# Edge Computing Offload and Resource Allocation Strategy with Pairing Theory

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**Abstract.** The contradiction between the explosive growth of data traffic and the lack of edge server resources brings great challenges to the resource allocation of mobile edge networks (MEC). In order to improve the utilization rate of the resources of the MEC, this paper proposes a resource allocation strategy based on stable user pairing. Firstly, the frame structure of the mobile edge computing network is optimized based on the user matching model, and the matching service is classified according to the elements in the frame structure. Secondly, a resource allocation protocol based on stable user matching is proposed. Then, the system utility analysis is carried out on the unloading benefit and pairing benefit of users, and the optimization function of maximizing the system utility is established. A dynamic task unloading and resource allocation mechanism based on pairing theory is proposed. The simulation results show that the proposed algorithm reaches the convergence value quickly and the system benefit is high. Compared with the resource allocation schemes of various algorithms, it is proved that the scheme can effectively improve the performance of system capacity, delay and fairness.

**Keywords:** Mobile edge networks · Computing offload · User pairing · Resource allocation · System utility

## 1 Introduction

In the actual network scenario, faced with diverse user needs and explosive growth of data traffic, 5G communication has become one of the indispensable technologies in society [1]. Mobile edge computing is a promising technology in 5G networks. In mobile edge networks, the key for MEC to complete computing tasks is to migrate application tasks, cloud resources, functions and services to the edge of the network [2–4]. However, MEC also confronts many challenges when it comes to the number of users in the network. Among many problems, computing offloading becomes one of the bottlenecks restricting communication quality, which involves wireless communication between terminal equipment and the edge cloud [5–7]. Therefore, the key to accomplish computing offloading depends on different factors, of which resource scarcity is one of the most important factors that cannot be ignored.

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In recent years, a large number of research results on resource allocation techniques in MEC network can be found in academia. Liping Qian et al. [8] studies the multi-access moving edge computing technology supported by non-orthogonal multi-access technology. In order to reduce the total delay of computing load completed by intelligent terminals, a mobile edge computing server with joint optimization of computing resource allocation is designed. Zubair Sharif et al. [9] presents an adaptive resource allocation mechanism that dynamically allocates available resources by considering the nature of incoming requests. Fitsum Debebe Tilahun et al. [10] investigates a joint resource allocation problem in cell-free mobile edge computing system which intends to minimize the number of users subjected to outage. Qiuqi Han et al. [11] investigates the resource allocation problem for MEC in non-orthogonal multiple access enabled small cell networks, where the small cell users can offload their computational tasks to the associated minor base station via non-orthogonal multiple access protocol. However, in the MEC networks, system utility is often a performance index that cannot be ignored. At the same time, how to effectively improve the competitiveness of users according to the characteristics of mobile edge computing network is very important for realizing reasonable and fair resource allocation. Matching game [12], a technique that can be used for resource share, which provides a new direction for resource allocation in MEC.

In this paper, we construct edge computing offload and resource allocation strategy with matching theory. We mainly study the the user pairing and calculate unloading to achieve optimal resources allocation in the MEC network. First, the value of pairing utility is calculated based on the user pairing model. Then, the resource allocation protocol is designed with the pairing utility and the pairing level. Finally, the system utility of the resource allocation scheme is solved. The main contributions are as follows,

- We provide a description of the user pairing and calculate unloading models based on user preferences, and study resource allocation by considering cost, preference and user utility (pairing utility and unloading utility).
- We deployed a frame structure model for the stable user pairing scheme. The service level of user pairing is classified with the control elements of frame structure, and a new resource allocation protocol is designed.
- By using genetic algorithm, we formulate the multi-objective optimization problem of system utility maximization.
- We conduct simulations to evaluate and demonstrate the performance of the proposed scheme. The results show that the objectives optimization of system utility and the resource allocation protocol can be achieved.

The remainder of the paper is organized as follows. Section 2 of the paper presents system model, which contains the network model and the frame structure model. Resource allocation protocol is given in Sect. 3. In Sect. 4, we analyze the utility functions and optimal user pairing - computing offload scheme. Simulation results analysis 5. Finally, we summarize the full work in Sect. 6.

