Computing and Informatics, Vol. 43, 2024, 974–992, doi: 10.31577/cai_2024_4_974

# EDGE COMPUTING APPLICATION OF EXPRESSWAY INTELLIGENT TRANSPORTATION SYSTEM BASED ON IOT TECHNOLOGY

Jianqiang Wang*, Peini Shang

*School of Information Engineering, Yulin University*
*Yulin 719000, Shaanxi, China*
*e-mail:* {wangjq, shangpeini}@yulinu.edu.cn

**Abstract.** With the comprehensive arrival of the fifth generation mobile communication technology (5G) era, the Internet of Things (IoT) has developed rapidly and is widely used in various industries. As one of the modern transportation signs, highways play an irreplaceable role in social and economic development. The research on Intelligent Traffic Systems (ITS) on highways has always been a hot topic. With the continuous improvement of the highway network and the increasing mileage, the efficiency of the existing highway ITS in processing information and solving problems is relatively low. Introducing new technologies to achieve breakthroughs has become a top priority. Edge computing is widely used in the Internet of Things technology because of its low latency and high response speed. Based on the characteristics of edge computing technology, this paper conducted in-depth research on expressway ITS, and analyzed the specific functions of intelligent system through IoT technology and edge computing technology. Through analysis and experiment, it is concluded that in the experimental highway area, the ITS using edge computing technology has slightly improved compared with the traditional ITS in all aspects. The response speed of the monitoring system has increased by 4.9 %, the congestion rate has decreased by 11.27 %, the congestion duration has decreased by 37.3 %, and the accident rate has decreased by 7.63 %. The edge computing application of expressway ITS based on IoT technology has improved the safety and comfort of residents' travel. It not only improves the intelligence level of intelligent transportation systems, but also enhances the safety and comfort of residents' travel, meeting the travel needs of modern people.

**Keywords:** IoT technology, intelligent transportation system, highway monitoring system, edge computing

* Corresponding author

## 1 INTRODUCTION

As a modern traffic sign, highways not only serve as transportation responsibilities, but also play a crucial role in promoting industrial development, driving residents' income, and improving quality of life, involving various fields such as economy and society. The stable and rapid development of highways has also caused some problems. Traditional intelligent transportation systems are unable to efficiently process the massive amount of existing traffic information data, resulting in the system's ability to handle problems that cannot meet existing needs. Therefore, based on the IoT technology and edge computing technology, this paper builds a model analysis of the existing ITS to improve the efficiency of the system and ensure the safety and convenience of residents' travel.

The improvement of ITS is currently a hot topic, and many scholars have conducted research on it. Zhu et al. believed that big data is a key research direction for ITS. The vast transportation network would generate massive amounts of data, and big data analysis and rational application would usher in vigorous development [1]. Jan et al. believed that smart transportation systems, as an important component of smart cities, should be deeply integrated with the IoT, enhance intelligence, and ensure the safety of residents' appearance [2]. Sumalee and Ho proposed that the development of the IoT makes it easier and cheaper to collect, store, analyze, use, and disseminate multi-source data. Actively introducing new technologies is beneficial for improving the overall performance of the system [3]. Mollah et al. proposed that better road safety and a more convenient information exchange platform are the expected goals of ITS [4]. Tian et al. believed that deep learning (DL for short here) can effectively improve the intelligence level of ITS and improve the accuracy of system predictions [5]. Ferdowsi et al. believed that achieving the true potential of ITS requires ultra-low latency and reliable data analysis. However, the existing cloud center data latency is too high, making it difficult to unleash the full potential of intelligent systems. Therefore, targeted development is necessary to tailor edge centric solutions for the system [6]. Balasubramaniam et al. believed that introducing blockchain can help ITS perform data analysis [7]. The conclusions of these researchers analyzed the existing ITS and pointed out the next development path of the system.

Research on edge computing is a hot topic in the IoT era. Deng et al. proposed the integration of edge computing and artificial intelligence, which promotes the development of each other and creates intelligent edge computing [8]. Chen and Ran proposed a multi application scenario for edge DL, which greatly expanded the practical application of edge computing and accelerated the development of edge computing [9]. Xie et al. proposed the network architecture and hierarchical structure of serverless edge computing network, and analyzed the development prospect of serverless edge computing network technology [10]. Xiao et al. believed that the development of the IoT has promoted the wide application of edge computing, but also ignored its security threats, and proposed the status quo and major challenges of edge computing security [11]. Wang et al. proposed the integration of edge computing and DL, pointed out that edge intelligence and intelligent edge are mutually beneficial and win-win, and proposed their application scenarios [12]. The research of these scholars on edge computing involves many fields, but the application of edge computing in ITS is less involved.

In order to address the shortcomings of insufficient capacity in existing highway transportation systems, this article introduces the relevant concepts of highway ITS and analyzes the basic elements of existing highway electrical systems. Its analysis includes as follows: monitoring systems, communication systems, and other modules in existing intelligent transportation systems; expressway intelligent transportation system based on the Internet of Things; expressway intelligent transportation system based on edge computing. Then based on the IoT technology, this paper improves the edge computing structure of DL. By adding the application of edge computing to the existing system, this paper analyzes the changes of the monitoring system response time, highway traffic congestion rate, highway congestion time, highway accident rate and other related indicators after the application of edge computing. Compared with traditional ITS, the improved system has improved in all aspects and provides more guarantee for traffic safety.

## 2 ELEMENTS OF EXPRESSWAY ITS

### 2.1 Expressway ITS

The ITS of highways is divided into the following systems (monitoring system, toll collection system, communication system) and tunnel electromechanical systems (on-site control network, traffic monitoring system, closed circuit television system, emergency telephone system, wired broadcasting system, and environmental detection system). In the highway monitoring system, there are three main components: information collection system, monitoring center, and information supply subsystem. ITS can effectively ensure the safety of drivers' travel and alleviate traffic congestion. However, due to the rapid development of highways, the mileage of highways is constantly increasing, and the number of cars is skyrocketing. There are some safety hazards in the existing ITS, and it is necessary to solve the safety problems in the system to make it more safe and reliable [13]. At the same time, the existing ITS cannot meet the travel needs of drivers, and there is an urgent need for technological improvement to enhance and improve the functions of the ITS.

