International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2022/211623 Volume 9, Issue 1, January – February (2022)

SURVEY ARTICLE

A Survey on Emergency Vehicle Preemption Methods Based on Routing and Scheduling

Shridevi Jeevan Kamble
School of Electronics and Communication, REVA University, Bengaluru, India
shridevi.havanoor@gmail.com

Manjunath R Kounte
School of Electronics and Communication, REVA University, Bengaluru, India
manjunath.kounte@gmail.com

Received: 03 December 2021 / Revised: 21 January 2022 / Accepted: 27 January 2022 / Published: 28 February 2022

Abstract – Emergency Vehicles (EVs) play a significant role in saving human lives and property damages. Reducing the time delay of emergency vehicles is important to enhance emergency service performance. The preemption methods are powerful strategies that assist emergency vehicles to reach the desired destination quickly by managing the competing normal traffic along the emergency vehicle approaching lane. The EV preemption models pre-clears the vehicles on the EV approaching lane by interrupting the signal timings and boosting EV arrival speed even the road traffic is high. With the assistance of preemption models, the EVs are not stopping or waiting at signalized intersections. Also, the preemption models diminish the vehicle conflict problems on the EV approaching lane. Moreover, the preemption models use different strategies to navigate the EVs on their routes efficiently. Hence, a detailed survey is needed to understand the different preemption strategies and analyze the gaps which are not effectively solved by existing literature. This paper attempts to survey the existing EV preemption methods with detailed discussions. For a clear view, the survey divides the existing preemption models into three types that are routing-based, scheduling-based, and miscellaneous. The survey compares the preemption methods with their advantages and limitations. Further, it analyzes the gaps which are not solved in existing solutions and describe the possible future directions that pave the way for innovating novel realistic preemption solutions.

Index Terms – Emergency Vehicles (EVs), Preemption Methods, Routing, Vehicle-to-Vehicle Communication, Connected Infrastructure, Scheduling, Intelligent Algorithm.

1. INTRODUCTION

Reducing travel time is significant for victorious emergency vehicle missions. The emergency vehicles receive high priority along their approaching route with the help of sirens and strobe lights. However, the intersections along the emergency vehicle path remain a critical task. The preemption strategies can remarkably assist emergency vehicles to reach the desired destination timely [1]. The preemption models reserve the right way to clear the emergency vehicle and assist the emergency vehicles to timely reach the destination spot, particularly at intersections. Thus, it saves human lives and costs. For instance, the American Heart Association stated that a minute delay in cardiac arrest patient treatment shrinks the survival chance by 7 to 10% [2]. A small fire can reach the flash at 7 minutes by doubling the fire every 17 seconds [3]. Hence, the rescue operation sets a delay bound below 7 minutes to emergency operations. The existing preemption models are worked based on the intersections-by-intersection [4]. The wireless sensor network or radio frequency identification detects the emergency vehicles on the roadside intersection, and the traffic lights individually tune its preemption phase. In such kinds of preemption models, the traffic lights adjust their phase after the arrival of emergency vehicles. In highly populated areas or peak hour traffic, emergency vehicles have to stop at intersections to clear the normal traffic. Thus, it creates negative impacts on emergency vehicle travel time. Also, the emergency vehicle preemption may delay emergency vehicle arrival to the destination, resulting in loss of lives or property damages.

The current preemption models aim to reduce the travel time delay of emergency vehicles by utilizing a connected vehicle infrastructure [5]. In this type, wireless communication such as vehicle to infrastructure or vehicle to vehicle is utilized to pre-clear the vehicles presented before the emergency vehicles. Albeit the connected vehicle infrastructure-based preemption assists in diminishing the emergency vehicle arrival delay, it can negatively impact entire normal traffic. An existing study [6] shows the advantages of the emergency vehicle preemption model at six locations of New York, whereas it demonstrates the disturbances at coordinated signalized intersections caused due to preemption. Some of the current preemption models use effective traffic light scheduling methods at intersections to improve the preemption strategy [7] [8]. Moreover, minimizing the travel time without disturbing the normal road traffic is a major

SURVEY ARTICLE

responsibility of preemption methods for emergency vehicles. Numerous current preemption models focus on diminishing the emergency vehicle delay without disturbing the normal traffic. This work surveys the existing emergency vehicle preemption models with their advantages and disadvantages. Also, it analyzes the gaps in the existing models and describes the possible future directions associated with emergency vehicle preemption.

1.1. Significance and Motivation

The connected vehicle infrastructure and traffic light scheduling-based emergency vehicle preemption models have the potential of reducing the emergency vehicle arrival time delay without creating negative impacts on normal traffic. However, a detailed study is needed to incorporate the most effective preemption model for successful emergency operations. In this circumstance, a comprehensive emergency vehicle preemption survey review work can play a good kick-starter for VANET researchers to insert effective novel ideas in current preemption models. Nevertheless, no detailed survey with recent works of emergency vehicle preemption models has been conducted to date. Apart from addressing the research gaps in existing models and describing the possible future directions in this area helps the researchers to improve the most effective emergency vehicle preemption methods, resulting in saving human lives and property losses.

1.2. Contributions

The prime key aspects of this survey are as follows.

- The main intention of this survey is to review the existing and current works proposed for emergency vehicle preemption. For clear investigation, the preemption methods are mainly categorized into routing-based, scheduling-based, and miscellaneous models.
- The preemption models are comprehensively reviewed with their procedures, advantages, and limitations. Further, a comparison is performed in tabular format based on the key techniques utilized for routing and scheduling.
- Finally, the survey discusses the open issues and challenges of exiting preemption models, giving significant guidelines for future research works.

1.3. Paper Organization

The paper is organized as follows. Section 2 reviews the existing literature related to connected infrastructure communication and scheduling-based emergency vehicle preemption models. Further, it compares the models with their advantages and limitations. Section 3 discusses the challenges and open issues not solved in existing models. Section 4 describes the possible future works of emergency vehicle preemption. Section 5 concludes this paper.

2. EMERGENCY VEHICLE PREEMPTION METHODS

A survey in [9] reviews various emergency vehicle preemption methods and route optimization strategies in detail. Figure 1 illustrates the emergency vehicle scenario.

