PRIORITY VEHICLE MANAGEMENT SYSTEM FOR URGENCY BASED SERVICES USING RFID TECHNOLOGY

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ABSTRACT
When it comes to urban traffic and different complex situations on the road, it is observed that these situations occur due to huge increase in the number of vehicles, fixed time signals and unruly vehicle drivers. Besides it there is a requirement of making special arrangements for priority vehicles and parked vehicles on the road without disturbing the usual traffic. There are some initiatives taken up currently by the traffic authorities, but still the different systems developed for handling different complex traffic situations do not work in unison. In this paper the design and development of a Priority Vehicle Management System (PVMS) is proposed to handle lifesaving emergency services or urgency-based services. PVMS is an automatic intelligent real time system which detects the presence of an emergency vehicle at the traffic signal and provides immediate access to the priority vehicle such as an ambulance, fire brigade, the police van, and the VIP (very important person) vehicle. The proposed solution is based on multistage decision-making approach where events occurring at different stages are unknown, but probabilities of occurrence of events are known. For practical implementation a shortrange RFID (Radio frequency Identification System) system is used. Priority algorithm and mission critical option table are used for decision making if more than one priority vehicle is detected. The proposed work is complete in all the respects for all the traffic situations.
Keywords: PVMS (Priority Vehicle Management System), Multistage decision making, Priority level, RFID (Radio Frequency identification System), RFID Tag/Transponders, VIP (Very important person)

Introduction

Global presence of ITS (Intelligent Traffic-control System)

(Manduca, 2013) EU directive 2010/40/EU defines Intelligent Traffic-control Systems (ITS) as systems in which information and communication technologies are applied in road transport. (Kim, 2014) Intelligent Traffic-control Systems are advanced applications which aim to provide services like different modes of transport, traffic management, access to better information of transportation networks for safe and more coordinated journey. Many countries have implemented ITS to manage the traffic using various technologies.

Intelligent Traffic-control Systems in India

Cosi Cost (Composite Signal Control Strategy), SCOOT (Split Cycle offset Optimization Technique) and ITACA (Intelligent Traffic Adaptive Control Area) have been implemented in India to control traffic at various traffic junctions (Mahavir, 2018), (Dadra, 2016). Though the introduction of flyover bridges or the government initiatives on the restriction of the number of vehicles on the road, “Connecting India like never before” under Bharatmala project by MoRTH (The Ministry of Road Transport and Highways) with a budget of Rs. 5,35,000 crores started in 2015(Malik, 2018), still the problem of congestion is not solved completely. Hence, there is a necessity to develop technologies for automated ITS which will make the existing road infrastructure more efficient and improved traffic conditions. Such technologies should be capable of sensing the real – time vehicle movement on the road automatically. Hence in this paper researcher has suggested the RFID enabled PVMS.

Literature review

A lot of research work is being carried out nationally and internationally in the field of traffic signal systems by using various technologies like RFID technology, GSM, network sensors etc. Various research papers, reports and books on the intelligent traffic management system, traffic management system for emergency services using various technologies are studied. The review of various studies in the same area is given below:

(Kapoor, 2017) monitors the patient’s various health parameters such as heart rate, body temperature, blood pressure and blood level are sent to the hospital using the onboard GSM unit. All these parameters are displayed in the hospital unit on a computer with the help of visual basic s/w. Simultaneously, if at all the ambulance encounters the traffic jam in the route, the driver is provided with the remote to control the traffic signals. The signal is made green for some time and after the ambulance passes by it again regains its original flow of sequence of signaling. In this paper control is in the hands of the driver to make the signal green which is not good. (Anand, 2014) and (Moje, 2016) provide an easy way for the ambulance by controlling the traffic lights and providing an optimized route based on its location. It uses sensors in the vehicles to convey location of accident to central system. The system (Balamurugan, 2015) acts as a life saver by establishing communication between traffic signal and ambulance by using required bandwidth and makes freeway for the ambulance. (Kale,

2013) and (Chavan, 2009) make use of sensor n/w and controls the Traffic Signal based on total traffic. This system increases road capacity and prevent traffic congestion. (Tank, 2015) uses sensors to detect emergency vehicle and provides an easy way to the ambulance by controlling the traffic signal. This project uses GPS to track automobile and sensors to monitor various health parameters such as pulse rate and body temperature and are sent to the hospital using the on-board GSM unit. (Walyekar, 2016) uses GPS to track automobile and sensors to monitor various health parameters such as pulse rate and body temperature and are sent to the hospital using the on-board GSM unit. The Department of Electronics & Information Technology in collaboration with CDAC is also working on projects such as Wireless Traffic Control System, The Real Time traffic Counting & Monitoring System, The Intelligent parking lot management System and RFID Based Congestion management system.

(Nellore, 2016) presents a survey of the current urban traffic management system for priority signaling to minimize traffic jams and waiting time of vehicles. It uses wireless sensor network to monitor traffic. Traffic is monitored by sensors by measuring various traffic parameters. The main node compiles the traffic data received from other nodes and data is passed to the traffic control system which takes appropriate action. This paper also discusses key issues in urban traffic management.

(Nellore, 2016) designs an intelligent urban traffic management system for emergency vehicles to save lives. It identifies the presence of the priority vehicle by the sound of the siren and calculates the distance of priority vehicle from the intersection by using Euclidian formula. It also senses the density of traffic by taking pictures. It sends a message to the middleware to control the signal as per traffic and calculates the delay time of priority vehicles.

(Bhardwaj, 2013) proposes a system using RFID Readers as roadside units which reads the unique ID of the emergency vehicle and passes it to the monitor unit. The monitor unit uses sensors to count normal vehicles and sends the information to the control unit. The control unit compares the count of vehicles at different lanes and changes the signal accordingly.

(Hegde, 2013) An RFID and GPS based system to provide a clear way to Ambulance and helps it to reach its destination. It detects the presence of the ambulance and clears its way by turning the signal to green. This paper makes use of RFID and GPS to track the ambulance and communication between the ambulance and the traffic signal.

