A Heuristic User Association Algorithm for Cross Infrastructure Wireless Network Virtualization

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Abstract

Wireless network virtualization allows multiple wireless virtual networks of mobile virtual network operators share the same wireless physical networks. In this paper, cross infrastructure wireless network virtualization is considered where user of particular mobile network operator could access one base station among the base stations purchased by that mobile virtual network operator to get the maximum data rate. To solve the isolation problem, fraction of resources purchased by mobile virtual network operator is defined. First, user association problem is formulated to maximize the revenue of mobile virtual network operator which also maximize the data rate of users. A heuristic user association algorithm is proposed to solve this problem. Then, simulation is performed to show that the algorithm maximize the revenue of mobile virtual network operators.

1. Introduction

Wireless network virtualization permits multiple mobile virtual network operators (MVNO) to share the same infrastructure and spectrum. So, the capital expenses and operational expenses of both infrastructure provider (InP) and MVNO can be reduced significantly. Wireless network virtualization can be regarded as dividing the entire system.[1] Therefore, isolation among users or MVNOs is the one of the challenges of wireless network virtualization.

In this paper, cross infrastructure wireless network virtualization is considered. One of the advantages of cross infrastructure virtualization is that user can access to the base station among others which gives the maximum data rate as long as user is in the area of that base station and user's MVNO purchased the resources from that base station. The drawback is that centralized controller is needed to make decisions and that neighbor base stations should have the same frequency.

Cheongchao Laing et al., [2] formulated the resource allocation problem and solved it by alternating direction method of multipliers (ADMM). But, they considered the problem in single cell. In [3], multi-cell scenario is taken into account but cooperation between InPs and isolation between MVNO are missing. Hao Zhou et al., [4] took the ABS adaptation to wireless virtualization. They proposed a dynamic programming based algorithm and ADMM for joint spectrum sharing and ABS adaptation problem.

In this paper, user association in cross infrastructure virtualization is considered. If the user is in the overlapping area of multiple base stations, he can access to the base station which give him maximum data rate as long as that base station is purchased by his MVNO. For this problem, centralized controller is required. Problem is formulated as optimization problem and a heuristic user association algorithm is proposed to solve this problem.

2. System Model

Fig. 1 is the example of physical model and Fig. 2 shows the virtualization model of this physical model. In Fig. 2, one base station is shared by two MVNOs. So, base station is virtualized into two base stations and each base station serves different MVNO. Here, we assume that each base station is owned by different InP. MVNO purchased resources from multiple InPs.

Since the area of base stations are overlapped, cell edge user of one base station might be the cell center of other base station. If no cooperation is allowed, user will get low data rate because he is at cell edge. But, if cooperation is allowed, he can connect to other base station and can have higher data rate. In terms of backhaul, if one base station is overloaded, some users of that base station can access to other base station.

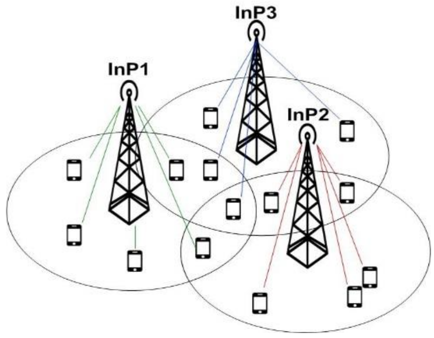

Fig. 1. Physical Model

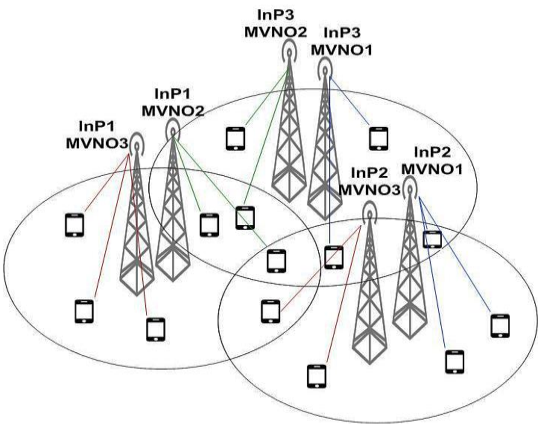

Fig. 2. Virtualization Model

3. Problem Formulation

The objective is to maximize the revenue of MVNO while maximizing the data rate of users.

