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An Adaptive Traffic Light Approach to Reduce the Emergency Vehicles Delay in Urban Environments

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Abstract

Emergency vehicles play an important role in saving lives and protecting property during emergencies. They are specially designed and equipped to provide rapid response and immediate assistance in emergency situations, such as fires, accidents, and medical emergencies .The importance of emergency vehicles lies in their ability to respond quickly and efficiently to emergencies. Their specialized equipment and highly trained staff can provide critical care and support to those in need. Emergency vehicles can transport patients to hospitals, rescue people from dangerous situations, and provide on-site medical treatment to injured people .Moreover, emergency vehicles also play an important role in managing disasters and emergencies that affect societies, such as natural disasters and terrorist attacks. They help evacuate people from dangerous areas, provide search and rescue operations, and deliver essential supplies and equipment to affected areas .In this research, a proposed model to solve the emergency vehicle congestion problem was discussed and linked as quickly as possible through adaptive traffic lights with the help of the RSU, and the ambulance was taken as an example for applying the proposed model. The results showed that the model is effective in reducing congestion significantly for emergency vehicles, which leads to reducing the time it takes for emergency vehicles to reach their destination, thus saving people's lives .This approach is adaptive and can adapt to changing traffic conditions in the future, making it suitable for different traffic scenarios.

Keywords: Vehicular Networks, Urban environment, Roadside Unit, Traffic lights, Emergency Vehicles

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نهج إشارات المرور التكيفية لتقليل تأخير مركبات الطوارئ في البيئات الحضرية

رنده مهدي كاظم [1] ، سعد طالب حسون [2]

المستخلص

تلعب سيارات الطوارئ دورًا مهمًا في إنقاذ الأرواح وحماية الممتلكات أثناء حالات الطوارئ. وهي مصممة ومجهزة خصيصًا لتوفير استجابة سريعة ومساعدة فورية في حالات الطوارئ ، مثل الحرائق والحوادث وحالات الطوارئ الطبية. تكمن أهمية مركبات الطوارئ في قدرتها على الاستجابة بسرعة وكفاءة لحالات الطوارئ. يمكن لمعداتهم المتخصصة وموظفيهم المدربين تدريباً عالياً توفير الرعاية الحرجة والدعم للمحتاجين. يمكن لمركبات الطوارئ نقل المرضى إلى المستشفيات وإنقاذ الأفراد من المواقف الخطرة وتوفير العلاج الطبي في الموقع للمصابين. علاوة على ذلك ، تلعب مركبات الطوارئ أيضًا دورًا مهمًا في إدارة الكوارث وحالات الطوارئ التي تؤثر على المجتمعات ، مثل الكوارث الطبيعية والهجمات الإرهابية. فهي تساعد على إجلاء الأشخاص من المناطق الخطرة ، وتوفر عمليات البحث والإنقاذ ، وتوصيل الإمدادات والمعدات الأساسية إلى المناطق المتضررة. في هذا البحث تمت مناقشة نموذج مقترح لحل مشكلة ازدحام مركبة الطوارئ وربطها بأسرع ما يمكن من خلال إشارات المرور التكيفية بمساعدة RSU ، وتم أخذ سيارة الإسعاف كمثال لتطبيق المقترح المقترح نموذج. وأظهرت النتائج أن النموذج فعال في تقليل الازدحام بشكل كبير لمركبات الطوارئ مما يؤدي الى تقليل الوقت المستغرق لوصول مركبات الطوارئ الى وجهتها وبالتالي الحفاظ على حياة الاشخاص. هذا النهج متكيف ويمكن أن يتكيف مع ظروف حركة المرور المتغيرة مستقبلا ، مما يجعله مناسبًا لسيناريوهات حركة المرور المختلفة.

الكلمات المفتاحية : شبكات المركبات اللاسلكية ، البيئة المدنية ، وحدات جانب الطريق ، اشارات المرور

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، مركبات الطوارئ

Introduction

Intelligent Transportation System (ITS) is an advanced technological system that enhances transportation efficiency, safety, and sustainability [1]. It integrates various technologies, such as communication systems, sensors, and computing systems, to provide real-time traffic information, improve traffic flow, reduce congestion, and enhance safety [2]. The application of ITS is not limited to roadways but extends to other transportation modes such as railways, airways, and waterways. ITS comprises several components, including advanced traffic management systems (ATMS), advanced traveler information systems (ATIS), and advanced vehicle control systems (AVCS) [3]. ATMS allows traffic operators to monitor and manage traffic conditions in real-time. It utilizes various technologies, such as CCTV cameras, sensors, and communication systems, to provide accurate and timely information about traffic flow, incidents, and congestion. This information is then used to optimize traffic management strategies, such as signal timing and ramp metering, to improve traffic flow and reduce congestion [2][3].

