# An Auction based Incentive Mechanism in Task Migrating in Vehicular Mobile Edge Computing

Tra Huong Thi Le, Choong Seon Hong
Department of Computer Science & Engineering, Kyung Hee University
huong_tra25@khu.ac.kr, cshong@khu.ac.kr

Abstract

Mobile edge computing (MEC) is an emerging technology to provide the low latency for computation intensive tasks. To solve the problem of reducing the deployment and maintaining the cost of MEC servers, we consider the problem of incentivizing the nearby vehicle in helping the base station to process computational tasks in peak time. The proposed incentive mechanism is based on the auction theory. 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

By migrating intensive computation tasks from user equipment to the physically adjacent edge servers, MEC is a promising technology to deal with the increasing popularity of new low latency high intensive computation required mobile applications. [1, 2]. MEC is considered as key technology to realize next generation wireless network [3].

However, there is a demand to deploy and maintain the large number of MEC servers to cover the large area. In addition, the MEC servers are high cost energy inefficient. As the result, capital expenditure (CAPEX) and operational expenditure (OPEX) for MEC servers increases significantly. Moreover, user demand is time-varying, which result in the wastage of resource during the off-peak time.

On the other hand, there are huge resources from neighboring vehicles which can be utilized. Vehicle in the future which are produced with the aim of improving driving safety, convenience, and satisfaction will be installed with more computation effective on board computers [4-6].

With all problem mentioned above, we propose to incentivize the nearby vehicle to offload the computation tasks in order to alleviate network congestion during the peak time without deploying additional servers. Our scheme based on auction theory. In our scheme, the BS acts as an auctioneer and vehicle act as bidders. Vehicles will submit bids to the auctioneer for computation resource and the cost. After receiving bids from the bidders, auctioneer will decide the winner determination problem and reward.

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

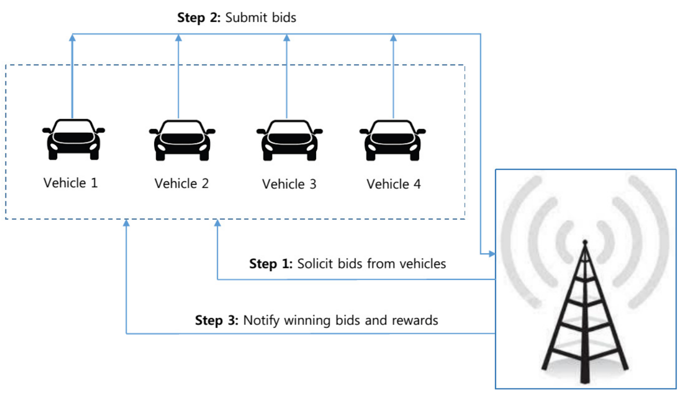


Fig. 1: System model

We consider the vehicular mobile edge computing, which is illustrated as Fig. 1. A base station in each cell can offload the computing application of users in this cell. During the peak time, the base station is congested by the demands of incoming computation. In one cell there are also vehicles with computing offloading ability. The base station can incentivize the nearby vehicle to share their computation resource for task processing.

We assume that the set of vehicles within the coverage of the base station remain fixed within each slot. There are K vehicle in the considering cell. We also denote the total sharing computation resource target set by the BS is W.

The BS solicits sharing bids (including the planned resource sharing and associated cost) from the vehicle. The BS then selects winning bids, decides reward to the winners, and notifies the vehicle of the auction outcome. Each vehicle $k \in K$ can submit one or many bids to the BS. Denote $B_k$ as the set of bids submitted by vehicle $k \in K$. Each bid $(b_{kj}, n_{kj}) \in Bi$ has two elements, $b_{kj}$, specifies the claimed cost due to resource sharing; $n_{kj}$ represents the planned resource sharing.

### 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 auction outcome. Here $J$ is the number of bids that BS $k$ is submitted.

However, in this paper, we apply the XOR-bidding language. In the other words, there is only one bid submitted by vehicle $k \in K$ can win, that is

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

Furthermore, the total resource sharing should be exceed the resource sharing target , that is

$$\sum_{k=1}^{K} \sum_{j=1}^{J} n_{kj} x_{kj} \geq W \tag{2}$$

Then the computation resource sharing incentive problem can be equivalent the following social cost minimization problem as following.

