A Cache Allocation in Mobile Edge Computing

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Abstract

Mobile edge computing (MEC) is an emerging technology for enhancing the computing and caching capacity of mobile devices. In this paper, MEC system consists of one MEC server of caching and computing capacities and multi BS. We consider the cache allocation in MEC server to BSs using the auction method. To solve the winner determination problem- an NP-hard problem, we propose a greedy algorithm. Some numerical results show the performance and individual rationality of the proposed schemes.

1. Introduction

Mobile video service is predicted to account for more than 70% of the total mobile data traffic in 2020. In addition, there is the demand for mobile video streaming with low latency [1]. On the other hand, the backhaul links between base station (BSs) and the core network are limited, which can cause the congestion when retrieving the required video from servers of the core network. On the other hand, the wireless channels of the radio access network (RAN) are time-varying. To deal with these challenges, Mobile Edge Computing (MEC) is considered as promising technology when it can provides computing and storage resources within RAN [2, 3].

The main idea of MEC is provide cloud-computing capabilities within the RAN in the close proximity to mobile users. This feature gives MEC the benefits of low latency, real time radio network information and location awareness [2, 4].

By deploying the storage resources in close proximity to mobile users, MEC servers could provide the content caching capacity to reduce the reduplicate data traffic of mobile video service. Several works have done in caching policy and cache allocation in mobile network. Most of works focused on the caching strategies at BSs [5, 6]. Since the storage resources at device or BSs are limited, caching at MEC server at the edge of the RAN can significantly improve the number of video files that could cached. When the requested video are cached in the MEC server, the requested video can be served to users with low latency [3, 7].

Motivated by the advantages of MEC, we propose the cache allocation in MEC server among the BSs. In our scheme based on auction theory. In our scheme, the MEC server's owner acts as an auctioneer and BSs acts bidders. BSs will submit bids to the auctioneer for cache amount and valuation. After receiving bids from the bidders, auctioneer will decide the winner determination problem and payment.

The rest of this paper is organized as follows. Section 2 describes the system model. Section 3 presents auction based mechanism design. Section 4 provides the simulation results and Section 5 concludes the paper.

2. System Model

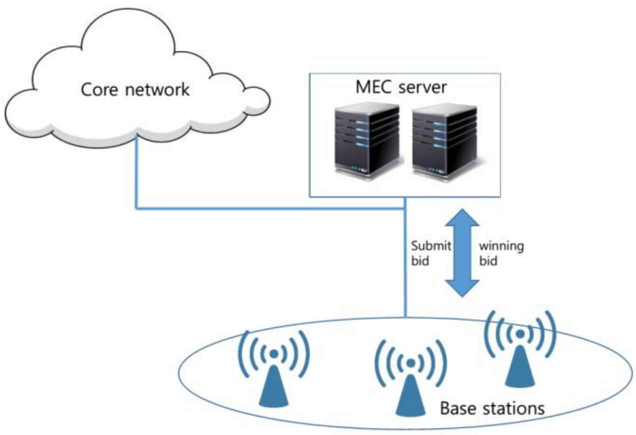

Fig. 1: System model

We consider the video downlink transmission scenario in mobile networks with MEC, which is illustrated as Fig. 1. The MEC server is located in the edge of RAN to provide the low-latency mobile video service. BSs are connected with the core network and the MEC server simultaneously. Compared with core network, MEC server is closer to BSs. The MEC server can either handle a user request and respond directly to the UE or forward the request to the core network. There are N BSs deployed in the network and K users to be served. We assume that each user associates with the closest BS. We also denote the total cache capacity of MEC server is W.

The MEC server's owner acts as an auctioneer who leases its cache storage to a number of BSs (bidders). Each BS $k \in K$ can submit one or more bids to the MEC server's owner. Let B_k denote all the bids submitted by BS $k \in K$. Each bid $(b_{kj}, n_{kj}) \in Bi$ has two elements, b_{kj}, specifies the price that is willing to be paid for the cache storage; n_{kj} represents the cache demand.

3. Auction based mechanism design

Let $X = \{x_{kj} | x_{kj} \in \{0, 1\}, \forall k, j\}$ denote a $K \times J$ binary matrix, describing the bidding result. Here J is the number of bids submitted by BS k.

By employing the XOR-bidding language in , we assume that only one bid can win among all the bids submitted by system $k \in K$, that is

$$\sum_{j=1}^{J} x_{kj} \leq 1, \forall k \in \mathcal{K}. \quad (1)$$

Furthermore, the total cache space demand for all CPs cannot exceed the bandwidth, that is

$$\sum_{k=1}^{K}\sum_{j=1}^{J} n_{kj} x_{kj} \leq W. \quad (2)$$

Then the cache allocation among heterogeneous BSs can be translated into the following optimization problem, with the objective of maximizing the aggregate profit (referred to as 'social welfare' in this paper).

The **Winner Determination Problem (WDP)** is formulated as

$$\max_{x_{kj}} \sum_{k=1}^{K}\sum_{j=1}^{J} b_{kj} x_{kj}$$
$$s.t. (1), (2), x_{kj} = \{0, 1\}$$

Solving the WDP is NP-hard. When the number of BSs and bids increases, the complexity to find the optimal bidding solution will grow exponentially.

