International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

Centralised Traffic Signal Preemption in the Internet of Things Platform

[1]*Adarsh Pradyut, [2]Archana.H, [3]B. Amutha

ABSTRACT--*Rapid growth in number of vehicles on the road has resulted in increased traffic congestion. Minimizing trip duration of an Emergency Vehicle (EV) from source to destination has become essential, potentially saving lives and properties. Some of the factors that have contributed to the time taken for EV to reach the destination are distance from source to destination, speed of vehicle and congestion at traffic intersections. Although emergency vehicle has been given priority among other vehicles in the traffic, without establishment of a proper traffic pre-emption system, an emergency vehicle can still be stuck in traffic due to time taken to clear traffic at the intersections. Another issue to be considered is the prioritization of multiple emergency vehicles arriving at an intersection. In this paper, a review of various approaches to traffic preemption systems and a centralised traffic preemption system based on Internet of Things platform is presented.*

Keywords--*Emergency Vehicle, GPS, Internet of Things, Traffic Control, Traffic Pre-emption*

I. INTRODUCTION

Traffic pre-emption system is a type of system which interrupts or pre-empts normal operation of traffic. This system is used to give way for EV to reach its intended destination as quickly as possible with possibly minimal loss of lives and property. According to a survey conducted, the total number of deaths caused by road accidents in Chennai in the year 2009 was 562[1] which could have been reduced by faster response times of the EVs.

Managing traffic at intersections is a vital, albeit complex process. Complexity of the process increases as the population of a country increases and correspondingly number of vehicles on the road. Manually controlling traffic signals or using predetermined fixed duration of traffic signal might become ineffective considering the increasing complexity and volume of traffic. Static fixed time traffic signal management could also lead to emergency vehicles being stopped and delayed due to unnecessary traffic at the intersections. Earlier traffic light control system did not consider the presence of emergency vehicles at the intersection.

Centralised traffic signal pre-emption system can help in reducing the delay due to fixed time traffic signal management by controlling signals in the path of the emergency vehicles, switching traffic signal to green as the emergency vehicle approaches the intersection and switching back to normal routing signals after the emergency vehicle has passed the intersection. Priority of clearing path will be based on First Come First Serve for the

[1] *Department of Computer Science and Engineering, SRM Institute of Science and Technology, SRM Nagar, Chennai, Tamil Nadu, India, adarsh.pradyut@gmail.com*

[2] *Department of Computer Science and Engineering, SRM Institute of Science and Technology, SRM Nagar, Chennai, Tamil Nadu, India, archana.harinarayanan.1@gmail.com*

[3] *Department of Computer Science and Engineering, SRM Institute of Science and Technology, SRM Nagar, Chennai, Tamil Nadu, India, bamutha62@gmail.com*

Received: 21 Dec 2019 | Revised: 18 Jan 2020 | Accepted: 05 Feb 2020

emergency vehicles in case of substantially different estimated time of arrival and priority in order of ambulance, fire engine and then police otherwise.

II. LITERATURE SURVEY

Eltayeb AS, Almubarak HO, Attia TA[2] in their paper, addressed the traffic control problem attached to emergency vehicles, the quick arrival of emergency vehicles to destination to reduce chance of loss of human lives and assets. The system proposed is an automated traffic pre-emption system controlling traffic signals on path of the emergency vehicle using GPS to track vehicle parameters like speed, location and using Global System for Mobile Communications (GSM) module to transfer control signals between emergency vehicle and traffic signal. Emergency vehicle's latitude, longitude and speed collected through GPS embedded in mobile device present in the vehicle was transmitted to the GSM Modem which further relays this information to the traffic controller. The same was done to pass static latitude and longitude of the traffic signal to the traffic controller. Traffic light side on the other hand receives information regarding emergency vehicle using a microcontroller and GSM Modem. Time to arrive (TTA) was calculated using velocity of vehicle and current distance between emergency vehicle and the traffic signal. Critical time (CT) was calculated by using count of vehicles at the intersection in direction of the emergency vehicle's path. If time to arrive was much greater than critical time than normal traffic light routine continues. If the time to arrive equals critical time, traffic light in direction of emergency vehicle's path is turned green. When emergency vehicle passed the intersection traffic light switches back to normal of operation. Figure 2.1. summarizes the flow of the traffic management system. On emergency vehicle side Visual Basic program was used to communicate to the GPS receiver and on traffic light side AtMega16 microcontroller is programmed to act and respond as GSM modem.