The emergency vehicle preemption methods are mainly categorized into three types that are routing-based, scheduling-based, and miscellaneous methods, as shown in Figure 2.

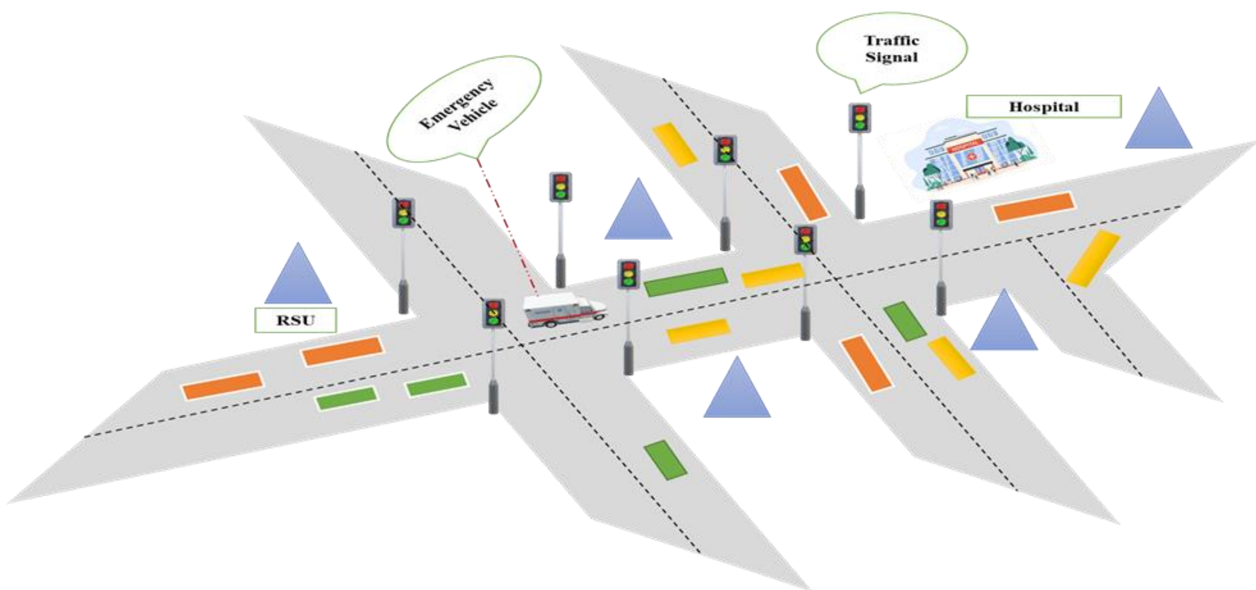

Figure 1 Emergency Vehicle Presence Scenario

SURVEY ARTICLE

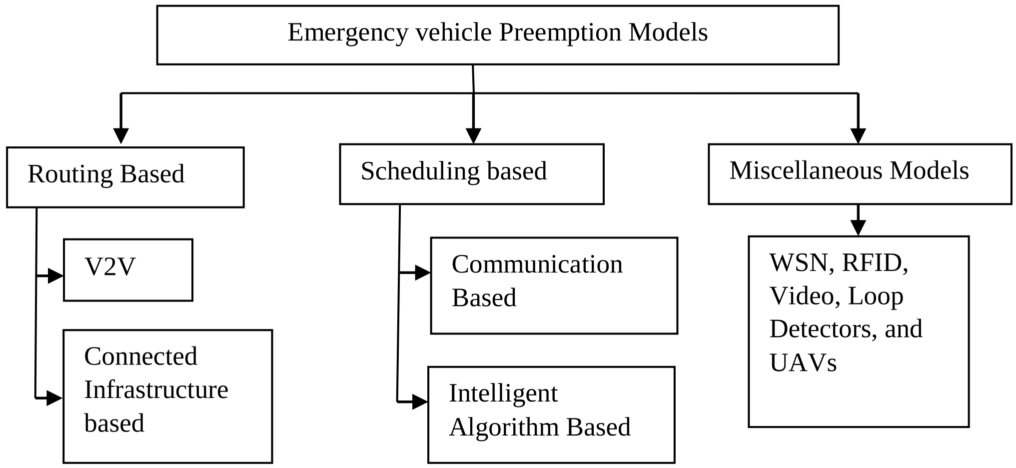

Figure 2 Classification of Emergency Vehicle Preemption Models

2.1. Routing Based Methods

Numerous works have been introduced in the existing literature to select optimal routes for emergency vehicles and pre-clearing with the assistance of real-time road traffic data and timing information [10] [11]. The routing-based emergency vehicle preemption methods are categorized into the following types that are vehicle to vehicle (V2V) based and connected infrastructure-based.

2.1.1. V2V Communication-Based Models

The V2V enables real-time wireless communication among the moving vehicles on the roadside to improve traffic efficiency and safe driving. The vehicles enable communication directly or with the help of routers to exchange information [12]. It is crucial to enhance road safety by considering the link characteristics of V2V communications with VANET mobility characteristics through introducing novel frameworks [13]. Moreover, the V2V communication-based road traffic congestion involves a significant responsibility in minimizing the overhead of networks by disseminating congestion information [14]. The study in [15] presents a novel emergency vehicle route-clarifying model that relies on vehicular traffic management and works under medium congested traffic scenarios. The route-clarifying model utilizes the V2V communication model to identify the nearest destination vehicle for travel time minimization. If the arrival message is received from an emergency vehicle, the nearest vehicle immediately communicates with neighboring vehicles on the corresponding road. Further, the emergency vehicle approaching lane is pre-cleared based on V2V communications, and the emergency vehicle reaches the destination at the right time. The route-clarifying model utilizes distance measurement and an optimization model to pass the emergency vehicle quickly at medium interference conditions.

2.1.2. Connected Infrastructure Based Models

The research work in [16] presents an emergency vehicle preemption strategy that can minimize the arrival delay of the emergency vehicle due to high road traffic conditions. The preemption strategy exploits connected vehicle infrastructure to manage the arrival time delay of emergency vehicles effectively. Also, the preemption model solves the worst-case waiting time problems of non-emergency vehicles. An emergency vehicle signal coordination strategy in [17] offers an efficient green wave method to emergency vehicles. The signal coordination method effectively clears the queue traffic on the road and creates a green phase for quick navigation of emergency vehicles. The research paper [18] proposes a message dissemination and rerouting planning strategy for emergency vehicles. In this model, a dissemination boundary is decided based on the road congestion level and timeout information of EV messages. Further, the EVs are efficiently rerouted based on the dissemination messages and planning model.