### 2.2 Expressway ITS Based on the IoT

The IoT technology plays an indelible role in urban transportation construction. Applying IoT technology to ITS can promote the construction process of cities, optimize traffic management models, and ensure residents' traffic safety. Driven by the development of the IoT, ITS have entered a rapid development stage, making the collection and entry of vehicle information more convenient, making vehicle tracking possible, and many transportation system problems have been solved. ITS combine existing technologies with terminal devices. The combination of various devices provides solutions to these problems. With the emergence of Internet of Things technology and fifth generation mobile communication technology, real-time vehicle tracking is gradually maturing, which can provide strong support for efficient traffic management.

As an important component of the IoT, cameras play an important role in ITS, providing real-time information of road vehicles for the system. However, the massive amount of videos brings difficulties and challenges to video retrieval. Therefore, a video retrieval method that can effectively extract key information from videos is needed to effectively shorten video retrieval time [14]. At the same time, the IoT also has outstanding performance in information transmission. By utilizing radio frequency identification technology and sensor network technology to achieve information transmission between related devices and driving vehicles, the technological advantages of the IoT can be fully utilized to improve the efficiency of ITS. Reasonable use of IoT technology can effectively alleviate traffic congestion and slow traffic information transmission [15]. Figure 1 illustrates the application of the IoT in ITS. Figure 2 illustrates the interface of an ITS.

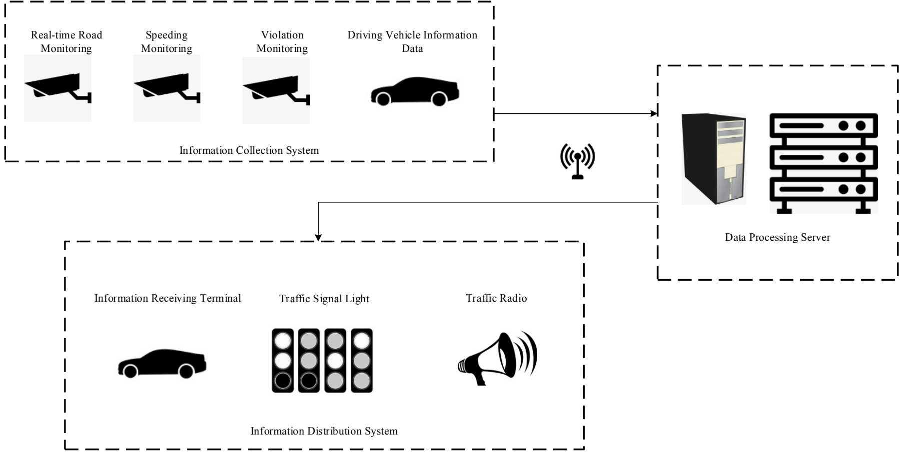


Figure 1. Application of IoT in ITS

### 2.3 Expressway ITS Based on Edge Computing

The development of the IoT has led to a sharp increase in the number of Edge device. The massive data generated by a large number of devices has greatly increased the computing pressure of the cloud computing center. At the same time, it would also waste the storage space of the cloud computing center, so edge computing

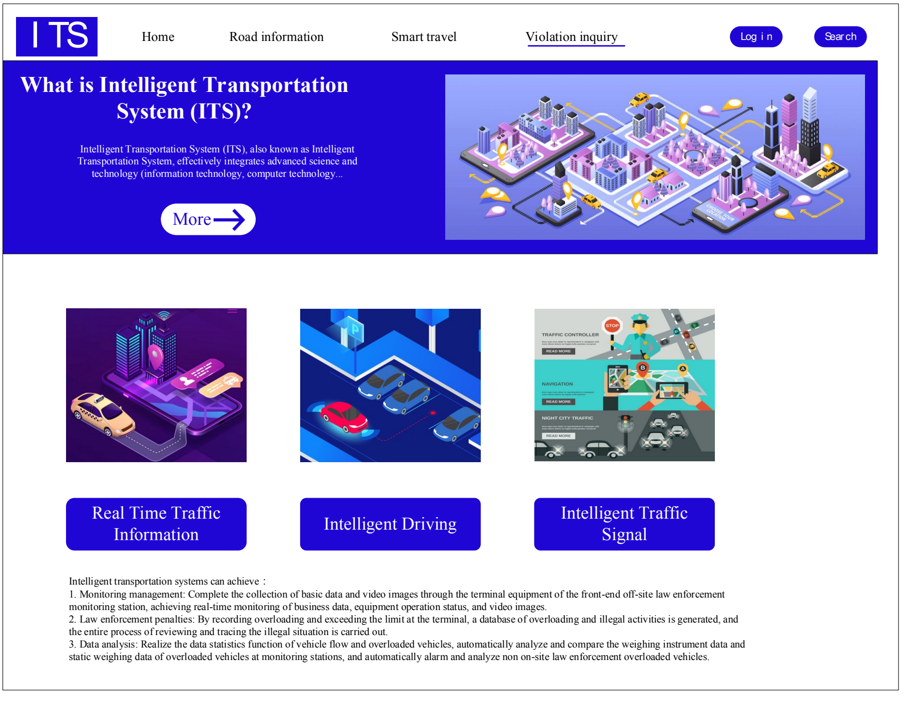


Figure 2. ITS interface

came into being [16, 17]. The monitoring system of the expressway network has a large number of cameras. One camera generates hundreds of gigabyte of data every week. If all this data needs to be uploaded to the cloud, it is undoubtedly a waste of computing power. Computing power can be added to the edge device to push data processing and decision-making to the edge device, preprocess the data uploaded, extract effective information and upload. It can save a lot of storage space, reduce dependence on central servers and network transmission pressure, improve information processing efficiency, and reduce information transmission delay. The ITS based on edge computing is shown in Figure 3.