In most of these research works, the traffic signals are controlled depending upon the volume of the vehicular traffic and the problem of the priority issue is not dealt in detail. For example, at a two –way road if two lifesaving emergency vehicles arrive at the same time, then which of the vehicle will be allowed to pass first. The same is the case at a four-way junction, if four lifesaving emergency vehicles arrive at the same time then, which of the vehicle will be allowed to pass first. The proposed research work first detects the lifesaving emergency vehicle wirelessly, and then control the traffic signals to provide quick, easy, and fast access for these lifesaving emergency vehicles.

Objectives of the study

1. To create the information system of the traffic along with the roads, signals, vehicles, emergency services, etc. and identification of priority vehicles.
2. To develop a system which can provide a quick and easy access for Life saving emergency service vehicles during traffic jams so that they can reach their respective destinations as early as possible.
3. Priority scheduling in case of two or more priority vehicles.
4. Keep record of services provided to the priority vehicles.

Secondary Data Analysis

Various latest technologies to be used to develop Intelligent Traffic System are Wireless and Wire line communication-based information and electronic technologies, GPS and GPRS, CAN-bus interface for communication and Radio Frequency Identification (RFID), Radar, Lidar & CCTVs, and video image processors. Capabilities of these technologies combined with Transportation System make them "Intelligent". Radio frequency identification system fulfills all the technical requirements of current research, hence is studied in detail.

RFID Technology

Radio Frequency Identification (RFID) is a system that uses radio waves to retrieve data from a device called a tag or a transponder (Lee, 2007). It is a contactless technology used to identify tagged objects/devices/vehicles/exhibits at any time and any place without line of sight. This technology is currently being used extensively in many countries for industrial applications, animal tracking, supply chain management, hospitals to keep records of patient history, at airports to keep track of luggage/baggage, to collect the toll at toll plazas, bus passes, railway tickets, passports, currency notes, and at many other applications.

Components of RFID technology consists of RFID Tag, Reader (RF Antenna & RFID Reader), Workstation (Processor or PLC). RFID tags are attached to the objects to be identified.

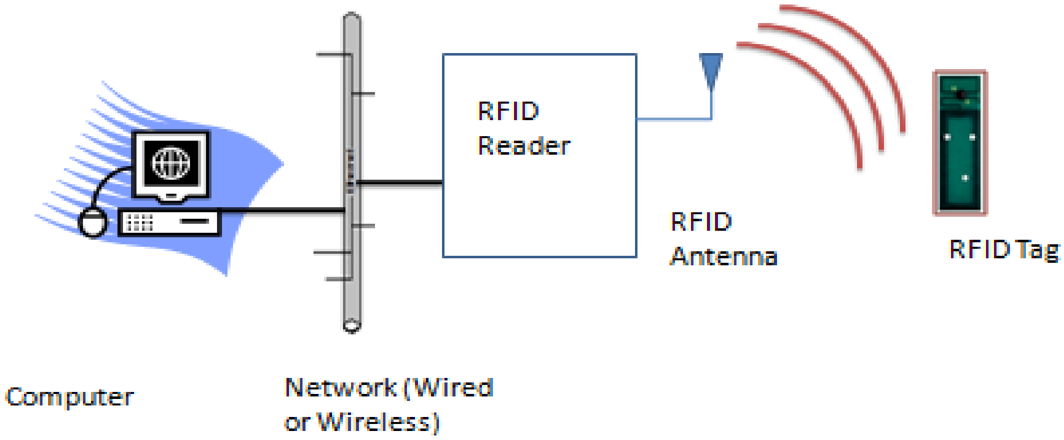

Figure 1: Components of RFID (Source: Generated by the researcher)

Tags can be classified as

A. Active or Passive. An active tag has its own battery and periodically transmits its ID. Passive tags don't contain any internal power source and are cheaper and smaller. They are activated when they come in the range of RFID system. Tags come in various sizes and shapes.
B. Tags may either be "Read-Only" or "Read/Write".
C. Tags can be classified as Generation-1 and Generation-2. They can also be classified as class0 through class5, depending upon their functionality (Schuster, 2015).
D. Tags can also be classified based on frequency ranges as Low (30 to 300 KHz), High (3-30 MHz) and Ultra High (300-3Ghz) frequency.

RFID readers and reader antennas work together to read tags. Reader antennas convert electrical current into electromagnetic waves that are then radiated into space where they can be received by a tag antenna and converted back to electrical current. There is a large variety of reader antennas. The optimal antenna selection varies according to the solution's specific application and environment. The two most common antenna types are:

A. Linear antennas that radiate linear electric fields have long ranges, high levels of power which enables their signals to penetrate through different materials to read tags. Linear antennas are sensitive to tag orientation; depending on the tag angle or placement, the linear antennas can have a difficult time reading tags (Geoffro, 2015).
B. Circular-polarized antennas that radiate circular fields are less sensitive to orientation, but are not able to deliver as much power as linear antennas.

The choice of antenna is also determined by the distance between the RFID reader and the tags that it needs to read. This is read range distance. The reader antennas operate in either a "near-field" (short range) or "far-field" (long range). In near-field applications, the read range is less than 30 cm, and the antenna uses magnetic coupling so the reader and tag can transfer power. In near-field systems, the readability of the tags is not affected by the presence of dielectrics such as water and metal in the field (Geoffro, 2015). In far-field applications, the range between the tag and reader is greater than 30 cm or up to several tens of meters. Far-field antennas utilize electromagnetic coupling and dielectrics can weaken communication between the reader and tags.

