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Research Article

Revolutionizing Technology Prioritizing Emergency Vehicles in Traffic

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Abstract: The following study brings to the fore a technology exclusively engineered to eradicate the snags and inadequacies persisting in the existing system of traffic control and thus aims to provide a sophisticated operation and uninterrupted course for the emergency vehicles. The traffic in Indian roads has shown a tremendous rise over the years and the conventional pre-timed traffic signals and frequent traffic congestions, delaying the road commuters, have led to outrage and chaos on several occasions. This traffic management system has proved a nuisance for the effective operation of emergency vehicles, with the public adding to the woes, as each driver races along with the signal, unmindful of the emergency vehicles. A life threatening scenario ensues when emergency vehicles get blocked by the traffic, due to inefficient traffic management system and subsequently these emergency vehicles get delayed. The existing system requires manual interruption to guide other vehicles when an emergency vehicle passes through traffic junctions. It is therefore essential to implement a self-regulating and automated system in the traffic signals to facilitate smooth movement of emergency vehicles without posing a danger to other vehicles. The innovative traffic control system devised by us provides a truly dependable alternative to monitoring traffic flow when emergency vehicles pass by.

Keywords: Emergency vehicles, frequency matching, General Purpose Input Output (GPIO), hybrid cloud server, raspberry pi, traffic junction, traffic signals, transmitters

INTRODUCTION

The changing trends in the Indian automobile market over the last decade have added to the aggression of the existing traffic snarls, with more of SUVs and mid range sedans dominating the roads. The existing traffic management system is not equipped to cope with the increasing traffic. In particular, this out-dated system poses numerous problems for emergency vehicles plying on roads. An efficient solution to clear the lane for an emergency vehicle to progress, while approaching a traffic junction, has been discussed. Papageorgiou *et al*. (2003) have illustrated the important reasons for infrastructure deterioration due to traffic congestion. Tzafestas (1999) discusses about the various ways though which an intelligent traffic system detects traffic.

As depicted by Nikunj and Dulari (2013), several techniques for preempting traffic signals when emergency vehicles approach a traffic junction have been proposed. IR (Infra Red) sensors, RFID (Radio Frequency Identification) tags and image processing methods employing cameras come handy for emergency vehicle prioritization in traffic junctions. These systems have several shortcomings. IR sensors should be built robustly and a secure casing is required for it. Reliability issues persist with RFID tags. Image processing techniques are not efficient enough to handle emergency vehicles approaching from two or more directions at the same instant. Integrating these systems with the existing traffic signals is much complicated.

Fundamental principle of operation: In the current traffic engineering scenario, vehicle actuated traffic signals are widely preferred over the out-dated pre-timed signals. This path-breaking technology when incorporated into the existing traffic control system could tweak the traffic signals temporarily, in an absolutely safe manner and facilitate movement of emergency vehicles without any hindrance. As is obvious from Fig. 1, the Raspberry Pi, a small computing device, is the core to this brand new idea. It monitors the presence of an emergency vehicle in the incoming traffic, through frequency detection and subsequent frequency matching techniques. The emergency vehicles like ambulances, fire engines and police cars are fitted with transmitters that emit radio waves of a specified frequency. A receiver is connected to the Raspberry Pi through an Analog to Digital

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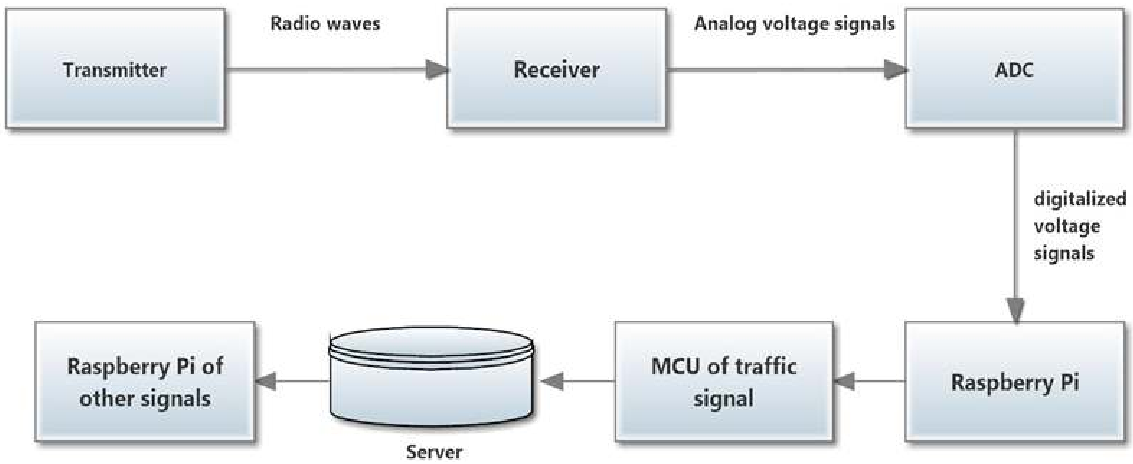