In addition, the expressway ITS based on edge computing also has stronger security and stability. Due to the distributed edge device deployment, it can quickly switch to the standby device in case of failure, reducing the risk of system failure and ensuring system security. At the same time, cloud collaboration can manage edge device and data, provide computing power to speed up data processing, and dynamically adjust algorithms in real time according to data to ensure system stability.

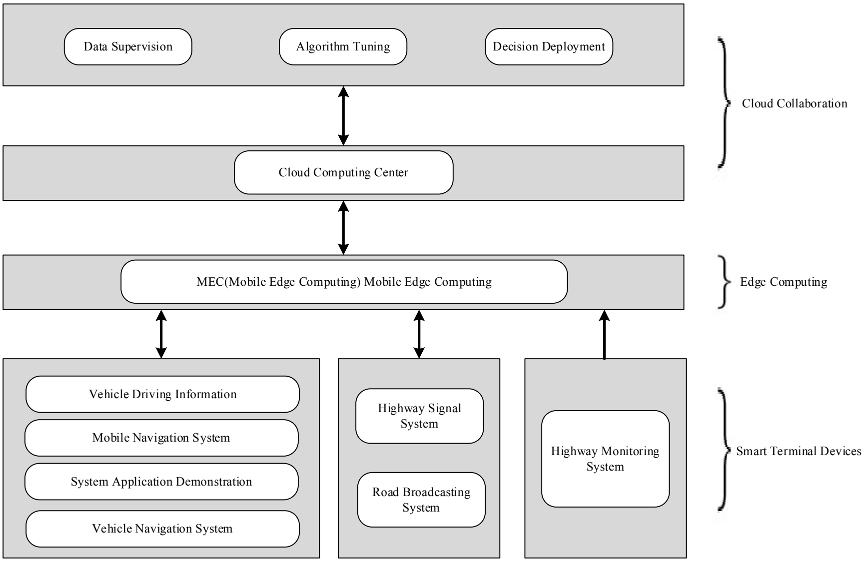


Figure 3. Intelligent traffic system of highway based on edge computing

## 3 APPLICATION OF EDGE COMPUTING IN EXPRESSWAY ITS

### 3.1 Electrical Equipment Access and Operation and Maintenance

A large number of electrical equipment has been deployed along the highway. Due to the lack of unified standards, the procurement and installation management of electrical equipment in the transportation system is chaotic, and there are various types and interfaces of electrical equipment in the ITS. There are problems with equipment matching and compatibility, which can cause great difficulties for device access. At the same time, there is a lack of unified standards for the management and maintenance of mechanical and electrical equipment. The maintenance of mechanical and electrical equipment involves multiple departments and personnel, leading to a significant increase in the cost of system operation and maintenance. After its application of edge computing, it can first provide localized services, provide personalized operation and maintenance services for different devices on the expressway, remove the centralized service structure, and reduce the operation and maintenance costs; Secondly, edge computing can quickly process and analyze data, install intelligent algorithms and models in the equipment, and put forward suggestions on optimizing equipment operation and maintenance through the analysis of various monitoring indicators; Finally, edge computing can visually display equipment data, provide users and operation and maintenance personnel with intuitive fault and operation status information, and facilitate targeted problem processing. In short, the application of edge computing can optimize the access of electrical equipment and reduce the cost of operation and maintenance, so as to ensure the safety of electrical equipment.

### 3.2 Road Monitoring

Based on the rapid development of cloud computing technology and the IoT, intelligent algorithms can be added to edge device. For example, simple intelligent algorithms can be added to cameras to send alarms and upload data only when traffic accidents are detected, foreign objects appear on the road, and the driving environment is too bad. The transmission data is greatly reduced, and the computing pressure of the cloud center is reduced. At the same time, edge computing can realize real-time data exchange and collaborative decision-making between vehicles and road equipment, and combat illegal acts. For example, edge computing can realize license plate recognition, face recognition, target tracking and other functions. However, due to the susceptibility of the video surveillance system to rain, snow, and heavy fog weather, it can lead to the failure of the surveillance system and cause traffic accidents. edge computing technology should be introduced to improve the collection means of road traffic data and give early warning to bad weather in time to ensure that traffic managers make correct judgments on road conditions.

Monitoring moving targets on highways is the core task of monitoring systems, therefore, necessary detection methods have become a top priority. The existing monitoring systems generally use algorithms such as inter frame difference, background difference, and three frame difference to detect moving targets.

The inter frame difference method is an algorithm that uses two adjacent frames of images for difference operations to obtain the appearance features of objects. In the monitoring screen, if there is abnormal target movement, there would be a significant difference between the adjacent two screens. It can then subtract these two images to obtain the absolute value of the pixel value difference in the corresponding image, determine whether it is greater than a certain threshold, and then analyze the object motion characteristics of the video or image sequence. This method has a high computational speed and good adaptability to dynamic environments, and is often used for road condition monitoring. The formula is as follows:

$$d(m,n) = \begin{cases} 1, & \text{if } |f_k(m,n) - f_{k-1}(m,n)| < T, \\ 0, & \text{else.} \end{cases} \tag{1}$$

Among them, $d(m,n)$ is the differential image, and $f_k(m,n)$ and $f_{k-1}(m,n)$ are the pixel values of adjacent two frames of images. $d(m,n) = 1$ represents the foreground, $d(m,n) = 0$ represents the background, and $T$ is the threshold.

Background subtraction, also known as background subtraction, is commonly used to detect moving objects in video images and is currently one of the mainstream methods for moving object detection. The basic principle is to subtract the current frame in the image sequence and the background reference model (background image) that has been determined or obtained in real-time, and calculate the area where the pixel difference with the background image exceeds a certain threshold as the motion area, in order to determine the position, contour, size and other features of the moving object. This algorithm overcomes the influence of environmental light to a certain extent and is often used for monitoring environments such as highway tunnels. The formula is as follows:

$$d(m,n) = \begin{cases} 1, & \text{if } |f_k(m,n) - b(m,n)| > T, \\ 0, & \text{else.} \end{cases} \tag{2}$$

Among them, $d(m,n)$ is the background image, $f_k(m,n)$ is the current frame image, and $b(m,n)$ is the background frame image. $d(m,n) = 1$ represents the moving target, $d(m,n) = 0$ represents the background area, and $T$ is the threshold.

