Admission Control Mechanism of Wireless Virtual Network Assisted by Vehicular Fog Computing

Zhanjun Liu, Ruifeng Hu(✉), Shuaishuai Xia, and Xia Peng

School of Communication and Information Engineering,
Chongqing University of Post and Telecommunications, Chongqing, China
939278797@qq.com

Abstract. In order to solve the problem of resources waste caused by insufficient computing resources and the lack of an effective admission mechanism in the service environment of wireless virtual network (WVN), this paper proposes an effective robust admission control mechanism. This mechanism mainly controls the access of user groups of WVN in a dynamic resource environment, which is in the assistance environment of vehicular fog computing (VFC). Firstly, considering the resource uncertainty caused by the characteristics of VFC, a robust optimization access model is established. It predicts the change of resources during the association of user time to determine whether to allow user groups access. Secondly, task offloading and the allocation of computing resources are processed. Since the coupling of task offloading and resource allocation leads to the non-convexity of the problem, we convert it into a convex optimization problem to resolve. Simulation results show that the admission control mechanism proposed in this paper can admit larger user groups in the assistance computing environment of VFC while ensuring the quality of user experience.

Keywords: Wireless virtual network · Vehicular fog computing · Admission control · Robust optimization

1 Introduction

With the development of 5th Generation Mobile Communication Technology, the network has increasingly shown heterogeneous characteristics [1], which brings challenges to the wireless network. To effectively overcome this situation, virtualizing the wireless network has been considered. The wireless virtual network (WVN) technology can improve resource utilization and integrates heterogeneous wireless networks efficiently. WVN also improves users' experience by

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fragmenting and efficient processing of the network [2]. Moreover, it can not only provide wireless access services to individual users, but also can request wireless access service for user groups in the future virtual network. The user groups are assigned a network virtual slice called virtual network (VN), and they can be provided services through mobile virtual network operators (MVNOs) [3]. In summary, using WVN technology to build a future network architecture can better meet the requirements of emerging network status [4,5].

However, there is a problem with the existing technology in WVN. When a large number of VN customers with computation tasks arrive at the same time, only relying on the computing resources of the infrastructure service provider may easily reach the peak of the resource load due to the unbalance of resources, which affects the quality of experience (QoE) of users and leads some unnecessary waste of resources. Consequently, it is necessary to find assistance computing resources.

Vehicle Fog Computing (VFC), an excellent assistant computing resource for task offloading and resources utilization, has certain computing and communication capabilities by aggregating vehicles. By integrating and utilizing the computing resources, vehicles can be turned into small infrastructure [6] to alleviate the load pressure of base stations (BSs). VFC also significantly reduce deployment costs and latency given that it relies on the cooperation of nearby vehicles, rather than sending information to a remote server. Recently, the research on VFC has been gradually developed. The works [7,8] regarded the parked vehicles as infrastructure, and they proposed the concept of parking vehicle assistance so that parked vehicles can join the vehicle network as static nodes. In addision, the authors in [9] considered using the resources of the available vehicles in the parking lot to assist BS for computation and proposed an incentive measure to encourage vehicles to share their resources. The authors in [10] proposed a task offloading mechanism in the case of information asymmetry and uncertainty. And the authors studied the system of VFC and proposed an effective parallel offloading scheme to solve the problem of task decomposition and task offloading delay in [11].

In the research of WVN technology, random access to user groups will result in the waste of resources and low service provider revenue. Therefore, effective access control for WVN is very necessary. A robust optimization problem for admission control of VNs has been proposed in [12], but this method is only suitable for single-user admission, having low benefits for user groups admission. In [13,14], the authors considered a fixed snapshot of user equipment for admission control, but they did not incorporate statistical specifications for traffic demand. And in [15], the authors formulated an admission control mechanism of WVN with heterogeneous traffic profiles and various quality of experience requirements. Most studies have achieved certain results in admission control, but using the auxiliary computing resources to assist BS is considered by few people in the admission control of WVN.