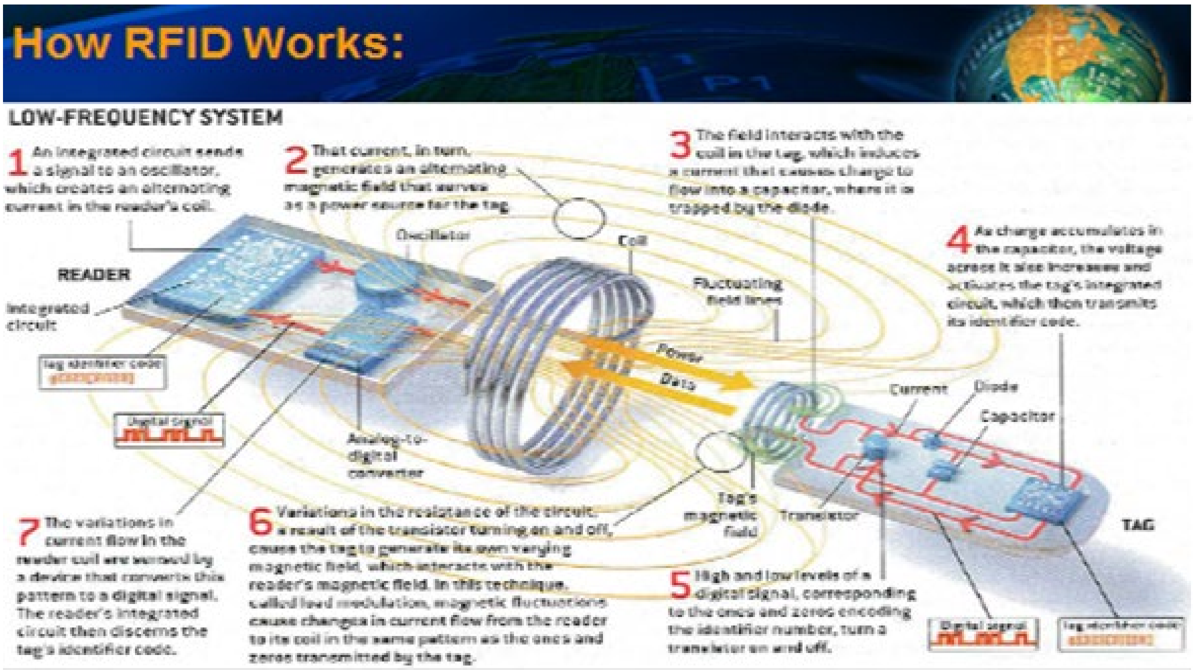

Figure 2: The working of RFID system (Source: Rafael Kleiman, Canada Research Chair in MicroElectroMechanical Systems, and professor of engineering physics)

The RFID Reader must be initialized and programmed with the application software which is known as the middleware. The main use of this middleware is to connect the RFID readers with the application they support. The middleware sends control commands to the reader and receives tag data from the reader. This process is carried out by the workstation. Depending on the application the workstation is a PC (Personal Computer), a PLC (Programmable Logic Controller) or Processor.

Methods and Materials

Research Methodology

The research methodology chosen here is action research. Action research is a generic term which covers the action-oriented research where the researcher wants to help authorities to improve certain conditions, identified as unsatisfactory by the people at large. The aim is not only to discover the facts but bringing about change in the existing system. There are four types of action research (AR): Diagnostic AR, Empirical AR, Participatory AR, and Experimental AR. To address the problem of developing "Priority Vehicle Management System", the following step by step method is used:

1. Diagnosis of existing traffic system.
2. Planning of how to regulate the traffic and provide priority to emergency priority vehicles.
3. Model real time traffic by experimental setup.
4. Development of software using radio frequency identification system.

The Description of PVMS

We propose to build a Priority Vehicle Management System to provide quick and easy access for life saving emergency services (for example, ambulance, fire brigade, the police van and VIP vehicles) and other priority vehicles with the following assumptions:

1. All the vehicles should be issued RFID Tags with a unique Identification number.
   A. This unique identification number should be e.g., the chassis number of the vehicle.
   B. Priority vehicles need to be registered with authorities as a priority vehicle and its type. This data should be saved in the database.
2. Data about vehicles and owners of vehicles should be saved in the database.
3. The connectivity to the Geographical Information System of the roads.
4. Rules for fine should also be defined so that.
   A. The nonpriority vehicle not giving the way to the priority vehicle should be fined.
   B. When priority and non-priority vehicles are moving together, the nonpriority vehicle should get the message to slow down the speed otherwise it will be fined.

5. We can have two types of lane systems on the roads: Static and Dynamic
   A. Static: Wherever there is space a separate lane can be marked for emergency vehicle. Any non-priority vehicle entering in the reserved lane should be penalized automatically
   B. Dynamic: Wherever space for the separate lane is not there, roads will be shared by priority and non-priority vehicles. On arrival of priority vehicle nonpriority vehicle should give way to priority vehicle otherwise they should be fined.

The Building Blocks of PVMS

PVMS is an automatic system which detects the presence of an emergency vehicle at the traffic signal and provides immediate access to the priority vehicle, such as an ambulance, fire brigade, police, and VIP. It is mandatory for priority vehicles to set the Mission Priority before starting the journey on the road. The traffic flow and traffic density on the road is unpredictable. Hence, it gives rise to situations of uncertainty, risk, and conflict, where decision making is based on attitude/perception of the decision maker. Here the signaling system will be an authority that needs to be programmed to make decisions as per Decision Theory Making choices.

A Multi-stage Decision Making (Composite Decision Making) approach is used where events to occur at different stages are unknown, but probabilities of occurrence of events are known. The most appropriate tool for this decision making for intelligent priority management is "Decision Tree". It exhibits all the decisions, all the situations, weights associated with situations and all the effectiveness measure values associated with decisions/situations.

Decision Theory based Priority Vehicle Management System

- Acts are changing of signal by the decision-making algorithm depending on the value of parameters of actions.
- Events are arrival of the priority vehicle with attributes as Priority Vehicle code, vehicle priority level, patient priority in case of ambulance and mission priority in case of the fire brigade, police and VIP and arrival time of priority vehicle at a Signal.
- The Outcome: Signal is made green for priority vehicle for which final decision value is maximum.
- The Payoff: The best possible time to reach to the destination.

Decision Tree is a graphical representation of various alternatives and sequence of events of priority vehicles. It consists of nodes and branches as shown in figure 3.