Owing to the NP-hard of the WDP, it seems impossible to solve this problem in polynomial time. Following, we present a biding strategy based on greedy algorithm, which is shown in the following steps:

Step 1: every BS will compute the valuation per unit of cache storage, that is $\theta_{kj} = b_{kj} / n_{kj}, \forall k, j$. Here, θ_{kj} represents the valuation per unit of cache storage.

Step 2: Resort all the bids according to the non-decreasing order of their valuation per unit of cache storage. The bid with maximum θ_{kj} wins the bidding.

Step 3: Remove BS k from the bidding. Then go back to Step 2 until either one of the following termination conditions is satisfied:

i) The MEC server has not enough cache capacity to support the demand;

ii) All the BSs won one bid.

The proposed greedy approximation algorithm is described in detailed in Algorithm 2, as shown in the following.

Algorithm 1: The Greedy Algorithm

X $= \{x_{kj}\} = \mathbf{0}$
for $k \in \mathcal{K}, j \in \mathcal{J}$ **do**
    $\theta_{kj} = \frac{b_{kj}}{n_{kj}}$
end
Resort θ in the non-decreasing order,
K=0
n=0
while $(W > K)$ *and* $(n < K)$ **do**
    $[\mu, \nu] = \text{argmax}\theta$;
    $K = K + n_{\mu,\nu}$
    if $W > K$ **then**
        $x_{\mu,\nu} = 1$;
        $n = n + 1$;
        if $x_{\mu,\nu} = 1$ **then**
            for $\forall j$ **do**
                $\theta_{\mu,\nu} = 0$
            end
        end
        Resort θ in the non-decreasing order,
    else
        break
    end
end

Payment

We denote S as the set of winning bids after solving the Winner Determination Problem, θ_{min} is the maximum of the valuation per unit of cache storage of the losing bids.

The payment for winning bids

$$p_{kj} = n_{kj}\theta_{min}$$

4. Numerical Results

In this section, the simulation is conducted to evaluate the proposed trading based spectrum sharing method. The number of BSs is set as 100, in order to show the performance for a relatively large-scaled scenario, the number of bids will vary from 1 to 8. In order to model this random characteristic, both the price b_{kj}, and bandwidth demand n_{kj} are randomly generated between 5 and 10. We run the simulation 300 times.

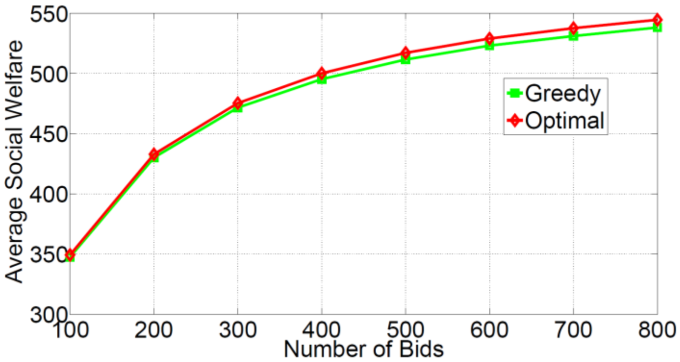

Fig. 2: Performance Valuation

Fig. 2 shows the average social welfare of the proposed greedy scheme and optimal solution. The performance of the proposed algorithm is approxiate to the optimal solution. In addition, the average social welfare increases when the number of bids increases. This is due to there are choices for the MEC server's owner to choose better bids so that it can optimize the social welfare.

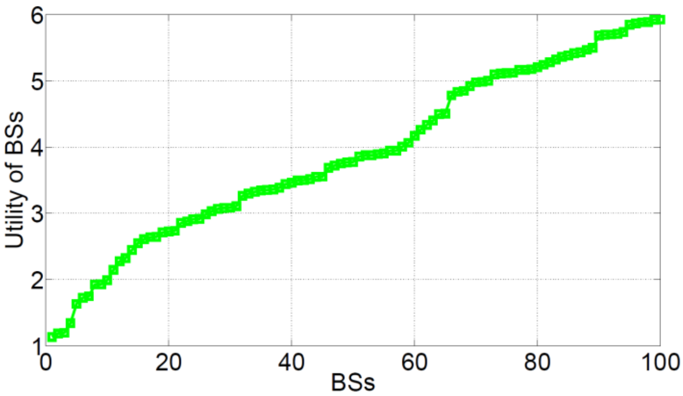

Fig. 3: Utilities of BSs

Fig. 3 shows the utilities of BSs when each BS can submit 2 bids. The utilities of BSs are non-negative. In the other words, the proposed auction scheme can satisfies the individual rational property.

5. Conclusions

In this paper, we have considered the problem of caching allocation among BSs in the MEC system. We propose auction based scheme where BSs are bidders and MEC server's owner is an auctioneer. Numerical results show that our proposed scheme can obtain the approximate solution compared with the optimal solution. In addition, the BSs in this scheme can get non-negative utilities. For future work, we plans to extend to consider multi MEC servers who provide and share cache space among BSs for energy saving.

Acknowledgment

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