A Smart Network Resource Management System for High Mobility Edge Computing in 5G Internet of vehicles

Shanchen Pang, Nuanlai Wang, Min Wang, Sibo Qiao, Xue Zhai, Neal N Xiong

***Abstract*—Smart Driving Vehicles (SDVs) are assisted by Mobile Edge Computing (MEC) to enhance the ability to deal with complex road conditions. Smart network composed of SDVs and MEC. The transmission of low delay is required in intelligent driving tasks. However, High Mobility Edge Computing Service Hand-Off (HMEC-HO) can cause retransmission delays and some security issues. To reduce delay in Smart network, a Hybrid Transmission and Reputation Management (HTRM) system is presented. Based on Fifth Generation Mobile Communications (5G) Vehicle-to-Everything (V2X) technology, an efficient hybrid Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Scheduling (EH-V2VV2I) algorithm is designed, which uses relay vehicles to help initiating-vehicles for task transmission. To enhance the reliability of V2V connection, an algorithm of Relay Vehicle Selection and Reputation Management (RV-SRM) is proposed for predicting the link survival time, selecting highly reliable relay vehicles, and managing vehicle credibility simultaneously. The simulation results show that HTRM makes the throughput of the tasks of edge server to meet the requirements of vehicles. The experiments show that the delay of our method is reduced by 41% and the reliability of V2V connection is improved by 31% than the hard handover method.**

***Index Terms*—Edge Computing, Internet of Vehicle (IOV), 5G, reputation management.**

I. Introduction

EDGE computing, which is an information hinge for vehicles and roadside facilities [1], can enhance the level of vehicle intelligence in the scene of vehicle-road synergy sensing [2]. Smart Driving Vehicles (SDVs) can perceive the surrounding environment depending on vehicle cameras, radar and other equipment. Roadside facilities (signal lights, roadside cameras, etc.) can also raise SDVs awareness. New Radio Vehicle-to-everything (NR-V2X) is becoming the key technology of Internet of Vehicle (IOV) [3]. The communication paradigm of NR-V2X is supported by 5th Generation Mobile Networks (5G). This technology greatly enhances the transmission capability of wireless networks. Vehicle-to-vehicle (V2V) and Vehicle-to-Infrastructure (V2I) are the important application of 5G [4]. The amount of data will be produced by vehicle and roadside facilities, which must be processed in a short period of time. The embedded systems often cannot support the Convolution Neural Network (CNN) algorithm with low delay [5]. Mobile Edge Computing (MEC) deploys servers to the edge of the network, bringing computing resources closer to users, and effectively reducing transmission latency [6]-[7]. Nevertheless, one edge server dominates one or more Base Stations (BSs), so the edge computing service is limited by the service area. The contradiction between high mobility of users and limited coverage of a single edge server seriously affects the performance of edge services, which may lead to a sharp decline in user's QoS and even service interruption [8]. High Mobility Edge Computing Hand-Off (HMEC-HO) involves not only switching between BSs but also between edge platforms. HMEC-HO is difficult to maintain task continuity and poses challenges for smart driving [9].

HMEC-HO is different from BS hand-off [10]: 1) It has a task continuity limitation. The topology of IOV changes rapidly. During hand-off, data transmission or task processing will be interrupted and tasks will be discarded, which result in retransmission delays [11]; 2) Data transmission requires a large number of spectral resources to be allocated. In order to ensure the low delay transmission, the pressure of cellular network should be reduced. The HMEC-HO mode based on service migration [10] is proposed, which is a promising way to reduce HMEC-HO delay by migrating unfinished tasks to the target server. However, the process of migration has transmission delay and occupies a large number of link resources. In [12], edge computing service migration for highly mobile vehicles makes it difficult to improve user's QoS. Hybrid transmission is a promising way to solve this problem. Y. Sun *et al.* [13] propose a hybrid transmission method which combines V2V with V2I to reduce the delay caused by retransmission.

V2X protocol is established in IEEE 802. 11p [14]. Intelligent vehicle transmission capacity is improved by V2V communication. V2V technology is based on Device-to-Device (D2D) communications. D2D connects two geographically close devices to achieve low latency communication. D2D can improve spectrum efficiency, reduce cellular network pressure and optimize network performance [15]. At the same time, the Multiple Input Multiple Output (MIMO) technology en-

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hances the forwarding capability of nodes and increases node throughput [16]. Vehicles On Board Unit (OBU) are connected to BS in the Release 14 [17], which is published by Third Generation Partnership Project (3GPP). Vehicles are allowed to schedule tasks independently in the mode 4 of Release 14. The transmission capacity of 5G V2X was significantly improved in Release 16 [18].

Data streams can be transmitted by V2V within 300 meters [19]. V2V initiator selects a relay vehicle within the transmission range, which connects with unfamiliar vehicle nodes inevitably. The problem of optimal path between vehicle nodes can be solved by heuristic algorithm [20]. Due to the huge volume of IOV, it may be affected by interference attack, error attack and reply attack, which will affect the overall security seriously [21] of the system and lead to transmission failure. The reputation management mechanism aims at establishing the trust relationship between nodes, which can provide safe and reliable services for users [22]. Establishing an effective credit management strategy can reduce the possibility of nodes being attacked and enhance the transmission reliability [52]. As a result, the choice of V2V relay vehicles is worth studying.

The contributions of this paper are summarized as follows:

(1) To solve the problem of high mobility SDVs edge service handoff, we propose a single hop hybrid transmission solution based on 5G-V2X.

(2) We propose an efficient hybrid transmission task scheduling strategy. The transmission mode is predicted and the task is scheduled according to the vehicle context. V2V transmission is adopted to minimize the delay when the task-initiating vehicle cannot complete the task independently.

(3) We propose a relay vehicle selection and reputation management strategy, which selects relay candidate vehicles according to context of SDVs. The evaluation function is proposed to ensure connection reliability. The optimal relay vehicle is selected under the constraint of link lifetime. Reputation management is carried out at the edge server, and the integral system is used to ensure relay vehicle to complete relay transmission on time.

The rest of the paper is organized as follows. Section II describes the work related to hybrid transport and reputation management. Section III introduces the functional scenario of V2V and V2I hybrid transmission in detail. Section IV describes the EH-V2VV2I and RV-SRM algorithm. The performance of the algorithm is simulated and analyzed in section V. Section VI concludes this paper.

II. Related Work

Traditional cloud computing can no longer meet the stringent low latency requirement of smart driving. Emerging computing mode represented by MEC is rising rapidly. MEC places computing units on the edge of the network, bringing computing resources closer to users than cloud computing. Edge computing combines wireless networks to provide efficient and flexible computing mode for wireless devices. How to manage the smart network composed of SDV and edge server is a research hotspot. K. Zhang *et al.* [23] introduce an intelligent driving service based on MEC, in which SVDs are assisted by edge server to process data. Compared with cloud computing, this paradigm can reduce transmission costs. Considering both energy consumption and latency [24], H. Yu *et al.* [25] used queuing theory and convex optimization theory to optimize resource allocation in MEC system. The application of 5G technology in MEC system greatly improves the transmission capacity of wireless network and provides power for the application of edge computing. In the study of [26], 5G combines with MEC for real-time context awareness, vehicle and MEC context can be quickly collected and distributed with the help of 5G when an instruction is received. K. Serizawa *et al.* [27] verified that 5G-V2X can effectively support the communication between vehicles and between vehicles and infrastructure. And 5G-V2X has higher flexibility and can allocate channel resources autonomously [28]. However, how to switch servers efficiently and securely is a challenge. Edge computing services need to be processed in the edge server. The coverage of 5G BS is smaller than that of 4G, and the mobility of vehicles is strong. Vehicles are easy to leave the service range in the upload, processing and download stages, causing retransmission delay. An efficient handoff authentication strategy based on 5G-V2X is proposed to reduce the communication delay in the authentication process [29]. But few people have studied it in depth. The cooperation between high mobility vehicles and edge servers is a hotspot in current research. T. Ojanper *et al.* [30] studied business continuity and data synchronization in the platoon management and shared world model for the frequent edge server handoff problem of high mobility vehicles. Inspired by traditional service migration methods, W. Nasrin *et al.* [20] propose a service migration method to solve the cross-platform problem. This method migrates incomplete tasks to the next server based on the vehicle context. However, the delay caused by the migration is not considered. Moreover, if the vehicle drives out of the service area in the task download phase, the service migration method can not work at this time, which will cause more delays. V2I V2V hybrid transmission based on 5G-V2X is a promising solution to HMEC-HO problems. When the V2I link is disconnected, the V2V link is used for transmission [51], so the V2X connection and reputation management are the urgent problems to be solved in this scheme. Then comes the security problem of establishing V2V connection between unfamiliar nodes. Effective reputation management is the key to solving the problem. We will conclude the literature on V2I and V2V transmission and reputation management in two parts:

One is to provide one-hop or multi-hop transmission schemes for vehicle-infrastructure collaboration, which focus on emphasizing transmission delay and energy consumption. The data transmission of V2V or V2I is given priority to obtain the maximum benefit in [14]. In this method, the transmission has to pass through a large number of nodes. The disadvantage is that it increases the transmission delay, which is intolerable in the driving environment of SDVs. In V2I phase, SDVs are connected to the target base station and the task transmission failure rate are reduced by planning the connection in advance [11]. The deep reinforcement learning neural network model can be applied to the joint optimization of network and computing resources between vehicle and MEC to optimize the cost of the vehicle in the process of intelligent driving [31]. Y. Liang *et al.* [32] constructed a V2I architecture to optimize the deployment of roadside communication units based on the established traffic model in order to minimize the cost. However, this kind of thinking is not flexible enough to cope with the real-time changes in the number of vehicles. For the high mobility of vehicles, a handoff strategy between V2I and V2V is proposed [33]. This strategy analyzes the heterogeneous network composed of V2I and V2V, and controls the intervention of vehicles in different networks to achieve the goal of minimal network overhead. However, switching between wireless local area networks and cellular networks will bring extra delay. In the V2V phase, SDVs can minimize transmission overhead through protocols[33]. Lower communication overhead can improve vehicle endurance and reduce carbon emissions [35]. Y. Wu *et al.* [36] propose a V2V data transmission method based on millimeter-wave scanning, which determines the width of millimeter-wave lobe under low delay constraints. This is a very meaningful research in 5g network. Jos Santa *et al.* [37] carried out a large number of experiments from the software and hardware level to verify the performance of V2V, and proved the feasibility of V2V communication mode, which can spread messages between vehicles both on the up-link and down-link. The above work considers the connection problem of V2I and V2V. In V2V communication mode, SDVs are usually connected to unfamiliar nodes, so it is difficult to guarantee the transmission reliability.

Another work focuses on IOV reputation management, which provides secure and reliable services in single or multi-hop scenarios. Reputation management for smart driving is an emerging area that requires lower latency than traditional reputation management. The reputation management model is divided into centralized and distributed. H. Xiao *et al.* [38] propose a centralized trust management protocol that stores reputation in a central reputation server. The reputation of users is managed by cloud servers. Centralized reputation management can manage reputation efficiently, but it cannot meet the requirements of SDV [39], because intelligent driving service requires response to complex roads in a very short time. Real-time management of reputation is required. Q. Li *et al.* [40] proposed a communication scheme based on reputation management for IOV. It evaluates the trustworthiness of nodes, chooses nodes with a high reputation for establishing connections, and handles malicious nodes. Truong *et al.* [41] propose a distributed reputation management model to recommend nodes, which is based on reputation and knowledge. Edge Server places computing nodes on the edge of the network, bringing their computing and storage resources closer to the user, so it is suitable for distributed reputation management scenarios. Establishing a reputation management model on edge nodes can avoid the delays which are caused by the interaction with cloud centers [42]. X. Huang *et al.* [43] subdivided IOV reputation management into reputation table maintenance, reputation performance, reputation update and reputation application, which makes reputation management more real-time and improves the efficiency of reputation management. However, when considering the reputation management scheme, the high mobility of the managed objects is ignored. When the edge server is used as the core of distributed reputation management, the high mobility of vehicles will challenge the effectiveness of management.

Unlike the above work, we propose a hybrid transmission and reputation management strategy to accommodate the fast-changing IOV topology and to meet the low latency requirements of intelligent driving tasks. Our strategy uses V2V2I mode to complete transmission with relay vehicles when task-initiating vehicles cannot upload or download independently within the service scope. Further, for the integrity of the strategy, we filter the relay nodes, select reliable relay vehicles, and rely on edge servers for distributed reputation management. The mobility of vehicles is modeled, and the distributed reputation management is improved to adapt to the characteristics of IOV topology changing rapidly.

III. SYSTEM MODEL AND DEFINITIONS

A. Preparatory Work

SDVs are moving at high speed in different scopes of service. The vehicle speed is fast and the network topology changes constantly under the car-road synergy environment. The data can be transmitted through V2I and V2V to complete the intelligent driving task: the vehicle can communicate with the base station directly, and relay vehicle can help to forward the data. In addition, the edge server must provide reliable services for vehicles to prevent the IOV nodes from being attacked maliciously. Generally, BS is considered to be completely reliable [44]. In this paper, the edge reputation management method based on integral system is adopted. The premise of this method is that the edge server has the ability to monitor attacks. We assume that edge servers have intrusion detection [45] capabilities. There is a control interval in the data transmission slot of each task to complete the context broadcast and establish the connection. The control interval is usually regarded as a constant [36]. At present, compared with the resource consumption of the driving vehicle, the communication consumption of the vehicle can be ignored, but the task delay has a greater impact on high-speed vehicles. The delay of automatic driving should be controlled within 5-10ms [46], so we only consider the impact of delay of SDVs. Furthermore, we assume that the network and computing resources for SDVs are sufficient to ensure low latency. Therefore, we assume that there is no queuing delay caused by network congestion and insufficient computing resources. Each vehicle broadcasts its context periodically when the vehicles cross the service area, which includes: (1) vehicle ID, (2) speed, (3) positioning coordinates, (4) reputation. We assume that the vehicles in this scenario are willing to be relay vehicles and that all vehicles are willing to be helped by other vehicles. What we do is to provide an efficient and reliable edge computing handoff strategy for smart vehicles. During the edge service handoff process, we consider using relay vehicles to help launch vehicles to complete uploads and downloads that cannot be completed within the service range. However, the problem is that vehicles must establish

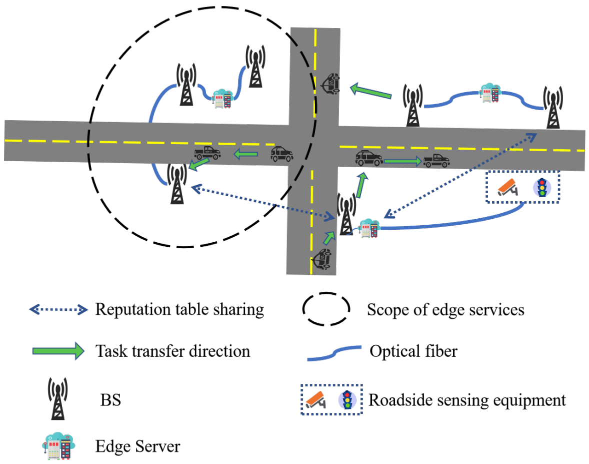


Fig. 1: The scene of car-road synergy

connections with unfamiliar vehicle nodes, which greatly increases the security risk. Malicious vehicles may attack other vehicles or edge servers to interrupt task transmission and tamper with reputation tables. So we assume that edge servers can detect malicious attacks, and vehicles can detect and report malicious attacks to edge servers.

B. Problem Formalization

As shown in Fig. 1, we assume that the MEC services provided by operators at the edge of the network. A service area is formed by a edge server and several BS. The BS and roadside sensing equipment as well as the edge server are connected by optical fiber, which provides the sensing service of cooperative between vehicle and road. As the information hinge of vehicle and roadside sensing equipment, edge server comprehensively processes the information collected by vehicle and roadside sensing equipment, then transmits the processing results to SDVs to complete the final decision. Vehicles'reputations are stored and updated on edge servers. We assume that there are M vehicles in the service area, denoted by the set $\mu = \{1, 2, ..., M\}$. Let's assume that within a service area, the vehicles have K tasks in total, denoted by the set $\kappa = \{1, 2, ..., K\}$. Vehicles can establish and transmit with BS directly by V2I, or relay vehicles can establish and transmit with BS by using V2V2I hybrid transmission mode. In collaborative car-road scenarios based on edge computing, it can improve the quality of service of users, among which delay is an important factor. Low-delay transmission can improve the response ability of smart vehicles to complex road conditions and improve the level of intelligence.

1) Transmission Delay: The decision vector $\zeta_k = [\eta_1, \eta_2, \eta_3, \eta_4]^T$ represents the transmission mode of task k, $(k \in \kappa)$. $\eta_1 = 1$ indicates that V2I mode is used to transmit data in upload, $\eta_2 = 1$ indicates that V2V mode is used to transmit data in upload, $\eta_3 = 1$ indicates that V2I mode is used to transmit data in download, $\eta_4 = 1$ indicates that V2V mode is used to transmit data in download. This paper focuses on the intelligent driving scenario in which the vehicle and edge computing work together to complete intelligent driving. Bandwidth allocation is not discussed in this paper. The task delay can be expressed as:

$$\begin{aligned} T_k = \eta_1 \cdot T^{u,k}_{i,BS} + \eta_2 \cdot max\left\{T^{u,k}_{i,j}, T^{u,k}_{j,BS}\right\} + \eta_3 \cdot T^{d,k}_{BS,i} \\ +\eta_4 \cdot max\left\{T^{d,k}_{BS,h}, T^{d,k}_{h,i}\right\} + T_{other}, \end{aligned} \tag{1}$$