A. The nodes are of two types:

(1) Decision or Act node: □

(2) Chance or Event node: ○

B. Branches are of two types:

(1) Main branches: They denote the strategies (Courses of action) originating from decision node. At the end of every main branch there is a chance node.

(2) Subbranches: They denote the chance events emanating from the chance nodes. At the end of each subbranch expected value of the outcome is shown.

C. The respective payoffs and probabilities associated with alternate courses of actions and chance events are shown along the subbranches.

D. If branches emanate from a chance node, the total expected payoff is calculated by adding up of the expected values of all the subbranches. Branches originating from the decision node, the expected return is calculated for each of its branch and the highest return is selected as shown in the figure.

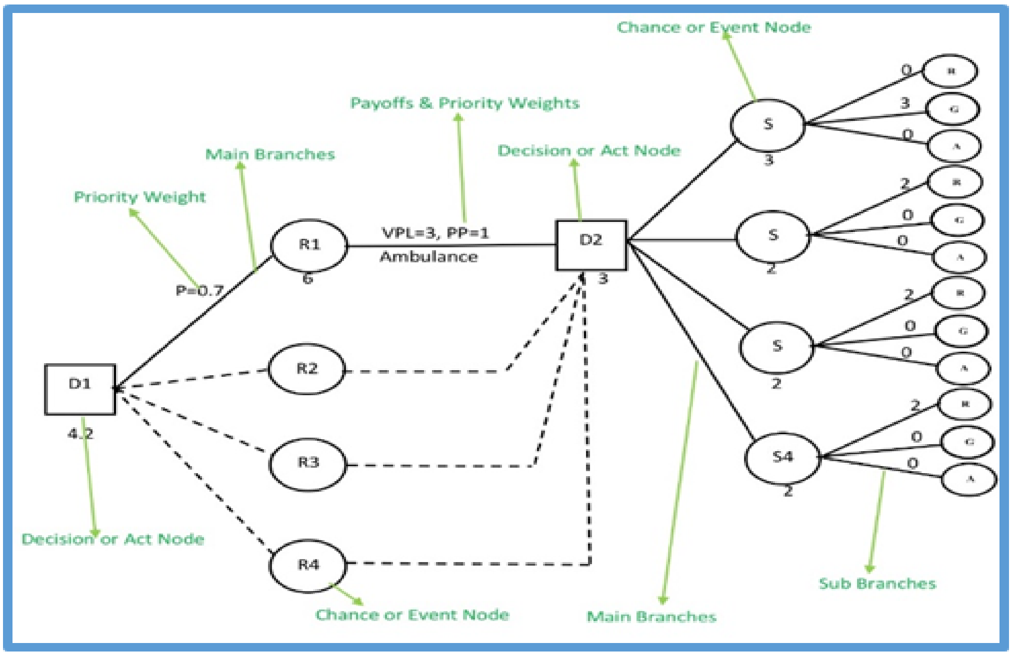

Figure 3: Decision Tree Model (Source: Generated by the researcher as per decision tree model for PVMS)

Working of PVMS
Following are the steps in construction of a decision tree.

Decision Tree (Decisions (D1, D2, D3, ……Dn), Events (E1, E2,……En), Prob., Payoffs)		
{		
	Step 1	Identify all the decisions and their order and the events for every decision
	Step 2	Draw the tree diagram with the sequence of decisions and chance events, the tree starting from the left and moving towards right, decision node, chance node for events
	Step 3	Find probability estimate of chances of each outcome's occurrence
	Step 4	Find estimates of chances of all possible outcomes and actions
	Step 5	Calculate the expected value of all possible actions
	Step 6	Select the action offering maximum possible expected value
}		

Table 1. Steps in Construction of a Decision Tree

After drawing the decision tree, analysis can be done by using the Back Tracking/Roll Back technique as follows:

1. Start from the end of the tree and move backward.
2. For each set of event branches calculate Expected value and select highest one
3. Repeat step 2 and keep moving back in the decision tree from one decision node to the preceding decision node, and so on till we reach the root decision node.

Rules to Calculate Payoffs:

a) Branches originating from a circle i.e., an event node, total expected payoff is calculated by adding up the expected values of all branches.
b) Branches originating from square i.e., node is a decision node, the expected return of each branch is calculated, and maximum highest return is selected.

Hardware Software Requirements for PVMS
A. Hardware Requirements (Considering a four-legged intersection)

- The Installation of RFID Readers capable of reading multiple tags on all the four approaches of roads of the intersection before Traffic signals.

- The Installation of Intelligent Control System using Embedded Computer
- Communication between the Control System and RFID system using the wired /wireless method.

B. Software requirements

- Installation of decision-making algorithm on Control System
- Communication between RFID System, decision making algorithm and the signal controller.
- Set up of the database.

C. Experimental setup

PVMS is developed using RFID reader and Smartcards of MIFARE along with LabVIEW 2010 to develop the middleware.

Architecture and Working Principle

The architecture of PVMS is given as below:

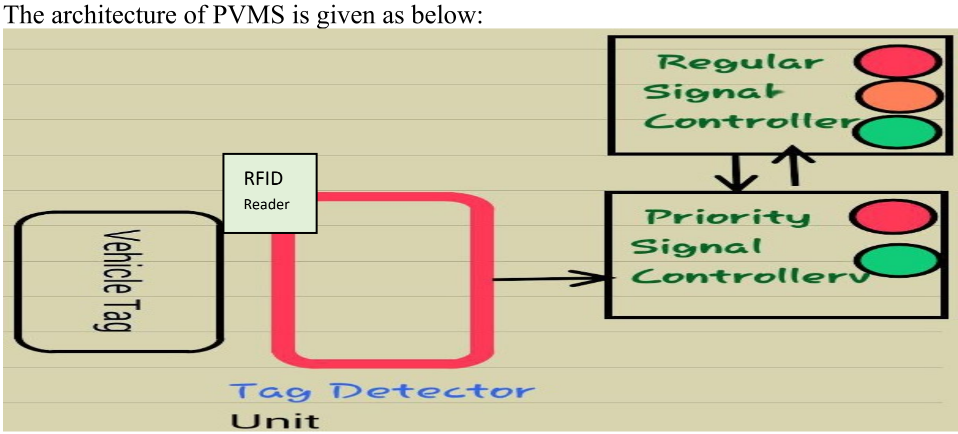

Figure 4: Architecture of PVMS (Source: Generated by the researcher)