The work in [19] considers the daily routing problems associated with emergency vehicle routing issues in a particular network with high spatial resolution. Thus, it supports efficient decision-making to emergency VANETs. To handle the routing issues of emergency vehicles, the spatial resolution model integrates two modern technologies such as the pre-hospital screening model and the lane pre-clearing model. The first technology provides injury diagnosis to the suffered people, and the second technology ensures that the emergency vehicle is migrated with desired speed on corresponding lanes. The spatial model also uses three different emergency vehicles like ambulances to support first aids for patients according to the information received from pre-hospital screening. Furthermore, it integrates the mixed-integer linear programming (MIP) method that allocates ambulances to the location of patients and promptly performs

SURVEY ARTICLE

emergency vehicle navigation through the shortest traveling routes. Finally, the spatial resolution model handles the ambulance fleet properly.

The research work in [20] proposes an emergency vehicle pre-clearing model that uses a connected vehicle communication model in a specified area to prioritize the emergency vehicles on the corresponding path. The pre-clearing strategy converts the cooperative driving problem of connected vehicle infrastructure as a mixed-integer nonlinear programming (MINP) to make sure the desired speed of emergency vehicles and to reduce the preemption impact on connected vehicles. Thus, it formulates the bi-level optimization method to accomplish the goals of MINP. Firstly, the MINP separates the preceding connected vehicles of the emergency vehicle into multiple blocks. Further, it applies an emergency vehicle sorting algorithm in every block to get vehicle sorting trajectories. Thus, the sorting trajectories are used to solve the MINP, and the emergency vehicles are permitted to move at their maximum speed on the corresponding path. Consequently, an efficient preemption strategy is presented in [21] to minimize the preemption that negatively impacts normal road traffic. Such a model pre-clears the approaching lane of the emergency vehicle using vehicular communication. Thus, the pre-clearance of emergency vehicle routes reduces the disturbances in normal road traffic. In table 1, various routing-based preemption models are compared with their advantages and limitations.

Existing Works	Description	Techniques used	Advantages	Limitations
Emergency vehicle preemption strategy [16]	It exploits connected vehicle infrastructure to diminish the emergency vehicle arrival delay	Connected vehicle communication infrastructure	Reducing travel time delay of emergency and non-emergency vehicles	The normal traffic create a negative impact when more than one emergency vehicle is presented
Emergency vehicle signal coordination strategy [17]	It aims to reduce travel delays by providing timely green waves to the emergency vehicles	Traffic signal coordination	Easy to implement and cost-efficient	It has little impact on the normal traffic, and it requires a centralized traffic controller
High spatial resolution based Routing Model [19]	Aims to solve daily ambulance routing issues	Pre-hospital screening, lane pre-clearing, and MIP	Properly manages the ambulance fleets	Creating a negative impact on general traffic
emergency vehicle pre-clearing model [20]	Aims to presents effective preemption for emergency vehicles	Vehicle to infrastructure communication	Queue based emergency vehicle preemption triggering minimizes the time delay	Fails under heavy road congestion situations and creates a negative impact on normal traffic

Table 1 Comparison of Different Routing Based Preemption Models

2.2. Scheduling Based Methods

The traffic light scheduling algorithms tune the traffic light signal timing based on the application types. Traffic light scheduling is classified into two types that are communication-based scheduling models and intelligent algorithms-based scheduling models, as depicted in Figure 3.

2.2.1. Communication Based Scheduling Models

The work in [22] proposes a Virtual Traffic Light plus for Emergency Vehicle (VTL+EV) model that prioritizes the emergency vehicles at the road intersection. The decentralized and self-coordinated traffic control VTL+EV system expedites the emergency vehicles' movement and minimizes the normal vehicle waiting time. The delay in emergency vehicle arrival is minimized by proposing a preemption-based traffic light model that utilizes a Global Positioning System (GPS) [23]. The emergency vehicle can become aware of its position and destination position based on the GPS data. The GPS integrates software programs to assist the preemption model and develops electronic maps to detect the shortest traveling routes. Thus, the emergency vehicle chooses the shortest traveling routes based on GPS data and arrives at its destination promptly. The GPS-based preemption strategy also pre-clears the normal vehicles at an emergency vehicle approaching lane by efficiently controlling traffic lights at intersections using transmitters. An innovative traffic signal control model proposed in [24] uses a connected vehicle infrastructure to reduce emergency vehicle response time. The innovative model sends alerts to the traffic lights about the arrival of the emergency vehicle based on the beacons received. The traffic light adjusts the green phase in advance to diminish the delay in emergency vehicle arrival. A priority-based signal control algorithm with transit signal priority in [25] enhances the performance of emergency vehicle preemption. It is an efficient method to offer a competent traffic operation quality in urban VANETs. The priority signal control strategy tunes the traffic signal phases at the right time to serve rapid preemptions of the emergency vehicle. Thus, it alleviates the arrival delay of emergency vehicles and shrinks the preemption impact on general traffic.

The research work in [26] presents a novel traffic light-assisted emergency vehicle preemption strategy at intersections. It uses wireless communication among connected vehicles, infrastructures, emergency vehicles, and traffic lights for effective preemption. It computes the vehicle density at intersections based on the received messages. Further, it constructs a dynamic mathematical strategy to eject the vehicles in the queue. A multiobjective programming model in [27] employs a preemption model to navigate emergency vehicles at intersections quickly. It also minimizes the preemption impact on general traffic and maximizes the passing rate of normal vehicles at intersections. The work in [28] primarily focuses on building efficient routes for emergency vehicles by integrating a realistic traffic-based optimization method. It uses Google Maps Distance Matrix API to obtain real-time traffic knowledge. Thus, it determines the less congested shortest traveling routes to the emergency vehicles.