$$b_{i_k,j} = \log_2(1 + \frac{g_{i_k,j}P_j}{\sum_{l,l\neq j} g_{i_k,l}P_l + n}) \quad (1)$$

$$R_{i_k,j} = \max_{N_{i_k}}\{x_{i_k,j}W_j b_{i_k,j}\} \quad (2)$$

$$\max \sum_{i\in I}\sum_{j\in J}\sum_{k\in K}\beta_k R_{i_k,j} - \mu_j R_{i_k,j} \quad (3)$$

s.t.

$$\sum_{i\in I} x_{i_k,j} \leq 1 \quad \forall i \quad (4)$$

$$\sum_{j\in J} R_{i_k,j} \geq \gamma_i \quad \forall i \quad (5)$$

$$\sum_{i\in I}\sum_{k\in K} R_{i_k,j} \leq B_j \quad \forall j \quad (6)$$

$$\sum_{i\in I} R_{i_k,j} \leq \alpha_{k,j}B_j \quad \forall k\ \forall j \quad (7)$$

$$x_{i_k,j} = \{0,1\} \quad (8)$$

First constraint ensures that one user can assign to only one base station. Second constraint is to make sure user satisfies his QoS requirement and third one is the backhaul constraint of base station. Fourth constraint is to check users of particular MVNO cannot use more data rate than the purchased data rate by MVNO. And, $x_{i_k,j}$ is the association variable.

Symbol	Meaning
i	Index of user
j	Index of base station
k	Index of MVNO
$x_{i_k,j}$	User i of MVNO k associated to BS j
$N_{i_k,j}$	Neighbor BSs set of user i of MVNO k
$R_{i_k,j}$	Received data rate of user i from BS j
$\alpha_{k,j}$	Fraction of purchased resource of MVNO k from BS j
μ_j	Buying price of MVNO from BS j
β_k	Selling price of MVNO k to users
γ_i	Minimum rate requirement of user i
B_j	Backhaul capacity of BS j
W_j	Bandwidth of BS j
$g_{i_k,j}$	Channel gain between user i and BS j
P_j	Transmit power of BS j
n	Additive white Gaussian noise

Table. 1. Table of Notations

4. Heuristic User Association Algorithm

In this section, a heuristic user association algorithm is proposed.

Heuristic User Association Algorithm

```
Input : γ_i for all i and α_k for all k
Output : Data rate r_{i_k,j} for all user i
Initialize x_{i_k,j} and r_{i_k,j} with 0 for all i,j
for all users i do
  Initialize temp |J|-vector with 0
  if N_{i_k} is not empty then
    for all base stations j in N_{i_k} do
      calculate R_{i_k,j}
      if x_{i_k,j} == 0 and R_{i_k,j} ≥ γ_i and
      Σ_{i∈I} Σ_{k∈K} R_{i_k,j} ≤ B_j and Σ_{i∈I} R_{i_k,j} ≤ α_{k,j}B_j
        temp_j ← R_{i_k,j}
      end if
    end for
  end if
  if temp is not empty then
    m ← the index of maximum data rate in temp
    x_{i_k,m} ← 1
    r_{i_k,m} ← maximum data rate
  end if
end for
```

First, we check the neighbor base stations set of user. Neighbor base station could be one or many base stations. If it is not empty, we iteratively calculate the data rate for a particular user from all base stations in the set and check the constraints individually. If calculation is done for all base stations in neighbor set, we find one base station giving the maximum data rate among other base stations. Then, user is assigned to that base station.