Working Principle is based on the following the assumptions:
1. Normal vehicles and priority vehicles have a separate lane.
2. There are 2 separate signal controllers for regular and priority vehicles. The controllers communicate with each other and can be disconnected for maintenance and up gradation.
3. Priority vehicles approaching the detectors when detected, the priority controller takes over and signals the regular signal controller to switch to ALL RED mode till all the priority vehicles are cleared.
4. Priority algorithm is used for decision making if more than one vehicle is detected till all priority status is exhausted, on the first come first basis.
5. When switched over from priority to regular controllers it is simple resuming of the last state of regular controller state from where it has stopped.

As mentioned in assumptions, priority vehicle will be issued RFID tag with pre-written UID (Unique Identification Number) and registered with the Road Traffic Office as a priority vehicle. UID will be the chassis number of the vehicle (In the present scenario the database maintained by the Traffic Authorities UID and Chassis number are different). In case of Priority Vehicle, a priority code is assigned as per the table 1 and is

saved in the database. Tables 2, 3, 4 and 5 show various priority level values and priority weights.

The Type of Priority Vehicle	**Priority Code (PC)**	**Vehicle Priority level (VPL)**
VIP	01	1
Police	02-03	2
Fire Brigade	04-07	3
Ambulance	08-10	3

Table 2. Vehicle Priority Code & Priority Level

All the vehicles providing emergency service are assigned a priority code and vehicle priority level as mentioned in the table 4.1. Priority Code is required to identify the emergency vehicles and priority level values are assigned to provide priority over other vehicles. More the value more the priority level. The weights assigned for the simultaneous occurrence of priority vehicles is as given in table 3.

No. of Priority Vehicles	Priority Weight(P)
E1: No priority vehicle	0.05
E2: Exactly one priority vehicle	0.70
E3: Two or more priority vehicles	0.25

Table 3. Weight for Priority Vehicle

To keep account of time, which priority vehicle has come first, second, third or fourth place time priority is assigned as per table 4.

Time	Priority (TP)
T1	-1
T2	-2
T3	-3
T4	-4

Table 4. Time Priority

Values are assigned to various signals to set on and off as per table 5.

Signal Status	On State	Off State
Green	3	0
Red	2	0
Amber	1	0

Table 5. Signal Status Values

To give the access to the priority vehicle at the signal, system considers following parameters.

- Priority Weight (P) for the number of priority vehicles
- Priority Code (PC)-Type of the priority vehicle
- VPL-Vehicle priority level
- Ti-Arrival time
- Priority of the patient in case of the ambulance (PP), Fire Brigade Mission priority (FBMP), Police Mission priority (PMP), VIP with value 0 or 1

A Low value i.e., zero means no priority is to be given to the priority vehicle. It may happen that Ambulance is going back to the hospital and is empty, fire brigade is returning to its station after completing the mission, the VIP vehicle is empty. There may be more than one priority vehicles approaching at the same intersection and want to go to different directions.

Considering the following four-way junction:

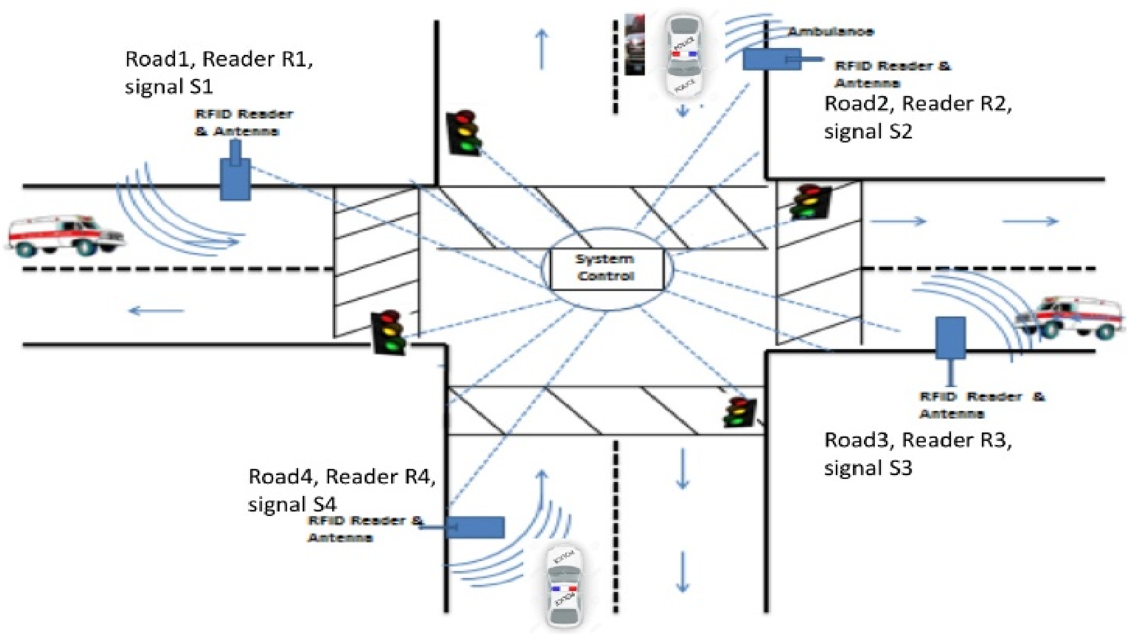

Figure 5: A Four-Legged Signalized Intersection (Source: Generated by the researcher)

In the above scenario (a four-way junction) the priority vehicle can come from any side. We need to install RFID readers on all the four roads before the signal, to detect the presence of priority vehicle. These readers will communicate with the central control system (middleware) which will control the signals on all four sides of roads as per decision-making algorithm. Readers are named as R1, R2, R3, and R4. Signals on all four sides are named as S1, S2, S3, and S4. Reader R1 is installed on the road with signal S1, Reader R2 on the road with signal S2, Reader R3 on the road with signal S3 and Reader R4 on the road with signal S4. Based on the above scenario various cases to be codified are decided. The formula used to calculate the expected effectiveness value called Laplace's Criteria is given below.