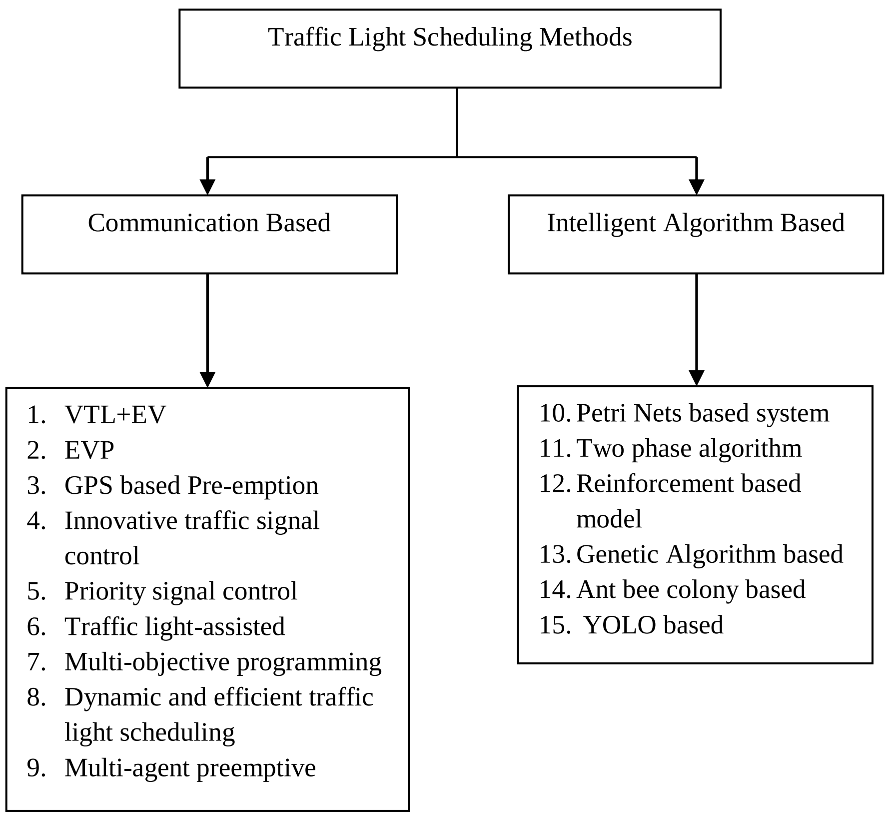

Figure 3 Classification of Traffic Light Scheduling Methods

The research paper [29] proposes a real-time traffic flow-based dynamic and robust traffic light scheduling technique. It tunes the finest green phase time at intersections based on real-time road traffic data. It also considers emergency vehicles during green phase time adjustment and helps to navigate the emergency vehicles quickly. The work in [30] proposes a multi-agent-based preemptive longest queue to manage the crossings of emergency vehicles. The research work in [31] introduces an Emergency Vehicle Pre-emption (EVP) model, which utilizes the battery-less wireless sensor networks to maintain the emergency vehicle speed at intersections. Initially, the EVP builds a collection tree between the traffic intersections and efficiently handles the preemption requests received from emergency vehicles. The EVP copes with the dynamicity of VANET topology and quick response time requests of emergency vehicles according to the pre-defined rules of the tree model.

International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2022/211623 Volume 9, Issue 1, January – February (2022)

SURVEY ARTICLE

2.2.2. Intelligent Algorithm Based Models

In recent years few intelligent algorithm-based works have been developed for emergency vehicle preemption. Among the existing intelligent algorithm models, major works employ Petri Nets-based preemption strategy to quickly clear the queued vehicles before the emergency vehicles [32]. The work in [33] employs Petri Nets-based route rerouting model in which the traffic signal controllers and dynamic message signs are considered. Thus, it assists the vehicles to cross the intersections without stopping or taking quick rerouting decisions under highly congested intersections. Similarly, the work in [34] utilizes timed colored Petri nets to control the traffic signals effectively for emergency vehicle preemption. Consequently, the work in [35] adopts a two-phase algorithm in which the signal transitioning is performed for both normal and emergency vehicles vice versa. The initial phase employs a relaxation strategy, whereas the final is a stepwise search model. The two-phase preemption model instructs the traffic lights to switch from the current state to the novel selected state when the sensors detect an emergency vehicle at the corresponding intersection.

The emergency vehicle is attached with a preemption device, and the device has sent a preemption request to the traffic lights for favorable crossing. To reduce the travel time of emergency vehicles along their route and maximize emergency response system efficiency, the work in [36] presents a two-level programming model for emergency vehicle route-oriented control strategy for signal coordination. It works based on the various priority types and levels of emergency vehicles. The work in [37] uses reinforcement learning for enhancing a multiobjective traffic signal control algorithm in urban VANETs. To achieve the objective, the reinforcement method considers the vehicle stops, the queue length capacity within intersections, and average waiting times.

Preemption Methods	Types	Description	Techniques Used	Advantages	Limitations
VTL+EV [22]	Communication-based	Expedites the emergency vehicles movement	Self-coordinated traffic system	Minimizes the normal vehicle waiting time without disturbing preemption	Fails under heavily congested intersections
GPS assisted preemption model [23]		Aims to solve an important traffic control problem associated with emergency vehicle arrival	Satellite assisted GPS based traffic light preemption	Aims to minimize the emergency vehicle arrival time at the destination	Do not consider the impact of preemption on general traffic
An innovative traffic signal control [24]		It aims to design an effective green phase adjustment to minimize the emergency vehicle time delay	V2I communication-based traffic light scheduling	Reduces the emergency vehicle response	Do not perform well under coordinated intersections
Priority signal control algorithm [25]		Aims to improve the emergency vehicle preemption	Transit signal priority model	Serves quick preemptions to an emergency vehicle	Fails under coordinated intersections, resulting in high delay at emergency vehicles
Novel traffic light-assisted emergency vehicle preemption [26]		Aims to prioritize the emergency vehicle on the corresponding path	Connected vehicle communication and dynamic mathematical strategy	Allows the emergency vehicles with the desired speed at intersections	Creates a negative impact on general traffic