The three frame difference method is a method of obtaining the contour of a moving object by performing differential operations on three consecutive frames of video image sequences. When abnormal target movement occurs in the monitoring scene, there would be significant differences between the adjacent three frames of images, which are subtracted in pairs to obtain the absolute value of the pixel value difference at the corresponding position of the image. Then, the results of these two differential operations are subjected to logical and operational operations, and finally, the moving target is extracted through the set threshold for segmentation. This algorithm is suitable for situations where objects move at a fast speed and is often used for vehicle monitoring, law enforcement capture, etc. The formula is as follows:

$$D(m,n) = d_1(m,n) \otimes d_2(m,n) = \begin{cases} 1, & d_1(m,n)d_2(m,n) \neq 0, \\ 0, & \text{else.} \end{cases} \tag{3}$$

Extract three consecutive frames of image $f_{k-1}(m,n)$, $f_k(m,n)$, $f_{k+1}(m,n)$, where $f_k(m,n)$ and $f_{k-1}(m,n)$ perform the operation of Formula (1) to obtain the differential image $d_1(m,n)$, $f_k(m,n)$ and $f_{k+1}(m,n)$ perform the operation of Formula (2) to obtain the differential image $d_2(m,n)$. $D(m,n)$ is the result of the logical sum of $d_1(m,n)$ and $d_2(m,n)$.

### 3.3 Traffic Control and Information Release

The ITS based on edge computing has good performance in traffic control, mainly reflected in:

**Traffic situation analysis:** real-time intelligent traffic control system based on edge computing + IoT can realize daily traffic control. This can improve traffic efficiency and quickly recommend escape plans for vehicles and personnel involved in emergency situations, effectively improving the level of urban traffic management and emergency management.

**Vehicle road collaborative control:** a large number of edge device deployed on the roadside can simply calculate the current road and vehicle information, so that connectivity and data sharing between vehicles and roads can be achieved. Both parties conduct collaborative decision-making on traffic behavior based on various data analysis, thereby providing suitable driving routes for vehicles and reducing accident rates.

**Accompanying information release:** with the frequent occurrence of large-scale traffic congestion accidents, the issue of traffic emergency command in emergency situations is becoming increasingly prominent. The intelligent terminal device that processes, uploads, and analyzes the information collected by the terminal device, and generates decision instructions that can be fed back in a timely manner, facilitating unified command and scheduling; At the same time, a transportation information network platform can be established to release road network information to the public through broadcasting, SMS (short message service), or online publishing.

## 4 IMPLEMENTATION SCHEME OF EDGE COMPUTING OF EXPRESSWAY ITS

### 4.1 Intelligent Terminal Deployment

By surveying the traffic flow and surrounding environment of a specific road, it can select appropriate locations and numbers to deploy edge computing nodes to ensure coverage and service quality. After comprehensive calculation, the deployment scheme can be formulated. According to the business type and complexity, appropriate hardware devices and software platforms can be selected to build edge computing nodes. In combination with system security, stability and other requirements, mobile containers can be deployed as edge computing nodes on specific roads, and existing operator links can be leased to upload to the data center cloud platform. Compared with the traditional outdoor unit mode, the mobile edge computing node has many advantages such as flexible deployment, cloud edge collaboration, flexible computing capacity expansion and one-stop delivery.

According to the business model, the deployment of edge device of the highway involves a variety of monitoring equipment, such as bayonet cameras (HD (high definition)), traffic video surveillance cameras, electronic police cameras, traffic signal controllers and traffic event monitoring cameras; Streaming media servers, application servers, other servers, and other data processing devices. The above configuration can ensure that edge computing nodes play a full role in the ITS. In addition to the collection end, the edge terminal also has control end devices and vehicle end devices. As a type of intelligent terminal, cars are also used to achieve functions such as intelligent driving, assisted driving, and information transmission. The control end is composed of traffic signal devices, traffic control platforms, navigation systems, and other devices or applications.

### 4.2 Establish Intelligent Edge Computing Platform

The architecture of the intelligent edge computing platform is generally divided into three layers. The first layer is the network layer, which provides access channels for the edge computing platform and supports multiple fixed and mobile access modes. Secondly, there is the edge host layer, which mainly includes edge hosts and host management layer systems. Edge hosts can provide a set of virtualized infrastructure and support various edge application software such as 5G and IOT. The application software accepts the management of edge platforms; The host layer management system is mainly composed of a Virtual Infrastructure Manager (VIM) system and an edge platform management system, providing management of virtual networks, computing, storage resources, and edge platforms. Finally, there is the edge system layer, mainly composed of edge orchestrators, providing global business orchestration capabilities and operational support capabilities. The intelligent edge computing platform can be used to extend video monitoring, toll audit, vehicle road collaboration and other businesses to edge nodes to achieve task, data, management, and security collaboration.

### 4.3 Data Analysis

The expressway ITS based on edge computing mainly adopts the "cloud edge end" architecture. "Cloud" refers to the use of data visualization, data encryption, data access, data replication, data management and other services provided by the cloud computing center. This can build a high-speed vehicle traffic data chassis to achieve data collection, storage, and analysis. The introduction of edge computing technology can not only realize data collection, but also realize big data application on roadside edge device. Further analysis and application of data based on data collection can improve the practicability and reliability of road detection. At the same time, due to the distributed deployment architecture of edge device, the fault tolerance rate of the platform is very high, and the collapse of the cloud computing platform does not need to be considered, leading to the paralysis of the expressway ITS. The cloud computing center selects or constructs appropriate data analysis models and algorithms based on analysis objectives and problems, such as statistical analysis, machine learning, DL, etc., to conduct descriptive, predictive, or inferential analysis of data, providing strong support for making final decisions.