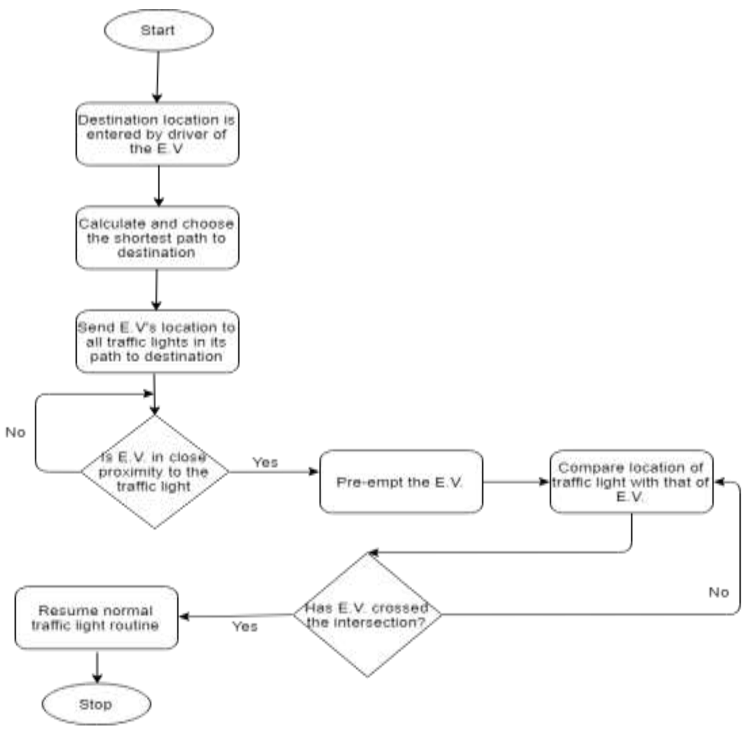

Figure 2.1. Flowchart for working of the traffic management system [2]

Use of GPS technology helps receive accurate location of emergency vehicle in the traffic, time. GPS integrated into electronic maps can also provide shortest path for an emergency vehicle to reach its destination. Although, usage of GSM module in transmitter on emergency vehicle side and receiver on traffic light side may lead to slower transmission due to sharing of bandwidth by multiple users and could also cause mild electronic interference with equipments like pacemakers due to its pulse-transmission technology. Considering the delay caused in transmission and reception of message faster methods of message transfer can be researched upon [2].

Kang W, Xiong G, Lv Y, et al.[3] in their paper, addressed the interruption caused by emergency vehicle pre-emption. This system may extend or shorten duration of green signal or change order of signal phase which disturbs the signal coordination. A system of pre-emption is proposed to reduce the travel time of emergency vehicles (EV) by coordinating the traffic signals in such a way that it seems like a "green wave" so that there is very less negative impact on normal traffic streams. The green wave is described as a situation when the driver of the emergency vehicle encounters a green light every time it reaches the intersections. Before an EV departs for the site, it should send a priority request to the control center for the signals, with information about the origin, destination, the path it will take and the approximated speed. The control system then executes the calculation process according to the request and set the traffic signal settings along the corridor. The system assumes green and red lights in phases of time intervals. After the EV reaches its destination it should send a request to the server so that the control system re-establishes the normal control.