Although we have been devoted to study VFC and the admission control of WVN to improve resource utilization and task computation efficiency, the admission control for user groups, which is in the assistance computing environment of VFC, has not been involved. According to the previous description, using VFC to provide services for WVN is a feasible solution to realize high resources utilization. Since the uncertainty of vehicles will result in the continued changes of resources in the assistance computing environment of VFC, the problem of the admission control for WVN is very difficult to solve. To solve the difficult problem, this paper further studies an admission control mechanism for user groups of WVN in the assistance computing environment of VFC, which is based on the traditional allocation problem of computing resources. The main contributions of this paper are as follows:

- This paper proposes a two-stage robust admission control mechanism. In the first stage, the user groups of WVN requesting service can be admitted in the assistance computing environment. And in the second stage, computing resource allocation and task offloading are performed for the admitted user groups.
- Since changes in the number of vehicles will cause fluctuations in computing resources, this paper models the WVN user group admission mechanism as a robust optimization problem in the first stage. Robust optimization can better solve some problems with uncertain data. At this stage, we need to predict the resource changes during the association time of users to determine whether to respond to the user's request.
- In the second stage, task offloading and resource allocation are performed for the user groups that have been admitted. Since the coupling of task offloading and resource allocation leads to the problem of non-convex, this paper decouples the problem of resource allocation and task offloading and transforms it into a convex optimization problem to solve. The task offloading position of users must be obtained firstly, and then computing resources will be allocated to users in this stage.
- Simulation results show that the admission control mechanism can effectively access the user groups of WVN while also ensuring the user's quality of experience (QoE).

The rest of this paper is organized as follows. In Sect. 2, we describe the system model under consideration and propose the problems that need to be solved. The admission control mechanism is elaborated and divided into two parts to solving them separately in Sect. 3. Section 4 presents and discusses the simulation results. Finally, this research is concluded in Sect. 5.

2 System Model and Problem Formulation

In this section, we firstly introduce the system model considered in this paper. And then, the wireless transmission model and delay model in the communication process are described, followed by the problem formulation is presented.

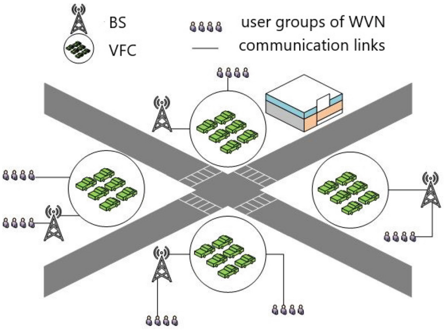

Fig. 1. System model

2.1 System Model

We assume that there are multiple BSs providing wireless access services in a two-dimensional region. According to the coverage of BS, we divide the area into multiple sub-areas. The computation capacity of vehicles with VFC in the sub-areas can be used by the BS to serve WVN. Among them, $b = \{1, 2, ..., B\}$ represents the set of BSs. Since the sub-area is defined as the coverage area of the BS, it also represents both the BS and the area. ϕ_b is used to indicate the number of vehicles with the function of VFC in area b, and its number obeys Poisson distribution. $w = \{1, 2, ..., W\}$ is represented as a set of WVN, and $m_{w,b} = \{1, 2, ..., M\}$ represents the user's set of the wth WVN in area b. Considering that users have two requirements: Firstly, each user carries a computing task, and $d^{comp}_{m,w,b}$ represents the amount of computing task of the wth WVN user which is represented by m in area b. The second, each user has a maximum tolerated delay, denoted by $T^{\max}_{m,w,b}$. The scene model in each area is shown in Fig. 1.

2.2 Wireless Transmission Model

In the Orthogonal Frequency Division Multiplexing (OFDM) communication environment, we assume that the position of users and vehicles will not change during the transmission process. The user tasks are processed in two cases, one is processed directly by the BS and the other is transmitted by the BS to vehicles for processing. The processed results are transmitted directly from the BS or vehicle to the user. Due to the orthogonality of OFDM resources, we assume that both vehicles and BSs have the same transmission mode, and there is no interference between them during communication. We suppose that the spectrum resource owned by vehicles is smaller than BSs and that the vehicle has the same bandwidth as the BS because of its own nature and limitations of the vehicle. Then the transmission rate between BS and users is $R = W \log(1 + S/N)$, where W is the fixed-size of sub-channel transmission bandwidth allocated to users by the BS or vehicles, S is the average transmission power of the channel, and N

is the additive white Gaussian noise with zero mean and its variance is σ^2. It is also applies between vehicles and users.

