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Traffic Signal Pre-emption system for Emergency Vehicles

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ABSTRACT: In India, vehicular traffic is constantly rising and can cause awful traffic congestion at intersections. Most of today's traffic signals have a fixed green light sequence, but the green light sequence is decided without taking into account the existence of emergency vehicles. Emergency services, such as ambulances, police cars, fire trucks, stucco engines, etc. stuck in traffic jams leading to the loss of life and property. This project presents a simple, yet efficient approach to solve this problem.

A traffic control pre-emption system uses the signal received by the Infrared receivers to give priority to Emergency vehicles at the intersection. The infrared transmitter is installed beneath the vehicle. A series of infrared receivers is installed at few meters away from each phase of the intersection in the form of horizontal strip covered by the protective material. The transmitter of the vehicle emits an encoded infrared signal and at the instance, when the vehicle passes upon the horizontal strip of infrared receivers, the presence of vehicle is sensed, and the appropriate action is taken to make the signal GREEN of the incoming vehicle lane and rest of the signals RED.

Again, a cross sensor strip is installed of a series of infrared receivers covered by the protective materials on the middle of the intersection. Its purpose is to sense the vehicle when it leaves the intersection. When the vehicle is sensed by the cross strip, means that it is leaved the intersection, and then an appropriate action is taken to make the signal operation normal again.

KEYWORDS: Vehicular traffic, Intersections, Traffic signals, Emergency vehicles, Infrared receivers, Infrared Transmitters, Encoded Infrared Signal, Cross Sensor Strip, Protective Material.

I. INTRODUCTION

The rising traffic is a common problem in India, but in case of emergency, the emergency vehicles stuck for longer times in the traffic leading to the loss of life and property. An individual spends between 30 minutes and two hours of their day driving on average. This translates to almost 360 hours in a year. Road transport accounts for almost 90% of passenger and commercial transportation. India is yet to realise the promise of railway and air transportation, resulting in significant traffic congestion on Indian highways. Since most highways are overburdened and exceedingly busy during the year, maintaining an effective flow of traffic becomes impossible in those circumstances.

Emergency services vehicles stuck these traffic congestions, near the intersection, which lead to delay. In the emergency conditions like fire, in each second, the fire intensity can get double. In the conditions of medical, each second, the patient's condition can get more severe. Therefore, there is a need to solve this global problem, which can add value to the society and can be scaled and sustained in the future.

In this approach, underneath the vehicle is an infrared transmitter installed. In the horizontal strip protected by the protective material, a series of infrared receivers are mounted a few meters away from each stage of the intersection. The transmitted vehicle emits an encoded infrared signal, and the presence of the vehicle is detected when the vehicle crosses over the horizontal strip of the infrared receiver, and sufficient action is taken to make the GREEN signal of the incoming vehicle lane and the rest of the RED signals.

Again, a cross strip is mounted in the centre of the intersection of a series of infrared receivers protected by protective materials. When it leaves the intersection, its aim is to sense the car. It implies that the intersection is left until the vehicle is detected by the cross strip, and then an appropriate step is taken to make the signal activity regular again. Paper is organized as follows. Section II similar work done using different approach. The detailed methodology and execution is given in Section III. Section IV presents experimental results showing results. Finally, Section V presents conclusion.

II. RELATED WORK

J. F. Paniati and M. Amoni[1] introduced a technique to sense the beam of strobe installed on the top of vehicle by the infrared receiver installed at the appropriate position on the signal bar to make the signal GREEN of appropriate Lane. Whenever a receiver catches the infrared signal of the vehicle, the respective lane is made GREEN. This solution solves reduces significant delays for emergency vehicles at the intersections. But it is useful when there are different lanes on the road for different vehicles as the infrared communication requires line of sight communication.

H. H. Song[2] proposed a technique of the Radio Frequency based method, in which sender sends a signal pre-emption message when it reaches near the traffic signal. But the problem for this method it a lot of latency, user have to manually perform actions to emit the radio frequency. The radio frequency is sensed by the receiver on the intersection which takes appropriate action to make the signal GREEN of appropriate Lane.