Vehicular Ad-hoc Networks (VANETs) are a type of wireless ad-hoc network that enables communication between vehicles and between vehicles and infrastructure. VANETs are an emerging technology that is expected to play a major role in improving road safety, traffic efficiency, and passenger comfort [4]. Vehicles in a VANET are equipped with wireless communication devices, such as Wi-Fi or Dedicated Short-Range Communications (DSRC) radios, that allow them to communicate with each other and with roadside infrastructure. VANETs use a variety of communication protocols, including IEEE 802.11p and Wireless Access in Vehicular Environments (WAVE), to facilitate communication between vehicles and infrastructure. One of the key applications of VANETs is improving road safety [2][3]. VANETs can be used to provide real-time information about road conditions, such as traffic congestion, accidents, and weather, to drivers. This information can help drivers make informed decisions and avoid potential hazards [5]. VANETs can also be used to provide warnings to drivers about potential collisions or other dangerous situations. Another important application of VANETs is improving traffic efficiency. VANETs can be used to provide real-time traffic information to drivers, allowing them to choose the most efficient route. VANETs can also be used to facilitate intelligent transportation systems (ITS), which use real-time data to optimize traffic flow and reduce congestion.

VANETs also have applications in entertainment and passenger comfort [4][6]. For example, VANETs can be used to provide Wi-Fi hotspots in vehicles, allowing passengers to connect to the internet and stream media. VANETs face several challenges, including limited bandwidth, high latency, and security issues. VANETs must also address issues related to privacy and data protection, as the communication between vehicles and infrastructure can contain sensitive information. Researchers are actively working on addressing these challenges to ensure the reliable and secure operation of VANETs [3].

Related Work

Partha Sarathi, et. al, 2015 proposed an algorithm for dispatching emergency vehicles in an intelligent traffic management system. The algorithm uses real-time traffic data to determine the fastest and most efficient route for emergency vehicles to reach their destination. The paper argues that this algorithm can significantly reduce emergency response times and improve the overall efficiency of emergency vehicle dispatching. The algorithm is adaptive and can adjust to changing traffic conditions in real-time. The paper also discusses the implementation of the algorithm in a simulation environment and presents the results of experiments that show the effectiveness of the proposed algorithm. The paper concludes that the proposed algorithm has the potential to make a significant contribution to emergency response times and traffic management in urban areas [5].

Jiangchen Li, et. al, at 2018 proposed a signal priority request delay modeling and mitigation approach for emergency vehicles in a connected vehicle environment. The proposed approach uses communication technologies to facilitate the communication between emergency vehicles and traffic signal controllers to provide real-time traffic signal priority. The paper argues that the proposed approach can significantly reduce emergency response times and improve the efficiency of emergency vehicle dispatching. The paper discusses the challenges in providing timely signal priority to emergency vehicles in a connected vehicle environment and proposes a novel solution to mitigate the delay in signal priority requests. The proposed solution includes an adaptive delay threshold algorithm that can adjust the signal priority request delay threshold based on traffic conditions. The paper also discusses the implementation of the proposed approach in a simulation environment and presents the results of experiments that demonstrate the effectiveness of the proposed approach in reducing signal priority request delay and improving emergency response times. The paper concludes that the proposed approach has the potential to make a significant contribution to emergency response times and traffic management in connected vehicle environments. The approach is adaptable and can adjust to changing traffic conditions in real-time, making it suitable for different traffic scenarios [6] .