SURVEY ARTICLE

A multiobjective programming model [27]		Aims to navigate the emergency vehicles quickly at intersections	Multiobjective programming model	It minimizes the preemption impact on general traffic	Not effective under high congested intersections
Realistic traffic-based optimization method [28]		Aims to build efficient routes for emergency vehicles	Google Maps Distance Matrix API	Quick emergency vehicle navigation	It does not consider the preemption impact on general traffic
Two-phase preemption algorithm [35]	Intelligent algorithm based	It aims to design a two-phase emergency vehicle preemption strategy	Transition signal priority	Prioritizes the emergency vehicles at intersections	Create a negative impact on normal traffic due to lack of considering green wave activation time
Multiobjective control algorithm [37]		Aims to design a multiobjective signal control model for urban VANETs	Reinforcement Learning	Efficient signal control at urban VANETs	Not specially proposed for emergency vehicle and impact on emergency vehicle delay
Signal setting model [38]		Aims to develop a dynamic model based on a path choice model	Genetic algorithm-based	Taking into account the congestion parameters improve the evacuation efficiency	Lacks to consider the emergency vehicle type
Real-time traffic light control algorithm [40]		Aims to manage the competing traffic flows at the intersection	Computer vision and machine learning, YOLO	Quick emergency vehicle navigation	Not realistic and have high computational complexity

Table 2 Comparison of Different Scheduling Based Preemption Methods

The research work in [38] develops a signal setting model that utilizes a genetic algorithm to manage the congestion and vehicular flow at intersections. Such work deals with an evacuation case. It also develops a path choice-based dynamic model in which the behavioral rules of various users are exploited to set the signal. However, the existing models lack

SURVEY ARTICLE

into account the types of emergency vehicles. The work in [39] proposes an Improved Ant Bee Colony (IABC) algorithm to solve the issues associated with urban traffic light scheduling. Consequently, the work in [40] proposes a traffic flow-based real-time traffic light control algorithm. It exploits intelligent machine learning to manage challenging traffic flows and signalized road intersections. The model includes a deep Convolutional Neural Networks-based real-time object detection method referred to as You Only Look Once (YOLO). It optimizes the traffic signal phases based on the collected preemption information like queue length and waiting time to pass emergency vehicles at intersections rapidly. The EMVLight in [41] designs a framework in which the dynamic route and traffic signal preemption decisions are taken based on the reinforcement learning model. It makes some extensions in Dijkstra's model and updates the EV routes in real-time even the road is congested. The work in [42] presents a dynamic queue jump lane strategy for EVs in which the realistically connected vehicle coordination is exploited for lane jumping. It utilizes a reinforcement learning algorithm to model the connected vehicle infrastructure and boosts the EV speed significantly. Table 2 compares different scheduling-based preemption models with their advantages and limitations.

2.3. Miscellaneous Methods

The sensing-based models detect emergency vehicles using Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Global Position System (GPS), and video-based systems (CCTV cameras). In an emergency vehicle preemption system, the vehicles are categorized into general and emergency, where the speed, count, location, and lane occupancy are unique parameters. An efficient preemption strategy instructs the signal controller to identify the emergency vehicles in advance [43]. The signal controller has to detect the emergency vehicle with a strict time delay bound that is necessary to pre-clear vehicles in the approaching lane of an emergency vehicle, resulting in the emergency vehicles are not stopped at intersections. The detection time or time delay bound is decided based on the traffic congestion at the intersection. Notably, the traffic controller has knowledge about the present location, speed, and distance to the intersection for effectively managing the preemption phase. Various kinds of sensing methods are utilized for detecting emergency vehicles that are WSN, inductive loops, RFID, video cameras, radio, microwave sensors, and GPS. The WSN is a type of sensor network in which numerous roadside sensors are deployed to detect emergency vehicles [44].

The inductive loops are generally placed in the road pavement to sense the emergency vehicle. Further, a most reliable loop detector-based emergency vehicle detection is employed in advanced traffic light controllers [45]. The magnetic sensors create a magnetometer sensor area with earth magnets to identify the emergency vehicle as a metallic object. The magnetic detectors are located under the horizontal road surface. Such a model can only identify the vehicle passage. Microwave radar sensors transmit and utilize electromagnetic signals to determine the emergency vehicle's presence, count, and speed. The Video-based detection models use CCTV cameras and advanced video processing features to identify the appearance, speed, and location of vehicles [46]. The GPS-based models can effectively detect the speed, location, and movement direction of vehicles presented in an emergency vehicle approaching a lane [47].

Some research works employ different methods like Unnamed Aerial Vehicles (UAVs) for emergency vehicle preemption. In UAV-assisted models, a set of UAVs are migrated over a particular region to monitor the traffic fluidity for emergency incident detection. Further, the UAV shares the monitored information with the other UAVs for a global vision of road traffic congestion. Thus, it assists the traffic controllers in suggesting appropriate road segments for quick navigation. Moreover, the UAVs reliably inform the arrival of emergency vehicles to the traffic controllers by employing an energy-efficient routing strategy. The main advantage of UAVs is sky-based substitution connectivity. In real-time, the ground-based VANET infrastructure may get damaged for many reasons. In such cases, the UAV models offer better connectivity to preempt emergency vehicles quickly.

An efficient method in [48] allows significant numbers of users and devices to enable UAV-based communication, where the data rate interference is the key parameter of UAV communication performance. Furthermore, a greedy forwarding routing protocol also has similar behavior is adopted in [49], whereas it is suffered by local optimum issue. A similar UAV-based model in [50] optimizes the communication efficiency over a particular area, neglecting the energy constraint of UAVs. Consequently, the work in [51] consolidates WSN architecture and UAVs and carries out the realistic disaster area assessment. However, it lacks to consider the constrained energy characteristics of sensors and UAVs. The UAVs with Unmanned Surface Vehicles (USVs) in [52] improve the rescue mission performance. However, it necessitates a human operator. The work in [53] uses the transit signal priority model to adjust the signal phases in real-time and speed up the EVs to the desired destination rapidly. It also handles the tram priority on the coordinated intersections of the tram. The IoT-based intelligent monitoring system in [54] determines the ambulance in a congested road to offer efficient facilities to save human lives. It incorporates IoT and Zigbee components to inform the medical need of the corresponding ambulance to the nearest hospital. Thus, it minimizes the treatment delay and saves the lives of humans. A traffic preemption system in [55] gives a high communication response to the ambulance driver and minimizes the delay at the airport runway intersection. The

SURVEY ARTICLE

work in [56] integrates three systems like city traffic lights, surveillance camera network, and emergency response center with the assistance of IoT. The miscellaneous preemption methods are compared in table 3.