J. F. Paniati and M. Amoni[1][3] focused on developing a new pattern of road in the traffic intersection, rather than bringing new technologies to the traffic pre-emption. This system has been tested in VISSIM simulator, which gave 60% less delay to the emergency vehicles. But it will require lots of efforts to convert the pre-existing traffic intersections into the proposed pattern.

P. B. Mirchandani and D. E. Lucas[4] proposed a technique to keep track of vehicle using GPS (Global Positioning Technology), the vehicle's latitude, longitude, speed and heading is constantly tracked by the GPS module installed in the vehicle. As the vehicle approaches reach a particular intersection, a signal is send to satellite and satellite forwards that signal to the reciver intersection. Then a dedicated controller installed near the intersection verifies the heading of vehicle and turns appropriate phase GREEN. This technique is highly effective, but it is very complex as cost associative.

Z.-S. Yang, X.-M. Sun, and P.-C. Sun[5] introduced a technique to give priority to Emergency vehicles near the traffic intersections using Radio Frequency Identification (RFID) technique, in this technique when, the vehicle is sensed when it is few meters away from the traffic intersection. When it is sensed, the RFID sensor sends the message to make the incoming lane signal GREEN to the Phase Selector installed at the intersection. The work of the Phase Selector here, is to control the flow of signal and pre-empt the appropriate lane as per the conditions. This system becomes complex in implementation, especially due to the addition of Phase Selector.

F. A. Marciandò, G. Musolino, and A. Vitetta[6] developed a framework to integrate s signal setting model and a on-the-go (dynamic) assignment models. The signal setting is simulated with various utility models. The signal data was calibrated and validated from real experimental urban evacuations. It portrayed the Decision support system for planning in emergency evacuations to urban transportation.

C. Ma and J. X. Cui[7] proposed an adaptive Traffic Signal Priority system. The new pre-emptive algorithm "Longest Queue First – Maximal Wright Matching (LQF-MWM) algorithm. The performance was measured in VISSIM traffic simulator.

J. Wang, W. Ma, and X. Yang[8] focused, to reduce the impact of emergency vehicles on normal traffic, a degree-of-priority-based control method for emergency vehicle pre-emption operation was developed.

X. Qin [9] introduced a two phase-algorithm for decreasing the response time for Emergency vehicles. The first phase focuses on state of signal and second is based on optimal control algorithm. The model was tested and verified in MATLAB.



T. J. Kimpel, J. Strathman, R. L. Bertini, and S. Callas[10] researched the trip-level data of an ambulance collected from TriMet’s Bus Station at Portland. The study focused on the common performance measures of the traffic signals with context to Emergency vehicles and how to solve them.

III. METHODOLOGY

The working of the system is divided into 3 steps:

1. Detection of Emergency vehicle and signal pre-emption.
2. Sensing of Emergency vehicle when it leaves the intersection.
3. Continuation of the original flow of traffic signal.

1. Detection of Emergency vehicle and signal pre-emption.

To detect an emergency vehicle at a few distance before the traffic intersection, the IR sensor strip is installed within the road. This IR sensor strip will only detect a special encoded IR signal which will be transmitted through the IR transmitter, which is installed on the bottom side of the emergency vehicle. Fig 1 shows the arrangement of IR sensors within the sensor strip.

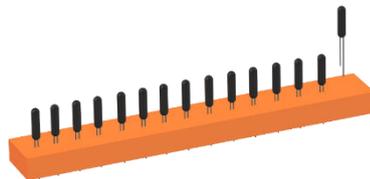


Fig. 1. Arrangement of IR sensors in sensor strip

The sensors are placed in conjunction with each other in order to increase the area of sensing. Fig. 2. Shows the actual position of IR sensors in the strip.

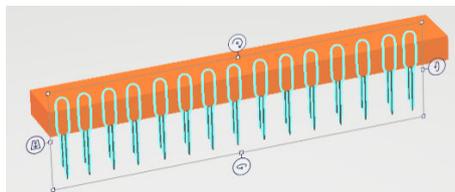


Fig. 2. Actual sensor’s position in strip

In actual implementation, the sensors are placed inside the protective strip within the road. Fig. 3. gives more clarity about the position of sensors on the road.