The system provides an effective decrease in emergency vehicle travel time will only be applicable in cities where centralised traffic signal control is implemented. The system is static and does not depend on the traffic density, road conditions and assumes that the EV travels at a constant speed throughout its journey. This system is applicable only in jurisdictions where centralised traffic signal control is implemented. There is no mechanism to ensure green light each time an EV arrives at an intersection. [3]

Kodire V, Bhasakaran S, Vishwas HN[4] in their paper, analyzed the problem of unnecessary stoppage of emergency vehicles even though higher priority is assigned to them due to lack of priority at traffic intersection leading to traffic jam at the intersections. This traffic signal pre-emption system used GPS to gather information like location, speed of vehicle and Zigbee module for communication with traffic light at intersection. Implementation is done using Arduino, GPS module and XBee module on the emergency vehicle side and Arduino and XBee module on traffic light side. The GPS and XBee modules are connected to the Arduino microcontroller for processing data coming from GPS, through serial port of the microcontroller. This system worked on the intersection level by checking if distance between emergency vehicle and the traffic light unit was less than previously decided pre-emption distance. If so, direction in which vehicle was approaching was determined and traffic signal for that direction was turned green. Once vehicle passes intersection normal traffic signal routine continues.

Usage of ZigBee module to communicate with traffic light at intersection provides a reliable message delivery avoiding delay caused by technologies like GSM. Wrong decision due to stray signals like in case of acoustic pre-emption is also avoided. Although this system does not require external sensors and detectors to find emergency vehicle entering at an intersection point, operation at individual intersection level can increase average delay considering the emergency vehicle's path may not be completely cleared before it reaches the traffic intersection. Also, additional Zigbee module increases hardware reliability [4, 5].

Attri P, Rafiqui F, Rawal N[6] in their paper discussed loss of considerable amount of time spent by an emergency vehicle in the traffic indirectly due to many number of traffic signals on the way to its destination and hence the congestion at the intersections. A traffic pre-emption system was proposed involving request from passenger in emergency vehicle and response from traffic light controller in form of change of traffic light at intersection to green light. Passenger in emergency vehicles sent an emergency interrupt request containing information like emergency vehicle coordinates, direction of vehicle, unique user ID, and authentication key to the web server. The web server received the data from GPS enabled device in emergency vehicle and generated an interrupt signal for the traffic signal with this information. After the interrupt signal was received from the web server, this request was sent to the closest traffic light depending on location and direction of emergency vehicle. After the emergency vehicle passed the intersection, normal traffic light routine was followed. Figure 2.2. depicts working of the traffic controller on receiving an emergency status request processed by the server. For the architecture of the pre-emption system, passenger's smart-phone was used to enable request to pre-empt the traffic signal. Built-in GPS in the same smart-phone monitored the location of the emergency vehicle and sends it to the web-server. Web server sent pre-emption signals to the controller when it received emergency status request upon which emergency vehicle receives green signal in its path. Since passenger requested for an emergency interrupt, authentication key pair using unique ID like Aadhar in India and current photo was generated for the requester, which was cross checked on reaching the destination.

This system addressed the issue of possibility of reducing delay in waiting for an ambulance instead making provisions for any person accompanying the victim to their destination by giving normal vehicle priority of an emergency vehicle. The mobile application has been developed on the Windows platform, the web server on the Linux platform and the intersection controller on the Arduino platform Using GPS technology for locating the emergency vehicle made it cost efficient and provided accurate coordinates of the vehicle. Although, manual selection of direction at each intersection leading to absence of trip planning could have a counter effect on the time efficiency and utmost importance would have to be given to securing the request process to prevent misuse of these requests such as for a non-emergency situation, which becomes relatively complex. It also becomes difficult to validate condition of patient in the emergency vehicle and hence determine priority of vehicle base on this factor [6].

