Resource Allocation in Wireless Virtualization Network with Non-orthogonal Multiple Access

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Abstract

In this paper, we study the problem of user clustering and resource allocation for wireless network virtualization (WNV) using non-orthogonal multiple access (NOMA). In this set-up, the resources (i.e., spectrum and power) of one base station (BS) are shared among multiple mobile virtual network operators (MVNOs), where the minimum reserved rate is considered for MVNOs' users for guaranteeing their isolation. We propose an optimization problem of the resource allocation to maximize the weighted total sum-rate while taking into account the isolation constraint of the MVNOs' users. The algorithm is based on the Lagrange dual approach and converges to an optimal solution in a limited iterations.

I. Introduction

Network virtualization is one of the main evolution trends in the forthcoming fifth generation (5G) cellular networks and are expected to provide higher data rates, lower end-to-end latency, improve spectrum/energy efficiency, and reduce costs [1]-[3]. The main idea of wireless network virtualization (WNV) is to enable resource sharing and to decouple the infrastructure from the service it provides. In this case, the roles of infrastructure providers (InPs) and mobile virtual network operators (MVNOs) can be logically separated and the physical resources (e.g., spectrum, base station (BS)) owned by an InP can be transparently shared by multiple MVNOs, while each MVNO virtually owns the entire BS and radio spectrum. Network virtualization involves abstraction and sharing of resources among different parties. However, due to the explosive growth of data traffic in mobile Internet and the dramatical increase of mobile devices, there are increasing demands for high spectrum efficiency and massive connectivity in 5G wireless communications. The abstraction and sharing of resource in WNV would not be effective due to the limitation of resource. Non-orthogonal multiple access (NOMA) has recently been considered as a key enabling technique for 5G cellular systems which help WNV significantly exploit the spectrum sharing for guaranteeing isolation among multiple MVNOs. In NOMA, by exploiting the channel gain differences, multiple users are multiplexed into transmission power domain and then non-orthogonally scheduled for transmission on the same spectrum resources.

In this paper, we consider the problem of resource allocation in LTE network with non-orthogonal multiple access (NOMA). We formulate a resource allocation problem in which the users of MVNOs will be grouped into a number of groups and each group will be allocated a number of LTE resource blocks. The proposed algorithm is based on the

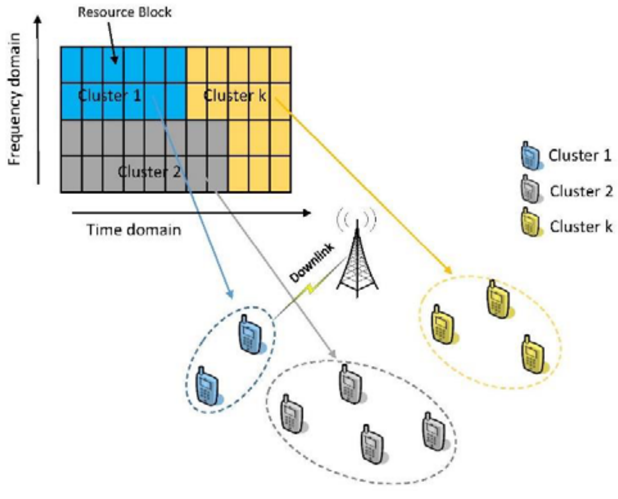

Figure 1: System model

Lagrange dual approach and it can converge to an optimal solution within a limited iteration.

II. System model

We consider the downlink of a single cell consisting single macro base station (BS). The MBS and spectrum are owned and managed by a single infrastructure provider (InP) who provides its virtual network service to a set of mobile virtual network operators (MVNOs) $\mathcal{M}$ by individual contracts. An MVNO $m \in \mathcal{M}$ provides its service to a set of subscribed users $\mathcal{U}_m$. Let $\mathcal{U} \triangleq \cup_{m=1}^{|\mathcal{M}|} \mathcal{U}_m$ denote the set of all users.

The InP owns a system bandwidth $\mathcal{C}$ which is divided into frequency resource blocks (RBs), each of bandwidth B. That is, the total number of RBs are given as $\Omega = \mathcal{C} / B.$ Users who are non-orthogonally scheduled over the same set of RBs form a NOMA cluster. However, each NOMA cluster operates on a set of RBs which is orthogonal to other sets of RBs belong to other clusters. The number of users per NOMA cluster ranges between 2 and $|\mathcal{U}|$. Also, the number of RBs allocated per cluster is represented by δ^k where $1 \le \delta^k \le \Omega$. Let $\mathcal{S}$ be the set of clusters and $\mathcal{S}_k$ be the set of active users grouped into cluster k th. The receiver of UE $j_n \in \mathcal{S}_k$ can cancell the interference from any other UE $i_m \in \mathcal{S}_k$ with channel gain $|h_{i_m}|^2 / z_{i_m} < |h_{j_n}|^2 / z_{j_n}$. The achievable throughput for UE j_n in downlink NOMA cluster k th can be expressed as

$$R^k_{j_n} = \delta^k B \log_2\left(1 + \frac{P_{j_n} |h_{j_n}|^2}{I^k_{j_n} + \delta^k B z_{j_n}}\right), \qquad (1)$$

where $I^k_{j_n}$ is the interference that UE $j_{\in \mathcal{U}_n}$ receives from other UEs in cluster k th.