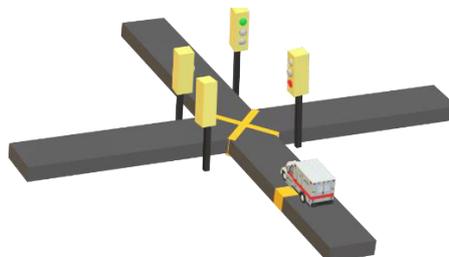


Fig. 3. Actual position of sensor strip on road

In the Fig.3 the yellow strips on road are the IR sensor strips. For demonstration, only one sensor strip is created on the lane, from which ambulance is approaching, but in the real implementation, it is installed on all the four lanes. These IR sensors are connected to the traffic signal controller, which controls the timings of traffic signal. When an emergency



vehicle is sensed, it gives signal to the traffic signal controller to pre-empt the signal and thus, the priority is given to emergency vehicle.

To transmit the IR signal from the emergency vehicle, an IR transmitter is installed on its bottom area. Fig. 4. shows the structure of IR transmitter.



Fig. 4. IR transmitter

It consists of a series infrared LED's which transmits a special encoded signal to IR receiver strips. Fig. 5. shows the actual position of IR transmitter on the emergency vehicle.

IR transmitter

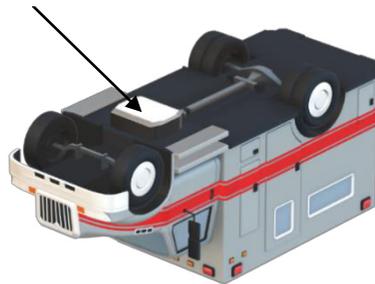


Fig 5. Position of IR transmitter on emergency vehicle

When the emergency vehicle passes above the IR sensor strip, the sensors will sense the infrared light which is being transmitted by IR transmitter from the vehicle and the signal will be pre-empted for the vehicle. Fig. 6 gives more clarity about the above statement.

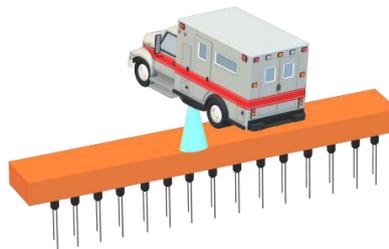


Fig 6. Emergency Vehicle Sensing action

2. Sensing of Emergency vehicle when it leaves the intersection.

Two cross strips of sensors are placed in the middle of the intersection to sense the vehicle when it is leaving the intersection as shown in Fig. 7.

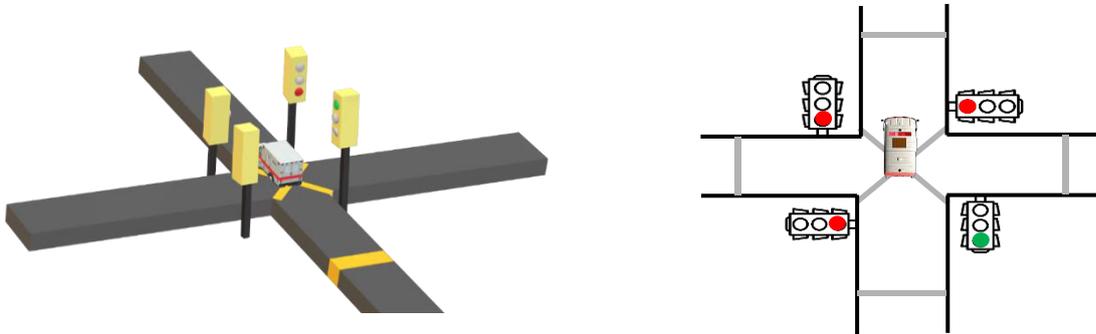


Fig 7. Detection of emergency vehicle leaving intersection.

When the Emergency vehicle is sensed on the intersection, the original flow of signal is resumed.

