# Resource Allocation for Virtualized Wireless Network with Mobile Edge Computing and Spectrum Sharing

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## Abstract

In this paper, we propose a virtualized wireless network architecture, where the resources of a set of Mobile Edge Computing (MEC) servers and unlicensed spectrum-based radio resources are virtualized from a mobile virtual network provider (MVNO) to provide an offloading-service to subscriber users. To reap the full benefits of the MVNO, an optimization problem is formulated, the aim is to minimize the total delay of the tasks while protecting the macrocell base station. The problem is become a combinatorial optimization problem, which is an NP-hard. A matching theory frame with a low-complexity solution is used to solve the above optimization problem. Simulation results show the benefit of the network architecture and formulated frame work.

## 1. Introduction

Recently, mobile edge computing as a promising solution in next generation wireless network, which enables an extension of computation using edge computing capability [1],[4]. By using MEC, we can provide computation services for mobile devices at anytime and anywhere with powerful computing capabilities. Besides, in order to adapt the increasing data traffic in the future, utilization of the licensed spectrum using sharing spectrum technology as a promising solution to allocate resource for small cell base stations [5].

Different from the previous works, in this paper, we propose a business model to provide offloading service that is provide by an MVNO. In this model, the MVNO leases radio resources from macrocell users to provide a communication between SUEs and MECs. Besides, MVNO also consider to lease computation capacity from MEC server providers to offload computation task from SUEs to MEC. By considering the joint subchannel allocation and MEC server selection, we formulate an optimization problem to guarantee benefit of the MVNO deployment. Moreover, in order to solve it, we propose a distributed solution based on matching game with low-complexity.

## 2. System model.

We consider a set of N SUEs (subscriber users) belonging to an MVNO that provides computation offloading services. These SUEs are located inside a small area. In the offloading service, computation tasks of the SUEs are offloaded to M servers that is collocated at M SBSs. To offload data to the servers, the MVNO rents a set of K sub-channels from multiple macrocell providers, to allocate for its subscribers. In this work, denoting by $v_{mkn}$ and $f_{nm}$ as the virtualized resource that are provided by the MVNO to allocate for subscriber users, in which denoting by $v_{mkn}$ as the index of {MEC-server, and subchannel} allocating to SUE n and $f_{nm}$ is CPU cycle of MEC-server allocate to SUE n.

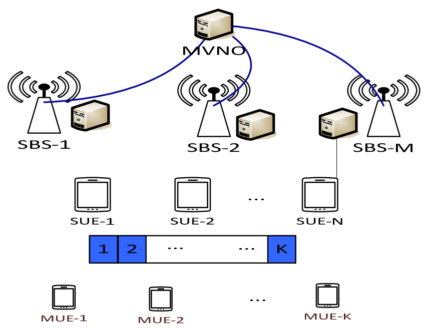


*Figure 1: system model*

## 3. Problem formulation

The problem of maximize network benefit of the MVNO is formulated as follows:

| | |
|---|---|
| OP1: $\theta\sum_{n=1}^{N} D_n^{-1} - \beta\sum_{k=1}^{K}\sum_{n=1}^{N}\sum_{m=1}^{M}\left(c_k * P_{nm}^k * g_{nk} + f_{nm}\right)v_{nm}^k$ | (1) |
| C1: $\sum_{n=1}^{N}\sum_{k=1}^{K} v_{nm}^k \le V_{m,\max}$ | (3) |
| C2: $\sum_{n=1}^{N}\sum_{m=1}^{M} v_{nm}^k \le 1$ | (4) |
| C3: $\sum_{n=1}^{N}\sum_{m=1}^{M} v_{nm}^k \le 1$ | (5) |

where $V_{m,\max}$ is the maximum amount of the computation task executed on the MEC server m at the same time; $P_{nm}^k * g_{nk}$ is the interference power at receiver on subchannel k; $\theta$ and $\beta$ are constant factors; $D_n$ is the profit getting from UEs for executing task following time delay which can be computed as follows:

$$D_n = \frac{c_n}{f_{nm}} + \frac{z_n}{R_n} \quad (6)$$

where $c_n$ denotes the computing ability required for accomplishing the task of SUE n; let $f_{nm}$ be the computation capability of SBS m assigned to SUE n which is fixed for each SUE at each MEC server provider; $z_n$ represents the size of the contents for the computation; $R_n$ is the data rate to transmit data of SUE n as follows:

$$R_n = \sum_{k=1}^{K}\sum_{m=1}^{M} v_{nm}^k B_k \log 2(1+\frac{P_n g_{nm}^k}{P_k g_{km}^k + \delta}) \quad (7)$$

Here, $P_k g_{km}^k$ is interference from macrocell provider on subchannel k; $B_k$ is bandwidth of the subchannel k; $g_{nm}^k$ is channel gain on subchannel k between SUE n and SBS m.