Fig. 1: Process of operation of innovative traffic signal monitoring system

Converter (ADC). The ADC sends the digitalized voltage signals, which is the equivalent of the radio waves incident on the receiver. A software package loaded into the Raspberry Pi via a Secure Digital (SD) card converts the input voltage value to the corresponding frequency value and compares this value with the values contained in its database. Now the emergency vehicle is precisely identified and a high output is generated, indicating a necessity to impose a change in the normal functioning of the traffic signals. The exquisite interface between the microcontroller unit in the traffic signal and the Raspberry Pi makes it possible to override the regular operation of the traffic signals, for the precise time frame.

Objectives of the emergency vehicle prioritizing technology: The technology discussed here provides a simple solution employing an embedded system; it could be efficiently built-in along with the existing system. For new traffic signal installments embedded system could be modeled to monitor traffic as soon as prioritize emergency vehicle, executing necessary algorithm.

According priority to emergency vehicles in the traffic holds paramount importance in executing life saving operations. Apart from clearing the rote and hastening the movement of an accident victim in an ambulance or allowing a fire engine to proceed rapidly to the scene of tragedy, this technology encompasses the potential to instruct the driver if the route he tends to choose is blocked.

MATERIALS AND METHODS

The prototype developed uses the Raspberry Pi with Internet access as a processing unit. The main aspects of this innovative traffic signal monitoring system as illustrated in Fig. 1.

Transmission and reception of radio waves: Emergency vehicles that need to get ahead of the tortuous traffic have to be fitted with transmitters that emit radio waves of a pre-defined frequency. Every traffic signal would have a receiver to receive signals from the vehicles approaching it at a distance of 50 m apart. The time taken to cover this distance allows the signals to change to amber before turning red. The receiver should be positioned such that it receives signals from only one direction. After receiving the radio waves, the receiver sends it out as voltage signals.

Analog to digital conversion: Since the Raspberry Pi can process only digital signals, the analog signals from the receiver are changed to digital form using an ADC having suitable sampling rate.

Frequency matching: The process of frequency matching is an exclusive function of the Raspberry Pi and the software in Python platform loaded into it. The Raspberry Pi is a computing device, the size of a credit card and contains an ARM (Advanced RISC Machine) processor (Matt and Shawn, 2012). It has all the essential peripherals found in any regular computing device. This innovation requires the internet for data transfer. Model-B version of the Raspberry Pi is used as it has an Ethernet port in it. However, Wi-Fi is accessible in both Model-A and Model-B. Ethernet is preferred to Wi-Fi due to security issues. The software has a pre-written database of the value of frequency emitted by the emergency vehicles. The ADC is connected to one of the GPIO (General Purpose Input or Output) pins. These GPIO pins can be configured to read an input or give an output. This value in the input pin is read by the software, compared with the value in the database and finally decision is made. If the frequencies match, an output pin (again a GPIO pin) gives a "HIGH" output or a "LOW" output on a case by case basis, filtering out the emergency vehicles caught in the convoluted traffic. It is quite essential to ensure that the frequency of radio waves emitted by the