3. Continuation of the original flow of traffic signal

Once the Emergency vehicle is sensed on the intersection, the original flow of signal is resumed from the same point at which it was pre-empted by the signal controller.

Step by Step Working

The following is the step by step working of the system.

- a. Fig. 8 shows the state of signal before the arrival of emergency vehicle.

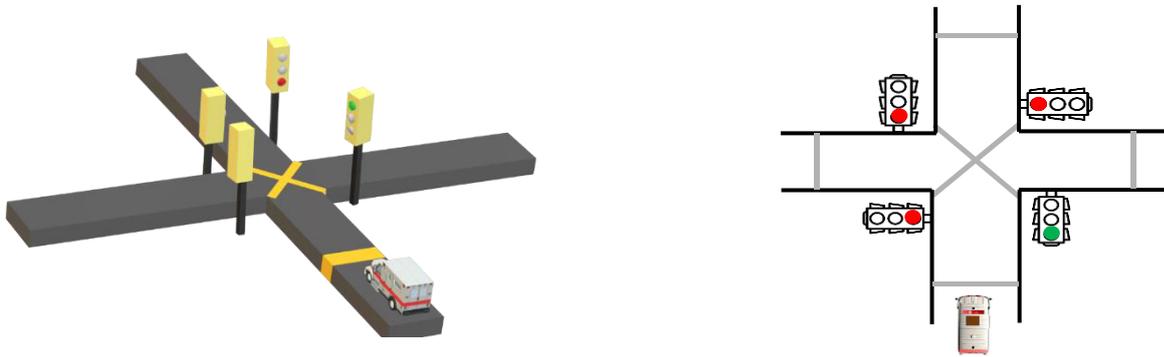


Fig. 8. Signal state before Emergency Vehicle arrival

- b. Fig.9 shows the state of signal at the arrival of emergency vehicle. In this case, the signal is pre-empted.

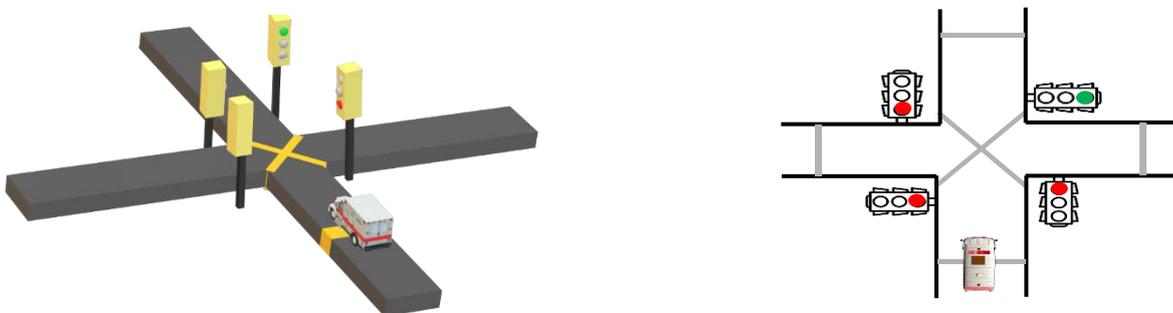


Fig. 9. Emergency vehicle detected by the sensors

- c. To continue the original flow of signal, once again, the vehicle is detected when it is going to leave the intersection by the cross strips of sensors, place on the middle of the intersection shown in Fig.10.