## 2 System Model

### 2.1 Network Model

Consider a MEC system with N users and multiple wireless access points. Each wireless access point connects to a high-performance mobile edge server to perform computational offload tasks. System users can choose to process the data locally or unload the data to the mobile edge server across the uplink. Due to the limited resources of WEC system, users form alliances to compete for resources through matching strategies. Pairing is essentially a cognitive process of preference. Therefore, the preferences between users determine the amount of computing offloads for users. Assume that the user calculates the unloading scheme as $\theta = (\theta_1, \theta_2, \ldots, \theta_N)$, where $\theta_i \in [0, 1]$ represents the preference rate of user $i$. For example, $\theta_i$=0 indicates that the secondary user chooses local processing; $\theta_i$= 1 indicates that secondary users uninstall all computing tasks to the edge server to complete the task processing. If the amount of computing tasks received by each edge server is random, we define the amount of computing tasks unloaded by the user as $l_i$, and $Z_i$ represents the number of CPU revolutions per bit of computing task completed (Fig. 1).

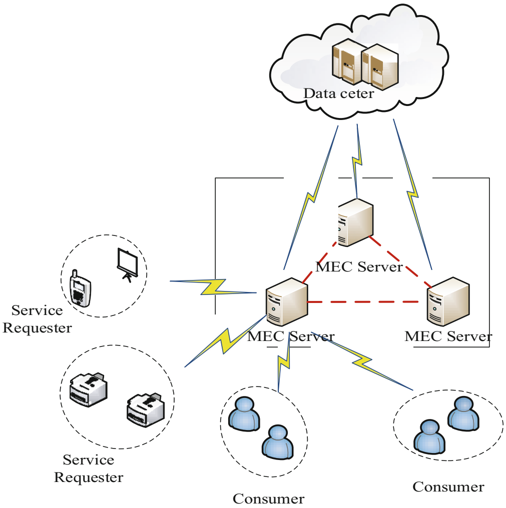

**Fig. 1.** Frame knot model of MAC system

### 2.2 Frame Structure Model

We deploy a frame structure model with $\tau$+1 time slots per frame for a stable user pairing scheme. It consists of an identification time slot, $\tau_1$ control time slot, and $\tau_2$ data time slot, where $\tau = \tau_1 + \tau_2$, as shown in Fig. 2. The control time slot is used to control the whole process of user pairing, including transmission power, delay and the economic

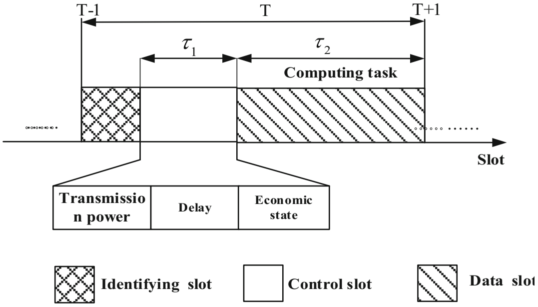

**Fig. 2.** Frame knot model of MAC system

status of the user in the network. The data time slot mainly represents the computing and unloading tasks of the MEC system.

In general, in order to maximize their own benefits, users will often compete for limited bandwidth resources to access MEC systems through cooperation with the best partners. Note that the opportunity to access each license channel of user is relevant to its partner. The more powerful the user is, the more opportunities he has to access the network, and the user's ability can be determined by the control information in his frame structure. Next, we design a resource allocation protocol based on stable user pairing by combining the control information of frame structure.

# 3 Resource Allocation Protocol

## 3.1 Pairing Service Level Classification

User pairing must meet different service quality requirements, such as transmission speed, reliability, and latency. In order to achieve this goal, the user pair forms the control information in the frame structure that depends on the user. In addition, given the limited resources and the impact of a large number of application businesses, the impact of the user's economic situation must be considered when designing resource allocation protocols on MEC networks. This is because as the financial power of the user increases, so does the probability that the user will be matched with the best partner. In other words, economic status is also one of the key factors in choosing a mate.

Consider matching service level to determine the priority of user matching, which is represented by symbol $W_C$. Each level contains the following parameters: transmission rate $r_{i,j}$, delay $\tau_{i,j}$, economic status $e_i$, reliability $r_e$. Without loss of generality, all user parameters should conform to the requirements related to the performance level and be sorted in descending order. The following Table 1 gives a summary of paired service level. Depending on the service level, it can be defined as level 0 to 3, where level 3 is super high, level 2 is high, level 1 is medium, and level 0 is low. Users can select the best partner for matching by referring to the criteria of the matching service category.