Preemption Methods	Types	Objectives	Advantages	Limitations
WSN-EVP [44]	WSN based Sensing	Aims to handle the emergency vehicle preemption using WSN	High scalability and cost-efficient	Energy constraints of WSN may create network failure at sometime
Framework [46]	Video-based sensing	Aims to detect the vehicles based on feature detection	Successful detection during day and night time	Do not specifically consider the emergency vehicles in the detection
GPS and Zigbee based model [47]	Sensing and communication based	Clears the emergency vehicle route using the V2I communication model	Effective preemption in the presence of multiple emergency vehicles	Do not consider the negative impact of preemption on normal traffic
Zigbee and IoT based preemption model [54]	IoT communication based	Aims to provide efficient facilities to the ambulances	Environment adoption based quick evacuation	Minimum scalability
Open IoT system based emergency response system [56]	IoT communication based	Design efficient dynamic traffic light system for emergency vehicles	Dynamic scheduling for green wave activation	Nor applicable for multiple emergency vehicle scenarios

Table 3 Comparison of Miscellaneous Pre-Emption Models

3. RESEARCH GAPS DISCUSSION

The survey reviews different emergency vehicle preemption methods, and the research gaps of such methods are discussed as follows.

- The existing works mainly focus on reducing the delay of emergency vehicles by considering the negative impact of normal vehicles on preemption. They lack to handle the negative impact of preemption on general traffic, which is crucial in a realistic environment.
- Most of the emergency vehicle preemption models are designed for a single emergency vehicle scenario. However, more than one emergency vehicle may present in the same lane. It is still a major issue in real-time scenarios.
- Most of the works lack realistic traffic data in traffic light scheduling based on emergency vehicle preemption.

4. FUTURE DIRECTIONS

The possible future directions of emergency vehicle preemption are as follows.

- Future works should consider the negative impact of preemption on normal traffic to optimize the entire performance of the vehicular system.
- To maximize the efficiency of emergency rescue operations, it is crucial to extend the current preemption models into multiple emergency vehicle scenarios.
- Validate the emergency vehicle preemption methods in real-time simulations by integrating the realistic vehicular road traffic characteristics.
- It is possible to improve emergency vehicle evacuation efficiency by integrating advanced networking structures like IoT, cloud, SDN, and big data.
- The fundamental mathematical programming models do not have the capability of meeting the real-time preemption calculations. Hence, it is crucial to incorporate novel intelligent algorithms into preemption design
- The existing traffic light scheduling methods also lack handling before, during, and after emergency vehicle preemption situations. It is essential to take the right time scheduling actions to reduce the negative impacts.

SURVEY ARTICLE

5. CONCLUSION

In this survey, many recent emergency vehicle preemption methods are reviewed with appropriate discussions. The existing preemption models are categorized into three types such as routing-based, scheduling-based, and miscellaneous for clear investigation. The comparison tables describe the techniques used for preemption and also discuss the advantages and limitations of the reviewed works. Moreover, the research gaps and future directions are discussed for further improvements in future preemption model designing.