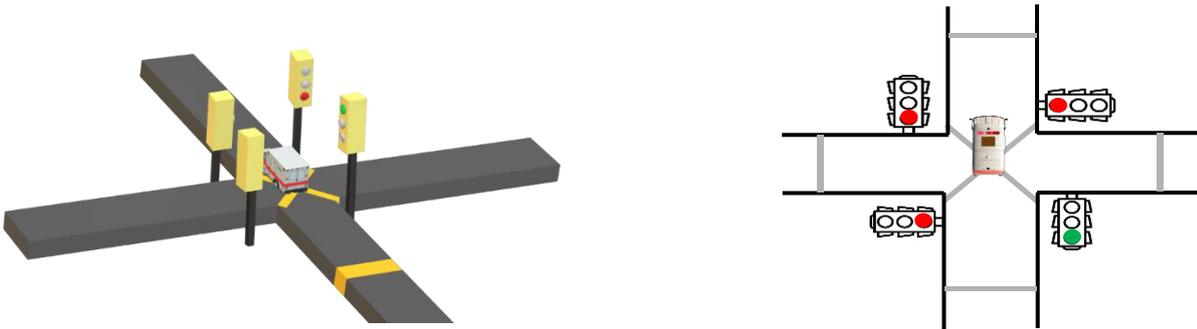


Fig. 10. Resuming the original flow of Signals

IV. PROPOSED SYSTEM ARCHITECTURE

Fig. 11. shows the block diagram of the system. Master is a micro-controller which controls the timing and flow of traffic signal. The surrounding Slaves are micro-controllers which are distributed across 4 lanes of the road. It senses the incoming Emergency vehicles and send signal to Master to pre-empt the respective lane. Amongst the slaves, there is a special Slavewhich is placed beneath the Master. It senses the Emergency vehicle when it leaves the intersection and it is placed in the middle of the intersection.

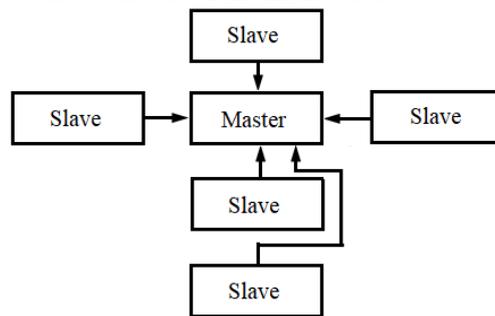


Fig. 11. Block Diagram of System

V. RESULTS AND DISCUSSION

Below figure shows the circuit created of the proposed system in TinkerCad simulator.

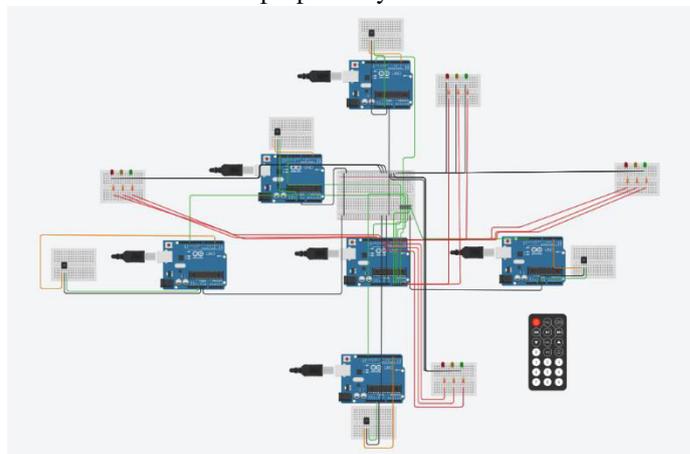


Fig. 12. Circuit in Simulator

In the simulation the GREEN signal sequence will progress in clock-wise direction, starting from top lane.