A. Super advanced (real-time/high transmission rate): This class must meet the requirements of high delay and high transmission rate at the same time. The corresponding

**Table 1.** Matching service level classification

| NO | Paired service level | $r_{i,j}$ | $\tau_{i,j}$ | $e_i$ | $r_e$ |
|---|---|---|---|---|---|
| 0 | Super advanced | 3 | 3 | 3 | 2 |
| 1 | Advanced | 1 | 3 | 2 | 2 |
| 2 | Medium | 3 | 1 | 2 | 1 |
| 3 | Low | 1 | 1 | 1 | 1 |

parameter delay $\tau_{i,j}$ and transmission rate $r_{i,j}$ level are defined as 3. If one of these requirements is not met, the communication performance of the user pair may deteriorate. At the same time, the more affluent users are, the more competitive they become. In the super senior economic state, therefore, as an important parameter, the influence of its performance indicators should belong to the highest, namely parameters level represented by $e_i$=3

B. Advanced (real-time/Low Transfer rate): This category consists mainly of user pairs that are delay-sensitive but have low transfer rates, i.e. $\tau_{i,j}$=3, $r_{i,j}$=1. According to the parameter Settings, the range of delay limit in the user pairing process is very strict. Compared with the high requirement of delay, the level requirements of economic state $e_i$ and reliability $r_e$ have been appropriately relaxed, and the parameter setting is often lower than the delay. In this way, the real-time communication between users will not be affected.

C. Medium (non-real time/high transfer rate): This category tolerates the transmission delay of the user pair while meeting the requirements of high transfer rate, i.e. $\tau_{i,j}$=1, $r_{i,j}$=3. If the actual transmission rate of the user pair is higher than the achievable transmission rate, the performance of the user pair can be improved. At the same time, we consider economic status as an important parameter, and reliability is a low ranking in this paired service class. The reason is that in a market economy where resources are limited, economically affluent users are usually in an advantageous position.

D. Low (non-real-time/low transmission rate): This category is at the lowest level and has low requirements on the transmission speed and delay of the system. That is, the transmission rate $r_{i,j}$ and delay $\tau_{i,j}$ are set to 1. At the same time, the economic status and reliability of users in this category are also low. However, the overall performance of the user pair must conform to tolerable limits for all parameters. Otherwise, user pairing will fail.

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### 3.2 Protocol Design

Next, we'll look at another part of the stable user pairing protocol (SUPP), which is the user pairing formation flow chart, as shown in Fig. 3. In this flowchart, the formation of user pairs can be divided into three steps.

Step 1: Based on the distance threshold, pairwise pairings are performed between users.

Step 2: The results of the first step are screened by using the systematic benefits of pairing.

Step 3: Whether to allocate resources based on the paired service level. If the paired service level is greater than 2, i.e. $w_c(i, j) > 2$, resources are allocated. Otherwise, normal communication is returned.

As a result, bandwidth resources can be shared only when two users are close to each other. More specifically, the user pairing is limited by the range of distance thresholds. Conversely, users above this threshold temporarily abandon pairing and switch to regular communication. In addition, pairing utility is considered to be the most important factor in resource allocation while assisting MEC systems to improve network benefits. Users who meet the distance requirement achieve an ideal pairing based on the utility of that user pair.