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

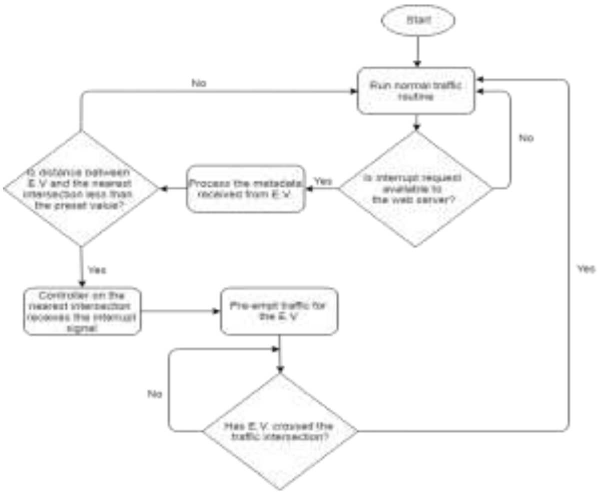

Figure 2.2. Flowchart for working of the traffic signal pre-emption system [6]

Shanthini E, Sreeja.G [7] in their paper proposed a system to control the traffic flow and pre-empt the traffic using RFID tags and RF readers. The RFID tags will be installed in the vehicles and the readers will be installed on the intersections. They also use the GPS modules to locate the position of vehicle whenever theft occurs. The RFID tags will be unique for all the vehicles and can be used for distinguishing vehicles and identifying Emergency Vehicles. As soon as a EV signal is detected the junction will be communicated to turn on the GREEN light on the lane. In case the tag read is of a stolen vehicle, the GSM module present on the reader sends an SMS to the police station with its location. Figure 2.3 depicts working of the traffic control system.

The system currently works only for single road of the intersection and could be expanded to all the roads in multi-road junction. Its performance can be improved by using the concept of IoT. The RFID tags should be secured properly in the vehicles and should not be easily removable. Installing active RFID readers on junction which require power supply are hard to install and have a high cost for maintenance. Putting RFID tags in all registered vehicles is not cost efficient and is a difficult job. [7].

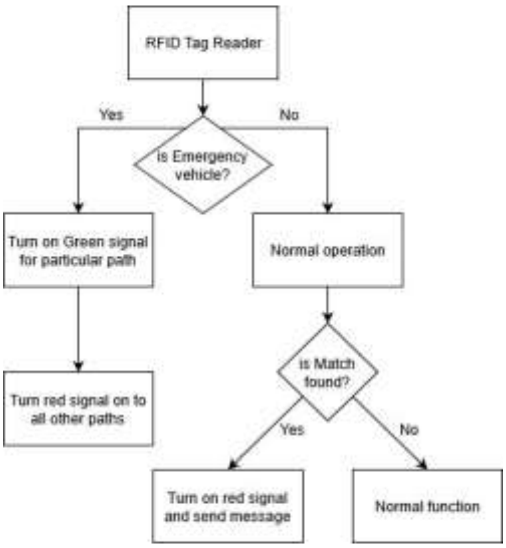

Figure 2.3. Flowchart for working of the traffic control system [7]

Received: 21 Dec 2019 | Revised: 18 Jan 2020 | Accepted: 05 Feb 2020

Paruchuri V[8] in his paper addressed the problem of extended delays for non-emergency vehicles due to pre-emption in addition to minimising delays for the emergency vehicles. A traffic control system utilizing route based traffic clearance with single initialization at start of trip of emergency vehicle was proposed in the paper. Traffic was controlled at each intersection based on optimality based queue length along the path of the emergency vehicle. On request from emergency vehicle, route from source to destination was computed and transmitted to the nearest traffic signal controller. When emergency vehicle received a call, path from source to destination was computed and transmitted to nearest traffic signal controller and to all further traffic signal controllers. Each traffic signal would estimate time of arrival of emergency vehicle at the traffic signal intersection. The traffic signal controller would also compute time taken to pre-empt queue at the intersection. A buffer time was also assigned to clear any stationary traffic for the emergency vehicle to have a smooth passage. For the system described in the paper, emergency vehicles were equipped with onboard units and stationary units were installed at the traffic signals. On board units installed on an emergency vehicle used technologies such as wireless communications, micro-sensors, GPS and embedded systems.