REFERENCES

[1] Wang, J., Ma, W., & Yang, X, "Development of Degree-of-Priority Based Control Strategy for Emergency Vehicle Preemption Operation", Discrete Dynamics in Nature and Society, pp.1–10, 2013
[2] Nicholas G. Bircher, Paul S. Chan, Yan Xu, "Delays in Cardiopulmonary Resuscitation, Defibrillation, and Epinephrine Administration All Decrease Survival in In-hospital Cardiac Arrest" Anesthesiology 2019
[3] Standard for the Organization and Deployment of Fire Suppression Operations, "Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments". 2001, National Fire Protection Association: Qunicy, MA.
[4] Yandong Pei, Bo Huang, Chunxia Zhao, and Gongxuan Zhang, "Modeling and Analyzing of Emergency Vehicle Preemption in a Four-phase Intersection via TPN", Journal of Traffic and Logistics Engineering Vol. 8, No. 2, 2020
[5] Y. Wang, Z. Wu, X. Yang, and L. Huang, "Design and implementation of an emergency vehicle signal preemption system based on cooperative vehicle infrastructure technology," Adv. Mech. Eng., Vol. 2013
[6] Teng, H.H., et al., "Simulation Testing of Adaptive Control, Bus Priority and Emergency Vehicle Preemption in New York City", In Transportation Research Board Annual Meeting, 2003
[7] V. Paruchuri, "Adaptive Preemption of Traffic for Emergency Vehicles", UKSim-AMSS 19th International Conference on Computer Modelling & Simulation (UKSim), pp. 45-49, 2017
[8] Almuraykhi, K. M., & Akhlaq, M, "STLS: Smart Traffic Lights System for Emergency Response Vehicles", International Conference on Computer and Information Sciences (ICCIS), 2019
[9] Subash Humagain, Roopak Sinha, Edmund Lai & Prakash Ranjitkar, "A systematic review of route optimisation and preemption methods for emergency vehicles", Transport Reviews, Vol. 40, No. 1, pp. 35-53, 2020
[10] P. Devi and S. Anila, "Intelligent Ambulance with Automatic Traffic Control", 2020 International Conference on Computing and Information Technology (ICCIT-1441), pp. 1-4, 2020, doi: 10.1109/ICCIT-144147971.2020.9213796.
[11] L. H. Ardekani, D. Haight, A. Ingolfsson, M. Salama, M. Stanton, "Scheduling and routing ambulances that provide inter-facility patient transfers Technical Report", Working paper, 2014
[12] Yang, L.; Li, H, "Vehicle-to-vehicle communication based on a peer-to-peer network with graph theory and consensus algorithm", IET Intell. Transp. Syst, Vol. 13, pp. 280–285, 2019
[13] Vinel, A.; Lyamin, N.; Isachenkov, P, "Modeling of V2V Communications for C-ITS Safety Applications: A CPS Perspective", IEEE Commun. Lett, Vol. 22, pp. 1600–1603, 2018
[14] Wang, R.; Xu, Z.; Zhao, X.; Hu, J, "V2V-based method for detection of road traffic congestion", IET Intell. Transp. Syst, Vol. 13, pp. 880–885, 2019
[15] Osman, R. A., Zaki, A. I., & Abdelsalam, A. K. (2021), "Novel Road Traffic Management Strategy for Rapid Clarification of the Emergency Vehicle Route Based on V2V Communications", Sensors, Vol. 21, No. 15, 2021
[16] Oza, P., & Chantem, T, "Timely and Non-Disruptive Response of Emergency Vehicles: A Real-Time Approach", 29th International Conference on Real-Time Networks and Systems, 2021
[17] Wenwen Kang, Gang Xiong, Yisheng Lv, Xisong Dong, Fenghua Zhu, & Qingjie Kong, "Traffic signal coordination for emergency vehicles", 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), 2014
[18] Meenaakshi Sundhari, R. P., Murali, L., Baskar, S., & Shakeel, P. M, "MDRP: Message dissemination with reroute planning method for emergency vehicle information exchange", Peer-to-Peer Networking and Applications, Vol. 14, No. 4, pp. 2285-2294, 2021
[19] Ziling Zeng; Wen Yi; Shuaian Wang; and Xiaobo Qu, "Emergency Vehicle Routing in Urban Road Networks with Multistakeholder Cooperation", Journal of Transportation Engineering, Part A: Systems, Vol. 147, No. 10, 2021
[20] Vít Obrusník, Ivo Herman, Zdeněk Hurák, "Queue discharge-based emergency vehicle traffic signal preemption", The research was funded by Technology Agency of the Czech Republic within the program Epsilon, the project TH03010155.,IFAC-PapersOnLine, Vol. 53, No. 2, 2020
[21] Laura Bieker-Walz and Michael Behrisch, "Modelling green waves for emergency vehicles using connected traffic data", 2019
[22] S. Humagain and R. Sinha, "Dynamic Prioritization of Emergency Vehicles for Self-Organizing Traffic using VTL+EV", IECON 2020 The 46th Annual Conference of the IEEE Industrial Electronics Society, pp. 789-794, 2020
[23] A. S. Eltayeb, H. O. Almubarak and T. A. Attia, "A GPS based traffic light preemption control system for emergency vehicles", International Conference on Computing, Electrical and Electronic Engineering (ICCEEE), pp. 724-729, 2013
[24] Hamed Noori, Liping Fu, and Sajad Shiravi, "A Connected Vehicle Based Traffic Signal Control Strategy for Emergency Vehicle Preemption", 2016
[25] Asaduzzaman, M., & Vidyasankar, K, "A Priority Algorithm to Control the Traffic Signal for Emergency Vehicles", IEEE 86th Vehicular Technology Conference (VTC-Fall), 2017
[26] Wu, J., Kulcsár, B., Ahn, S., & Qu, X, "Emergency vehicle lane pre-clearing: From microscopic cooperation to routing decision making", Transportation Research Part B: Methodological, pp. 223–239, 2020
[27] Mu, H., Song, Y., & Liu, L, "Route-Based Signal Preemption Control of Emergency Vehicle", Journal of Control Science and Engineering, pp. 1–11, 2018
[28] Rathore, N., Jain, P. K., & Parida, M, "A Routing Model for Emergency Vehicles using the Real Time Traffic Data". IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI), 2018
[29] Younes, M.B., Boukerche, A, "An efficient dynamic traffic light scheduling algorithm considering emergency vehicles for intelligent transportation systems", Wireless Networks, pp. 2451–2463, 2018
[30] Louati, A., Elkosantini, S., Darmoul, S., & Louati, H, "Multi-agent preemptive longest queue first system to manage the crossing of emergency vehicles at interrupted intersections", European Transport Research Review, Vol. 10, No. 2, 2018
[31] Shaaban, K., Khan, M. A., Hamila, R., & Ghanim, M, "A Strategy for Emergency Vehicle Preemption and Route Selection", Arabian Journal for Science and Engineering, 2019, doi:10.1007/s13369-019-03913-8
[32] Zhao, L., Pu, L., Zhao, Z., Huang, B., Hao, J., & Huang, Y, "Emergency Vehicle Preemption Control of T-shaped Intersection with Time Petri Nets", Chinese Automation Congress (CAC), 2018
[33] Qi, L., Luan, W., Liu, G., Lu, X. S., & Guo, X, "A Petri Net-Based Traffic Rerouting System by Adopting Traffic Lights and Dynamic Message Signs", IEEE International Conference on Networking, Sensing and Control (ICNSC), 2020
[34] Mu, H., Liu, L., & Li, X, "Signal preemption control of emergency vehicles based on timed colored petri nets", Discrete Dynamics in Nature and Society, 2018

SURVEY ARTICLE

[35] Qin X, Khan AM, "Control strategies of traffic signal timing transition for emergency vehicle preemption", Transp Res C Emerg Technol, Vol. 25, pp. 1–17, 2012

[36] Yao, J., Zhang, K., Yang, Y., & Wang, J, "Emergency vehicle route oriented signal coordinated control model with two-level programming", Soft Computing, Vol. 22, No. 13, pp. 4283–4294, 2017

[37] Houli D, Zhiheng L, Yi Z, Pappis C, Mamdani E, Trabia M et al, "Multiobjective reinforcement learning for traffic signal control using vehicular ad hoc network", EURASIP J Adv Signal Process, 2010

[38] Marcianò, Alessandro F, Musolino G, Vitetta A, "Signal setting optimization on urban road transport networks: the case of emergency evacuation", 2014

[39] Gao, K., Yicheng Zhang, Sadollah, A., & Rong Su, "Improved artificial bee colony algorithm for solving urban traffic light scheduling problem", IEEE Congress on Evolutionary Computation (CEC), 2017

[40] K. Zaatouri and T. Ezzedine, "A Self-Adaptive Traffic Light Control System Based on YOLO", International Conference on Internet of Things, Embedded Systems and Communications (IINTEC), pp. 16-19, 2018

[41] Su, H., Zhong, Y. D., Dey, B., & Chakraborty, A, "EMVLight: A Decentralized Reinforcement Learning Framework for Efficient Passage of Emergency Vehicles", arXiv preprint arXiv:2109.05429, 2021