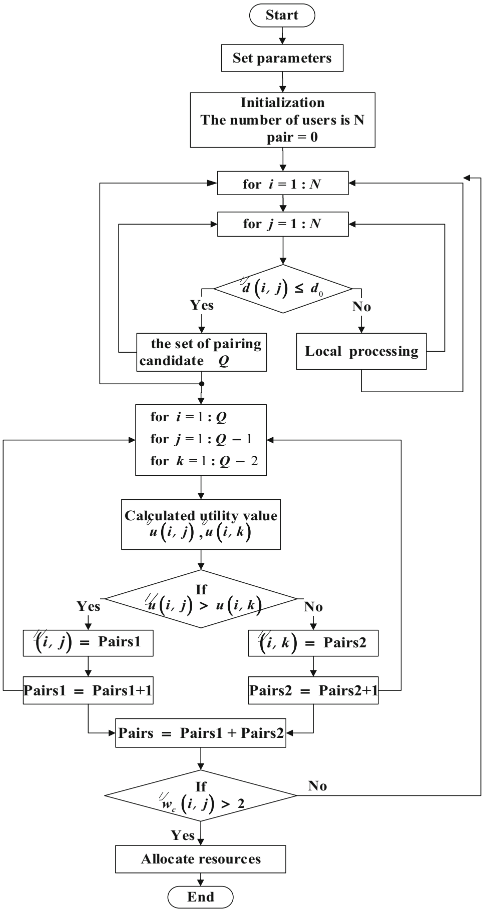

**Fig. 3.** Resource allocation protocol flowchart

# 4 System Utility

## 4.1 Utility Function

In the research model of this paper, the goal of user matching is to select other users to match in the lowest cost way, so as to maximize its own benefits. But cost and benefit are often contradictory, in order to achieve the highest system benefits, it is necessary to seek a balance between the two. Therefore, in the management of computing offload and resource allocation strategy, we must consider their respective benefits. In MEC networks, user benefits include pairing benefits and computational offload benefits.

The benefit function of user pairing consists of the benefit of pairing and the cost of pairing. The income of user pairing includes the profit obtained from users' interest similarity, while the cost is the loss of time delay and transmitting power caused by the pairing process. So the utility function for each paired user can be expressed as follows:

$$u_{\theta}(i,j) = \sum_{i,j \in S} f\left(\frac{\theta_i l_i}{\tau_{ij} \cdot d_{ij} \cdot p_{ij}}\right) \tag{1}$$

where, $\tau_{ij}$ is the average service delay of data access between two users, $d_{ij}$ is the transmission distance between two users, $p_{ij}$ is the transmitted power from user $i$ to user $j$, $\theta_i$ is the preference for the amount of tasks between any two users.

Considering the computational unloading scheme, for user $i$, the utility function of computational unloading can be expressed as:

$$Y[u_i] = l_i Z_i - X_i - F_i \tag{2}$$

where, $l_i Z_i$ represents the computing benefit obtained by user $i$, including the benefit of local processing and unloading calculation. $F_i$ indicates that each user needs to pay for free resources. $X_i$ represents the cost required by user $i$ to complete the computing task, which is mainly composed of the computing cost $X_i^{local}$ for local processing, $X_i^{pair}$ for the loss from pairing, and $X_i^{delay}$ for total delay. They can be calculated as:

$$\begin{cases} X_i^{local} = (l_i - \theta_i l_i) Z_i \pi_i \\ X_i^{pair} = \theta_i l_i \phi_i \\ X_i^{delay} = \theta_i l_i \big/ r_{i,AP} \end{cases} \tag{3}$$

where, $(l_i - \theta_i l_i)$ represents the number of computing tasks processed locally, and $\pi_i$ indicates the average power consumption cost per CPU revolution. $\phi_i$ represents the average unloading cost of a computing task. $r_{i,AP}$ is the uplink transmission rate between user $i$ and the wireless access point.

In order to further simplify the calculation, relevant variables are defined as follows,

$$V_i(\theta_i) = l_i Z_i - X_i^{local} - X_i^{pair} = l_i Z_i - (1 - \theta_i) l_i Z_i \pi_i - \theta_i l_i \phi_i \tag{4}$$

By substituting formula (4) into formula (3), the unloading utility function of user $i$ can be obtained as

$$Y[u_i] = V_i(\theta_i) - \theta_i l_i \big/ r_{i,AP} - F_i \tag{5}$$

Considering the unloading benefit and pairing benefit comprehensively, the user benefit function can be calculated as:

$$\begin{aligned} E[U] &= \sum_{i=1}^{N} u_\theta(i,j) + \sum_{i=1}^{N} Y[u_i] \\ &= \sum_{i=1}^{N} u_\theta(i,j) + \sum_{i=1}^{N} V_i(\theta_i) - \sum_{i=1}^{N} F_i - \sum_{i=1}^{N} \theta_i l_i \big/ r_{i,AP} \end{aligned} \tag{6}$$

## 4.2 Optimal Problem Algorithm Design

In MEC network, the optimization goal is to maximize the system benefit. System benefit function maximization problem and its constraints can be described as:

$$\begin{aligned} &[\theta, F] = \arg\max E[U] \\ &s.t.\, C1: 0 \le \theta_i \le 1, \forall i \in N \\ &C2: F_i \ge 0, \forall i \in N \\ &C3: \theta_i = \arg\max_{\tilde{\theta}_i} V_i\big(\tilde{\theta}_i\big) - F_i - \tilde{\theta}_i l_i \cdot W_i(T_i) \\ &C4: V_i(\theta_i) - F_i - \theta_i l_i \cdot W_i(T_i) \ge 0, \forall i \in N \\ &C5: u_\theta(i,j) > 0, \forall i,j \in N \end{aligned} \tag{7}$$

Constraint C1 represents the range of user preference rates. Constraint C2 guarantees that each user pays for resources; Constraints C3 and C4 represent individual rationality and motivation requirements respectively. Constraint condition C5 ensures that the efficiency of user pairing is increased.