Where T_k indicates the delay of the k th task. $V_i (i \in \mu)$

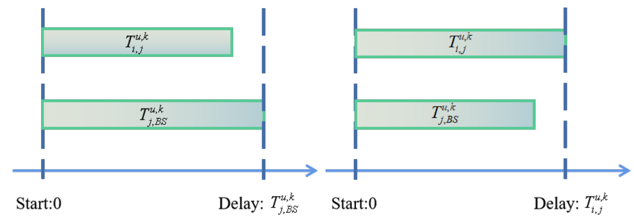


Fig. 2: Delay of Hybrid transmission

represents the vehicle i which initiates the task. $V_j (j \in \mu/i)$ represents relay vehicle j, $T^{u,k}_{i,BS}$ represents the upload delay of task k transmission from V_i to BS. $T^{u,k}_{i,j}$ represents the upload delay of task k from V_i to V_j. $T^{d,k}_{BS,i}$ is the unload delay from BS to V_i. $T^{d,k}_{BS,h}$ represents the transmission delay from the BS to another relay vehicle $V_h (h \in \mu/i, j)$. We assume that the computing and network resources are sufficient, so we use T_{other} to represent some minor delays, such as control delay and edge server processing delay. To model the V2I transport mode, we define the path loss as d^{ϑ}, where d represents the transmission distance ϑ represents the path-loss exponent. W is defined as bandwidth. The channel fading coefficient is denoted by h. When the vehicle uploads the k th task to BS, the transmission rate is given by:

$$r^k_{i,BS} = W log_2 \left(1 + \frac{P_i \left|h\right|^2}{\mu_0 (d_{i,BS})^{\vartheta}}\right), \tag{2}$$

where P_i is the transmission power of vehicle i, μ_0 denotes the white Gaussian noise power, $d_{i,BS}$ is the distance from vehicle i to BS. The upload delay $T^{u,k}_{i,BS}$ can be expressed as:

$$T^{u,k}_{i,BS} = \frac{B^u_k}{r^k_{i,BS}}, \tag{3}$$

Where B^u_k represents the size of task k when uploaded, B^d_k represents the size of the task k at download time. $r^k_{i,BS}$ is the rate of task transmission from V_i to BS, and is related to transmission distance when network resources are sufficient [47] [48]. When the SDV cannot complete the transmission task independently, it can be assisted by a relay vehicle. The relay transmission rate is expressed as:

$$r^k_{i,j} = W log_2 \left(1 + \frac{p_i \left|h\right|^2}{\mu_0 (d_{i,j})^{\vartheta}}\right), \tag{4}$$

Where $d_{i,j}$ is the distance between task-initiating vehicle i and relay vehicle j. The relay transmission delay can be modeled as:

$$T^{u,k}_{i,j} = \frac{B^u_k}{r^k_{i,j}}, \tag{5}$$

Where $r_{i,j}^k$ represents the task transfer rate from V_i to V_j. According to the characteristics of image transmission, the task transmission delay is the maximum value of the task initiating vehicle to BS and the relay vehicle to BS delay in the hybrid transmission. The process is shown in Fig. 2. In addition, the continuity of the transmission process is weak and the ability of picture process as well as the analysis process is strong due to the SDVs need to collect photos and other information. Therefore, the hybrid transmission can be synchronized, the relay-vehicle can forward task immediately at the beginning of the receiving task, but the task transmission can not be synchronized with the edge server processing.

2) Range of Transmission Modes: In this paper, we use the location relationship between vehicle and vehicle, vehicle and BS to predict the transmission range of vehicle i according to the vehicle speed, task size and transmission rate, and select the transmission mode based on the prediction results. We divide the edge service scope into three sub-scopes. Vehicles get their own location information according to satellite positioning, judge which transmission range they are in according to this information, and select the transmission mode based on the transmission range. If the vehicle will drive out of the service range in the process of downloading the result from BS, V2V transmission mode should be used when downloading, and the transmission should be completed with the help of relay vehicle. If the vehicle will drive out of the transmission range in the process of task upload or processing, then V2V transmission mode should be used in upload and download to complete the transmission with the help of relay vehicle. If the vehicles can upload and download within the scope of service, they can complete the transmission of intelligent driving tasks only by using V2I mode instead of using V2V transmission mode.

range 1: Transfer mode is not assisted by V2V (TNA): SDVs are driving in the range of TNA and the whole task process can be completed only by establishing a connection between the vehicle and the BS. The premise of TNA is to complete the task download before the vehicle leaves the scope of services. This paper simplifies the scope of services into a single BS coverage. The transmission range of TNA is denoted as:

$$L_1 = 2\sqrt{R^2 - sin^2\theta_{i,BS} \cdot d_{i,BS}^2} - T_k \cdot v_i, \quad (6)$$

Where R is the BS communication radius, in which the V_i can directly establish transmission with the BS. $v_i$represents the speed of the V_i. In reality, roads usually have multiple lanes, and vehicles don't always travel along the x-axis, so we introduce θ to get closer to reality. θ is the angle between the vehicle and the BS and the horizontal line. The introduction of θ is helpful to express the position relationship between vehicle and BS on the road. Before V_i sends a task request to the edge server, V_i calculates whether the vehicle is within L_1. If V_i is within L_1, the vector of task k is set to $\zeta_k \leftarrow [\eta_1 = 1, \eta_2 = 0, \eta_3 = 1, \eta_4 = 0]^T$, and when a task request is sent, the ζ_k is sent to the edge server.

range 2: V2V-assisted transport mode during download (V2V-AD): Task-initiated vehicle completes the task upload before driving out of the scope of services in V2V-AD mode. At the same time, the relay vehicle helps transmit the results when downloading. The decision tuples V2V-AD is denoted as $\zeta_k \leftarrow [\eta_1 = 1, \eta_2 = 0, \eta_3 = 0, \eta_4 = 1]^T$ The V2V-AD range L_2 can be expressed as:

$$L_2 = 2\sqrt{R^2 - sin^2\theta_{i,BS} \cdot d_{i,BS}^2} - T_{i,BS}^{u,k} \cdot v_i - L_1. \quad (7)$$

range 3: V2V-assisted mode is for both upload and download (V2V-AUD): If the task cannot be completely uploaded to BS before the vehicle drives out of scope of services, the edge server selects v_j to assist the task-initiated vehicle to upload task. Because the vehicle drives out of the scope of services when uploading the task, it still needs the assistance of the relay vehicle when the task is downloaded. Edge server selects the relay vehicle again before the edge server unloads the task. The vector of V2V-AUD is denoted as $\zeta_k \leftarrow [\eta_1 = 0, \eta_2 = 1, \eta_3 = 0, \eta_4 = 1]^T$. The transmission range of V2V-AUD is denoted as:

$$L_3 = 2\sqrt{R^2 - sin^2\theta_{i,BS} \cdot d_{i,BS}^2} - (L_1 + L_2). \quad (8)$$

3) Relay Vehicle Selection: The task-initiating vehicle needs a relay vehicle to assist in completing the task when the task-initiating vehicle can not complete the upload or download task independently in scope of services. Three issues should be considered when the relay vehicle is selected.

Reputation management: There are two difficulties in relay selection. First, the relay vehicle does not send the task to BS in time after receiving the task. Second, the task-initiating vehicle is attacked after establishing a connection with the unreliable vehicle. In order to solve the first problem, we propose a credit scoring mechanism to reward the relay vehicle which finishes the task timely. Accumulated points can be exchanged for rewards to encourage relay vehicles to complete relay tasks on schedule. In order to solve the second problem, we propose a reputation management mechanism. The edge server collects the vehicle information and establishes the vehicle reputation table after the vehicles enter Scope of services. After the task-initiated vehicle initiates the relay task request, the edge server selects the relay vehicle and broadcasts to inform the relay vehicle. Edge Server rewards relay vehicle with Credit +1 when it completes its task on time. The credit score of the relay vehicle will be set to -1 if the relay vehicle is malicious attacked. Naturally, the malicious attacked vehicle will be disqualified from enjoying the edge service. Reputation tables are stored together by multiple edge nodes when they are updated.

In the intelligent driving scenario supported by edge computing described in this paper, the main role of edge computing is computing and storage. In this paper, the role of edge computing is also to store user reputation tables and manage user reputation. Edge computing server is closer to users, matches the concept of distributed reputation management, makes reputation management more convenient and fast.

Relay vehicle candidate range: The tasks transmission of smart vehicle requires higher stability. In the same V2V link, the more relay nodes, the worse the transmission stability [49]. We use single hop relay transmission. Only one vehicle is selected as the relay node between the task-initiating vehicle and the BS when the task-initiating vehicle needs the assistance of the relay vehicle. Therefore, the relay vehicle should complete the transmission before leaving the scope of services. The selection range of relay vehicles should satisfy two conditions:

• Condition 1: relay vehicle completes transmission task between BS before driving out of scope of services. We model the selection range of relay vehicles:

$$L_4 = 2\sqrt{R^2 - sin^2\theta_{j,BS} \cdot d_{i,BS}^2} - T_{j,BS}^{u,k} \cdot v_j. \quad (9)$$

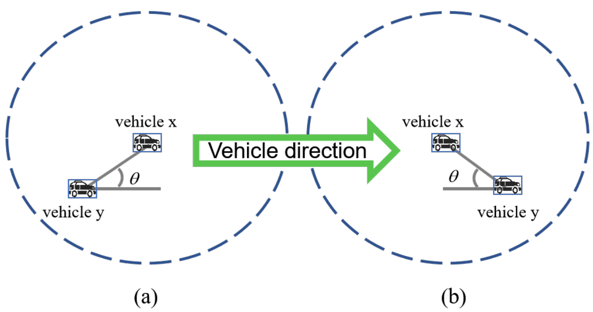


Fig. 3: Location relationship between vehicles

When the relay vehicle is within the L_4 range, it can ensure that the relay vehicle will not drive out of the Scope of services during the upload process and avoid unnecessary delay. v_j is the speed of the relay vehicle for upload, $\theta_{j,BS}$ denotes the angle between the connecting line relay-upload vehicle and BS and the x-axis.

$$L_5 = 2\sqrt{R^2 - sin^2\theta_{h,BS} \cdot d_{h,BS}^2} - T_{BS,h}^{u,k} \cdot v_h. \quad (10)$$

The relay vehicle is within L_5 range to ensure that the relay vehicle will not leave the scope of services during download. $\theta_{BS,h}$ denotes the angle between the connecting line relay-download vehicle and BS and the x-axis of line. v_h is the speed of the relay vehicle for download.