$$I^k_{j_n} = \sum\nolimits_{i_m \in \left\{\mathcal{S}_k \mid \frac{|h_{i_m}|^2}{z_{i_m}} > \frac{|h_{j_n}|^2}{z_{j_n}}\right\}} P_{i_m} |h_{j_n}|^2 . \qquad (2)$$

We now define a user clustering (grouping) variable $\beta^k_{j_n} = 1$ if UE is j_n grouped into cluster k, and 0 otherwise. The isolation constraint for UE j th of MVNO n th is given as follows

$$\sum_{k \in \mathcal{S}} \beta^k_{j_n} \delta^k B \log_2\left(1 + \frac{P_{j_n} |h_{j_n}|^2}{I^k_{j_n} + \delta^k B z_{j_n}}\right) \ge R^{\min}_n, \forall j \in \mathcal{U}_n$$

(3)

III. Problem Formulation and Algorithm

$$\max_{\boldsymbol{\delta}} \sum_{n \in \mathcal{M}} \sum_{j \in \mathcal{U}_n} \omega_{j_n} \sum_{k \in \mathcal{S}} \beta^k_{j_n} \delta^k B \log_2\left(1 + \frac{P_{j_n} |h_{j_n}|^2}{I^k_{j_n} + \delta^k B z_{j_n}}\right)$$

$$\text{s.t.: } C_1 : \sum_{k \in \mathcal{S}} \beta^k_{j_n} \delta^k B \log_2\left(1 + \frac{P_{j_n} |h_{j_n}|^2}{I^k_{j_n} + \delta^k B z_{j_n}}\right) \ge R^{\min}_n, \forall j,$$

$$C_2 : \sum_{k \in \mathcal{S}} \delta^k \le \Omega, \qquad (4)$$

$$C_3 : \delta^k \in \{1, 2, ..., \Omega\}, \forall k.$$

The objective function of problem (4) is concave for positive δ^k. Then the optimal RBs allocated for each cluster k satisfies

$$\frac{\partial L(\delta^k, \lambda_{j_n})}{\partial \delta^k} = \sum_{j_n \in \mathcal{S}_k} \Big\{ (\omega_{j_n} + \lambda_{j_n}) B \log_2\left(1 + \frac{P_{j_n} |h_{j_n}|^2}{I^k_{j_n} + \delta^{k*} B z_{j_n}}\right)$$

$$- \frac{(\omega_{j_n} + \lambda_{j_n}) \delta^{k*} P_{j_n} |h_{j_n}|^2 B^2 z_{j_n}}{(I^k_{j_n} + P_{j_n} |h_{j_n}|^2 + \delta^{k*} B z_{j_n})(I^k_{j_n} + \delta^{k*} B z_{j_n})} \Big\} = 0$$

(5)

where $L(\delta^k, \lambda_{j_n})$ is the Lagrangian and λ_{j_n} is the multiplier correspond to the constraints C_1. To optimally solve (4) with zero gaps for δ^*, we use dual based approach as shown in Alg. 1

Algorithm 1: Resource Algorithm:

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1. Update number of resource blocks $\delta^k[t+1]$ by using Lagrange dual method.
2. Normalize:
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$$\delta^k[t+1] \leftarrow \min\left\{\delta^k[t+1], \frac{\delta^k[t+1]\Omega}{\sum_{s\in\mathcal{S}}\delta^s[t+1]}\right\}, \qquad (6)$$

IV. Numerical Results.

The network scenario in our numerical simulation is shown in Fig. 2, where MVNOs' subscribed users are randomly deployed inside 3 macro cell of radius 500m which belong to the InP. We consider three MVNOs with 10 subscribed users for each MVNO. We assume number of available LTE resource blocks is 100 each of which has a total bandwidth of 180 KHz. We set the $P = 40W$. The noise power is assumed to be 10^{-13} W for all subchannel. Channel gains are set as $g_{n,j} = \chi\, d_{n,j}^{-\beta}$, where χ s a random value generated according to the Rayleigh distribution, $d_{n,j}$ is the geographical distance between BS n and user j of $\beta = 3$ is the pathloss exponent.

It can be seen that the Alg. 1 converges very fast to the optimal value.

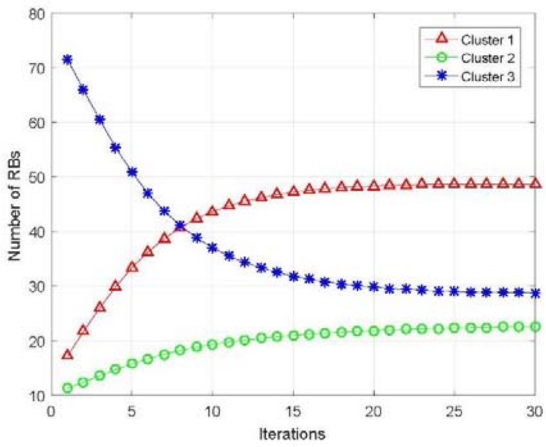

Figure 2: Network Throughput.

V. Conclusions

We have developed a Lagrange dual based algorithm to optimally solve the problem of resource allocation in LTE wireless virtualization with non-orthogonal multiple access. Our proposed algorithm aims to allocate number of LTE resource blocks to each group of users in which every users share the same that number of resource blocks. Numerical results show that our proposed algorithm converges quickly to an optimal solution.

Acknowledgement

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