Expected effectiveness value= Σ(weight)*(Effectiveness value)
The flow chart for the working of PVMS is as given in figure 6.

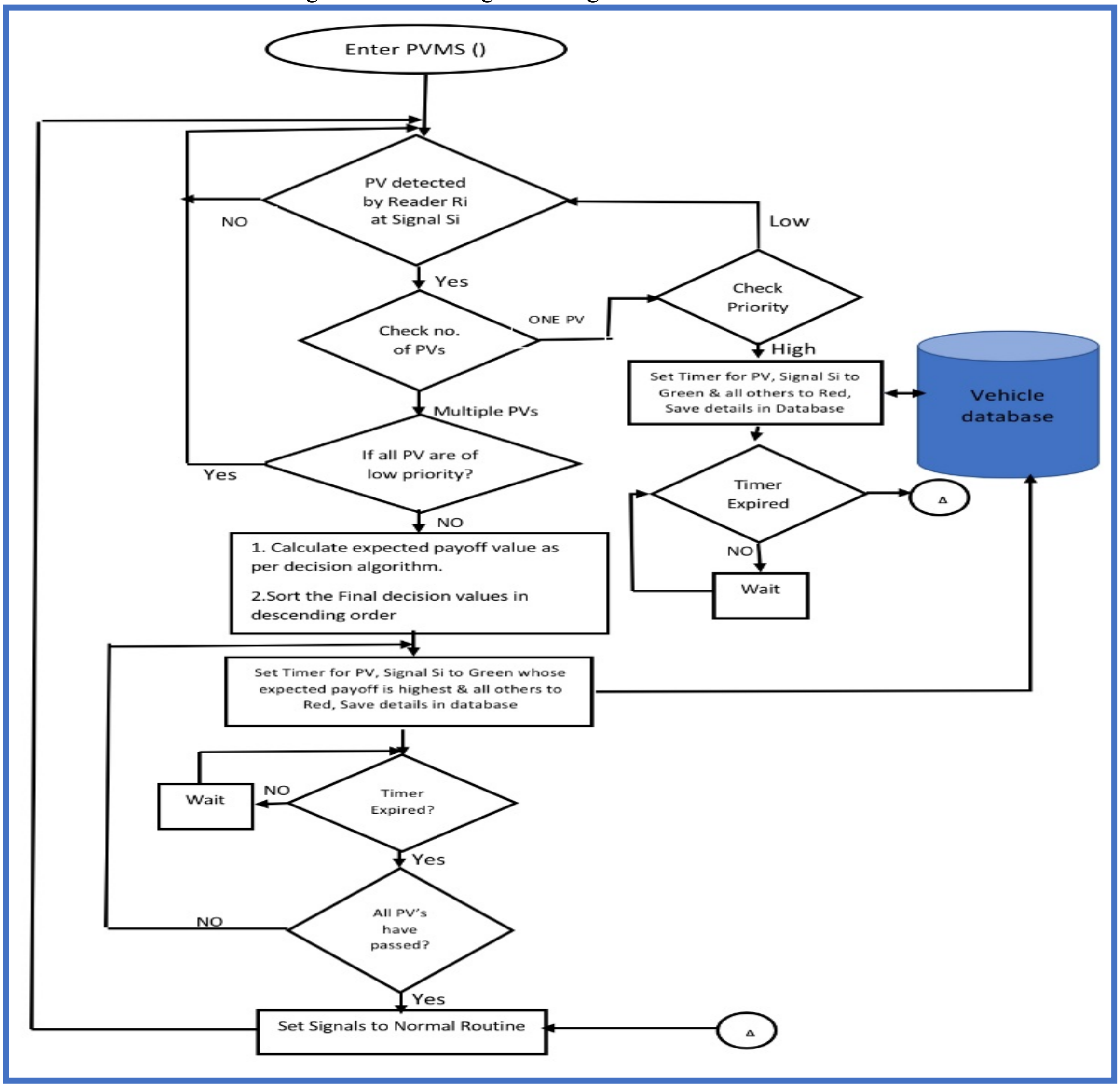

Figure 6: Flowchart of PVMS (Source: Generated by the researcher)

Results

Priority Signal is an extension to the existing signaling system, which will take control from the regular signal controller when a priority vehicle approaches the intersection and make the signal green for the priority vehicle. Working of Priority Signal for different situations is as given in figure 7,8,9.