Problem (7) is NP-hard problem. In order to solve the optimization problem of system utility, a low complexity approximate optimization scheme is proposed. Based on the relationship between preference and computational offloading, a convex optimization problem is developed with user pairing and computing offload scheme and maximize the system benefit.

The objective of this study is to maximize the system benefit by developing the optimal computing offload strategy and user pairing scheme. User pairing affects the strategy of computing offload. To solve this problem, we propose an optimal user pairing - computing offload (UPCO) scheme $\theta$.

$$\begin{aligned} &\theta = \arg\max E[U] = \arg\max \sum_{i=1}^{N} V_i(\theta_i) - \sum_{i=1}^{N} \theta_i l_i \big/ r_{i,AP} \\ &s.t.\, 0 \le \theta_i \le 1, \forall i \in N \end{aligned} \tag{8}$$

Next, $\theta^* = \left(\theta_1^*, \ldots, \theta_N^*\right)$ is assumed to calculate the optimal solution of the pairing and unloading scheme. By applying the KKT condition to the operation, it can be calculated as,

$$
\begin{aligned}
&\frac{\partial V_i(\theta_i)}{\partial \theta_i} - \frac{l_i}{r_{i,AP}} - \eta_i + \rho_i = 0, \forall i \in N \\
&0 \le \theta_i \le 1, \forall i \in N \\
&\eta_i \theta_i = 0, \forall i \in N \\
&\rho_i (1 - \theta_i) = 0, \forall i \in N
\end{aligned}
\tag{9}
$$

where, $\eta_i \ge 0$ and $\rho_i \ge 0$ correspond to Lagrange multiplier factors of constraint variables $\theta_i \ge 0$ and $\theta_i \le 1$ respectively.

In the MEC network, since users are always greedy and selfish, they need to obtain the current pairing utility and offloading utility when considering the next pairing and offloading strategy to ensure that their own strategy can be adjusted with the scheme changes of other users. According to the gradient descent algorithm, it can be obtained,

$$
\theta_i^{n+1} = \theta_i^n + \delta \cdot \theta_i^n \cdot \frac{\partial \theta}{\partial \theta_i} \tag{10}
$$

where, $\theta_i^n$ and $\theta_i^{n+1}$ respectively represent the current paired unloading strategy and the next paired unloading strategy. The first derivative $\partial \theta \big/ \partial \theta_i$ of the system utility function reflects the rise and fall of the current user utility, and the paired unloading strategy can be dynamically adjusted on the basis of the change of the partial derivative value.

## 5 Performance Evaluation

This section provides the simulation results to evaluate the performance of the system. In this simulation, the simulation scenario is set as a small base station located in a cell with a radius of 100 m, and 100 user devices are uniformly deployed in the coverage environment of the cell. We set the total bandwidth resource to 5 *MHz*. It is assumed that the delay limit of user pairing obeys $[0.1, 0.2]s$ uniform distribution and the economic state of user obeys [30, 60] uniform distribution (Table 2).

**Table 2.** Simulation Parameters

| NO | Simulation Parameters | Value |
|---|---|---|
| 1 | Number of users | [5,100] |
| 2 | Number of channels | [5, 15] |
| 3 | Transmission power | 100*mw* |
| 4 | Task package size | [400,600] mbps |
| 5 | CPU cycle | [800,1200] *MHz* |

In the Fig. 4, the convergence of UPCO algorithm is verified as the number iterations increases. It can be observed that UPCO scheme can converge to a stable value after about 15 iterations. At the same time, it found that the unloading benefit of the algorithm grew faster as the number of users increased. Thus, the increase of the number of users cause the growth of computing tasks, in order to gain more system utility.