We can see that the OP1 is an NP-hard [3]. To solve this optimization problem, we propose an algorithm based on one-to-many matching game [2].

## 4. Proposed algorithm

We can see that, the OP1 can be formulated as a one-to-many matching game with low complexity. In this game, each SUE n will be matched with each virtual resource $v_{nm}^k$, and vice versa. Then, the solution for the OP1 can be perform as below algorithm (M-VRA):

**Algorithm 1: Distributed virtual resource allocation for SUEs of the MVNO.**

*Stage I: Discovery and utility computation*

1) SUE sends request to MVNO to process its data.
2) MVNO collects channel gain information from all SUEs and determines price for each virtual resource.
3) SUE calculates and sorts its preference list based on (6)

State 2: Swap matching to find a stable matching

1) SUE sends a bit on virtual resource in the first of its preference list.
2) MVNO collects information from user requests and perform a swap matching to maximize (1) and guarantee (3), (4) and (5).

Outputs: $v^*$ and Stable matching $\mu^*$ [2]

## 5. Simulation results

In this section, we present our simulation using Python to evaluate the performance of our proposals. Some parameters are installed as follows: M = 5 MEC servers or SBSs; N = 5 SUEs; K = 10 subchannels; $P_n$ = 100mW; $\sigma^2$ =-105dBm; $B_k$ =180 kHz. The channel gain is assumed to be i.i.d. Rayleigh random variables with mean value $h(d) = h_0(d/15)^{-4}$ where $h_0$ is a reference channel gain at a distance 15 m. Moreover, we set $z_n$ =250 Mb, $c_n$ = n Gigcycles (n=1,2,⋯,N), $f_{nm}$ =m GHz (m=1,2,⋯,5), $c_k$ =k (k=1,2,⋯,10), $\theta$ =$10^3$, $\beta$ =$10^7$. To estimate optimality gap, e find an upper bound by using cvxpy after relaxing $v_{nm}^k$ = [0,1], namely, (UB-VRA). Moreover, we compare with an greedy algorithm, named G-VRA.

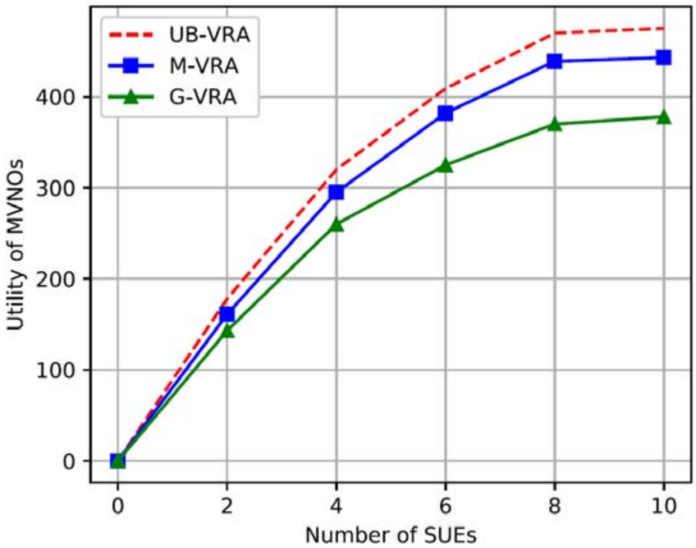


Figure 2. Networks utility following the number of SUEs using offloading service in the MVNO.

In Figure 2, we show results of the proposed algorithm. We see that our proposed closes to upper bound of the OP1 problem. Moreover, our proposed algorithm outperforms the G-VRA algorithm.

## 6. Conclusions

In this paper, we have studied a resource allocation for a MVNO that provides offloading service. We have considered a joint subchannel and MEC server selection for allocating virtual resource to the SUEs of the MVNO. Next, to guarantee the benefit of the MVNO deployment, we have proposed a distributed solution based on one-to-many matching game. Simulation results show that our solution can obtain a small optimality gap with low-complexity while outperforming the greedy algorithm.

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