### 4.4 Decision Feedback

The ultimate goal of highway ITS is decision feedback, which is based on perceived environmental information and vehicle status. Through advanced algorithms and models, traffic operations are analyzed, evaluated, and optimized to generate reasonable control strategies and instructions, which are fed back to vehicles or drivers through execution systems or vehicle networking technology to achieve safe and efficient transportation. The feedback content includes but is not limited to: signal control, vehicle navigation, emergency reminder, etc.

### 4.5 Data Security

Due to the intensive deployment of edge device and mobile terminals, a large amount of users' data would be collected, which inevitably involves users' personal privacy. For data involving privacy, multiple security technologies should be used to protect data security and system users' privacy. For example, data encryption involves encrypting sensitive data transmitted and stored to prevent unauthorized third-party access. At the same time, it is necessary to choose an appropriate encryption algorithm and regularly update the key to ensure the security of the data. Identity verification is a process that requires authentication for users or devices with access to sensitive data, such as username, password, fingerprint, or facial recognition, to ensure that data is only accessed by authorized personnel or devices. Access control is the setting of access permissions, granting different access permissions to different levels of users or devices to prevent unauthorized access and operations. The flow chart of the implementation scheme of edge computing of expressway ITS is shown in Figure 4.

## 5 APPLICATION EXPERIMENT OF EDGE COMPUTING IN ITS

### 5.1 Edge Computing Improves the Capability of the Monitoring System

With the development of modern society, the number of cars in use is increasing, and driving has become a choice for more and more people. However, the increase in the number of cars has also led to more emergencies and more complex special situations on highways. Therefore, it further tests the ability of the highway monitoring system to detect unexpected events. Whether it is for traffic accidents, road abnormalities, or other special situations, the monitoring system should quickly detect them. It responds promptly by reminding traffic management personnel to complete subsequent traffic safety work and ensure the traffic safety of travelers. Based on the above purposes, it urgently needs to build a monitoring system that applies edge computing. Applying edge computing technology on monitoring equipment can preprocess the monitoring video, remove redundant and unnecessary information, and then retrieve the remaining information. Its focus is on monitoring road conditions, emergency parking, and vehicle aggregation in non congested situations. This can timely detect emergencies on highways, which is beneficial for traffic management and safety.

First of all, through the data statistics of the selected five highways in a specific time period, this paper compares the detection capability of the monitoring equipment for emergencies between the traditional expressway ITS and the system

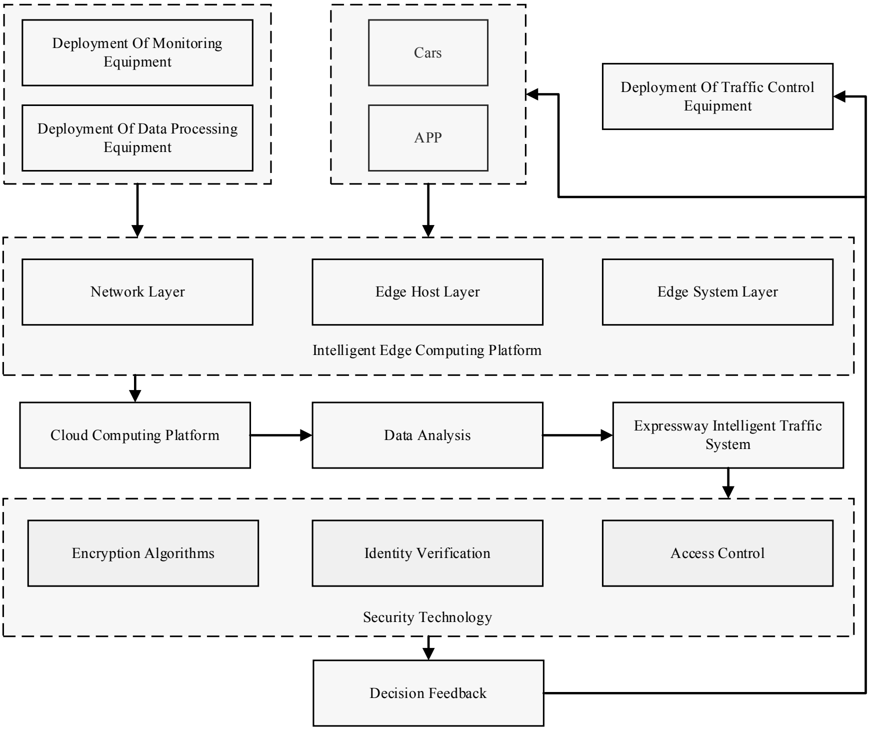


Figure 4. Solution flow of edge computing for highway ITS

after the application of edge computing. As shown in Figure 5, this paper tests the traditional monitoring system and the monitoring system after applying edge computing. It can be found that the number of emergencies detected by the monitoring equipment of the system after the application of edge computing in five highways has increased. Highway A and B are selected for periods with sufficient lighting and superior lighting conditions, while Highway C and D are selected for periods with low visibility such as rain, snow, and heavy fog. In the period of bad lighting conditions, Highway E selects the tunnel part for comprehensive comparison. The experimental results show that the average index of monitoring emergencies by the monitoring system using edge computing is 5.7 % higher than that by the traditional monitoring system.