2.3 Delay Model

In this paper, the task processing time and the downlink transmission time are considered only in the whole process. For each user group of WVN, we use $\varepsilon \in \{0,1\}$ to indicate whether it is admitted or not. $\varepsilon = 0$ means that users are blocked, and when users are accessed, $\varepsilon = 1$. Assuming that BSs can offload the user's computing task to the BS or VFC, the binary variable $\alpha \in \{0,1\}$ is used to indicate the offloading position. When $\alpha = 1$, the task is handled by BSs, and the task is handled by the VFC as $\alpha = 0$.

Delay Model of BS. When BSs transfer the computing task of users to the local, the computation delay of task is

$$t_{m,w,b}^{comp} = \frac{d_{m,w,b}^{comp} Q_m}{q_{m,w,b}^{B}} \tag{1}$$

where $d_{m,w,b}^{comp}$ is the size of data of the computing task carried by the user, Q_m is the computation rate depending on the data type, and $q_{m,w,b}^{B}$ is the computation rate allocated by the BS to users of WVN. When the task is completed and transmitted to the user, downlink time data transmission of the user is

$$t_{m,w,b}^{tran} = \frac{d_{m,w,b}^{in}}{R_{m,w,b}^{B}} \tag{2}$$

where $d_{m,w,b}^{in}$ is the size of downlink data transmitted by the BS to users, and $R_{m,w,b}^{B}$ is the rate of data transmission, which depends on the sub-channel transmission bandwidth allocated by the BS. In summary, the total delay for users who offload tasks to the base station is

$$T_{m,w,b} = t_{m,w,b}^{comp} + t_{m,w,b}^{tran} \tag{3}$$

Delay Model of VFC. When tasks of users are offloaded to vehicles, the delay can be divided into three parts: (1) The transmission delay that BS transmits the data to target vehicles. (2) The computation delay of VFC. (3) The downlink transmission delay. The transmission delay of the first part is

$$t_{m,w,b}^{\mathrm{tran1}} = \frac{d_{m,w,b}^{\mathrm{comp}}}{R_{m,w,b}^{BV}} \tag{4}$$

where $R_{m,w,b}^{BV}$ is the transmission rate, and its value depends on the transmission bandwidth of the sub-channel when BS communicates with vehicles. The delay of the second part is

$$t_{m,w,b}^{comp} = \frac{d_{m,w,b}^{comp} Q_m}{q_{m,w,b}^{V}} \tag{5}$$

where $q^{V}_{m,w,b}$ is the computation rate of VFC to serve the users of WVN. The delay of the third part is

$$t^{\text{tran}\,2}_{m,w,b} = \frac{d^{in}_{m,w,b}}{R^{V}_{m,w,b}} \tag{6}$$

where $R^{V}_{m,w,b}$ is the data transmission rate when VFC communicates with users, depending on the transmission bandwidth of the sub-channel allocated by VFC. Therefore, the total delay of the user who offloads tasks to VFC is

$$T_{m,w,b} = t^{comp}_{m,w,b} + t^{tran1}_{m,w,b} + t^{tran2}_{m,w,b} \tag{7}$$

In summary, the user's delay mainly consists of two parts: the transmission delay and the computation delay. The required computing resources are only related to the amount of the calculation task, and the transmission delay is related to the position of the task offloading after admission. Since the unload location of tasks cannot be determined before the network access, the downlink transmission delay is only considered when admitting. The minimum amount of computation required at each time is

$$\bar{q} = \frac{d^{comp}}{T^{\max} - t^{tran}} \tag{8}$$

Since the resources of VFC are affected by vehicle density in time-varying, estimating the total utilization computing resources of vehicles is necessary. At the same time, when users are applying for access, the system can judge whether the network is admitted to accessing based on the existing available computing resources.

To ensure that enough computing resources can be obtained for the access of user groups, the computing resources in the system need to be considered. We use C_b to represent the total computing resources that can be used by BS in area b, and its total amount remains unchanged. $C_v(t)$ denotes the sum of available computing resources of VFC in area b at time t. Consequently, the available computing resources at each moment can be expressed as $C_b + C_v(t)$. Considering the continuous association of user tasks, we estimate the computing resources in subsequent moments and analyze the number of computing resources required by users in the network through multiple time scales. We use δ to represent a time interval. During the associated time, sufficient computing resources should be available for users at each $T^{\max}/\delta$ moment, which is represented by n.