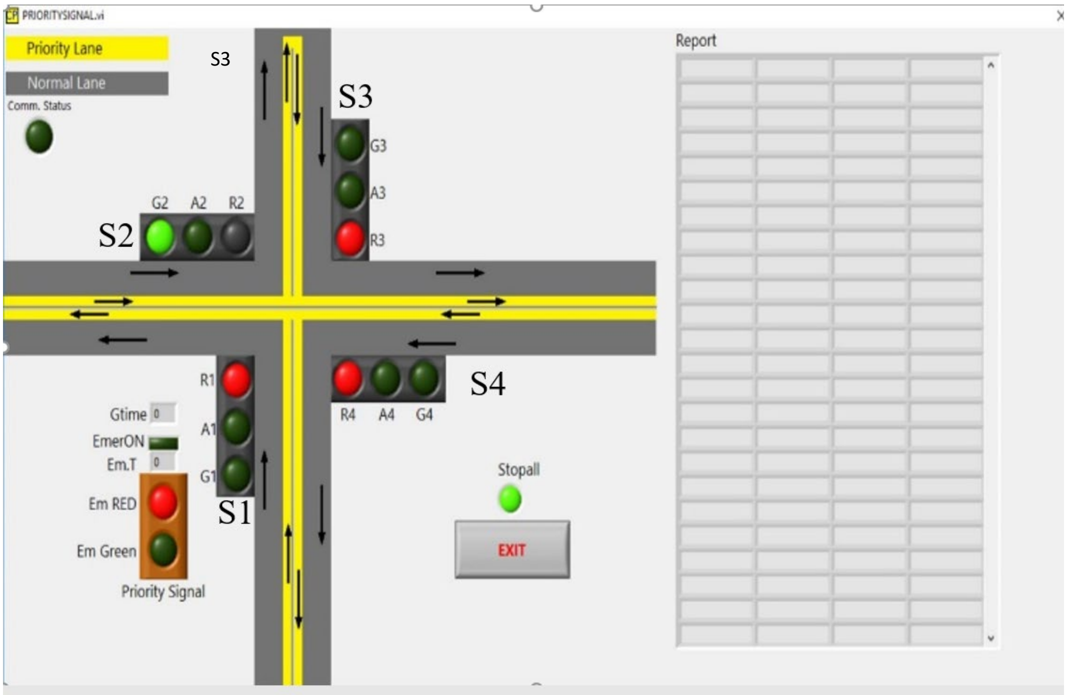

Figure 7: Interface for PVMS (Source: Generated by the researcher)

In the above figure lane marked as yellow is the lane for priority vehicle and grey for normal vehicles. Signals are shown as S1, S2, S3 and S4 on all four sides of intersection. Signal S1 is shown as Green. One Priority Signal is shown, which is an additional attachment to the Normal Signal (Priority Signal will be on all four sides along with Normal Signal in actual set up). It is having Emergency Green (Em Green) and Emergency RED (Em RED), Emergency Timer (Em. T), Emergency on Status (EmerON). Gtime shows Green Time for Normal Signals and Em. T shows time for priority vehicle. As soon as the RFID reader detects the presence of a priority vehicle, the normal signal working is stopped immediately by putting them on All RED mode on all four sides and control is switched to priority signal.

As soon as the priority vehicle is detected the EmerON signal is activated as shown in figure 8 The currently running signal S2 is first turned to Amber then to RED as shown in figure 8 and all others S1, S3 & S4 are also turned to RED. Priority Signal takes control and Emergency Timer (Em. T) for priority vehicle starts as shown in figure 9.

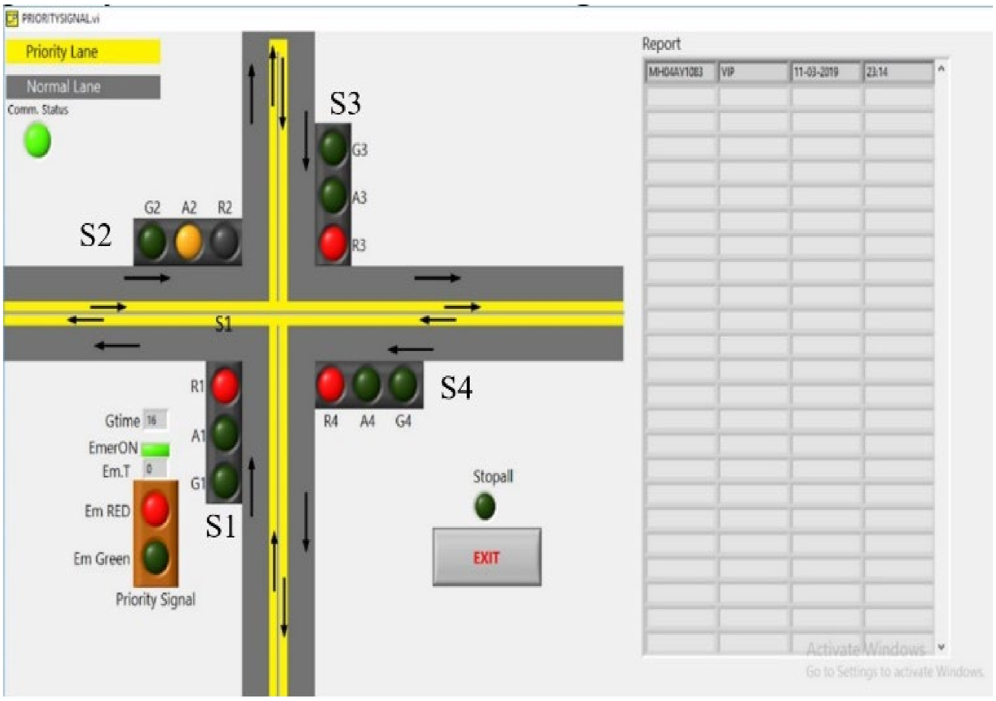

Figure 8 Emergency Signal On (Source: Generated by the researcher)