Secondly, this article conducts data statistics on the selected highways during the designated time period. This paper compares the response time of the traditional expressway ITS and the system monitoring equipment after applying edge computing to detect abnormalities. As shown in Figure 6, this paper tests the response speed of the traditional monitoring system and the response speed of the monitoring system after the application of edge computing. By comparison, it is found that edge com-

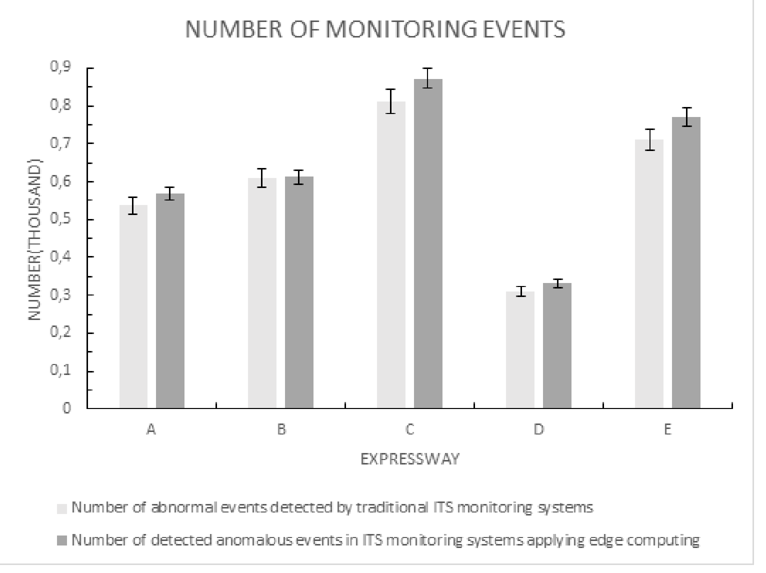


Figure 5. Detection capability improvement of ITS monitoring system by edge computing

puting technology can improve the response speed of the monitoring equipment. Among them, daytime working time is selected for Highway A and B, nighttime working time is selected for Highway C and D, and legal holidays are selected for Highway E. The experimental results show that the application of edge computing technology improves the response speed of the monitoring system by 4.9 %.

Finally, both monitoring of emergencies and rapid response to abnormal conditions are aimed at reducing the incidence of traffic accidents on highways and ensuring the safety of travelers. As shown in Figure 7, this paper makes statistics on the accident rate of the selected roads, and the traffic accident rate of the road where the monitoring equipment using edge computing is located decreases as a whole. The traffic flow on Highway A and B is relatively low, while the traffic flow on Highway C and D is relatively high, while the traffic flow on Highway E is relatively moderate. The application of edge computing technology has reduced the overall accident rate of expressway by 7.63 %. It can be seen that edge computing has significantly improved the capabilities of the monitoring system. It not only increases the number of emergency detection, shortens response time, reduces accident rates, but also ensures the safety of travel.

### 5.2 Mitigation of Edge Computing on Expressway Congestion

With the development of the economy, people's living needs are constantly changing, and holiday travel has gradually become a choice for more and more people. Espe-

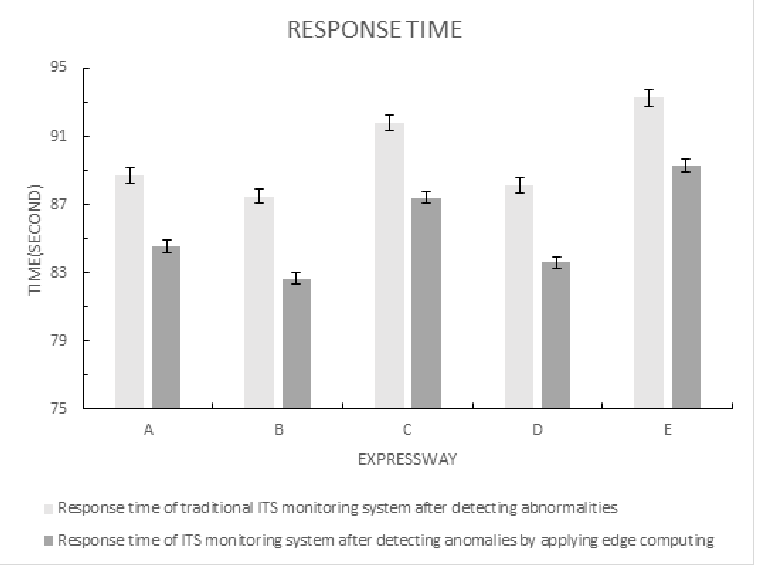


Figure 6. The improvement of edge computing on the response speed of surveillance system after detecting anomalies

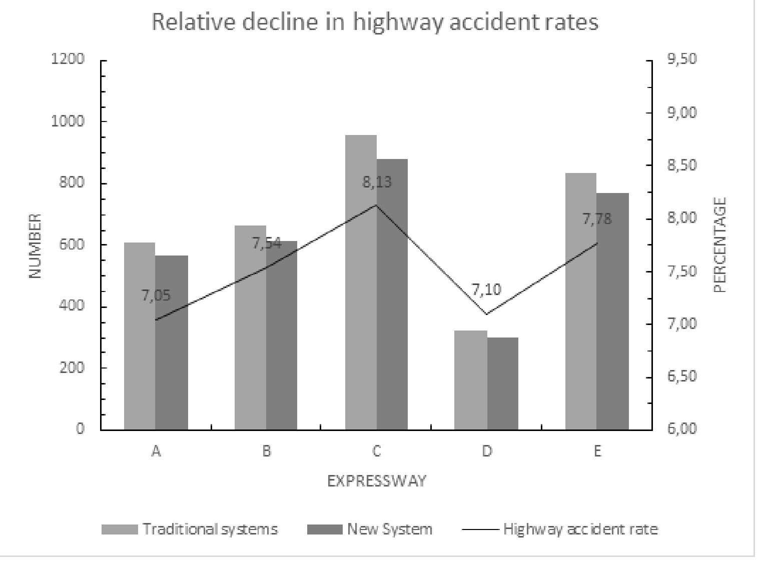


Figure 7. The positive effect of edge computing on reducing the accident rate of expressways

cially during holidays such as National Day, and Spring Festival, residents' travel demand has become increasingly strong. In addition, during holidays, highways are free, and most people choose to drive themselves for travel. Additionally, the morning and evening rush hours caused by daily commuting hours have also led to traffic congestion in specific situations. Therefore, the traffic command and early warning of navigation system are becoming more and more important, and the application of edge computing makes the ITS of expressway make a difference in traffic command and information release. The intelligent terminal provides vehicle location information at any time, and the system analyzes the current level of road congestion and provides real-time feedback to the vehicle's navigation system. It also plans forward routes and divides vehicles into congested and upcoming sections. This effectively alleviated traffic congestion and directly improved residents' travel experience.