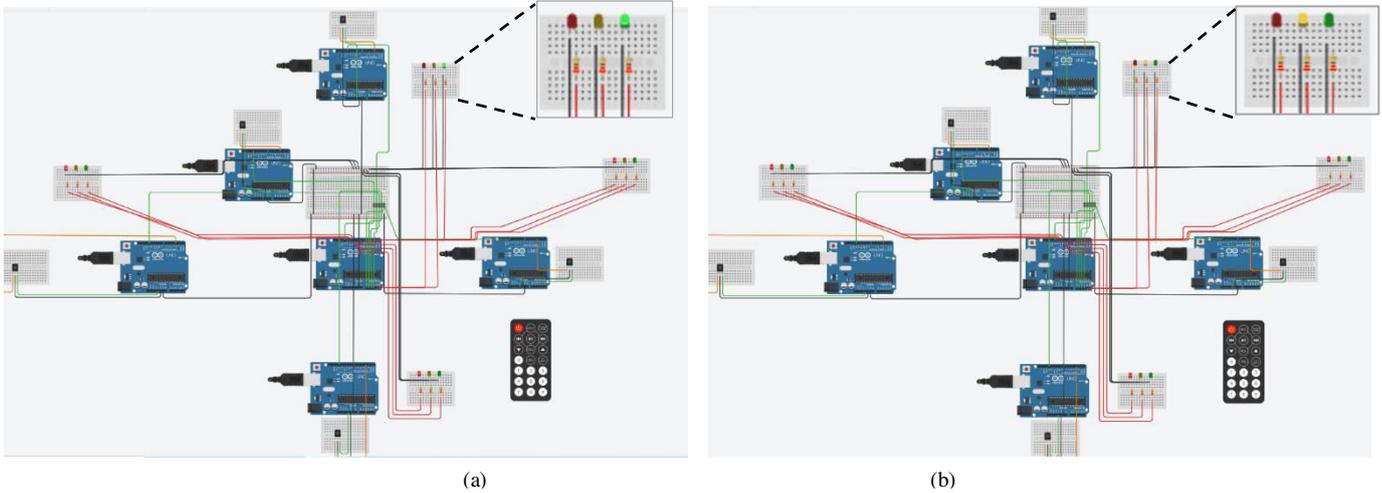


Fig. 13. Normal flow of Signal

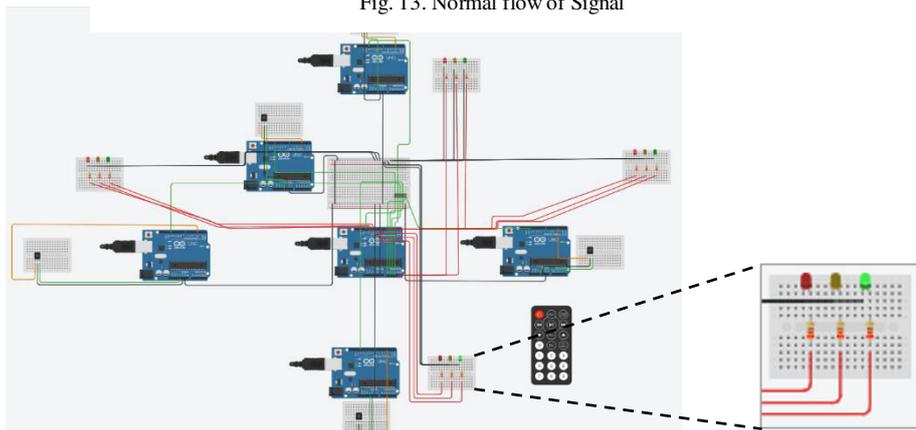


Fig. 14. Bottom signal made GREEN on demand and signal pre-empted

In this simulation IR Remote is used as a transmitter to send the signal and pre-empt the traffic signal. But in actual implementation the IR transmitter will be installed on the bottom of the Emergency Vehicles and whenever they will pass from above the IR sensors, the appropriate lane will be made GREEN and the priority will be given to them.