Maryam and Rachid at 2018 proposed an adaptive traffic signal optimization algorithm that considers emergency vehicle preemption and tram priority. The algorithm uses real-time traffic data to optimize traffic signal timings, taking into account the presence of emergency vehicles and trams. The paper argues that this algorithm can significantly reduce travel time for emergency vehicles and trams while also improving traffic flow for other vehicles. The algorithm is based on the PVS algorithm, which is a meta-heuristic optimization algorithm that can find optimal solutions to complex optimization problems. The paper discusses the implementation of the algorithm in a simulation environment and presents the results of experiments that show the effectiveness of the proposed algorithm. The paper concludes that the proposed algorithm has the potential to make a significant contribution to traffic management in urban areas, particularly in situations where emergency vehicle preemption and tram priority are important considerations [7].

Majed Al-qutwani and Xingwei Wang at 2019 proposed a traffic management system that uses Vehicular Named Data Networking (VNDN) to improve the efficiency of traffic lights. VNDN is a communication protocol designed specifically for vehicular networks that can handle large amounts of data traffic. The system uses VNDN to communicate between traffic lights and vehicles to provide real-time traffic updates and control traffic lights. The paper argues that this system can reduce traffic congestion, improve traffic flow, and reduce the time that vehicles spend waiting at traffic lights. The system is adaptive and can adjust to changing traffic conditions. The paper concludes that the proposed system has the potential to significantly improve traffic management in urban areas and enhance the overall driving experience for commuter [8].

Seniman et al., at 2020 proposed a traffic light control system that uses GPS tracking and GPRS network to prioritize the passage of emergency vehicles through traffic lights. The system uses GPS tracking to monitor the position of emergency vehicles and communicate with traffic lights through GPRS network to provide real-time control of traffic signals. The paper argues that this system can significantly reduce emergency response times and improve the efficiency of emergency vehicle dispatching. The system is adaptable and can be customized to different traffic scenarios. The paper discusses the implementation of the system in a simulation environment and presents the results of experiments that show the effectiveness of the proposed system. The paper concludes that the proposed system has the potential to make a significant contribution to emergency response times and traffic management in urban areas [9].

Mohamed Gamal, et. al, at 2022 proposed a traffic control system that can detect the presence of an emergency vehicle in traffic and adjust traffic signals to give the emergency vehicle priority. The system uses a combination of cameras, sensors, and communication technology to detect the emergency vehicle's approach and to communicate with traffic signals to make real-time adjustments. The paper argues that this system can reduce emergency vehicle response times and improve overall traffic flow in the vicinity of the emergency. The proposed system is adaptable to different traffic scenarios and can integrate with existing traffic control systems. The paper concludes that the proposed system has the potential to make a significant contribution to emergency response times and traffic management in urban areas [10].

The effect of congestion on emergency vehicles

An emergency vehicle is a specialized vehicle used by emergency services such as police, fire, and ambulance to respond to emergencies quickly [6][9]. These vehicles are equipped with sirens, lights, and other specialized equipment to provide rapid response and save lives.

The importance of reaching emergency vehicles first and not being congested lies in the critical nature of emergency situations.

In many cases, time is of the essence, and delays in emergency response times can have severe consequences, including loss of life. Emergency vehicles need to reach their destination as quickly as possible to provide immediate assistance to those in need [5].