2.4 Problem Formulation

To sum up, the problem of the admission control mechanism proposed in this paper is formulated as admission control for simultaneously incoming user groups of WVN. The strategy for the allocation of computing resources is executed for the user groups that are allowed, and the rejection strategy is executed for the blocked user groups. In order to ensure the quality of service for users after being admitted by WVN, we minimize the delay of users. Therefore, the problem can be expressed as

$$\begin{aligned} &\min_{\{\varepsilon,\alpha,q\}} \sum_{b}^{B} \varepsilon \sum_{w}^{W} \sum_{m}^{M} T_{m,w,b} \\ s.t.\ & C1 : \varepsilon, \alpha \in \{0,1\} \\ & C2 : \varepsilon \sum_{w}^{W} \sum_{m}^{M} \alpha q_{m,w,b}^{B} \leq q_{b}^{B}, \forall m, w, b \\ & C3 : \varepsilon \sum_{w}^{W} \sum_{m}^{M} (1-\alpha) q_{m,w,b}^{V} \leq q_{b}^{V} \phi_{b}, \forall m, w, b \\ & C4 : T_{m,w,b} \leq T_{m,w,b}^{\max}, \forall m, w, b \\ & C5 : \sum_{0}^{n} C_{b} + C_{v}(t) \geq n\varepsilon \sum_{m}^{M} \bar{q}_{m}, \forall m, w, b \end{aligned} \tag{9}$$

Constraint C1 indicates the binary variable for admission and task offloading. The constraint C2 represents that the computing resources used by users whose tasks are offloaded to the BS cannot exceed the total computing resources owned by BS, and q_b^B represents the maximum computation rate of that the BS can provide for services. Constraint C3 means that the computing resources used by users whose tasks are offloaded to the VFC cannot exceed the total computing resources owned by VFC, where q_b^V is the maximum computation rate that the VFC can serve the users of WVN, and its value which is not fixed, determined by the total amount of computing resources owned by the vehicles forming the VFC. Constraint C4 expresses that the delay of users cannot exceed the maximum delay tolerated by users, which ensures the user quality of service. Constraint C5 denotes that the computing resources required for the admitted user groups cannot exceed the total computing resources possessed by the system. Since the total computing resources in this constraint include the computing resources of transient vehicles, it will change with the dynamics of the number of vehicles, and this change is not negligible, otherwise it will lead to access failure, which is very bad for the experience of users.

3 Admission Control Mechanism in WVN

In this section, we divide the admission control mechanism into two stages. Firstly, we implement robust admission control for user groups. Secondly, task offloading and resources allocation are processed for the admitted user groups.

3.1 Robust Admission Control

The problem mentioned in (9) cannot be solved directly since it contains two binary variables. In this paper, problem (9) is decomposed into two sub-problems to solve them separately. As the offloading position and the computation rate to be allocated are difficult to determine before the admission control for WVN, we model the two sub-problems as an admission problem and a resource allocation problem, which will be described in detail as follows.

The admission problem is a mixed-integer linear problem because ε is a binary variable in the problem (9), where $\varepsilon_{w,b}$ will be extended to a range of real numbers. Accordingly, the admission problem can be expressed as

$$\begin{aligned} &\max_{\{\hat{\varepsilon}_{w,b}\}} Q(\{\hat{\varepsilon}_{w,b}\}) \\ s.t.\ &C6 : \hat{\varepsilon}_{w,b} \in [0,1] \\ &C7 : n\hat{\varepsilon}_{w,b} \sum_{m}^{M} \bar{q}_m \leq \sum_{0}^{n} C_b + C_v(t), \forall m, w, b \end{aligned} \tag{10}$$

The problem (10) is formulated as the maximum number of users allowed. We need to note that in constraint C7, the number of vehicles in each area mentioned earlier is variable. Changes in the number of vehicles can lead to changes in the resources that can be aggregated by VFC. This is an obvious uncertainty problem, and the quality of service for user groups of WVN is not guaranteed due to the uncertainty of resources. Therefore, it is necessary to optimize this problem using robust optimization.

