# Dynamic Resource Allocation in Wireless Network Virtualization

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## Abstract

The proliferation of cellular devices and novel application in the current cellular networks possess a significant challenge for efficient resource allocation in upcoming fifth generation (5G) networks. Wireless network virtualization (WNV) is identified as a key enabling technology that can satisfy the requirements of efficient resource allocation to fulfill the demands of 5G networks. In this paper, we consider a practical deployment of a WNV that involves a multi-cell scenario where the coverage area of a specific region will be serviced by a set of infrastructure providers (InPs). We propose an efficient resource allocation scheme based on many to many matching game that can achieve an efficient solution. Simulation results reveal the performance improvement of our proposal in terms of average rate and we provide comparison with the currently deployed fixed sharing scheme where there is no wireless network virtualization.

## I. Introduction

The growth of modern network devices and applications over the current network has congested the network due to the limited network resources and high demands which cannot be fulfilled using the existing cellular networks. One key technology that can support this deluge of cellular traffic is wireless network virtualization (WNV). It is identified as one of the key enabling technologies to bring fifth generation networks into fruition [1]. In WNV, infrastructure providers (InPs) sell their resources (physical) to the mobile virtual network operators (MVNOs). Then, these resources are utilized by the MVNOs to serve its associated users. An InP abstracts the physical resources (i.e., spectrum, power, and antennas) into isolated virtual resources (i.e., slices) which are then sold and shared between different MVNOs.

Efficient resource allocation (slices) to MVNO users have received significant attention in a single-cell WNV scenario and a number of efficient solutions have been presented to address this problem [1]. However, in a practical deployment of WNV, an MVNO may buy resources from multiple InPs, i.e., the coverage area of a specific region will be serviced by a set of InPs rather than a single InP [2]. In such a scenario, the traditional approaches based on single-cell scenario do not directly apply for a realistic or practical scenario. Thus, in a practical setting, the goal is to achieve an efficient allocation of the resources such that the total performance of WNV over a specific region is improved.

In this work, we aim is to maximize the utility for the complete network by assigning the resources in an efficient manner. We consider a user are pre-associated to MVNOs. Furthermore, we suppose slowly changing transmit power (fixed power) from all the InP-BSs during a timeslot. This proposed problem is a combinatorial and NP-hard. To solve this problem, we develop a novel efficient allocation algorithm based on the concept of many to many matching game.

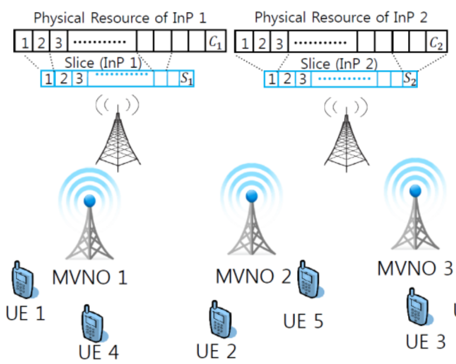


*Fig.1. System model*

The rest of the paper is organized as follows: Section II presents the network model, problem formulation and the proposed allocation scheme using matching theory. In Section III, numerical results are presented. Finally, we conclude in section IV.

## II. System model and Optimization Problem

We consider a downlink network that consists of $N$ BSs, and each BS is owned by an InP. Each InP owns a set of $C$ orthogonal channels. Moreover, it sells its resources (i.e., channels) to a set of $M$ MVNOs in the form of a slice based on individual contracts with each

MVNO as illustrated in Fig. 1. Note that, here, we assume that each MVNO *m* have a set of pre-associated users who require resources from different InPs.