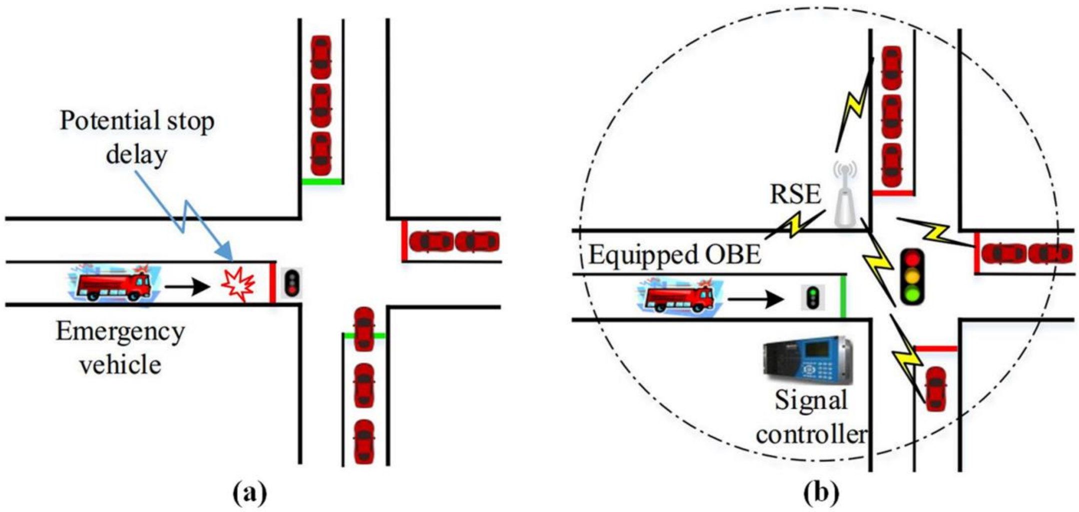

Figure (1): Delay illustration for emergency vehicle's response time: (a) typical stop delay for emergency vehicle (3); (b) a representative CV-based preemption system with communication delay [6]

As shown in Figure (1) if emergency vehicles are over congestion or delayed due to traffic congestion, their ability to respond to emergencies is severely hampered. In such cases, a few extra minutes can make a significant difference in the outcome of an emergency situation [6]. Prioritizing emergency vehicles' passage through traffic lights and ensuring they have clear roads can reduce response times and improve the chances of saving lives. Hence, it is crucial to manage traffic flow efficiently and prioritize emergency vehicles' passage to ensure the fastest response times possible [4][8][9].

Proposed Adaptive Traffic Light for emergency vehicle

Emergency vehicles such as ambulances, fire engines, and police cars require the use of traffic lights in urban environments to ensure they can quickly and safely reach their destination.

In most countries, emergency vehicles are equipped with sirens and flashing lights that are used to alert drivers and other pedestrians of their presence. When an emergency vehicle approaches an intersection, it usually activates sirens and flashing lights to notify other drivers that they need to go through the intersection.

Traffic lights are designed to help manage traffic flow and keep drivers and pedestrians safe. If an emergency vehicle is present, traffic lights can be temporarily bypassed or altered to ensure that the vehicle passes safely through the intersection.

To solve this problem, we suggested preparing the roads, especially near and before the traffic lights, according to the ring, with roadside units, which can communicate with the vehicle at a distance of 1 km. When the emergency vehicle approaches an intersection, it sends a signal to the roadside unit located in the road, which in turn determines its location and speed.

The distance between the vehicle and the RSU is calculated instantly by the distance law and by using the speed equation:

$$d = \sqrt{(x_2 - x_1)^2} \qquad (1)$$

Where:

d: is the distance between the vehicle and the traffic light

Then can derive the equation of time as follows:

$$t = \frac{d}{v} \quad (2)$$

Where the RSU is able to turn on the signal a minute before the time of the arrival of the emergency, so that the street is completely empty when the emergency vehicle arrives, so that it turns green for emergency vehicles and red for other vehicles. This helps clear the intersection and ensures that the emergency vehicle passes safely.

Implement the proposed model in simulation

To implement the proposed model in this paper, a network simulation (Net Logo) is used to build a virtual urban map consisting of roads with an intersection. The RSUs are distributed according to their coverage. They are located at a distance of 2 km between one RSU and the other to ensure communication between them, as shown in Figure (2).