This system used an approach called traffic adaptive optimality based pre-emption to achieve optimal traffic pre-emption along a route which is a route based clearance method. The method mentioned above could reduce the negative effect on overall traffic than that by the intersection based traffic pre-emption system. Java platform was used to model the simulator for this system. Since this method was based on optimal queue length at intersection calculation of estimated time of arrival at the intersection was calculated dynamically in real-time, performing better than traffic pre-emption system working on individual intersection basis. Although, this system increased overall system delay [8].

Asaduzzaman M, Vidyansankar K[9] in their paper addressed issues of increasing overall delay due to traffic preemptions and failure to prioritize among conflicting pre-emption requests. A system is proposed with an algorithm for priority signal control. Transit Signal Priority techniques have been used to improve the Emergency Vehicle Pre-emption. The algorithm divides signal change cycle into phases. The traffic lights are changed according to the phase in which they arrive and the phase which they request. Either the green light time is increased, or the Red-light time is decreased. If multiple EVs arrive at the same time and request for different phases, then the priority weight associated with each emergency request is served first. The multiple request algorithm is obtained by sorting all the active requests from the active request queue and assign schedule for all of them. This method when used on the right time can assure the free movement of the EV as well as keeping disruption to traffic flow at a minimum level.

The research work is focused on improvement of EVP control, but the arrival time predictions should be improved, and artificial intelligence and connected vehicle technologies should be incorporated. The traffic density should also be considered at the time of calculation for the Estimated Time of Arrival [9].

Saini A, Chandok S, Deshwal P[10] in their paper addressed the problems due to increasing traffic in Delhi which is leading to harm to environment due to increasing pollution by vehicles in traffic and the harm medically caused to humans stuck in the traffic. A system is proposed to establish a Real-time Traffic Management System using RFID. In this system all registered vehicles in Delhi will have a Passive RFID tag attached to it. This tag will be read by RFID readers present near the intersections. The RFID tag will contain alphanumeric string (Car plate number) and will send this detail with the location to the RFID reader. The system will contain RFID readers at the junction and 100m away on each road. This will help to detect the density of the traffic. There will be 2 RFID reader on each road. The system could be used for Adaptive traffic light systems, Vehicle theft control, Fully automatic electronic tolls etc.

Dividing and distributing traffic to alternate paths will help reduce traffic density at an intersection. Challan system can be automated with the installation of RFID tags. Inclusion of main server can prove useful as it can maintain record of malfunctioning of traffic lights. Since this system uses RFID tags and readers, the system becomes less cost efficient to implement. This system has no centralised monitoring and thus there is no way to detect failures. The passive tags on the cars, if ripped off, cannot be detected automatically. Also installing RFID tags on large number of cars will be challenging and burdensome [10].

George AA, Krishna A, Dias T, et al[11] in their paper addressed the problem of managing the traffic so that emergency vehicles get a clear way to reach their destination. A system is proposed to manage the traffic so that emergency vehicles get a clear way to reach their destination. This system uses GPS modules present on the ambulance to send its location continuously to the central server. Once the ambulance reaches a traffic light that is red at that moment a signal is sent to the traffic light to change it to green. By this, it clears the traffic ahead so that the ambulance gets a congestion freeway. As soon as the ambulance crosses the intersection, the server sends another signal to change the light back to the previous saved state and the periodic timer continues. The system contains a mobile application on the ambulance which can track the vehicle in real time. This application is properly secured, and an authentication is set so that no misuse can be done. Figure 2.4 summarizes what purpose the GPS module, traffic control module and central server serve.

The system currently is only applicable to ambulances and should be expanded to multiple emergency vehicles with priority algorithm in place. The system uses authentication to allow mobile applications to connect to the server but requires better backend servers and security layers to be in place [11].