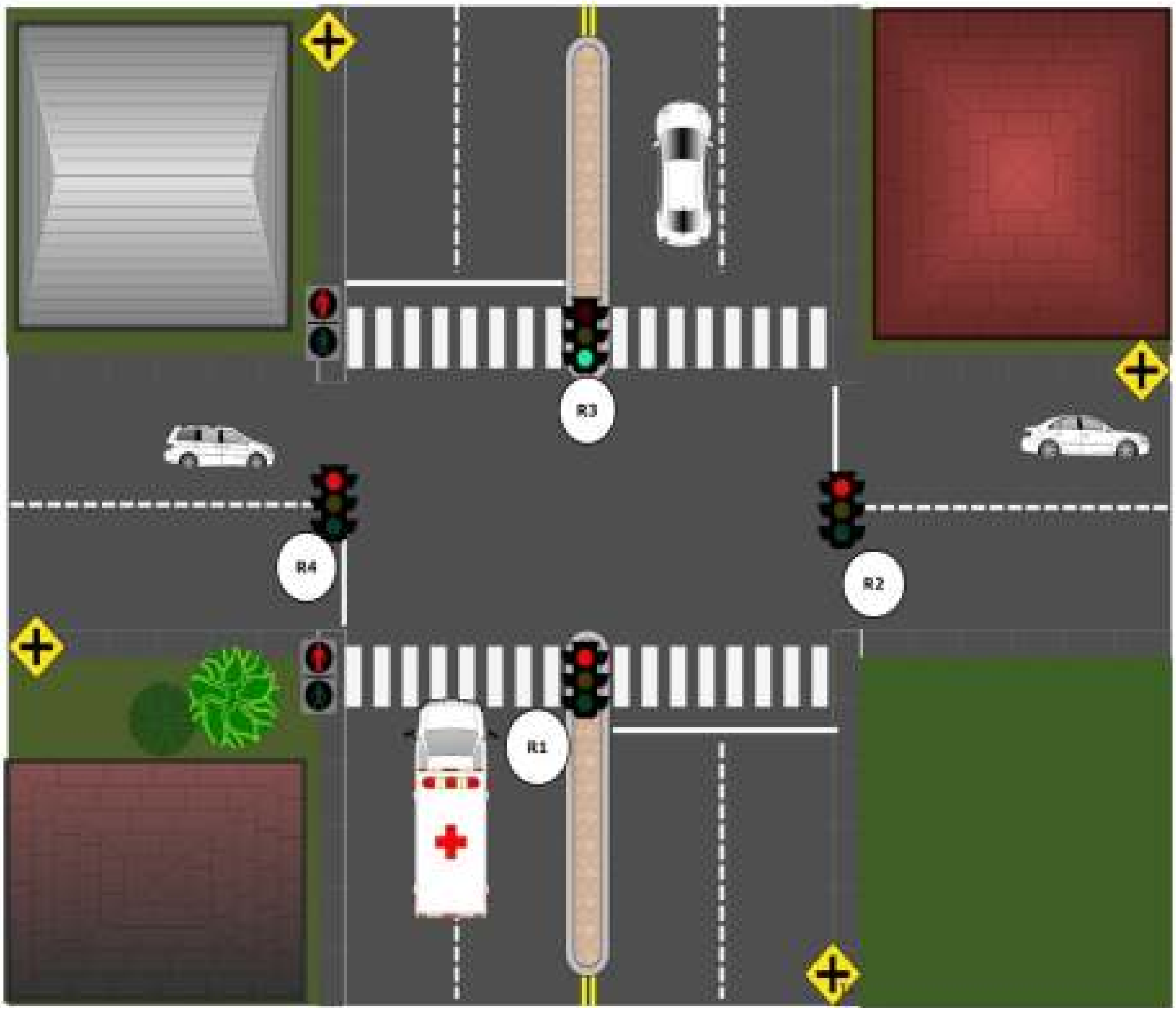

Fig. 2: Colour change in traffic signal

emergency vehicles is not mimicked by any other source in the traffic.

Internet enabled data transmission: The server receives data from the Raspberry Pi and after processing, the server sends processed data to the Raspberry Pi units of the other traffic signals. The data from the output pin is transferred to a central server, preferably a hybrid cloud server. The server carries the output to the Raspberry Pi units of the other three traffic lights. "LOW" output does not affect the functioning of the traffic lights. "HIGH" output acts as an interrupt signal to the microcontroller, that is, the microcontroller stops its original function to carry over a function indicated by the interrupt signal. The server also facilitates communication with the next set of four traffic signals in the emergency vehicle's route. This could help in notifying the driver of the emergency vehicle if the route he chooses is heavily jammed and in clearing the next junction prior to the arrival of the emergency vehicle. This should be supported by an input provided from the emergency vehicle's starting point regarding the vehicle's destination and preferred route. A hybrid cloud server leaves part of the server in public domain while a part of it is privatized. This part in public domain is where information about the emergency vehicle's destination and route could be entered. Strictly speaking, this is not to be accessed by the entire public, but only by authorities in the emergency vehicle's starting point. The privatized data is to be handled by the traffic control authorities and has highly sensitive data in its domain like the time for which the signal is to be green and the logistics of the traffic signal operation.