• Condition 2: receiving vehicle should be in transmission range of sending vehicle during transmission. We model the lifetime of relay link:

$$T_l^a = \begin{cases} \frac{\sqrt{R_x^2 - sin\theta \cdot d_{x,y}^2} + cos\theta \cdot d_{x,y}}{V_y - V_x} & V_x < V_y \\ \frac{\sqrt{R_x^2 - sin\theta \cdot d_{x,y}^2} - cos\theta \cdot d_{x,y}}{V_x - V_y} & V_x > V_y; \end{cases} \quad (11)$$

$$T_l^b = \begin{cases} \frac{\sqrt{R_x^2 - sin\theta \cdot d_{x,y}^2} - cos\theta \cdot d_{x,y}}{V_y - V_x} & V_x < V_y \\ \frac{\sqrt{R_x^2 - sin\theta \cdot d_{x,y}^2} + cos\theta \cdot d_{x,y}}{V_x - V_y} & V_x > V_y. \end{cases} \quad (12)$$

The V2V link connection in IOV can be divided into two situations. One is that the initial vehicle is in front of the receiving vehicle (see Fig. 3(a)). Another is that the initial vehicle is behind the receiving vehicle (see Fig. 3(b)). v_x indicates the speed of the vehicle that will initiate the V2V transmission. v_y indicates the speed of the vehicle that will receive the V2V transmission. R_x is the transmission range of vehicle x. $d_{x,y}$ is the distance between vehicle x and vehicle y. For example, when the speed of the initiating vehicle is equal to that of the receiving vehicle, the lifetime $T_{l|v_x=v_y} = \infty$.

Connection reliability: The use of V2V transmission mode can help vehicles that can not complete the transmission within the service scope to reduce retransmission. However, using V2V transmission mode, it is inevitable to establish a connection with a strange node, and malicious vehicles will attack other vehicles. In order to avoid establishing a connection between the task-initiating vehicle and the malicious vehicle, it is necessary to select the relay vehicle. We consider selecting the relay vehicle with high reliability as the support of the proposed strategy. The success rate of task transmission is inversely proportional to the transmission distance [15]. The transmission distance $d_{i,BS}$ in V2V relay mode includes two parts: one is the distance $d_{i,j}$ which is between task-initiating vehicle and relay vehicle, another is the distance $d_{j,BS}$ which is between relay vehicle and BS. It is worth studying how to select reliable vehicles within the relay selection range when selecting relay vehicles. We propose a reliability evaluation function that considers reputation and transmission distance. This function selects a relay vehicle with high reputation and high success probability of transmission, which is defined as:

$$\omega_j = \gamma \cdot ({f_j}' + 1) + (1 - \gamma) \cdot g(-{d_j}' + 1); \quad (13)$$

$${f_j}' = \frac{f_j - f_{mean}}{f_{max} - f_{min}} \; {d_j}' = \frac{d_j - d_{mean}}{d_{max} - d_{min}}; \quad (14)$$

$$d_j = d_{i,j} + d_{j,BS}, \quad (15)$$

Where ${f_j}'$ is the normalized reputation of f_j, ${d_j}'$ is normalized of d_j. Among them, $\gamma \in [0, 1]$ is the weighting coefficient, which can adjust the contribution of reputation and distance in the evaluation function. The larger the ω_j, the more likely the vehicle j is to be chosen as the relay vehicle. The edge serve will performs the relay selection when it receives a relay request. The vehicle with the highest ω_j will be selected as the relay vehicle.

IV. Our Proposed HTRM Scheme

In this section, the proposed algorithms are described in detail. Intelligent driving vehicles, which rely on edge computing, travel in different edge service areas, and traditional handoff modes cause excessive delays for users. Frequent retransmissions can prevent users from responding in time to changes in road conditions. Therefore, we propose a V2V relay transmission method to eliminate the impact of handoff on driving, while ensuring that a reliable relay vehicle is selected before the V2V is connected. Vehicles with malicious attacks can cause task transmission to fail, spread harmful information, and attack servers to tamper with data that is not good for them. We propose a distributed reputation management algorithm based on edge servers. In practice, two algorithms make decisions at the edge server based on the context and reputation of the vehicles in each time slot, while meeting the task requirements. EH-V2V2I algorithm can provide efficient task scheduling method for vehicles, select the transmission mode of task, decide whether V2V is needed, and when to use V2V transmission. Furthermore, when a vehicle uses V2V transmission, the RV-SRM algorithm can select a relay vehicle based on reputation, and under the constraint of link lifetime, and ensure that the selected relay vehicle will not travel out of the current service range during transmission. Finally, the algorithm relies on edge servers for distributed reputation management.

A. *efficient hybrid V2V and V2I scheduling algorithm*

Algorithm 1: EH-V2VV2I

Input: L_1, L_2, L_3, Location of V_i, f_i.
Output: ζ_k

```
1: for all V_i, i ∈ [1, M] do
2:   if f_i ⩾ 0 then
3:     if V_i in L_1 then
4:       ζ_k ← [η_1 = 1, η_2 = 0, η_3 = 1, η_4 = 0]^T
5:     else if V_i in L_2 then
6:       ζ_k ← [η_1 = 1, η_2 = 0, η_3 = 0, η_4 = 1]^T
7:     else
8:       ζ_k ← [η_1 = 0, η_2 = 1, η_3 = 0, η_4 = 1]^T
9:     end if
10:  end if
11: end for
```

EH-V2VV2I is proposed to eliminate the retransmission delay to realize the high efficiency of transmission. The task-initiating vehicle V_i calculates the three transmission regions when it has a service demand. V_i sends a request to the edge server, which allocates resources according to the decision vector. The edge server only provides services for vehicles with a reputation value which is greater than 0. If the task-initiating vehicle is in the range of L_1 and the credit score is greater than 0, the task-initiating vehicle adopts the TNA mode for task transmission, lines 1-4. If the task-initiating vehicle is in the range of L_2 and the credit score is greater than 0, the task-initiating vehicle adopts V2V-AD mode during upload phase for task transmission, lines 5-6. If the task-initiating vehicle is within the range of V2V-AUD and the credit score is greater than 0, the task initiating vehicle will transmit the task by V2V to upload and download, lines 7-8. The algorithm transforms the complex scheduling information into decision vectors to determine whether V2V assistance is needed for the transmission between task-initiating vehicle and BS, and which transmission stage needs V2V assistance. The EH-V2V2I algorithm undergoes a one-level loop to classify tasks based on vehicle locations, so the time complexity is $O(n)$.

B. *Relay Selection and Reputation Management Algorithms*

V. Performance Analysis

RV-SRM is proposed to control the connections of V2I and V2V. Relay selection decision is made at the edge server. First, the vehicles broadcast their own context periodically. The RV-SRM algorithm should ensure that the relay vehicle does not leave scope of services during the relay transmission. When the vehicle is in the range of L_4, and there is no malicious attack record, these vehicles can be used as relay vehicles