5. Evaluation

In evaluation, three base stations and 30 users are considered. Each base station has total transmit power of 46 dBm, bandwidth of 10 MHz and backhaul capacity of 100 Mbps. The radius of each base station is 1 km with some overlapping area of other base stations The power density of thermal noise power is −174dBm/Hz. We use the long distance path loss model which is $PL = 40\log_{10}(d_0) - 10\log_{10}(Gh_t^2 h_r^2) + 10\gamma\log_{10}\frac{d}{d_0} + X_g$ where d_0 and d are critical distances, h_t and h_r are heights of transmitter and receiver, G is the product of transmitter's gain and receiver's gain and X_g is the random variable with normal distribution. The buying price and selling price of MVNO are the uniform distribution of 8 to 10 and 20 to 25units per Mbps respectively. And, minimum data rate requirement of users also follows uniform distribution which is between 0.5 and 1 Mbps.

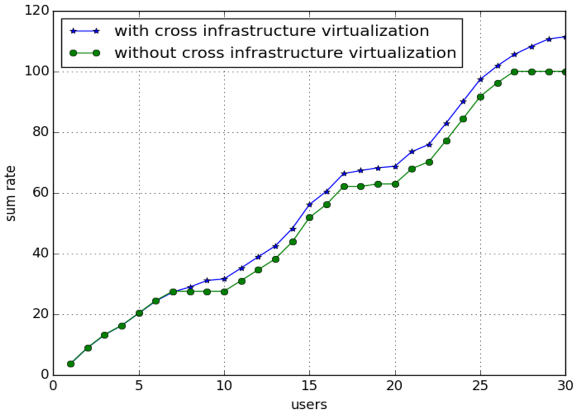

Fig.3 Sum Rate of users

Fig 3 and 4 show the sum rate of users and revenue of MVNO respectively when cross infrastructure virtualization is used and not used. The results are different in a few numbers because fixed pricing is used in this paper and base stations are not heavily loaded. To use the variable pricing and make the user association decision dynamically is the future work.

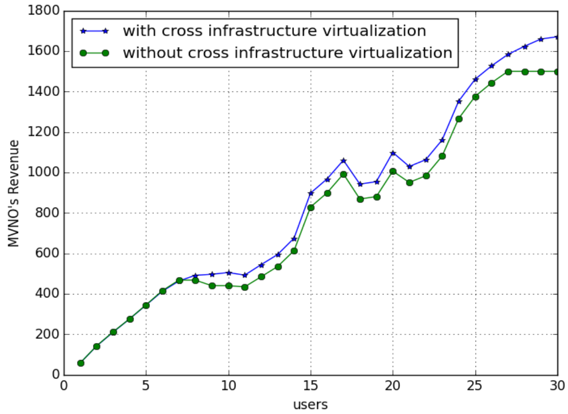

Fig. 4 Revenue of MVNO

6. Conclusion

In this paper, heuristic algorithm is proposed to solve the user association in cross infrastructure wireless network virtualization. Centralized decision maker is needed to perform the association decisions. Simulation results show that user can receive more data rate with virtualization than without virtualization. In future, variable pricing and solving the optimization problem efficiently will be considered.

Acknowledgement

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References

[1] Chengchao Liang, F. Richard Yu, "Wireless Network Virtualization: A Survey, Some Research Issue and Challenges", IEEE Communications Surveys and Tutorials, Volume 17, Issue 1, March 2015, pp. 358-380

[2] Chengchao Liang, F. Richard Yu, "Distributed resource allocation in virtualized wireless cellular networks based on ADMM", 2015 IEEE Conference on Computer Communications Workshops, May 1 2015, pp. 360-365

[3] Mahmoud I. Kamel, Long Bao Le, André Girard, "LTE Multi-cell Dynamic Resource Allocation for Wireless Network Virtualization", 2015 IEEE Wireless Communications and Networking Conference, March 2 2015, pp. 966-971

[4] Hao Zhou, Yusheng Ji, Xiaoyan Wang, Shigeki Yamada, "Joint Spectrum Sharing and ABS Adaptation for Network Virtualization in Heterogeneous Cellular Networks", 2015 IEEE Global Communication Conference, Dec 10 2015, pp. 1-6