First of all, this paper collects data on selected roads in a specific time period, and compares the ability of ITS using edge computing technology with traditional transportation systems to ease traffic congestion. As shown in Figure 8, roads A and B are selected for the morning and evening peak periods during commuting, while roads C and D are selected for the free time periods on highways during holidays. This paper selects a period of time when the traffic volume of Highway E is less than that of the former, and makes a comprehensive comparison. The data results show that the edge computing technology improves the traffic congestion rate of ITS to 11.27 %.

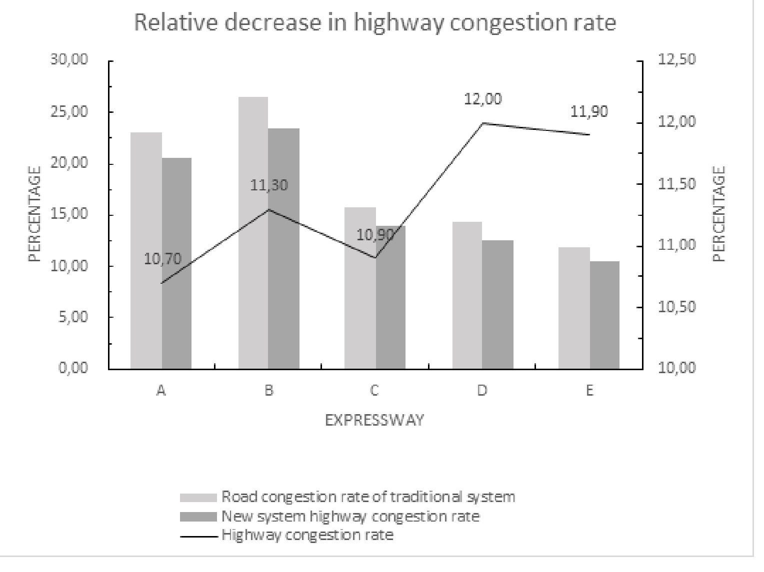


Figure 8. Alleviation of highway congestion rate by edge computing

Secondly, for the road sections that have formed congestion, this paper conducts reasonable intervention, and shortening the congestion duration is also an important task of the ITS. Through data collection on selected roads in a specific time period, comparative analysis is made on the improvement of edge computing technology in the rectangular area when the intelligent transportation reduces congestion. As shown in Figure 9, roads A and B are selected for free periods on highways during holidays, roads C and D are selected for peak morning and evening commuting periods, and roads E are selected for periods with relatively low traffic flow compared to the former. The data results show that the application of edge computing technology improves the congestion duration of ITS by 37.3 %. It can be seen that edge computing has a positive effect on the intelligent transportation system to make correct decisions. It not only monitors the congestion rate of roads, but also shortens the congestion time and ensures the comfort of travelers.

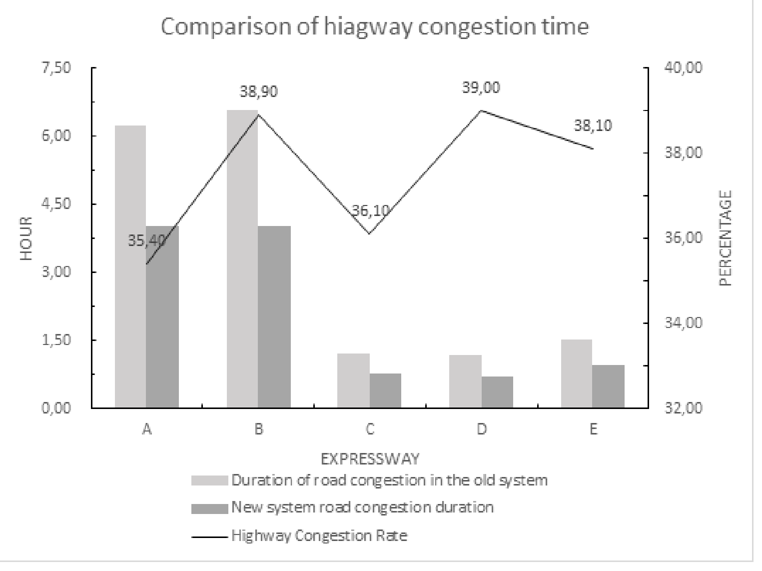


Figure 9. The positive effect of edge computing on reducing highway congestion time

## 6 CONCLUSIONS

Transportation has always been a hot topic of concern for people. The rapid development of the economy has made driving a choice for more people, and the change in travel methods also reflects the changing needs of residents. People have put forward higher requirements for the safety and comfort of transportation. However, the existing ITS have poor data processing capabilities, limited feedback, and little improvement in safety, which cannot meet the travel needs of residents. Introducing new technologies has become the key to breakthroughs. The combination of edge computing and the IoT technology has brought new vitality to many fields. The introduction of edge computing and the IoT technology has also led to the rapid development of expressway ITS. This paper combs the research and application of edge computing based on IoT technology in ITS. Overall, this experiment verifies the positive role of edge computing in the expressway ITS. The average index of monitoring emergencies has slightly increased, the response speed of the monitoring system has slightly improved. The congestion rate has slightly decreased, the congestion duration has significantly decreased, and the accident rate has slightly decreased. It significantly improves system efficiency, alleviates cloud computing pressure, and meets people's transportation and management needs.

## Acknowledgement

This work was supported by the Shaanxi Provincial Science and Technology Plan Project (grant No. 2023-YBNY-200); the Yulin Science and Technology Plan Project (grants Nos. CXY-2020-012-08, CXY-2020-007-03); and the Yulin National High-Tech Industrial Development Zone Science and Technology Plan Project (grant No. CXY-2021-14).