[42] Su, H., Shi, K., Chow, J., & Jin, L, "Dynamic Queue-Jump Lane for Emergency Vehicles under Partially Connected Settings: A Multi-Agent Deep Reinforcement Learning Approach", arXiv preprint arXiv:2003.01025, 2020

[43] W. Min, L. Yu, P. Chen, M. Zhang, Y. Liu and J. Wang, "On-Demand Greenwave for Emergency Vehicles in a Time-Varying Road Network With Uncertainties", in IEEE Transactions on Intelligent Transportation Systems, Vol. 21, No. 7, pp. 3056-3068, 2020

[44] Masoud, M., & Belkasim, S, "WSN-EVP: A Novel Special Purpose Protocol for Emergency Vehicle Preemption Systems", IEEE Transactions on Vehicular Technology, Vol. 67, No. 4, pp. 3695–3700, 2018

[45] Bharadwaj, R., Deepak, J., Baranitharan, M., Vaidehi, V, "Efficient dynamic traffic control system using wireless sensor networks", In IEEE International Conference on Recent Trends in Information Technology (ICRTIT), pp. 668–673, 2013

[46] Robert, K, "Video-based traffic monitoring at day and night vehicle features detection tracking". In: 12th International IEEE Conference on Intelligent Transportation Systems, (ITSC'09), pp. 1–6, 2009

[47] Kodire, V., Bhaskaran, S., Vishwas, H, "Gps and zigbee based traffic signal preemption", In IEEE International Conference on Inventive Computation Technologies (ICICT), Vol. 2, pp. 1–5, 2016

[48] S. A. R. Naqvi, S. A. Hassan, H. Pervaiz, and Q. Ni, "Drone-aided communication as a key enabler for 5G and resilient public safety networks," IEEE Communications Magazine, Vol. 56, No. 1, pp. 36–42, 2018

[49] L. Lin, Q. Sun, S. Wang, and F. Yang, "A geographic mobility prediction routing protocol for Ad Hoc UAV Network", In Proceedings of the Globecom Workshops (GC Wkshps). IEEE, pp. 1597–1602, 2012

[50] A. Merwaday, A. Tuncer, A. Kumbhar, and I. Guvenc, "Improved throughput coverage in natural disasters: Unmanned aerial base stations for public-safety communications", IEEE Vehicular Technology Magazine, Vol. 11, No. 4, pp. 53–60, 2016

[51] M. Erdelj, M. Krol, and E. Natalizio, "Wireless sensor networks and multi-UAV systems for natural disaster management", Computer Networks, Vol. 124, pp. 72–86, 2017

[52] X. Xiao, J. Dufek, T. Woodbury, and R. Murphy, "UAV assisted USV visual navigation for marine mass casualty incident response", In Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, pp. 6105–6110, 2017

[53] Chentoufi, M. A., & Ellaia, R, "A Novel Met heuristic for Adaptive Signal Timing Optimization Considering Emergency Vehicle Preemption and Tram Priority", SAE International Journal of Transportation Safety, Vol. 7, No. 2, pp. 129-152, 2019

[54] Godwin J.J., Krishna B.V.S., Rajeshwari R., Sushmitha P., Yamini M, "IoT Based Intelligent Ambulance Monitoring and Traffic Control System", Advances in Internet of Things in Biomedical and Cyber Physical Systems. Intelligent Systems Reference Library, Vol. 193, 2021

[55] G. Eromosele and D. Gerhard, "Integrating a Traffic Preemption System on an Emergency Vehicle and Airport Runway System," IEEE 6th World Forum on Internet of Things (WF-IoT), pp. 1-6, 2020

[56] L. A. Magre Colorado, J. Franco Ibañez and J. C. Martinez-Santos, "Leveraging Emergency Response System Using the Internet of Things. A Preliminary Approach", 17th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), pp. 1-6, 2020.

Authors

Mrs.Shridevi Jeevan Kamble is a research scholar at REVA University. She holds a Bachelor of Engineering from VTU Belgaum, Karnataka, and an M.Tech in Digital Electronics from VTU Belgaum, Karnataka. She is an IEEE student member. She has over nine years of Teaching, Research, and Administrative experience. Her research area includes the internet of vehicles, Cyber-physical system, Machine Learning, and Deep learning VANETs. She has also published books "Electronics Product Design" for SPPU and "Control System-II" for Mumbai University for final year Engineering students. Mrs.Kamble received a "Letter of Appreciation" for three consecutive years, 2015, 2016, and 2017 for improving the university result in the subject control system, Operating system, and Fiber optics communication. Published papers at International conference paper at Elsvier, Springer and IEEE explore. She has also published journal paper in IJERT, IJACSA, Lecture Notes on Data Engineering and Communications Technologies, vol 31. Springer, Cham. 2018.

Dr. Manjunath R. Kounte is an Associate Professor in School of Electronics and Communication Engineering, REVA University, Bangalore, India. He has over 12+ years of Teaching, Research and Administrative experience. His teaching interests are Mathematical Oriented and Programming Subjects like Circuit Analysis. Dr. Kounte has received "Best Teacher Award" from REVA University for the Year 2017. He has over 16 Publications in International Conferences and over 8 Articles Published in reputed International Journals. His research interests include Machine Learning, Neuromorphic Vision Systems, Cognitive Neuroscience, and Signal Processing. Dr. Manjunath R Kounte is a Senior Member of IEEE, USA, Life Member of ISTE, India and Life Member of IETE, India. Dr. Kounte has mentored over 12 UG Projects and 12 PG Projects. One of the Student group under his guidance has received a grant for research project from Vision Group of Science and Technology, Govt of Karnataka. He has also guided a student group who received grant from Karnataka State Council of Science and Technology (KSCST). Currently he is guiding 4 research scholars and looking for active researchers interested to do PhD under in his guidance in the area of Machine Learning, Deep Learning, Artificial Intelligence, Internet of Things, Computer Vision, Machine Vision, and Computational Cognitive Neuroscience. More details about him can be found in his website https://www.kountesir.com/.

SURVEY ARTICLE

How to cite this article:

Shridevi Jeevan Kamble, Manjunath R Kounte, "A Survey on Emergency Vehicle Preemption Methods Based on Routing and Scheduling", International Journal of Computer Networks and Applications (IJCNA), 9(1), PP: 60-71, 2022, DOI: 10.22247/ijcna/2022/211623.