Algorithm 2: RV-SRM

Input: $f_j, \zeta, L_4, L_5, T^l_{i,j}$.
Output: $U^n_{V2I}, D^n_{V2I}, R^n_{V2V}, f_n$.

```
1: for all V_j, j ∈ [1, M] do
2:   if V_j in L_4 and f_j ⩾ 0 then
3:     add V_j into φ^u
4:   else if V_j in L_5 and f_j ⩾ 0 then
5:     add V_j into φ^d
6:   end if
7: end for
8: if η_1 = 1 then
9:   Vehicle i connects directly to the BS during the
     upload phase.
10: else if η_3 = 1 then
11:   Vehicle i connects directly to the BS during the
      download phase.
12: else if η_2 = 1 then
13:   for all V_j in φ^u do
14:     if T^{u,k}_{i,j} ⩾ T^l_{i,j} then
15:       find out the maximum ω_j
16:       Vehicle i connects with BS using relay vehicle j
          during the upload phase.
17:     end if
18:     if Relay vehicle completes transmission on time
        then
19:       f_j ← f_j + 1
20:     else if The relay vehicle initiated an attack then
21:       f_j ← −1
22:     else
23:       f_j ← f_j − 1
24:     end if
25:   end for
26: else
27:   Repeat the above process, select the relay vehicle h,
      and manage its reputation
28: end if
```

during the upload phase and the edge server stores information about the vehicles in a table φ^u. When the vehicle is in the range of L_5, and there is no malicious attack record, these vehicles can be used as relay vehicles during the upload phase and the edge server stores information about the vehicles in a table φ^d. The edge server updates φ^u and φ^d periodically, lines 1-7. In the decision vector ζ, $\eta_1 = 1$, it means that in the upload phase, the vehicle does not need the help of V2V, and the vehicle directly connects to the BS, lines 8-9. In the decision vector ζ, $\eta_3 = 1$, it means that in the download phase, the vehicle does not need the help of V2V, and the vehicle directly connects to the BS, lines 10-11. In the decision vector ζ, $\eta_2 = 1$, which means that in the upload phase, the task-initiating vehicle needs the help of V2V, so the algorithm starts relay selection action. The first step is to select the vehicles whose link lifetime is longer than the transmission time from the table φ^u, lines 13-14. The second step is to calculate the connection reliability evaluation function of the selected vehicles and select the vehicle with the largest ω_j,

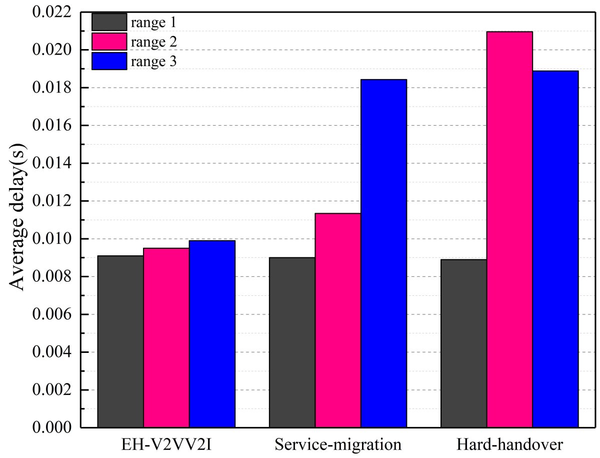


Fig. 4: Delay analysis verification

lines 15-17. The third step, When the relay vehicle completes the task in time, the edge server gives bonus points. When the relay vehicle launches a malicious attack, the edge server sets the reputation of the vehicle to - 1. If the relay vehicle fails to complete the forwarding in time, the edge server will deduct its product, lines 18-25. Unlike traditional cloud-based centralized reputation management, edge computing is a distributed system, with each edge server acting as a node, which is the inherent advantage of edge servers for distributed reputation management. Distributed credit management, such as block chains, performs well in tamper prevention. Edge servers can collect and manage the reputation of vehicles within service. Reputation tables are then shared to other nodes and periodically checked to prevent tampering with the reputations of an edge node. In the decision vector ζ, $\eta_4 = 1$, which means that in the download phase, the task-initiating vehicle needs the help of V2V, so the algorithm starts relay selection action. Repeat the above process, select the relay vehicle h, and manage its reputation, lines 26-28. The RV-SRM algorithm performs a maximum of two layers of loops, the first one determines the lifetime of the relay link of the vehicle, and the second one finds the maximum value of ω_j, so the time complexity is $O(n^2)$.

In this section, the proposed strategy will be validated and compared with existing migration-based and hard handover strategies. Our goal is to propose an efficient and reliable edge server handoff strategy. Edge server handoff is different from base station handoff. When the vehicle leaves, the task may be transmitting or processing. A good handoff strategy can reduce the transmission delay. The current switching method based on service migration is the mainstream idea. The article [50] compares the proposed service migration strategy with a hard handover, so we compare the proposed strategy with the service migration method and hard handover. This paper studies the problem of vehicle switching between edge computing platforms. Specifically, when the vehicle runs in different service areas, there is a cross service area task processing problem, A HTRM strategy is proposed, which is divided into two algorithms: 1) Based on vehicle context, each task transmission mode is predicted by EH-V2VV2I algorithm to achieve efficient transmission. V2V communications can assist task initiation vehicle to complete task transmission when task-initiating vehicle can not upload or download independently. 2) In order to establish a reliable relay link, we propose a RV-SRM. First, the edge server periodically collects each vehicle context and establishes a set of qualified candidate vehicles according to the task-initiating vehicle requirements. Then, the optimal link reliability relay vehicle is selected by combining the link life time with the link reliability evaluation function. Motivate the relay vehicle to complete its mission completely and quickly through reward and punishment system. To ensure the authenticity of the assessment as much as possible, we choose the scene of dual lane expressway to evaluate the algorithm performance. The average latency, instantaneous and cumulative throughput, and number of attacks are used to measure the performance of each algorithm, and the change in evaluation function and reputation under the control of our proposed strategy is observed.

A. Delay analysis verification

The delay is an important standard to evaluate the algorithm, and the delay control is particularly important in the intelligent vehicle network. First, we compare the proposed EH-V2VV2I algorithm with MEC service migration algorithm and the hard handover method. After 50 experiments, the average delay of each algorithm in the TNA range (range1), V2V-AD range (range2) and V2V-AUD range (range3) calculated respectively.

TABLE I: SIMULATION PARAMETERS

Parameter	Value
Coverage radius of base station	200m
Vehicles'Speed	[20,30]m/s
Angle θ	[0,1/2]π
Transmission speed of V2I	[500,700]Mbit/s
Transmission speed of BS	[400,600]Mbit/s
Coverage radius of V2V	50m
Size of task on upload	[1,10]Mbits
Size of task on download	[1,4]Mbits

As can be seen from Fig. 4. **Range 1:** the average delay of the three algorithms in range 1 is similar, because in range 1, the task-initiating vehicle directly establishes a connection with BS for uploading and downloading, so the delay is low. **Range 2:** EH-V2VV2I is assisted by V2V link during download. According to the migration algorithm of MEC service, the task-initiating vehicle uploads the task to BS in range 2. The server migrates the service to the next server to ensure the continuity of the task when the vehicle is in range 2. However, the additional delay of task migration increases the average delay. In traditional mode, the task may start to be processed when the vehicle leaves, so the delay of retransmission is maximum. **Range 3:** in the three modes of range 3, the upload and download of task-initiating vehicle is assisted by V2V link in the EH-V2VV2I algorithm. In the other two modes, the task-initiating vehicle leaves the service range during upload, which causes the retransmission delay. The average delay of EH-V2VV2I is the smallest in the 3 range, which indicates that the algorithm performs better in reducing delay. We calculated the average transmission delay of the vehicles in three ranges and found that the EH-V2VV2I algorithm reduced the average delay by 41% compared with the hard handover method.

B. Throughput analysis verification

The throughput comparison is given in Fig. 5. The proposed EH-V2VV2I algorithm is compared with the MEC service migration algorithm and the hard handover method. In this paper, edge server throughput is based on task upload and download. Instantaneous throughput is the throughput of edge server after vehicles request service at the same time. Accumulated throughput is the cumulative number of completed tasks as the number of vehicles increases. This paper measures the performance of the algorithm by task throughput, and can observe the utilization of MEC servers in a certain time slot and in multiple time slots. With a certain number of tasks, the higher the task throughput, the better the scheduling algorithm performance and the higher the computing resource utilization of the MEC server.

As can be seen from Fig. 5(a) and Fig. 5(b), under the EH-V2VV2I algorithm scheduling, the task-initiating vehicle is assisted by V2V link to transmit tasks in range 2 and range 3. As a result, instantaneous throughput and cumulative throughput are the highest. The service migration algorithm can only control the task migration through wireless or wired within range 2. Retransmission is still generated within the range 3. The hard handover method completes the task only within range 1, and only retransmit the task in range 2 and range 3. Naturally, instantaneous throughput and cumulative throughput are the lowest. In the process of observing the instantaneous throughput, the three algorithms schedule the same number of tasks in a certain time slot. With the increase in the number of vehicles, our algorithm can better meet the needs of vehicles. Under the service migration algorithm and the hard handover method, vehicles in range 2 and range 3 have worse performance, so the instantaneous throughput performance is worse. Then, we observe the cumulative throughput of tasks. Because of the superiority of our algorithm, the gap of task throughput is further widened with the increase of vehicle number. Therefore, our proposed algorithm can improve throughput.

C. Performance of connection reliability

In this paper, a connection reliability evaluation function is proposed as a criterion for selecting relay vehicles. ω_j is the connection reliability evaluation function of V_j, RV-SRM chooses the vehicle with the largest ω, which increases probability of successful transmission of the selected relay vehicle. The baseline algorithm selects the vehicle within the range as the relay vehicle randomly. γ is the weighting coefficient, which can adjust the contribution of reputation and distance in the evaluation function. For example, if the task has a high reputation requirement for the relay vehicle, the γ-value can be increased appropriately, and if the task requires a higher transmission success rate, the γ-value can be decreased appropriately. In Fig. 6, after fifty experiments, we get images of ω varying with the number of relay vehicles. The reliability of the connection can be analyzed by observing that when γ is 0.3, 0.5 and 0.7. For easy observation, we smoothed the curves. The RV-SRM curve is relatively gentle. However, the baseline algorithm exhibits more random properties. The reason is that, based on reputation and transmission distance, the RV-SRM algorithm selects the vehicle with the best connection performance under the constraint of link lifetime. As the number of relay vehicles increases, the number of vehicles available for RV-SRM selection is increasing. The edge server selects the relay vehicle with the best connection reliability. More vehicles to choose from make it more likely that vehicles with higher ω will appear. Therefore, as shown in Fig. 6, ω of RV-SRM increase and then tends to be flat. In contrast, baseline curves have more random characteristics with lower ω. The average ω of RV-SRM algorithm is 31% higher than the traditional method at different γ values. So RV-SRM performs better in connection reliability.