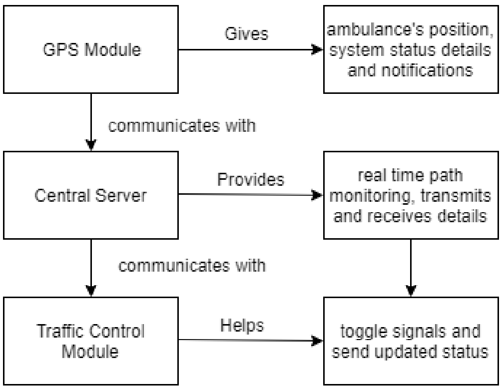

Figure 2.4. Architecture Block Diagram for the traffic management system [11]

Javaid S, Sufian A, Pervaiz S, Tanveer M[12] in their paper addressed the problem of current traffic management systems being centralised which may increase the possibility of crash in case of network issues and lack of focus on fluctuation in traffic flow. A traffic pre-emption system implemented in an Internet of Things environment was proposed, controlling traffic sensed through surveillance camera, ultrasonic sensors and RFID tags placed on the roadsides. In this system, sensors' data was processed at individual node level and videos' data, from surveillance

Received: 21 Dec 2019 | Revised: 18 Jan 2020 | Accepted: 05 Feb 2020

camera was processed at local server level and the combined traffic density was determined. The pre-emption system described in the paper consisted of three stages. First stage was collection of data, which consisted of the ultrasonic sensors, surveillance cameras, RFID readers, flame sensors and smoke sensors. Second stage was for processing data and making decision, where traffic was controlled based on various factors, based on if an emergency vehicle was present in a lane or not, if traffic density at intersection was high or low and if it was at that point of time a rush interval or not and subsequently varying signal time according to traffic density, and lastly application and actuation stage, in which both duration of a green light at the traffic signal is conveyed, and daily, weekly or monthly reports is presented for administration and future traffic planning purpose.

In addition to sensors and camera being used to detect traffic density on road, artificial intelligence was used to devise an algorithm to predict traffic density to reduce future traffic congestion. Also graphical methods were used to represent real time traffic data helping traffic related authorities to manage traffic congestion and for future planning. Although this system includes traffic data collection for future traffic planning purposes in addition to controlling current traffic situation at intersections, RFID tags increased hardware dependency installation and maintenance of which could lead to additional cost. Also image processing for information received from surveillance camera could increase cost and efforts to properly implement the traffic analysis [12].

III. PROPOSED SYSTEM

The proposed system is based on the Internet of Things Platform. It uses mobile applications where the driver gets all the information about the trip and path details. The mobile app is used for tracking the EV location. On reception of an emergency call, an EV is assigned with the driver. This assignment sets the source and destination for the emergency. The driver gets a notification on his mobile device. The driver then logins into the system and starts the trip with already fed in trip details. The mobile device now updates the EV's location to the central server. With every new trip starting, the server dedicates a thread for the trip and tracks all the changes of the trip like location updates, intersections crossed and forthcoming intersections. When a trip is started by a EV driver, the path of the trip is fetched from 3rd party API (Google API) and is converted into a list of coordinates. The trip path coordinates are now used to fetch the list of coordinates from the database of all the intersections in the city. The found intersection coordinates are sorted with the order of occurrence in the route. The continuous location update is used to get the next intersection in the route. The direction of approach to the next intersection is calculated and estimated to of approach (ETA) of the EV at the intersection. This eta is compared with the critical ETA and the decision for preemption is made by creating the preferred state of the intersection controller. A state of an intersection controller is the traffic light colour of each lane on the intersection. The preferred state of the next intersection is sent to the intersection controller using MQTT protocol. The intersection controller then changes its current state with the preferred state obtained from the central controller. Algorithm 3.1 depicts working of the centralised server in the Traffic Preemption System.