Since ϕ_b is time-varying, the amount of VFC resources C_v is also time-varying. But in the long time run, the number of vehicles is averaged at a certain value, that is $\bar{\phi}_b$. To simulate the variability of density, we suppose that the relationship between the actual number of vehicles and the average number of vehicles is affected by two bounded but random parameters, which are γ and θ. At any time $\phi_b = (1+\gamma\theta)\bar{\phi}_b$, where $\gamma > 0$ is the parameter with the largest magnitude that affects the uncertainty of ϕ_b, and θ is the zero-mean random variable between [–1,1], which defines the possible volatility of the number of vehicles. It means that the number of vehicles cannot deviate from the estimated number of vehicles by more than $\theta\bar{\phi}_b$, and the possible deviation level is controlled by the parameter γ.

The BS can change parameters for robustness adjustments based on robustness levels and historical statistics, which is the data on the number of vehicles. Problem (10) can be expressed as a robust problem based on the definition of the robust linear problem and similar expressions in [16–18]. When $\theta = 0$, it means that there is no uncertainty in the problem, otherwise, the problem (10) is represented by a robust correspondence problem. In the robust model proposed by the authors in [16], the corresponding robust feasible solution must satisfy the constraint of high probability if the uncertainty coefficient has bounded symmetry. Since $\bar{\phi}_b$ in $[\bar{\phi}_b - \gamma\bar{\phi}_b, \bar{\phi}_b + \gamma\bar{\phi}_b]$ has boundedness and symmetry, and the mean value is $\bar{\phi}_b$, the problem (10) follows the model proposed in [16]. The constraint C7 also can find a feasible solution $\hat{\varepsilon}_{w,b}$ when the condition is satisfied with a high probability.

Dealing with the problem (10) is very simple according to the conclusions in [17,18]. According to the method, if this paper defines the reliability level as ζ, which means that the maximum probability of dissatisfying the constraint C7 is ζ, then finding a feasible solution to problem (10) is equivalent to solving the following problem

$$\begin{aligned} &\max_{\{\hat{\varepsilon}_{w,b}\}} Q(\{\hat{\varepsilon}_{w,b}\}) \\ s.t.\ &C6 : \hat{\varepsilon}_{w,b} \in [0,1] \\ &C8 : n\hat{\varepsilon}_{w,b} \sum_{m}^{M} \bar{q}_m - nC_b - \sum_{0}^{n} C_v(t) \\ &\quad - \gamma\tau \sqrt{\sum_{0}^{n} C_v^2(t))} \le 0, \forall m, w, b \end{aligned} \tag{11}$$

where $\zeta = \exp\{-\tau^2/2\}$. ζ can be interpreted as the overload probability of the embedded WVN. Allowing some users of WVN to exceed the system capacity with such a low probability is reasonable since the network capacity and vehicle traffic conditions change with time in practical applications. Therefore, this paper can also use the probability constraint (12) to express the constraint C8

$$\Pr\{n\hat{\varepsilon}_{w,b} \sum_{m}^{M} \bar{q}_m \le \sum_{0}^{n} C_b + C_v(t)\} \le \zeta, \forall m, w, b \tag{12}$$

Since ε is non-negative, the problem (11) is a convex problem based on robustness parameters (γ, ζ) and the constraint C8 is convex, whose objective functions are all linear functions. Solving the problem (11) has many ways when specific parameters (γ, ζ) are given, and in this paper, we use convex optimization to solve the problem. It is necessary to note that $\hat{\varepsilon}_{w,b} \in \{0,1\}$ is a real value bounded on [0,1], which can represent some users who are admitted to the network. However, marginal benefit [19] will be used to recover $\hat{\varepsilon}_{w,b}$ from $\varepsilon_{w,b}$ if partial admission is not allowed in the network.

3.2 Task Offloading and Resource Allacation

At this stage, we conduct traditional task offloading and resource allocation to users of WVN who have already been admitted. We do not consider the multiple associations for the time being between users and BSs or between users and VFC. For the users of WVN that have been admitted, the paper uses w_b^{ε} to indicate the set of them, which is denoted as

$$w \in \begin{cases} w_b^{\varepsilon},\ \varepsilon_{w,b} = 1 \\ w_b - w_b^{\varepsilon},\ others \end{cases} \tag{13}$$