## REFERENCES

[1] Zhu, L.—Yu, F. R.—Wang, Y.—Ning, B.—Tang, T.: Big Data Analytics in Intelligent Transportation Systems: A Survey. IEEE Transactions on Intelligent Transportation Systems, Vol. 20, 2019, No. 1, pp. 383–398, doi: 10.1109/tits.2018.2815678.

[2] Jan, B.—Farman, H.—Khan, M.—Talha, M.—Din, I. U.: Designing a Smart Transportation System: An Internet of Things and Big Data Approach. IEEE Wireless Communications, Vol. 26, 2019, No. 4, pp. 73–79, doi: 10.1109/mwc.2019.1800512.

[3] Sumalee, A.—Ho, H. W.: Smarter and More Connected: Future Intelligent Transportation System. IATSS Research, Vol. 42, 2018, No. 2, pp. 67–71, doi: 10.1016/j.iatssr.2018.05.005.

[4] Mollah, M. B.—Zhao, J.—Niyato, D.—Guan, Y. L.—Yuen, C.—Sun, S.—Lam, K. Y.—Koh, L. H.: Blockchain for the Internet of Vehicles Towards Intelligent Transportation Systems: A Survey. IEEE Internet of Things Journal, Vol. 8, 2021, No. 6, pp. 4157–4185, doi: 10.1109/jiot.2020.3028368.

[5] Tian, Y.—Du, Y.—Zhang, Q.—Cheng, J.—Yang, Z.: Depth Estimation for Advancing Intelligent Transport Systems Based on Self-Improving Pyramid Stereo Network. IET Intelligent Transport Systems, Vol. 14, 2020, No. 5, pp. 338–345, doi: 10.1049/iet-its.2019.0462.

[6] Ferdowsi, A.—Challita, U.—Saad, W.: Deep Learning for Reliable Mobile Edge Analytics in Intelligent Transportation Systems: An Overview. IEEE Vehicular Technology Magazine, Vol. 14, 2019, No. 1, pp. 62–70, doi: 10.1109/mvt.2018.2883777.

[7] Balasubramaniam, A.—Gul, M. J. J.—Menon, V. G.—Paul, A.: Blockchain for Intelligent Transport System. IETE Technical Review, Vol. 38, 2021, No. 4, pp. 438–449, doi: 10.1080/02564602.2020.1766385.

[8] Deng, S.—Zhao, H.—Fang, W.—Yin, J.—Dustdar, S.—Zomaya, A. Y.: Edge Intelligence: The Confluence of Edge Computing and Artificial Intelligence. IEEE Internet of Things Journal, Vol. 7, 2020, No. 8, pp. 7457–7469, doi: 10.1109/jiot.2020.2984887.

[9] Chen, J.—Ran, X.: Deep Learning with Edge Computing: A Review. Proceedings of the IEEE, Vol. 107, 2019, No. 8, pp. 1655–1674, doi: 10.1109/jproc.2019.2921977.

[10] Xie, R.—Tang, Q.—Qiao, S.—Zhu, H.—Yu, F. R.—Huang, T.: When Serverless Computing Meets Edge Computing: Architecture, Challenges, and Open Issues. IEEE Wireless Communications, Vol. 28, 2021, No. 5, pp. 126–133, doi: 10.1109/mwc.001.2000466.

[11] Xiao, Y.—Jia, Y.—Liu, C.—Cheng, X.—Yu, J.—Lv, W.: Edge Computing Security: State of the Art and Challenges. Proceedings of the IEEE, Vol. 107, 2019, No. 8, pp. 1608–1631, doi: 10.1109/jproc.2019.2918437.

[12] Wang, X.—Han, Y.—Leung, V. C. M.—Niyato, D.—Yan, X.—Chen, X.: Convergence of Edge Computing and Deep Learning: A Comprehensive Survey. IEEE Communications Surveys & Tutorials, Vol. 22, 2020, No. 2, pp. 869–904, doi: 10.1109/comst.2020.2970550.

[13] Dai, P.—Luo, J.—Zhao, K.—Xing, H.—Wu, X.: Stacked Denoising Autoencoder for Missing Traffic Data Reconstruction via Mobile Edge Computing. Neural Computing and Applications, Vol. 35, 2023, No. 19, pp. 14259–14274, doi: 10.1007/s00521-023-08475-3.

[14] Thakur, S.—Dharavath, R.—Shankar, A.—Singh, P.—Diwakar, M.—Khosravi, M. R.: RST-DE: Rough Sets-Based New Differential Evolution Algorithm for Scalable Big Data Feature Selection in Distributed Computing Platforms. Big Data, Vol. 10, 2022, No. 4, pp. 356–367, doi: 10.1089/big.2021.0267.

[15] Humayun, M.—Jhanjhi, N. Z.—Hamid, B.—Ahmed, G.: Emerging Smart Logistics and Transportation Using IoT and Blockchain. IEEE Internet of Things Magazine, Vol. 3, 2020, No. 2, pp. 58–62, doi: 10.1109/iotm.0001.1900097.

[16] Yedurkar, D. P.—Metkar, S.—Al-Turjman, F.—Yardi, N.—Stephan, T.: An IoT-Based Novel Hybrid Seizure Detection Approach for Epileptic Monitoring. IEEE Transactions on Industrial Informatics, Vol. 20, 2024, No. 2, pp. 1420–1431, doi: 10.1109/tii.2023.3274913.

[17] Chithaluru, P.—Al-Turjman, F.—Kumar, M.—Stephan, T.: Energy-Balanced Neuro-Fuzzy Dynamic Clustering Scheme for Green & Sustainable IoT Based Smart Cities. Sustainable Cities and Society, Vol. 90, 2023, Art. No. 104366, doi: 10.1016/j.scs.2022.104366.

**Jianqiang Wang** received his Master's degree from the Xidian University, P.R. China. Now, he works in the School of Information Engineering, Yulin University. His research interests include Internet of Things application technology and embedded systems.

**Peini Shang** received her Master's degree from the Xidian University, P.R. China. Now, she works in the School of Information Engineering, Yulin University. Her research interests include big data analysis and Internet of Things architecture.