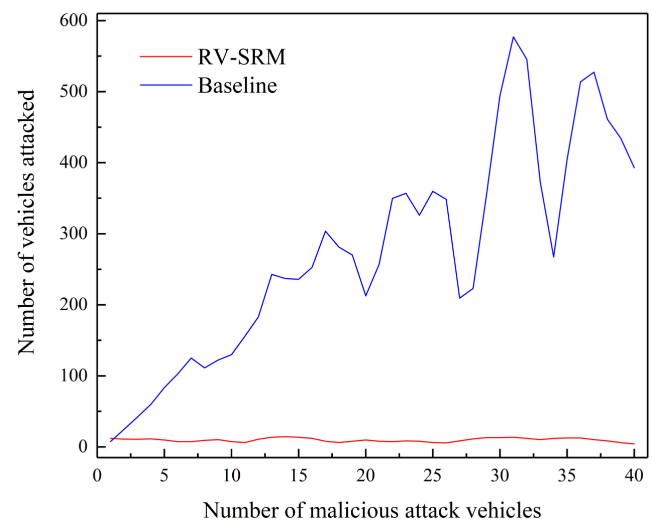
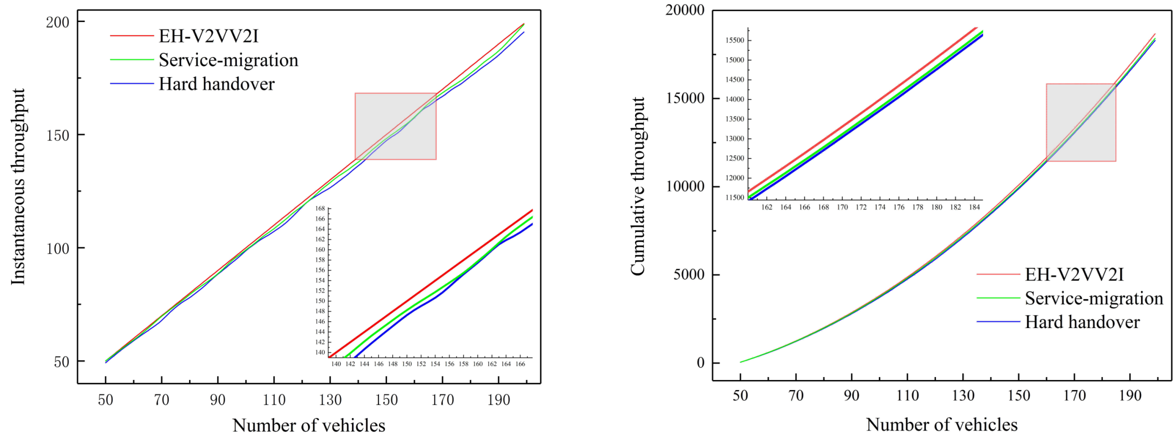


Fig. 7: Verify the performance of the two methods in preventing attacks

In the dual lane environment simulated in this paper, there are malicious attack vehicles that enter randomly. When malicious attack vehicles enter the road segment, they drive like other vehicles. In each slot, one or more vehicles are attacked by one malicious vehicle, which threatens the safety of users' lives and properties. The advantage of distributed reputation management is that, compared with centralized reputation management based on cloud computing, distributed reputation management based on edge computing can respond to the behavior of vehicles in a timely and effective manner, quickly penalize malicious attacking vehicles and vehicles that delay transmission, and reward vehicles that complete relay transmission in a timely manner.

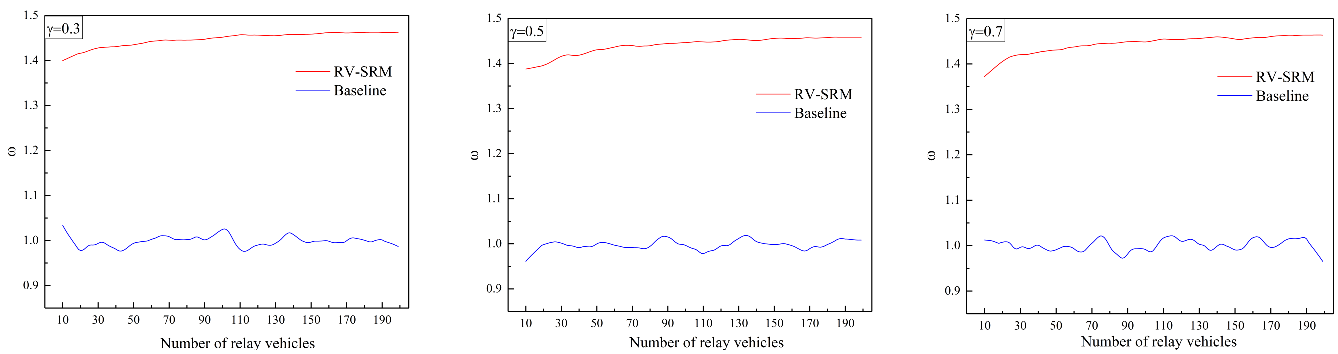
D. Performance of reputation management

When a malicious attack vehicle is discovered, the RV-SRM will exclude the vehicle permanently from the service group to avoid the other vehicles being attacked. In Fig. 7, we simulate the relationship between the malicious attacking vehicles and



(a) instantaneous task throughput (b) cumulative task throughput

Fig. 5: Analysis verification of task throughput



(a) Connection reliability(γ=0.3) (b) Connection reliability(γ=0.5) (c) Connection reliability(γ=0.7)

Fig. 6: Performance of connectivity feasibility

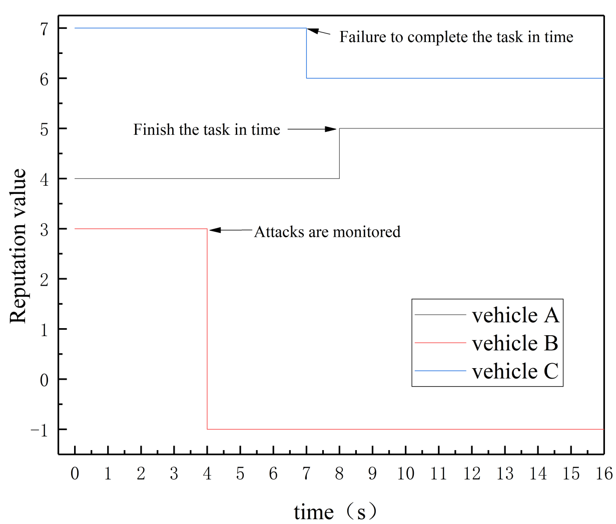


Fig. 8: Verification of the effectiveness of reward and punishment system

the attacked vehicles in the same time slot. For easy observation, we smoothed the curves. When a malicious attacking vehicle is discovered, the edge server sets the reputation of the vehicle to -1 and broadcasts the reputation table to other edge service nodes. The malicious attacking vehicle will be refused to establish a connection with other vehicles or BS. Each malicious vehicle is discovered and its connection is blocked, which minimizes the damage probility and reduces the number of attacked vehicles. However, baseline has no reputation management mechanism. The number of attacked vehicles has risen sharply because of the increase in malicious attacking vehicles. As a result, it is necessary to research reputation management.

After the above simulation, it is not difficult to see that the reputation management module in RV-SRM can effectively prevent the secondary occurrence of malicious attacks. In order to more intuitively show the principle of reputation management of RV-SRM algorithm, we show the change of reputation of three vehicles corresponding to three behaviors respectively. In Fig. 8, three behaviors are simulated for three vehicles: 1) completing tasks on time 2) failing to complete tasks on time 3) launching malicious attacks. When three vehicles are driving, vehicle A completes the relay task in time at 8, and edge server adds 1 point award to credit. Vehicle B is found to have malicious attack by edge server at 4, and the reputation award of vehicle B is set at -1. Vehicle C fails to complete the relay task in time at 7, and edge server minus 1 point to credit. Thus, RV-SRM can effectively reward and punish the relay vehicle's behavior in a timely manner. When the relay vehicle launches a malicious attack, it will be excluded from the service object. When the relay vehicle completes the relay transmission in time, it will be rewarded with credit. When the relay vehicle forwarding delay exceeds the requirements, the edge server will be punished with credit deduction. RV-SRM can motivate relay vehicles to complete forwarding in time.