As mentioned above, the unload position of users task is represented by a binary variable α, and the optimization goal of resources allocation and task offloading is the total delay of users. Thus, the problem of resource allocation and task offloading can be represented as

$$\begin{aligned} &\min_{\{\alpha,q\}} \sum_{b}^{B}\sum_{w}^{W}\sum_{m}^{M} T_{m,w,b} \\ s.t.\ &C1: \alpha \in \{0,1\} \\ &C2: \sum_{w}^{W}\sum_{m}^{M} \alpha q_{m,w,b}^{B} \le q_{b}^{B}, \forall m,w,b \\ &C3: \sum_{w}^{W}\sum_{m}^{M} (1-\alpha) q_{m,w,b}^{V} \le q_{b}^{V}\phi_{b}, \forall m,w,b \\ &C4: T_{m,w,b} \le T_{m,w,b}^{\max}, \forall m,w,b \end{aligned} \tag{14}$$

The simultaneous presence of variables α and q makes constraints C2 and C3 non-convex, resulting in problem (14) not being solved directly by convex optimization. Therefore, it is necessary to make a decision on the user's offloading position firstly by fixing the average rate $\bar{q}_{m,w,b}^{B}$ and $\bar{q}_{m,w,b}^{V}$. The offloading problem can be expressed as follows

$$\begin{aligned} &\min_{\{\alpha\}} \sum_{b}^{B}\sum_{w}^{W}\sum_{m}^{M} \alpha t_{m,w,b}^{tranb} + (1-\alpha) t_{m,w,b}^{tranv} \\ s.t.\ &C1: \alpha \in \{0,1\} \\ &C2: \sum_{w}^{W}\sum_{m}^{M} \alpha \bar{q}_{m,w,b}^{B} \le q_{b}^{B}, \forall m,w,b \\ &C3: \sum_{w}^{W}\sum_{m}^{M} (1-\alpha) \bar{q}_{m,w,b}^{V} \le q_{b}^{V}\phi_{b}, \forall m,w,b \\ &C4: T_{m,w,b} \le T_{m,w,b}^{\max}, \forall m,w,b \end{aligned} \tag{15}$$

Problem (15) is a mixed-integer linear programming problem, which can be solved by methods such as the branch-and-bound method to obtain the user offloading location. Once the user's offloading decision is obtained, it is substituted into the problem (14) so that it can be transformed into a convex optimization problem to be solved with the CVX tool.

4 Performance Simulation and Discussions

In this section, the proposed model is systematically verified and simulated in various aspects to demonstrate the effectiveness of the admission mechanism. We use the MATLAB platform to carry on the simulation, and the concrete parameters used in the simulation process are shown in Table 1. Considering that the focus of this paper is admission control, we carried out the admission

Table 1. The Simulation Parameters

parameters	Numerical value
System Bandwidth	10 MHz
Transmission Power	24 dbm
Noise Power Density	–174 dbm/H
Task Size	1–10 Mbits
Task Rate	500–1000 CPU Cycle/bit
Computing Rate of BS	15*10ˆ11 CPU Cycle/s
Computing Rate of VFC	1*10ˆ10 CPU Cycle/sehicles
Vehicles	Poisson distribution
User Groups of WVN	5–20/group /area
Users of WVN	5–9/person/WVN

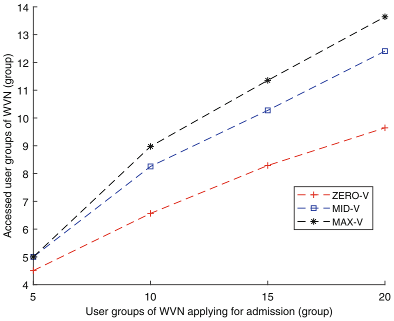

Fig. 2. Accessed number of WVNs in three cases

control simulation for user groups of WVN applying for admission. We also simulate the total delay of users after the resource allocation. The simulation results are as expected.

In order to verify the effectiveness of the admission mechanism proposed in this paper, we conduct simulation for the system performance of the different number of vehicles in the VFC assistance environment, as shown in Fig. 2. The simulation result of non-vehicular fog computing assistance is called ZERO-V. In addition, two cases with different numbers of vehicles are selected for simulation. One scenario has 30 vehicles in each area to form the VFC environment and the simulation result is called MID-V. And another has 50 vehicles, called MAX-V. It can be seen from Fig. 2 that with the assistance of VFC, more user groups of WVN can be admitted, and the more assistance vehicles, the more users will be admitted. On the other hand, the figure reflects that the system with VFC assistance can improve the admission rate effectively only when more user groups applying.