The Winner Determination Problem (WDP) is formulated as

$$\begin{aligned} \min_{x_{kj}} \quad & \sum_{k=1}^{K} \sum_{j=1}^{J} b_{kj} x_{kj} \\ s.t. & \sum_{j=1}^{J} x_{kj} \leq 1. \forall k \in \mathcal{K}, \\ & \sum_{k=1}^{K} \sum_{j=1}^{J} n_{kj} x_{kj} \geq W \\ & x_{kj} = \{0, 1\}. \end{aligned}$$

Solving the WDP is NP-hard. When the number of vehicle 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 as followed:

*Step 1:* Every vehicle will compute the valuation per unit of resource, that is $\theta_{kj} = b_{kj} / n_{kj}, \forall k, j$. Here, $\theta_{kj}$ shows the cost per unit of computation resource.

*Step 2:* Resort all the bids according to the non-increasing order of their cost per unit of resource. The bid with minimum $\theta_{kj}$ wins the bidding.

*Step 3:* Delete vehicle $k$ from the list of bidders. Then go back to Step 2 until satisfying one of the following termination conditions:

i) The BS can achieve its resource sharing target;

ii) All the vehicle already won the auction.

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

**Algorithm 1:** The Greedy Algorithm

$\mathbf{X} = \{x_{kj}\} = \mathbf{0}$
**for** $k \in \mathcal{K}, j \in \mathcal{J}$ **do**
  $\theta_{j,k} = \frac{b_{k,j}}{n_{k,j}}$
**end**
Resort $\theta$ in the non-increasing order
$C = 0$
$n = 0$
$M = \max\theta$
**while** $W > C$ *AND* $n < K$ **do**
  $[\mu, \nu] = \text{argmin}\theta$
  $C = C + n_{\mu,\nu}$
  $x_{\mu,\nu} = 1;$
  $n = n + 1$
  **if** $x_{\mu,\nu} = 1$ **then**
    **for** $\forall j \in \mathcal{J}$ **do**
      $\theta_{\mu,\nu} = M$
    **end**
  **end**
  Resort $\theta$ in the non-increasing order
**end**

### Reward

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

The reward for winning bids

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

### 4. Numerical Results

In this section, the simulation is conducted to evaluate the proposed incentive mechanism. The number of vehicle is set as 100. Moreover, the number of bids submitted by one vehicle varies from 1 to 8. In order to model this random characteristic, both the claim cost $b_{kj}$, and sharing target $n_{kj}$ are randomly generated between 5 and 10.

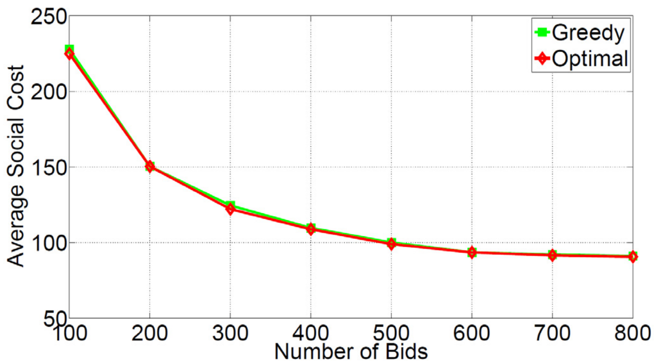


Fig. 2: Performance Valuation

Fig. 2 shows the average social cost 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 cost decreases when the number of bids increases. This is due to there are choices for the BS to choose better bids so that it can optimize the social cost.

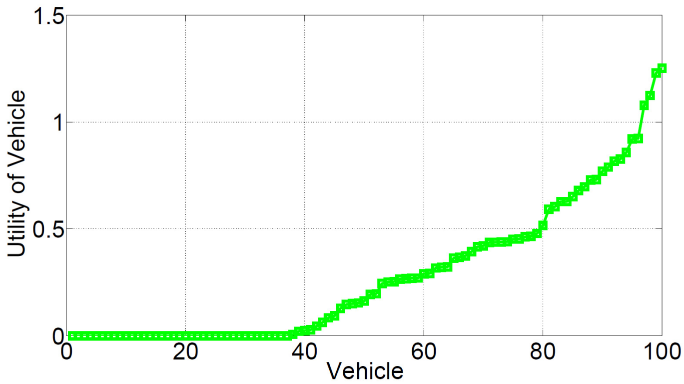


Fig. 3: Utilities of vehicles

Fig. 3 shows the utilities of vehicle. The utilities of vehicle 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 incentivizing the vehicle surround the BS to help the BS offloading the computation tasks in peak time. We propose auction based scheme where vehicle are bidders and the BS is an auctioneer. Numerical results show that our proposed scheme can obtain the approximate solution compared with the optimal solution. In addition, vehicle in this scheme can get non-negative utilities.

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*Dr. CS Hong is the corresponding author

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