Color change in traffic lights: Consider a junction where four roads R1, R2, R3 and R4 meet. Assume an emergency vehicle approaching the junction along R1. The signals are fitted as depicted in the adjoining Fig. 2. R3 is opposite to R1 and the signal near R3 has its lights facing R1. Therefore, the drivers on R1 are controlled by the signal near R3. But it is the signal near R1 that would detect the radio waves emitted by the emergency vehicle. When the microcontroller of the signal near R1 receives the interrupt signal, it goes red after turning amber for a few seconds and stops vehicles on R3. The server has data about the location of the signals and it detects the signal (here the signal near R3) directly opposite to that signal (here the signal near R1) which initially sent it information. The signal near R3 turns green allowing drivers from R1 to continue movement. The other two signals on R4 and R2 turn red after a short stint of turning amber. The first signal whose receiver detects the radio waves goes red by default. The color change of the other three signals would be as per instructions from the server. For instance, the Raspberry Pi of the opposite signal is instructed by the server to suitably instruct to interrupt the microcontroller unit of that signal to turn green. The logistics for color change in traffic lights might vary depending upon the positioning of the signals on the roads and has to be worked out accordingly.

DISCUSSION OF THE SOLUTION ARCHITECTURED

Simple algorithm: Faye *et al*. (2012) and Al-Nasser and Rowaihy (2011) have discussed the problem of controlling traffic lights with wireless sensors at the intersection. A simple software package would suffice to handle the intricate logistics of traffic signal monitoring. The software developed for the prototype is based on Python platform which is best suited for the Raspberry Pi. An "if…else" condition holds the entire essence of the software. For practical applications, when the Raspberry Pi is replaced with a PIC microcontroller unit, an equally easy algorithm could be utilized to develop the required software.

Controlling more than one emergency vehicle at the same instant: Consider a situation where there are two emergency vehicles approaching a junction, there will be a time lag between the receptions of radio waves from the two emergency vehicles by the two receivers (Faubion, 2011). The receiver which is first to receive the signal, responds by transmitting data to the server and the server apart from sending processed data to the microcontroller units of the traffic signal, it also stops the other Raspberry Pi units, except the one connected to the receiver that was first to respond, from making any further responses even when they detect a frequency match, until the first emergency vehicle passes through. However, after the first emergency vehicle crosses the junction, the traffic signals are not allowed to resume normal functioning, as they have to handle the interrupt signal produced by the now responding Raspberry Pi, which matches the frequency of the second emergency vehicle in the traffic. Under no circumstances would two receivers receive radio signals simultaneously without any time lag, thus avoiding any needless panic and confusion. A time lag of the order of just a few milliseconds would be enough to execute this wonderful arrangement without errors. The algorithm is shown in Fig. 3.