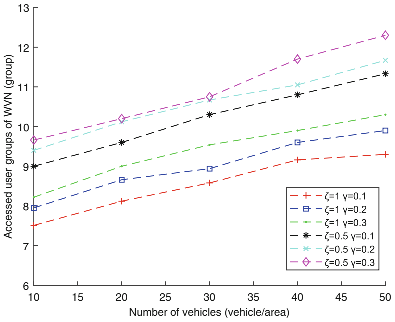

Fig. 3. Accessed number of WVNs in different environment

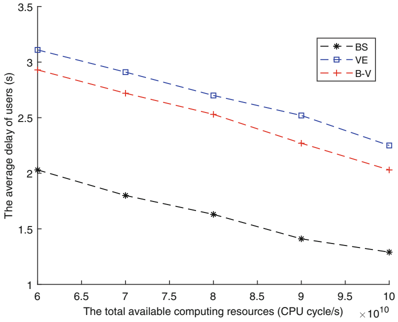

Fig. 4. The average delay of users in different environment

In Fig. 3, different robustness optimization parameters are set to evaluate its effect on the number of accessed user groups in the environment of VFC assistance in different vehicle densities. From Fig. 3, we can conclude that when ζ (user tolerance probability) is constant, the larger γ (resource fluctuation parameter) is, the more user groups can be admitted. When γ is constant, the lower ζ is, the existing system, with enough resources, can better meet the requirements of user groups so that the system can access more user groups of WVN. The number of admitted user groups will also increase as the density of vehicles increases. From the analysis of the results, it is noticeable that setting different robustness parameters plays an effective role in the admission mechanism proposed.

For verifying the total delay of the users with the assistance of VFC, we use the average delay to simulate it. The case without VFC assistance is called BS. As VFC assistance is provided, it is called B-V, and when only VFC is used for computation, we call it VE. Under three different environments, the relationship between the total available resources and the average user delay is shown in Fig. 4. When all tasks are offloaded to BSs, the users can obtain the minimum delay. However, the load of BS can easily reach the peak level, which also affect the system to access more user groups. When all tasks are offloaded to VFC

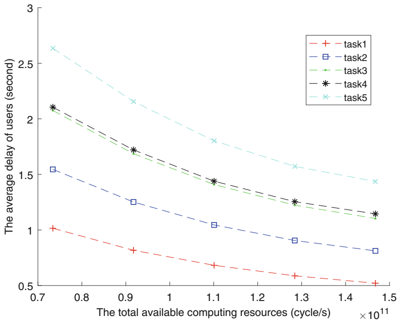

Fig. 5. The average delay of different types of users

to deal with, the delay will increase relatively. While in the case of B-V, the latency is not too high and the computational resources are guaranteed, which keeps the load of BS in a balanced state. Therefore, with the assistance of VFC, the system can increase the total number of available resources, greatly relieving the load pressure of BS, and ensuring the delay requirements of users effectively.

Finally, the task processing delay of users is evaluated. As the available computing resources will inevitably increase linearly when the number of vehicles increases, we use the total available computing resources for simulation. When the number of admitted networks is constant, we simulate the task processing delay, analyzing the relationship between the task type (mainly point to the size of the task) and the delay, as well as the task delay and the total available computing resources. The simulation result is shown in Fig. 5. It can be concluded that the average delay of users will decrease as the number of available resources increases when a certain number of WVN are admitted, which will inevitably decrease the total delay.

5 Conclusions

In this paper, we propose a robust admission mechanism for user groups of WVN in VFC assisted environment, mainly for the problems of the uncertainty of resources and low resource utilization caused by random access of user groups. This mechanism can provide effective access control for user groups of WVN with guaranteed user latency requirements and dynamic changes in resources. The mechanism has two stages. Firstly, the robust optimization model is performed to solve the admission problem of user groups in a resource-uncertain environment, and the best user groups are admitted to improve resource utilization. The second stage is traditional task offloading and resource allocation for admitted users to ensure users latency requirements. Simulation results show that the mechanism can solve the problems of user-resource mismatch and resource uncertainty in VFC. In addition, it can guarantee the QoE of users as well while accessing more user groups.

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