We consider a system with static inter-InP interference such that the interference from other InPs is absorbed into the background noise. Moreover, equal power on every channel of an InP *n* is assumed and an InP *n* provides isolated services by a set of *S* slices which constitutes different number of channels based on MVNOs demand. Then the achievable rate of an MVNO *m* for a slice *s* acquired by InP *n* is given as:

$$R^{s}_{n,m} = W\log(1+SINR^{s}_{nm}) \quad (1)$$

Where *W* is the bandwidth available and $SINR^{s}_{nm}$ is the received SINR on slice *s* for MVNO *m* on InP *n*. Let $y^{s}_{m,n}$ be the binary variable to represent the slice *s* is allocated to MVNO *m*. Then the optimization problem can be written as:

$$\begin{aligned} &\max_{y^{s}_{m,n}\in\{0,1\}} \sum_{m\in M}\sum_{s\in S_n} y^{s}_{m,n}(R^{s}_{n,m}+\omega\beta^{I}_{n}\,|\,s\,|) \\ &\text{s.t.} \sum_{m\in M}\sum_{s\in S_n} y^{s}_{m,n} \le |\,S\,|, \\ &\sum_{s\in S_n} y^{s}_{m,n}R^{s}_{n,m} \ge d_m, \forall m \end{aligned} \quad (2)$$

The objective function represents the network sum rate and InP revenue in the first and second term, respectively. Here, $\omega$ represent the weight that balances between the sum rate and revenue achieved by an InP whereas $\beta^{I}_{n}$ is the cost per slice that InP *n* charges to MVNOs. The first constraint ensure that allocated slices are less than total slices owned by an InP *n* while the second constraint ensures the contract agreement between the MVNO *m* and InP *n* to provide the minimum rate ,i.e., $d_m$. This is also considered as an isolation constraint in WNV. Isolation is the fundamental requirements of WNV through which different MVNOs achieve a guarantee predetermined requirement or contract service agreement (e.g., minimum share of resource or data rate) by the InP [1].

This problem is known as a combinatorial problem and thus falls in the NP hard category which can have suboptimal solution [3]. In order to solve this combinatorial problem we use the concept of matching theory which can solve this problem in distributed manner. In order to solve the above problem, we develop a matching game that consists of two set of players, i.e., InPs and MVNOs. In matching games, both set of players make a preference profile to rank each other [3], [4].

The preference profile in case of the MVNO is based on cost per slice. An MVNO prefers an InP which provides the cheapest price and ranks them according to their offered cost that is given by the following equation:

$$U_m(n) = \beta^{I}_{n} \quad (3)$$

Then the second side, i.e., the InP considers both the achievable rate and its revenue as its preference function to rank all MVNOs that is given as:

$$\mathrm{U_n(m)} = R^{s}_{n,m} + \omega\beta^{I}_{n}\,|\,s\,| \quad (4)$$

In our matching game, an MVNO can buy resources from multiple InPs and similarly each InP can sells its resources to multiple MVNOs. Then our design corresponds to a many to many matching game. Inspired by the traditional Gale-Shapley algorithm, we propose the modified, and low-complexity algorithm. The key idea is that each MVNO *m* proposes to an InP *n* based on its preference profile, where the InP *n* accepts and rejects the MVNO *m* based on its preference profile ranks and quota |*S*| which is given in constraint 1 of problem (2) [3] [4]. Then all rejected MVNOs propose to the next preferred InP based on their respective preference profiles. This process is carried out until there are no more InPs to propose or no MVNO is willing to make new proposals [4].

## III. Numerical Results

We consider a network with 5 MVNOs that rent slices from *N* InP-BSs inside the coverage area of 1000 m. Each InP owns a band of 5 MHz (i.e., 25 resource blocks (RBs)). In our simulation, each MVNO *m* has a demand which is uniformly distributed in the range of $d_m$={5-10} bps/hz and is generated by the number of users associated to it. We set the prices for each InP that is also uniformly distributed in the range of $\beta^{I}_{n} = \{3-6\}$ monetary units/bps/hz, Furthermore, all results are obtained by averaging over a large number of independent simulation runs, each of which realizes random traffic demands, pricing, locations of InP-BSs, and channel power gains. For comparison purposes, we compare the proposed algorithm with a fixed sharing scheme, where each MVNO reserves equal number of the channels. This fixed sharing scheme can be considered the case of traditional multi-cell environment in which there is no wireless virtualization [2]. Fig.2 presents the average sum-rate versus the network size, (i.e., number of UEs in the network) for the proposed matching game and fixed sharing scheme. Note that, here, we increase the number of users staring from two per MVNO to six per MVNO (i.e., 10 to 30 users in network). It is observed that the sum-rate increases with network size, which, however, saturates as the network size becomes sufficiently large. Moreover, we achieve a performance benefit of 48% in terms of average sum-rate when compared to the fixed sharing scheme for a network size of 25 and above.