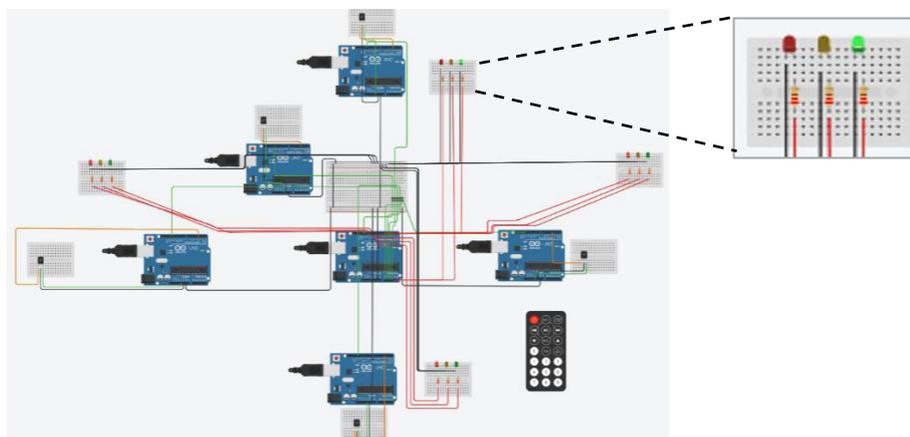


Fig. 15. Top lane made GREEN on demand and signal pre-empted

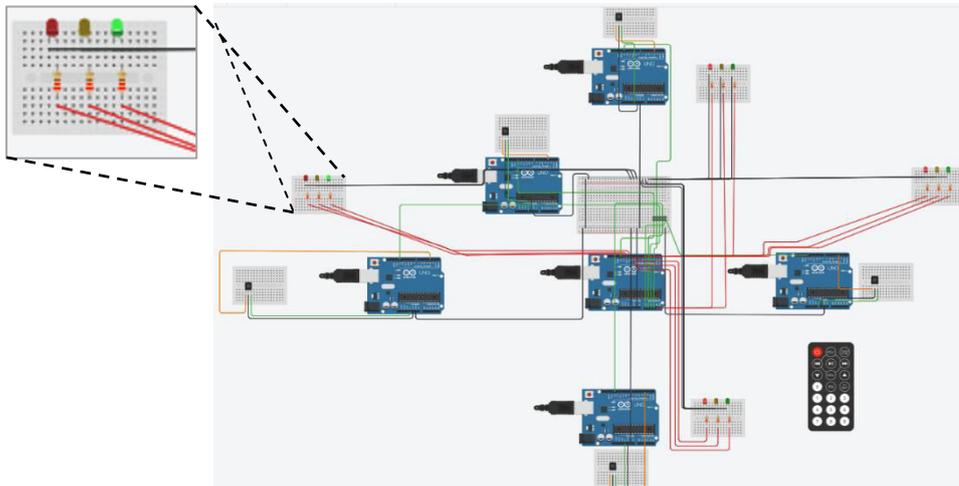


Fig. 16. Left lane made GREEN on demand and signal pre-empted

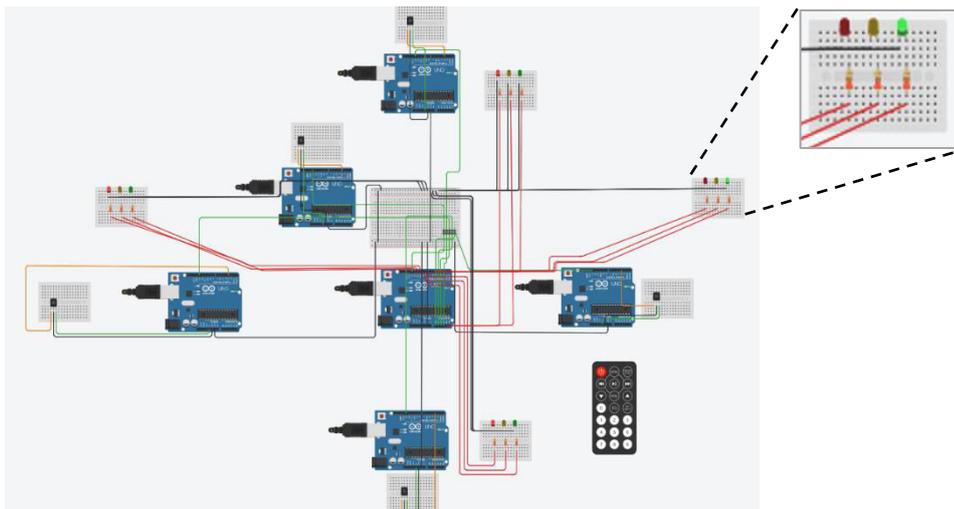


Fig. 17. Right lane made GREEN on-demand and the signal is pre-empted

VI. CONCLUSION

The technique to give priority and reduce delay times to Emergency vehicles in context to traffic congestion is successfully implemented. The prepared system successfully pre-empted the traffic signal and made it GREEN for the Emergency vehicles. The model is tested on TinkerCad simulator, and it successfully controls and pre-empted the traffic signal as per the demand.

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