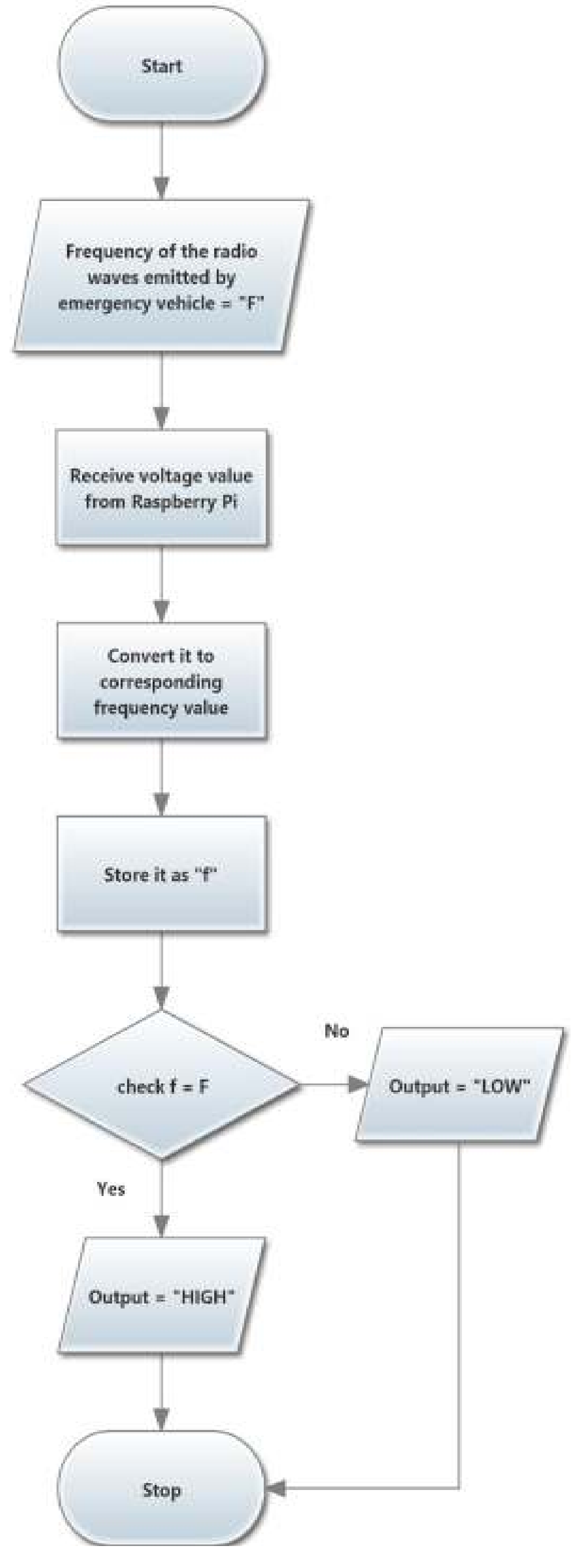

Fig. 3: Algorithm

Effectiveness of the hybrid cloud server: Like any other cloud server, the hybrid cloud server has several advantages over the physical sever. It handles the data and logistics efficiently and the traffic authority need not spend more time and money in the technical aspects of the server. Choosing a hybrid platform privatizes and keeps secure the highly sensitive data while it also allows data to be entered from the emergency vehicle's starting point.

TECHNICAL HINDRANCES

Weather vs. radio waves: As with all electromagnetic waves, moisture content of atmosphere also has an adverse effect on radio waves. Rain drops act as poor dielectrics and absorb power from the radio waves and then dissipate it in the form of heat loss. This effect is highly prevalent only in frequencies of the order of gigahertz.

Effective implementation and further economizing: The prototype of the frequency based emergency vehicle prioritizing system makes use of the Raspberry Pi, for ease of internet access through its Ethernet port and for connecting a Wi-Fi dongle via one of its two USB (Universal Serial Bus) ports. Internet access is required for the traffic signals within the same junction and those at other junctions to communicate with each other through a hybrid cloud server. This technology is truly effective and absolutely dependable, but the $50 price tag of raspberry pi could come as a bit of a dampener for the cost conscious. As a viable alternative solution the Raspberry Pi could be replaced with a simple PIC (Peripheral Interface Controller) microcontroller unit and the necessary circuitry for frequency detection could be incorporated, with the software written in the microcontroller unit assisting it in frequency matching.

Internet access: Wireless data transfer is the order of the day. Wi-Fi signals could be effectively used to access the internet using the Raspberry Pi. The security hassles prevailing in Wi-Fi signals render it unfit for such sensitive uses. So, as an alternative Ethernet cables have to be connected to the Raspberry Pi, that facilitate internet access.

FUTURE DEVELOPMENTS

Single microcontroller unit-all operations: Instead of a using a separate embedded system like the Raspberry Pi or the PIC microcontroller unit to prioritize emergency vehicles and accordingly control traffic lights, a single microcontroller unit that regulates the traffic lights both in the presence and absence of emergency vehicles could be used. Internet access could be provided to this microcontroller unit by utilizing an inbuilt Ethernet port or by connecting extra peripherals to plug-in an Ethernet cable. This microcontroller unit could also be originally installed in the traffic light system. Kothari *et al*. (2012) and Sawhney (1987) explains the basics of the embedded systems.

Vehicle actuated traffic signals: The discussed technology has the potential to only change the cyclic operation of the traffic signals when an emergency vehicle is found in the traffic. Vehicle actuated traffic signals can remove pre-timed signals from the scene. Here, the timer would be set each time depending upon the traffic density. It could be implemented by fixing IR (Infra Red) sensors and simple counters along roadsides and the counter could transmit the traffic density data to the microcontroller unit of the traffic signal via internet.

CONCLUSION

The innovative technology briefed here is quite efficient in detecting the presence of an emergency vehicle in the traffic. The suggested technology is simple enough to be adopted and could be easily incorporated in the existing traffic control systems. The logistics have been clearly worked out for all possible scenarios like the presence of more than one emergency vehicle approaching the junction. Simple improvisations like placing IR sensors along with counters could impose a remarkable effect on the entire traffic control system that could eventually make way for an advanced vehicle actuated traffic control system. This technology has the potential to make emergency vehicles operate with ease and put an end to traffic congestion on roads.

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