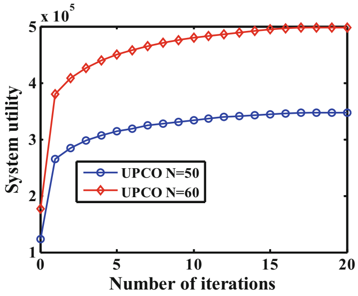

**Fig. 4.** Convergence validation of UPCO

In order to verify the effectiveness of the algorithm, the UPCO scheme in this paper is simulated with other computational unload algorithms, such as non-cooperative game based computational unload scheme(NOCO) [13] and energy-efficient computational offloading and resource allocation for mobile edge computing(ECO) [11], local computing. NOCO is a non-cooperative game for mobile users to study computational offloading, while ECO focuses on optimizing computational offloading and resource allocation by considering power control, computation resource and subchannel resource allocation.

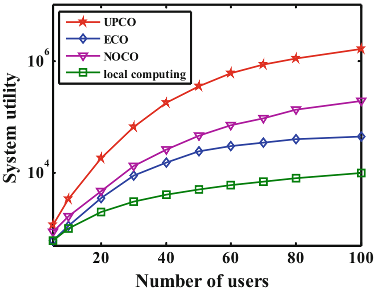

**Fig. 5.** System utility with varying of the number of users

As shown in Fig. 5, the change of system utility of different algorithms is verified with the number of users increasing. Intuitively, system utility increases as the number of users increases. This is because more users mean more computing tasks and a higher total benefit value for processing tasks. Our algorithm takes user pairing into account to maximize system utility, which ensures that a single mobile user has no incentive to deviate from the optimal solution. Therefore, we find that the UPCO algorithm has the best performance relative to other algorithms.

Next, we evaluate the performance of the proposed stable user pairing protocol against other pairing solutions, such as maximum system capacity pairing (MSCP), individual preference aware caching pairing (IPAC) [14] and random pairing (RP).

Figure 6 shows the system capacity changes of different algorithms. It can be seen from the figure that the system capacity of SUPP is obviously larger than that of MSCP and IPAC, but slightly smaller than that of the former. As the number of users increases, the system capacity of SUPP tends to the maximum capacity. Since the RP randomly selects users for pairing regardless of any factors, it is obvious that its system capacity is minimal.

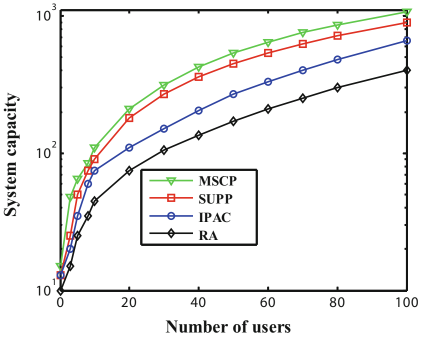

**Fig. 6.** System capacity with varying of the number of users

When the number of users is equal, the cumulative distribution function of the user capacity of different algorithms is simulated to judge the fairness of the algorithm. As can be seen from Fig. 7, SUPP remains at the far right of RP and IPAC, indicating that the system capacity of stable SUPP is the largest. Moreover, the system capacity of this algorithm changes less, so SUPP is fairer to cognitive users than the other two algorithms. In order to verify the accuracy of the fairness of the scheme, we further calculated the variance of user communication capacity of RP, IPAC and SUPP successively, and obtained the results of 2.7939, 2.6742 and 1.947 respectively. Simulation results show that SUPP has higher system capacity and better fairness to users.

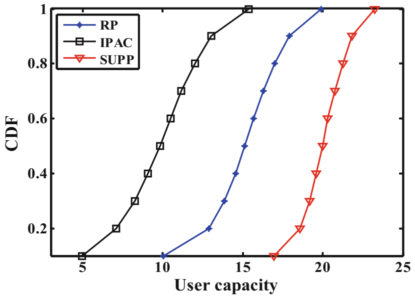

**Fig. 7.** CDF of different algorithms

Figure 8 shows the comparison between the average delay of SUPP and IPAC with respect to the change of the number of users. As shown in the figure, the average latency of the two algorithms increases as the number of users increases. This is because the increase of the number of users leads to the increase of pairing time and the increase of data transmission delay. However, relative to the average delay growth rate of IPAC, the stable alliance pairing algorithm is obviously slower.This verifies that the proposed algorithm strategy effectively improves the similarity between users, so that users can be quickly paired.

