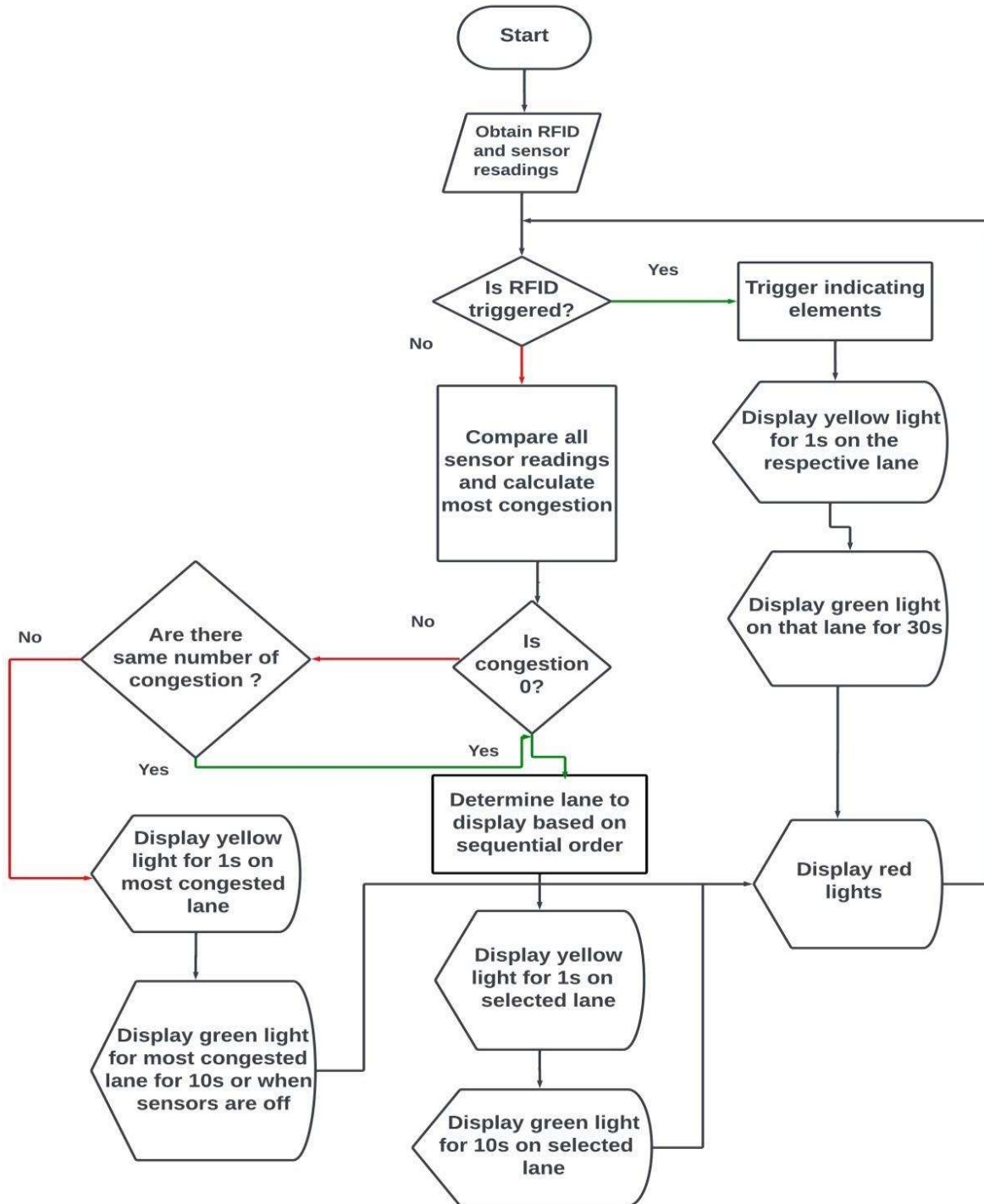


Figure 2: Flowchart of the proposed system

3. RESULTS AND DISCUSSIONS

The accuracy of the STSM was evaluated based on traffic congestion and emergency.

3.1. Congestion

The proposed system reduced traffic congestion with the help of the IR sensors which serve as counters. The following results were observed for the four scenarios that were considered.

Case 1: No traffic

When there is no traffic, the system operates in a sequential manner allocating ten seconds to each lane starting from lane one.

Case 2: Uneven Congestion

For example, if two cars first arrive on lanes one and two, and three cars later arrive on lanes three and four respectively, it was observed that the system first allowed the green signal to lane one and switches from lane one to lane four (which has

higher congestion) after ten seconds or when the sensors have become inactive.

Case 3: Even Congestion

For example, if two cars first arrive on lane one and two cars later arrive on lanes two and four respectively, it was observed that the system first allowed the green signal to lane one and switches from lane one to lane three after ten seconds before switching to lane four. It switches sequentially. Lane one goes first, followed by lane three, and then lane four.

Case 4: Successive Operation

We carried out 7 tests on the system. Table 1 is a table of results obtained when the system experienced congestion in successive operations. Based on this test, the traffic is cleared within twenty-two seconds on average.

Table 1: Congestion results.

TEST		NUMBER OF VEHICLES				TIME TO DECONGEST(s)
		LANE 1	LANE 2	LANE 3	LANE 4	
TEST	TEST 1	2	3	2	1	22
	TEST 2	1	3	2	2	20
	TEST 3	1	3	3	2	24
	TEST 4	3	3	2	1	25
	TEST 5	3	3	3	3	30
	TEST 6	2	1	1	1	16
	TEST 7	1	1	1	1	14

3.2. Emergency

During emergencies, the emergency vehicle tag/card is scanned by the RFID reader. It was observed that if the card was registered, the microcontroller prioritizes that lane by assigning a fixed green light duration of thirty seconds, regardless of congestion on other lanes. Table 2 shows the tests that were carried out for emergencies with the lane containing the emergency vehicle (EV) marked as E. On average, the emergency vehicles took 16.6 seconds to leave the intersection upon arrival.

Table 2: Emergency results.

TEST	TEST	NUMBER OF VEHICLES			TIME FOR EV TO LEAVE (s)
		LANE 1	LANE 2	LANE 3	
	TEST 1	2	3(E)	2	15
	TEST 2	1	3	2(E)	18
	TEST 3	1	3	3(E)	17
	TEST 4	3	3	2 (E)	16
	TEST 5	3	3	3(E)	19
	TEST 6	2(E)	1	1	16
	TEST 7	1(E)	1	1	15

4. CONCLUSION

The necessity for an efficient road transport system is paramount in cities owing to increasing urbanization. With the escalating demand for road infrastructure due to the surge in vehicle numbers, traditional road transportation network. The system proposed in this paper incorporates IR sensors, RFID technology, and a microcontroller. By optimizing lane usage at intersections, it effectively mitigates accidents, minimizes delays, reduces fuel consumption, and lowers collision rates. Most notably, the system facilitates expedited access for emergency vehicles to reach their destinations, underscoring its significant contribution to enhancing overall road safety and efficient transport.

5. RECOMMENDATION

With the aid of artificial intelligence, a camera can be incorporated into this work. It will be very helpful in detecting multiple vehicles on an expanded lane. IR sensors are very sensitive to light. Hence, the use of other sensors that possess less variation to light like ultrasonic sensors or laser sensors are recommended. The RFID system can be improved to support vehicle identification, which will be useful in preventing cases of theft.

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