Algorithm 3.1

```
PathCoordinates = GetTripPathFrom ( coordinate_start, coordinate_end)
IntersectionCoordinates = GetFromDBInWay (PathCoordinates)
IntersectionCoordinates = SortAccordingToPath (IntersectionCoordinates)
While (!Trip.isCompleted)
        PreviousIntersectionCoordinate , NextIntersectionCoordinate =
        GetNextIntersectionCoordinateFrom (IntersectionCoordinates,
        UpdatedTripCoordinate)
        TripPath = MakeLine (PreviousIntersectionCoordinate,
        NextIntersectionCoordinate)
   If (UpdatedTripCoordinate not on TripPath) then
        UpdatedTripCoordinate = ProjectionOn (TripPath)
   End If
   ETA = CalculateETA (UpdatedTripCoordinate, NextIntersectionCoordinate)
        DirectionOfApproach = CalculateDirection (from: UpdatedTripCoordinate, to:
        NextIntersectionCoordinate)
   PreferredState = GeneratePreferredState (NextIntersectionCoordinate,
DirectionOfApproach)
   If (ETA < CriticalETA) then
       SendToIntersection (PreferredState)
   End If
End While
End
```

IV. CONCLUSION

Traffic signal pre-emption, especially for emergency vehicles is of utmost importance in today's world, potentially saving lives and property. Various methods have been utilized to pre-empt the traffic and are having their own benefits and limitations. The Centralised Traffic Signal Pre-emption System aims to address these limitations by increasing the message transfer rate, dealing with real-time changes, handling more than one Emergency Vehicle at an intersection and making a centrally monitorable, cost efficient system.

REFERENCES

1. Amutha, B., Renganathan, K. AccSearch: A Specialized Search Engine for Traffic Analysis. International Journal of Computer Science and Information Security. 2010; 8(2):264-271.

2. Eltayeb, A.S., Almubarak, H.O., Attia, T.A. A GPS based traffic light pre-emption control system for emergency vehicles. International Conference on Computing, Electrical and Electronic Engineering. Khartoum. 2013: 724-729
3. Kang, W., Xiong, G., Lv, Y. et al. Traffic Signal Coordination for Emergency Vehicles. IEEE 17th International Conference on Intelligent Transportation Systems (ITSC). Qingdao.. 2014: 157-161.
4. Kodire, V., Bhasakaran, S., Vishwas, H.N. GPS and ZigBee traffic signal preemption. International Conference on Incentive Computation Technologies. Coimbatore. 2016: 1-5.
5. Amutha, B. and Ponnavaikko, M. Location update accuracy in human tracking system using ZigBee modules. arXiv preprint arXiv:0912.1019, 2009
6. Attri, P., Rafiqui, F., Rawal, N. Traffic Signal Pre-emption (TSP) System for Ordinary Vehicles in case of Emergency based on Internet of Things Ecosystem. 3rd International Conference on Computing for Sustainable Global Development(INDIACom). New Delhi. 2016: 85-59.
7. Shanthini, E., Sreeja, G**.** Improved Traffic Control Systems for Emergency Vehicle Clearance and Stolen Vehicle Detection. International Research Journal of Engineering and Technology. 2016; 3(3): 630-635.
8. Paruchuri, V. Adaptive pre-emption of traffic for emergency vehicles. UKSim-AMSS 19th International Conference on Modelling and Simulation. Cambridge. 2017: 45-49.
9. Asaduzzaman, M., Vidyansankar, K. A Priority Algorithm to Control the Traffic Signal for Emergency Vehicles. IEEE 86th Vehicular Technology Conference (VTC-Fall). Toronto. 2017: 1-7.
10. Saini, A., Chandok, S., Deshwal, P. Advancement of Traffic Management System using RFID International Conference on Intelligent Computing and Control Systems. Madurai. 2017: 1254-1260.
11. George, A.A., Krishna, A., Dias, T. et al. Golden Aid, An Emergency Ambulance System International Conference on Networks & Advances in Computational Technologies. Trivandrum. 2017: 473-476.
12. Javaid, S., Sufian, A., Pervaiz, S., Tanveer, M. Smart Traffic Management System using Internet of Things 20th International Conference on Advanced Communication Technology. Korea(South). 2018: 393