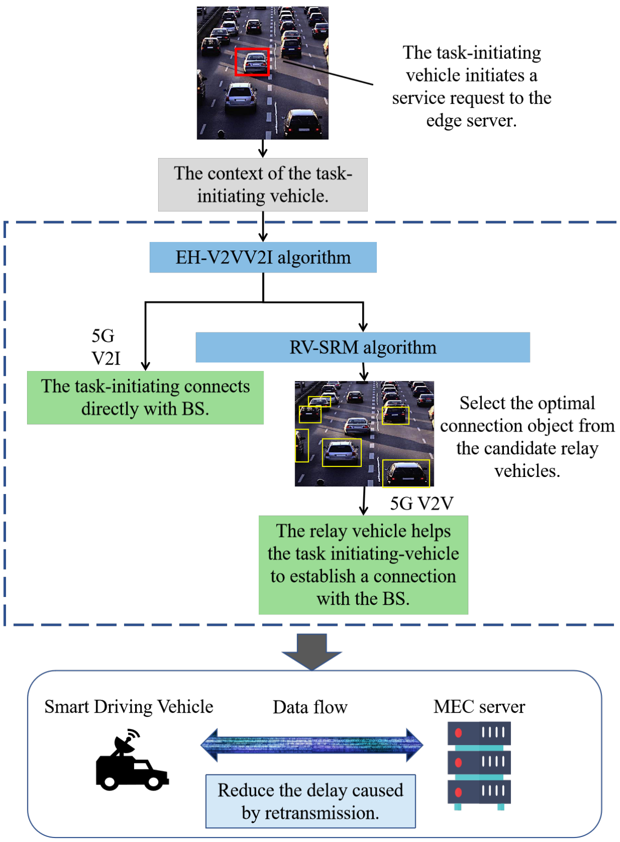


Fig. 9: Application of EH-V2VV2I algorithm and RV-SRM algorithm in intelligent vehicle driving

E. Application in road

In reality, vehicles often drive in complex conditions, and it is difficult for SDVs to complete calculation in time in a complex environment. Therefore, intelligent driving based on 5G and edge computing is the direction of future development. However, 5G + edge computing makes the structure of the Internet of vehicles more complex. The high-speed vehicles make the network topology change faster. How to switch the service area is an important problem before the vehicle leaves the service area. If the vehicle leaves the service area in the process of transmission or edge server processing, the task will be lost, resulting in retransmission. Intelligent driving is a typical scenario with low delay requirements, any additional delay may lead to traffic accidents. In the intelligent Internet of vehicles with edge servers as the core, how to ensure the smooth and safe operation of vehicles is the problem.

As shown in Fig. 9, the EH-V2VV2I algorithm is proposed to solve the problem of retransmission delay caused by frequent server handoff when high-speed vehicles and servers jointly process tasks. When sending a service request, the task initiatin-vehicle inputs its context into EH-V2VV2I algorithm. The algorithm determines whether the task initiating-vehicle needs the help of relay vehicle. If the assistance of relay vehicle is not needed, the task initiating-vehicle will establish V2I connection with BS directly. If the algorithm determines that the task initiating vehicle needs the assistance of the relay vehicle, the edge server will execute the RV-SRM algorithm, select the optimal connection object among the candidate relay vehicles, and then guide the task-initiating vehicle to establish a connection with the relay vehicle. With the support of the two algorithms, the network resource management system can ensure the continuity of SDV's task processing and greatly reduce the possibility of retransmission. It is of great significance to the safe and stable operation of SDVs in an actual situation.

VI. Conclusion and Future Work

In this paper, the task transmission of intelligent driving in edge computing is studied, which is to determine how and who to connect within a time slot to reduce transmission delays and security risks. We propose EH-V2VV2I algorithm and RV-SRM algorithm to solve the above problems. The EH-V2VV2I algorithm determines whether a vehicle needs auxiliary transmission of V2V. After that, if the request is received by the edge server, relay vehicles with high connection reliability are selected by RV-SRM algorithm and vehicle reputation is managed by edge servers. In order to prove the superior of our algorithms. A simulation environment of one-way with dual-lane expressway is established to simulate the driving of vehicle groups in the road. Simulation results show that EH-V2VV2I algorithm can effectively reduce transmission delay and improve the edge server throughput. The RV-SRM algorithm provides more reliable V2V connection mode for vehicles and effectively reduces the number of attacked vehicles in the system.

In the future, we plan to further refine the HMEC-HO problem and study more task scheduling and reputation management strategies. The task scheduling method based on deep reinforcement learning will be studied, combined with MEC efficient and convenient computing mode, to optimize the task scheduling problem. The hybrid transmission task scheduling algorithm proposed in this paper will be closely combined with high mobility intelligent vehicles to solve the problem of high latency in edge service switching. At the same time, relay selection and reputation management algorithm will be more applied to the scenario with relay requirements to verify the effectiveness of the algorithm.

References

[1] S. M. Khan, M. Chowdhury, E. A. Morris, L. Deka, Synergizing roadway infrastructure investment with digital infrastructure for infrastructure-based connected vehicle applications: review of current status and future directions. Journal of Infrastructure Systems, 25(4), December 2018.

[2] Baigen Cai, Congcong Wang, Wei ShangGuan, Jian Wang, Research of information interaction simulation method in Cooperative Vehicle Infrastructure System, in 17th International IEEE Conference on Intelligent Transportation Systems (ITSC). Qingdao, China, pp. 45-50, Oct 8-11, 2014.

[3] W. Anwar, N. Franchi and G. Fettweis, Physical Layer Evaluation of V2X Communications Technologies: 5G NR-V2X, LTE-V2X, IEEE 802.11bd, and IEEE 802.11p, in 2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall), Honolulu, HI, USA, pp. 1-7, Sept 22-25 2019.

[4] A. Kumar, M. Gupta, A review on activities of fifth generation mobile communication system, Alexandria Engineering Journal, January 2017.

[5] M. Aazam, S. Zeadally, K. A. Harras, Offloading in fog computing for IoT: Review, enabling technologies, and research opportunities, Future Generation Computer Systems, 87, pp. 278289, October 2008.

[6] J. Xu, S. Wang, B. K. Bhargava and F. Yang, A Blockchain-Enabled Trustless Crowd-Intelligence Ecosystem on Mobile Edge Computing, in IEEE Transactions on Industrial Informatics, 15 (6), pp. 3538-3547, June 2019.

[7] S. Pang, S. Qiao, T. Song, J. Zhao and P. Zheng, An Improved Convolutional Network Architecture Based on Residual Modeling for Person Re-Identification in Edge Computing," in IEEE Access, 7, pp. 106748-106759, August 2019.

[8] A. Machen, S. Wang, K. K. Leung, B. J. Ko, T. Salonidis, Poster: Migrating Running Applications Across Mobile Edge Clouds, MobiCom 2016.

[9] Y. Dai, D. Xu, S. Maharjan, G. Qiao and Y. Zhang, Artificial Intelligence Empowered Edge Computing and Caching for Internet of Vehicles, in IEEE Wireless Communications, 26(3), pp. 12-18, June 2019.

[10] W. Nasrin and J. Xie, SharedMEC: Sharing Clouds to Support User Mobility in Mobile Edge Computing, 2018 IEEE International Conference on Communications (ICC), Kansas City, MO, pp. 1-6, May, 20-24, 2018,

[11] S. H. Ahmed, S. H. Bouk, D. Kim, Target RSU Selection with Low Scanning Latency in WiMAX-enabled Vehicular Networks. Mobile Networks and Applications, 20(2), pp. 239250, February 2015.

[12] S. Wang, J. Xu, N. Zhang and Y. Liu, A Survey on Service Migration in Mobile Edge Computing, in IEEE Access, 6, pp. 23511-23528, April 2018.

[13] Y. Sun, L. Xu, Y. Tang and W. Zhuang, Traffic Offloading for Online Video Service in Vehicular Networks: A Cooperative Approach, in IEEE Transactions on Vehicular Technology, 67(8), 7, pp. 630-7642, Aug 2018.

[14] J. Ahn, Y. Kim, R. Kim, A Novel WLAN Vehicle-To-Anything (V2X) Channel Access Scheme for IEEE 802.11p-Based Next-Generation Connected Car Networks, Applied Sciences, 8(11), 2112, November 2018.

[15] J. Liu, N. Kato, J. Ma and N. Kadowaki, Device-to-Device Communication in LTE-Advanced Networks: A Survey, in IEEE Communications Surveys and Tutorials, 17(4), pp. 1923-1940, Fourthquarter 2015.

[16] Bo Wang, Junshan Zhang and A. Host-Madsen, On the capacity of MIMO relay channels, in IEEE Transactions on Information Theory, vol. 51, no. 1, pp. 29-43, Jan. 2005.

[17] 3GPP, Evolved Universal Terrestrial Radio Access (E-UTRA) and E-volved Universal Terrestrial Radio Access Network (E-UTRAN), 3GPP TS, 2010.

[18] S. A. Ashraf, R. Blasco, H. Do, G. Fodor, C. Zhang and W. Sun, Supporting Vehicle-to-Everything Services by 5G New Radio Release-16 Systems, in IEEE Communications Standards Magazine, vol. 4, no. 1, pp. 26-32, March 2020.