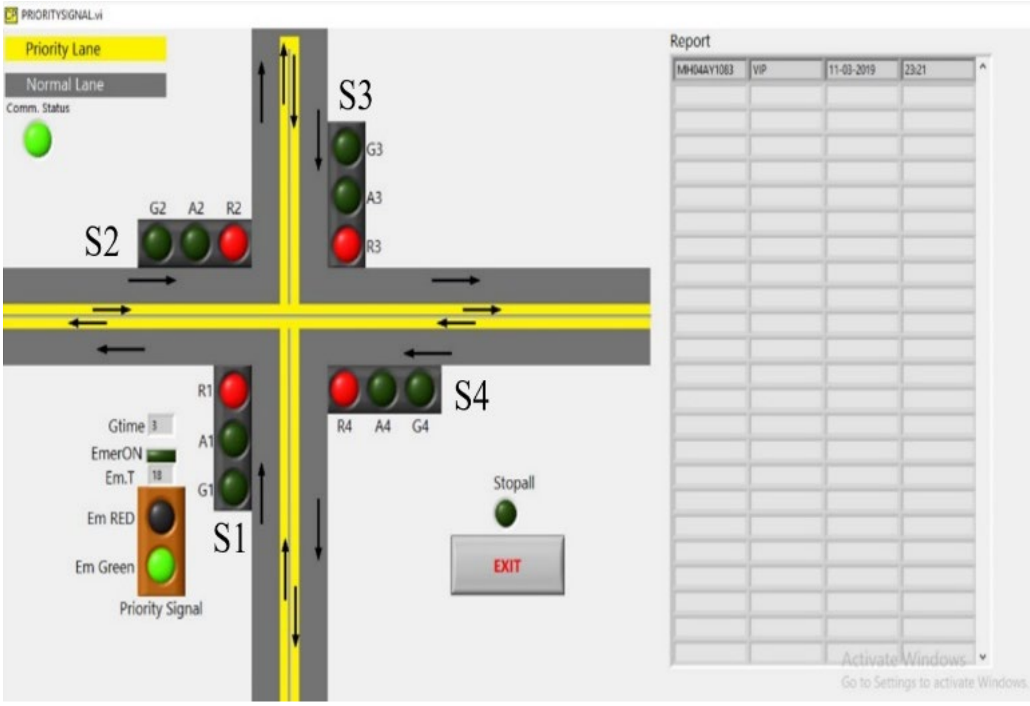

Figure 9: All Normal Signal Put on RED Mode (Source: Generated by the researcher)

As soon as timer for the priority signal expires, Normal Signal takes over the control and signals start functioning in the normal routine from where they have left. PVMS was run many times as shown in figure 10 and it gave desired results. Any priority vehicle passing the intersection and using priority service its data (Vehicle UID, Vehicle Type, Date and Time) is saved in the database which can be used to generate various reports.

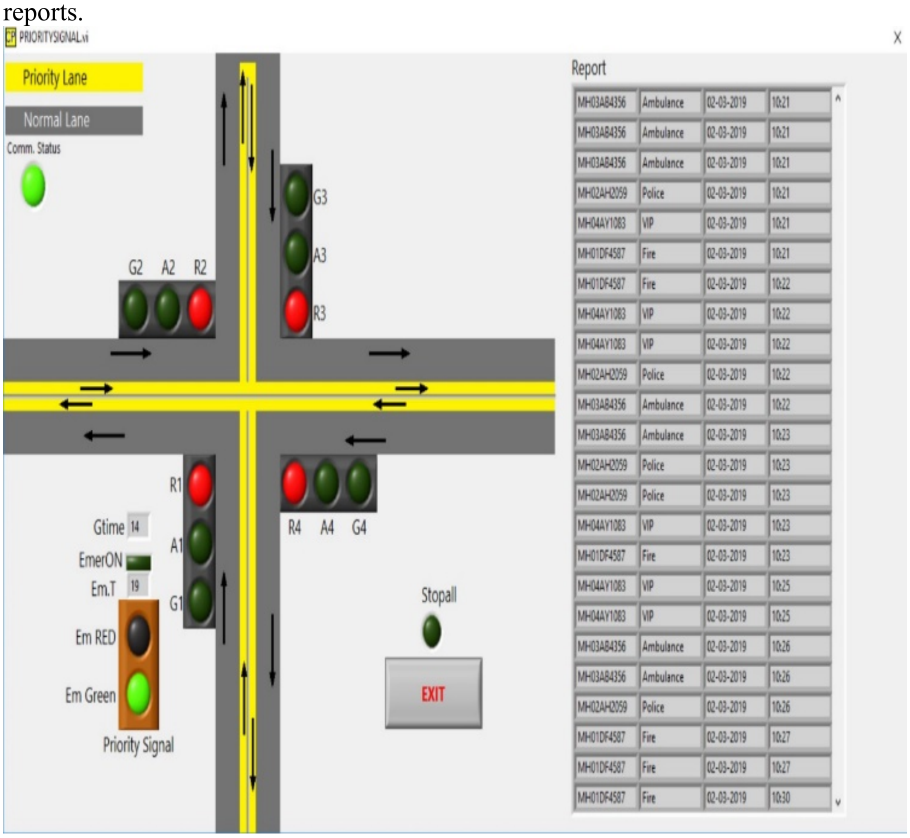

Figure 10. Showing Various Runs (Source: Generated by the researcher)

Algorithm for all the cases for priority vehicle based on decision theory, give the correct results, and achieves the exact timing for making signal green for priority vehicle. Currently, it is implemented only for one signal because of the experimental setup (hardware) limitations. It needs to be tested in real time with the long range RFID System.

5. To create the information system of the traffic along with the roads, signals, vehicles, emergency services, etc. and identification of priority vehicles.
6. Priority scheduling in case of two or more priority vehicles
7. To develop a system which can provide a quick and easy access for Life saving emergency service vehicles during traffic jams so that they can reach their respective destinations as early as possible.
8. Keep record of services provided to the priority vehicles.

Findings of the study

1. The PVMS simulates traffic system along with roads, signals, vehicles, emergency service vehicles and identifies the priority vehicles.
2. The PVMS makes the signal green on arrival of emergency service vehicles to enable them to reach their destination as early as possible.
3. System also does priority scheduling in case of two or more priority vehicles.
4. Vehicle number, type of vehicle, date and time stamp are saved in the database in real time.

Conclusion

An attempt has been made to develop a system which would provide priority to priority vehicles to reach the destination in best possible time. The proposed work is complete in all the respects except we need to replace the RFID Reader, which is a short-range system with a long-range RFID System. With the support of Government initiatives to make it compulsory for all the vehicles to be tagged with unique ID and enforce various rules as mentioned in the assumptions of PVMS, the successful implementation of the system will guarantee improved road situations.

FASTag has been made mandatory for all vehicles recently. It has provided an opportunity to PVMS, which can easily detect the presence of the priority vehicle and make the signal green. Algorithm developed for PVMS work as desired in all type and number of signals and any number of priority vehicles.

With more research in future, integrating PVMS with the bigger system can be of great interest to all budding researchers. (Chandra, 2017) As per Highway Capacity Manual, including capacity and level of service of mid – block sections, saturation flow, signalized and signalized intersections, roundabouts, multilane interurban highways, Urban roads, and expressways, have introduced many opportunities to budding researchers.

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