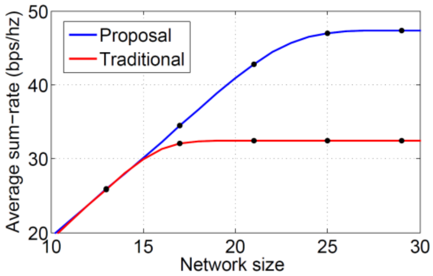


*Figure. 2 Average sum-rate.*

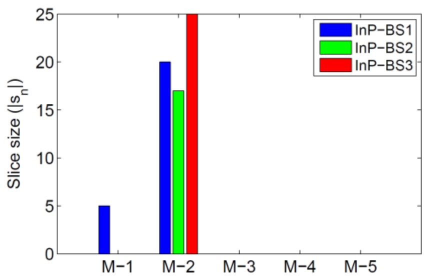


*Figure. 3 Slice size for bandwidth 5 MHz.*

Fig.3 presents the slice size provided to each MVNO by all InP-BSs with system bandwidth 5 MHz and network size of 30 UEs. It can be seen that MVNO 2 is allocated the complete bandwidth (i.e., 25 RBs) of InP-BS 3 as a slice, 80 % bandwidth from InP-BS 2 and 68 % from InP-BS 1 as a slice. This is based on its demand for each InP-BS from MVNO 2. Similarly only MVNO 1 has received the remaining 20% bandwidth of InP-BS 1 as a slice. Note that, both InP-BS 1 and 3 have allocated all its channels to MVNOs' whereas InP-BS 2 still have additional channels. This is due to the fact that under this scenario, no MVNO has further demand from InP-BS 2. Then, we rerun the simulation (considering the same simulation setup) by increasing the network bandwidth to 10 MHz (50 RBs). The results as shown in Fig. 4. Here, we observe that MVNO 2 is allocated a larger slice (additional bandwidth) from InP-BS 3 while the slice size from other InP-BS remains the same. Note here that as the slice size from other InP-BS remains the same in both scenarios, there exist no more demands from this MVNO towards these InPs. Moreover, MVNO 1 is also allocated additional bandwidth (larger slice) from InP-BS1 and InP-BS3. Similarly MVNO 3 is also receives a share of bandwidth (slice) from InP-BS 3. However, other MVNOs are not allocated any slice. From this, we can infer that the size of allocated slice depends upon the MVNOs' demands and preference of InP-BS. For instance, in this simulation scenario, three MVNOs (MVNO 1, MVNO 2 and MVNO 3) required a slice from InP-BS 3. However, InP-BS 3 first served MVNO 2, then MVNO 1, and finally MVNO 3 following its preference profile.

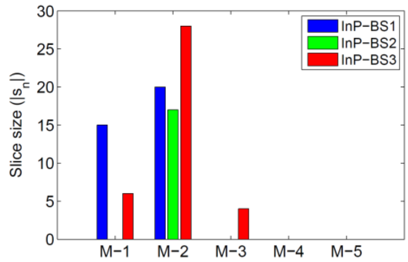


*Figure. 4 Slice size for bandwidth 10 MHz.*

## IV. Conclusions

Enabling wireless network virtualization can enhance the resource usability of the current cellular architecture which leads to a higher network sum-rate. We in this work, propose a resource allocation problem for WNV considering multiple InP-BSs setting with isolation constraint that is solved using matching theory. Our proposal will allow network to maximize the average sum rate and enhance resource reusability for the network. Simulation results reveal the convergence in terms of average sum-rate and dynamic slicing based on MVNO's demand. In future, we intend to include dynamic pricing for different InP-BSs and would study its effect on the resource allocation.

## Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea Government (MSIP) (NRF-2017R1A2A2A05000995). *Dr. CS Hong is the corresponding author.

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