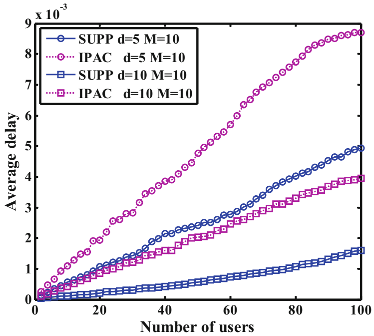

**Fig. 8.** Average delay with varying of the number of users

## 6 Conclusion

This chapter focuses on resource allocation in a MEC network based on matching theory technology, and proposes a joint optimal computing offloading and resource allocation scheme based on the preference perception. The scheme consists of resource allocation protocol and system benefit maximization. In resource allocation protocol, a frame structure of mobile edge network is designed based on user pairing model. According to the control information in the frame structure control slot, the matching service level is classified. The resource allocation protocol is designed by considering the benefit value of user pairing and the pairing service level. In the process of maximizing system benefits, combining with matching strategy, a resource allocation scheme based on the preference perception is proposed, which improves the probability of users accessing spectrum.

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## References

1. Gao, X.: The research of resource allocation method based on GCN-LSTM in 5G network. IEEE Commun. Lett., 27(3), 926–930 (2023)
2. Liu, J.: Resource provision and allocation based on microeconomic theory in mobile edge computing. IEEE Trans. Serv. Comput., 15(3), 1512–1525 (2022)
3. Jiang, J.: Computing resource allocation in mobile edge networks based on game theory. In: IEEE 4th International Conference on Electronics and Communication Engineering (ICECE), pp. 179–183. IEEE, Xi'an, China (2022)
4. Song, S.: Clustered virtualized network functions resource allocation based on context-aware grouping in 5G edge networks. IEEE Trans. Mob. Comput. 19(5), 1072–1083 (2020)
5. Liao, J.X.: Resource allocation and task scheduling scheme in priority-based hierarchical edge computing system. In: 19th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES), pp. 46–49. IEEE, Xuzhou, China (2022)
6. Ragasriswathi, M.: Novel multi-channel energy harvesting scheme for dynamic resource allocation in mobile edge computing systems. In: 4th International Conference on Inventive Research in Computing Applications (ICIRCA), pp. 956–964. IEEE, Coimbatore, India (2022)
7. Zhang, S.: Joint computing and communication resource allocation for satellite communication networks with edge computing. China Commun. 18(7), 236–252 (2021)
8. Qian, L.P., Shi, B.: NOMA-enabled mobile edge computing for internet of things via joint communication and computation resource allocations. IEEE Internet of Things J. 7(01), 718–733 (2020)
9. Sharif, Z.: Adaptive and priority-based resource allocation for efficient resources utilization in mobile-edge computing. IEEE Int. Things J., 10(04), 3079–3093 (2023)
10. Tilahun, F.D.: Delay-aware joint resource allocation in cell-free mobile edge computing. In: 2022 27th Asia Pacific Conference on Communications (APCC), pp. 81–82. IEEE, Jeju Island, Korea (2022)
11. Han, Q.: Energy-efficient resource allocation for mobile edge computing in NOMA-enabled small cell networks. In: IEEE 20th International Conference on Communication Technology (ICCT), pp. 415–419. IEEE, Nanning, China (2020)
12. Fang, H.: Matching game based task offloading and resource allocation algorithm for satellite edge computing networks. In: International Symposium on Networks, Computers and Communications (ISNCC), pp. 112–116. IEEE, Shenzhen, China (2022)
13. Lottici, V.: Efficient distributed joint path selection and resource allocation in non-cooperative wireless relay networks. In: Assembly and Scientific Symposium of the International Union of Radio Science, pp. 130–135. IEEE, Rome, Italy (2022)
14. Lee, M.-C.: Individual preference aware caching policy design in wireless D2D networks. IEEE Transactions on Wireless Communications 19(8), 5589–5604 (2020)
15. Wang, M.: Intelligent resource allocation in UAV-enabled mobile edge computing networks. In: IEEE 92nd Vehicular Technology Conference (VTC2020-Fall), pp. 180–183. IEEE, Victoria, BC, Canada (2020)
16. Sun, X.: Resource allocation and load balancing based on edge computing in industrial networks. In: IEEE International Conference on Smart Internet of Things (SmartIoT), pp. 250–251. IEEE, Suzhou, China (2022)