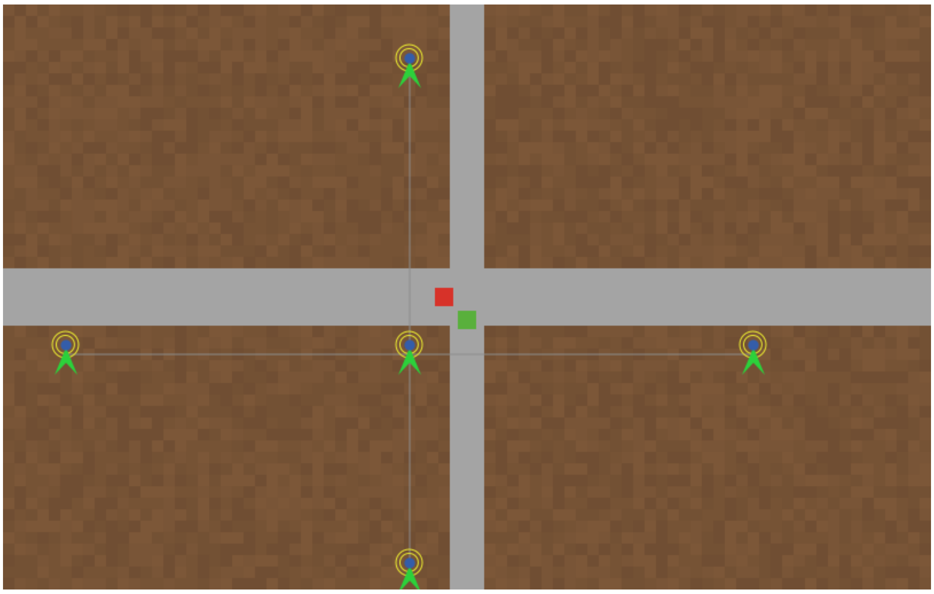

Figure (2): Proposed interconnected network

As shown in Figure 3, the scenario begins with several vehicles entering the roads, including an ambulance. The ambulance moves on the road with constant contact with the roadside units, and when the ambulance arrives at the roadside unit that precedes the roadside unit connected to the traffic light, the roadside unit sends a notification to the roadside unit connected to the traffic light to open the traffic signal before (5 Ticks) The arrival of the ambulance. The continuous arrival time is calculated by the previously proposed equations. After the ambulance has passed, the traffic light will return to normal operation. Thus, ambulances avoid traffic jams and arrive as quickly as possible.

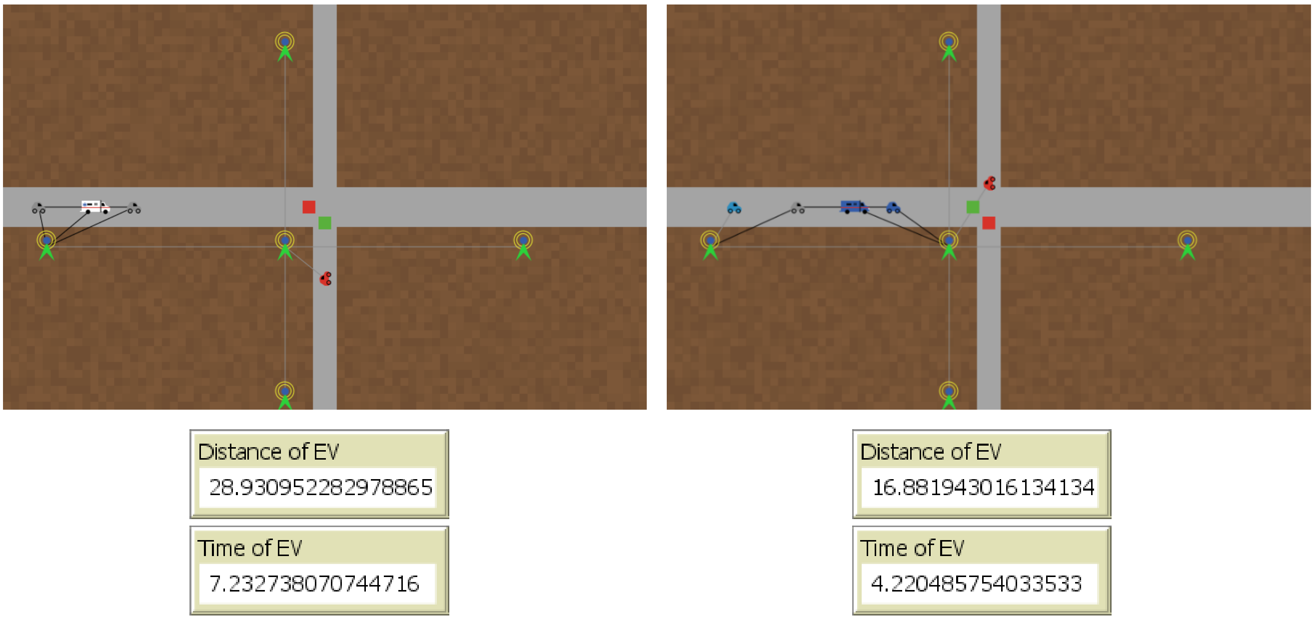

Figure (3): Simulation for Adaptive Traffic

Figure 4 shows a schematic diagram showing the vehicles that wait at the traffic lights. Opening the emergency vehicle's traffic light increases the waiting time for the rest of the vehicles in other directions of the vehicle, but the total average waiting time indicates that it does not significantly affect the system. This means the stability of the system. While Figure 5 shows an analysis of the general car speed on the map in terms of the average, the highest and lowest speed values. Calculating the mean speed of vehicles is necessary to find out the time required to open the parking lot before the emergency vehicle reaches the traffic light so that all vehicles stopped in the traffic light can pass before the arrival of the emergency vehicle.