[19] M. Jerbi, P. Marlier and S. M. Senouci, Experimental Assessment of V2V and I2V Communications, 2007 IEEE International Conference on Mobile Adhoc and Sensor Systems, Pisa, Italy, pp. 1-6 , Oct, 2007.

[20] M. Wang, T. Ma, G. Li, X. Zhai and S. Qiao, Ant Colony Optimization With an Improved Pheromone Model for Solving MTSP With Capacity and Time Window Constraint, in IEEE Access, 8, pp. 106872-106879, June 2020.

[21] Q. Zhang, C. Zhou, N. Xiong, Y. Qin, X. Li, S. Huang, Multimodel-based incident prediction and risk assessment in dynamic cybersecurity protection for industrial control systems, IEEE Transactions on Systems, Man, and Cybernetics: Systems 46 (10), pp. 1429-1444, July, 2015.

[22] O. Muoz, A. Pascual-Iserte and J. Vidal, Optimization of Radio and Computational Resources for Energy Efficiency in Latency-Constrained Application Offloading, in IEEE Transactions on Vehicular Technology, 64(10), pp. 4738-4755, Oct 2015.

[23] K. Zhang, Y. Mao, S. Leng, Y. He and Y. ZHANG, Mobile-Edge Computing for Vehicular Networks: A Promising Network Paradigm with Predictive Off-Loading, IEEE Vehicular Technology Magazine, 12(2), pp. 3644, April 2017.

[24] U. U. Tariq, H. Ali, L. Liu, J. Hardy, M. Kazim, W. Ahmed, Energy-aware Scheduling of Streaming Applications on Edge-devices in IoT based Healthcare, IEEE Transactions on Green Communications and Networking, in press, 2021.

[25] H. Yu, Q. Wang and S. Guo, Energy-Efficient Task Offloading and Resource Scheduling for Mobile Edge Computing, in 2018 IEEE International Conference on Networking, Architecture and Storage (NAS), Chongqing, China, pp. 1-4, 11-14 Oct. 2018.

[26] S. Nunna, A. Kousaridas, M. Ibrahim, M. Dillinger, C. Thuemmler, H. Feussner, A. Schneider, Enabling Real-Time Context-Aware Collaboration through 5G and Mobile Edge Computing, 2015 12th International Conference on Information Technology - New Generations, April, 13-15, Las Vegas, NV, pp. 601-605, USA, 2015.

[27] K. Serizawa, M. Mikami, K. Moto and H. Yoshino, Field Trial Activities on 5G NR V2V Direct Communication Towards Application to Truck Platooning, 2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall), Honolulu, HI, USA, 2019.

[28] C. Campolo, A. Molinaro, F. Romeo, A. Bazzi and A. O. Berthet, 5G NR V2X: On the Impact of a Flexible Numerology on the Autonomous Sidelink Mode, 2019 IEEE 2nd 5G World Forum (5GWF), Dresden, Germany, 2019.

[29] G. Li and C. Lai, Platoon Handover Authentication in 5G-V2X : IEEE CNS 20 Poster, 2020 IEEE Conference on Communications and Network Security (CNS), Avignon, France, 2020.

[30] T. Ojanper, H. van den Berg, W. IJntema, R. de Souza Schwartz and M. Djurica, Application Synchronization Among Multiple MEC Servers in Connected Vehicle Scenarios, in 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall), Aug, 27-30, Chicago, IL, USA, pp. 1-5, 2018.

[31] Q. Luo, C. Li, T. H. Luan and W. Shi, Collaborative Data Scheduling for Vehicular Edge Computing via Deep Reinforcement Learning, in IEEE Internet of Things Journal, vol. 7, no. 10, pp. 9637-9650, Oct. 2020.

[32] Y. Liang, H. Liu and D. Rajan, Optimal Placement and Configuration of Roadside Units in Vehicular Networks, in 2012 IEEE 75th Vehicular Technology Conference (VTC Spring), May, 6-9, Yokohama, Japan, 2012.

[33] K. Shafiee, A. Attar and V. C. M. Leung, Optimal Distributed Vertical Handoff Strategies in Vehicular Heterogeneous Networks, in IEEE Journal on Selected Areas in Communications, 29 (3), pp. 534-544, March 2011.

[34] J. Costa, W. Lobato, A. M. de Souza, D. Rosrio, L. A. Villas and E. Cerqueira, Centrality-based data dissemination protocol for vehicular ad hoc networks, 2017 IEEE 16th International Symposium on Network Computing and Applications (NCA), Cambridge, MA, USA, pp. 1-4, 30 Oct.-1 Nov. 2017.

[35] W. Wu, N. Xiong, C. Wu, Improved clustering algorithm based on energy consumption in wireless sensor networks, IET Networks, 6 (3), pp. 47-53, April, 2017.

[36] Y. Wu, L. Yan and X. Fang, A Low-Latency Content Dissemination Scheme for mmWave Vehicular Networks, in IEEE Internet of Things Journal, 6(5), pp. 7921-7933, Oct 2019.

[37] Jos Santa, Antonio F. Gmez-Skarmeta, Marc Snchez-Artigas, Architecture and evaluation of a unified V2V and V2I communication system based on cellular networks, Computer Communications, 31 (12), pp. 2850-2861. July 2008.

[38] H. Xiao, N. Sidhu and B. Christianson, Guarantor and reputation based trust model for Social Internet of Things, 2015 International Wireless Communications and Mobile Computing Conference (IWCMC), Dubrovnik, Croatia, Aug, 24-28, 2015.

[39] J. Zhao, Z. Wu, Y. Wang, X. Ma, Adaptive optimization of QoS constraint transmission capacity of VANET, Vehicular Communications, March 2019.

[40] Q. Li, A. Malip, K. M. Martin, S. Ng and J. Zhang, A Reputation-Based Announcement Scheme for VANETs, in IEEE Transactions on Vehicular Technology, 61(9), pp. 4095-4108, July 2012.

[41] N. B. Truong, G. M. Lee, A Reputation and Knowledge Based Trust Service Platform for Trustworthy Social Internet of Things, 19th International Conference on Innovations in Clouds, Internet and Networks, 2016.

[42] R. Iqbal, T. Butt, M. Afzaal, K. Salah, Trust management in social Internet of vehicles: Factors, challenges, blockchain, and fog solutions, International Journal of Distributed Sensor Networks, 15(1), November 2018.

[43] X. Huang, R. Yu, J. Kang and Y. Zhang, Distributed Reputation Management for Secure and Efficient Vehicular Edge Computing and Networks, in IEEE Access, 5, pp. 25408-25420. November 2017.

[44] Y. Gao, W. Tang, M. Wu, P. Yang and L. Dan, Dynamic Social-Aware Computation Offloading for Low-Latency Communications in IoT, in IEEE Internet of Things Journal, vol. 6, no. 5, pp. 7864-7877, Oct. 2019.

[45] K. Huang, Q. Zhang, C. Zhou, N. Xiong, Y. Qin, An efficient intrusion detection approach for visual sensor networks based on traffic pattern

learning, IEEE Transactions on Systems, Man, and Cybernetics: Systems, 47 (10), pp. 2704-2713, May 2017.

[46] M. Patra, R. Thakur, C. S. R. Murthy, Improving Delay and Energy Efficiency of Vehicular Networks Using Mobile Femto Access Points. IEEE Transactions on Vehicular Technology, 66(2), pp. 14961505, Feb 2017.

[47] Z. Zhang, G. Mao and B. D. O. Anderson, On the Hop Count Statistics in Wireless Multihop Networks Subject to Fading, in IEEE Transactions on Parallel and Distributed Systems, vol. 23, no. 7, pp. 1275-1287, July 2012.

[48] Y. Yang, N. Xiong, N. Y. Chong and X. Dfago, A Decentralized and Adaptive Flocking Algorithm for Autonomous Mobile Robots, in 2008 The 3rd International Conference on Grid and Pervasive Computing - Workshops, May, 25-28, Kunming, China, pp. 262-268, 2008.

[49] Y. Hu, H. Li, Z. Chang, R. Hou and Z. Han, End-to-end backlog and delay bound analysis using martingale for Internet of vehicles, 2017 IEEE Conference on Standards for Communications and Networking (CSCN), Helsinki, 2017.

[50] S. Zhou, P. P. Netalkar, Y. Chang, Y. Xu and J. Chao, The MEC-Based Architecture Design for Low-Latency and Fast Hand-Off Vehicular Networking, 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall), Chicago, IL, USA, pp. 1-7, 2018.

[51] Y. Xia, L. Wu, Z. Wang, X. Zheng and J. Jin, Cluster-Enabled Cooperative Scheduling Based on Reinforcement Learning for High-Mobility Vehicular Networks, IEEE Transactions on Vehicular Technology, vol. 69, no. 11, pp. 12664-12678, Nov. 2020.

[52] D. Mahdi, and Z. Xi, and Y. Xia and X. Xu and J. Alireza and K. Ali and T. Usman and D. Yu and Vasilakos, Athanasios V, Investigating the Prospect of Leveraging Blockchain and Machine Learning to Secure Vehicular Networks: A survey, IEEE Transactions on Intelligent Transportation Systems, 2020.

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