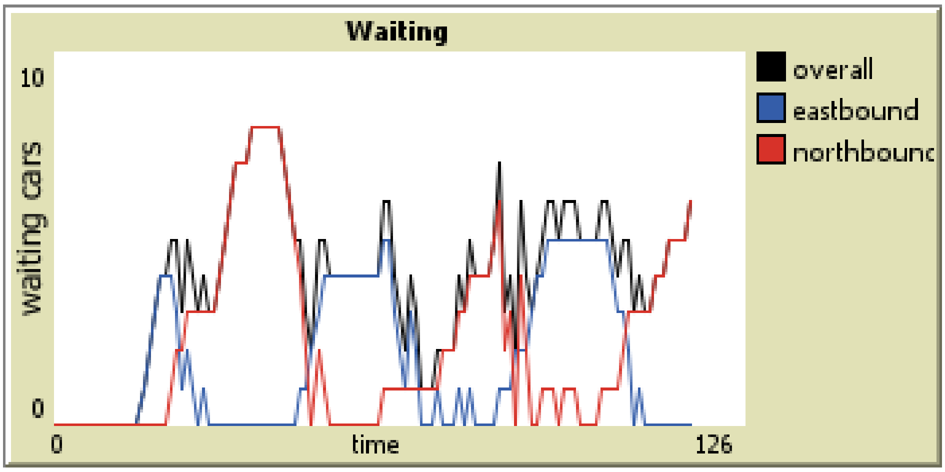

Figure (4): Waiting for vehicles

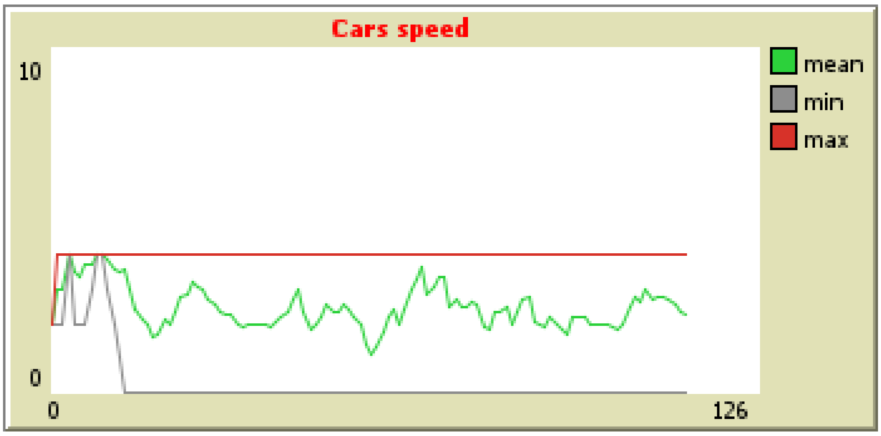

Figure (5): Mean, Max and Min of Cars Speed

Conclusions

Emergency vehicles play a crucial role in saving lives and protecting property during emergency situations. They are specially designed and equipped to provide rapid response and immediate assistance in emergencies, such as fires, accidents, and medical emergencies. The importance of emergency vehicles lies in their ability to respond quickly and efficiently to emergencies. Their specialized equipment and highly trained personnel can provide critical care and support to those in need. Emergency vehicles can transport patients to hospitals, rescue individuals from dangerous situations, and provide on-site medical treatment to injured people. Furthermore, emergency vehicles also play a critical role in managing disasters and emergencies that affect communities, such as natural disasters and terrorist attacks. They help to evacuate people from dangerous areas, provide search and rescue operations, and deliver essential supplies and equipment to affected areas. In this paper, a proposed model was discussed to solve the problem of congestion of the emergency vehicle and to connect it as quickly as possible through adaptive traffic light using the assistance of the RSU, and the ambulance was taken as an example for applying the proposed model. The results showed that the model is effective in reducing congestion significantly for emergency vehicles. This approach is adaptive and can adapt to changing traffic conditions in real time, which makes it suitable for different traffic scenarios.

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