Spectrum Sharing in Cross-Infrastructure Virtualization using Convex Optimization

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Abstract

Wireless network virtualization enables multiple virtual networks running on a physical network simultaneously by allowing to share wireless substrate resources. The objective of this paper is to efficiently allocate the spectrum resources to multiple virtual networks. In this paper, one virtual network can share the spectrum resources from one or more physical networks as long as the virtual network is in the range of those physical networks in order to increase spectrum utilization. First, the problem is formulated as a convex problem and solve it by using convex optimization solver. Then, simulation is performed to show the revenue of the system in terms of virtual networks.

1. Introduction

In wireless network virtualization, an infrastructure provider (InP) can slice its physical resources into slices so that service providers (SP) can use these slices to serve their subscribers [1]. In fact, wireless network virtualization can have a wide range spanning from spectrum sharing, infrastructure virtualization, to air interface virtualization. In order to share physical resources efficiently to different service providers, the physical wireless infrastructure and radio resources need to be abstracted and isolated to a number of virtual resources [2].

Xin Wang et al., [3] proposed three paradigms for wireless network virtualization taking the idea of InPs and SPs, namely: (1) universal, (2) cross-infrastructure and (3) limited intra-infrastructure. These three paradigms are different in terms of which level can the network virtualization be done. Universal virtualization is a grand view of wireless virtualization which is more similar to cloud like virtualization. In cross-infrastructure, virtualization is performed across InPs and within InPs. For limited infrastructure, virtualization is possible only within a single InP. In this paper, spectrum sharing is considered in cross-infrastructure environment.

The difference between the previous works and the proposed system is that most of the previous works only take the virtualization on a single physical network. In the paper proposed by Mao Yang et al., even though the authors consider the multiple physical networks for spectrum sharing, one virtual network can share spectrum from only one physical network at a time. No virtual network can allocate the spectrum from multiple physical networks simultaneously [4].

In this paper, the idea is that the virtual network can share the spectrum resources from multiple physical networks at the same time if the virtual network is in the area of those physical networks. This allows the resource allocation more effective. For instance, in limited infrastructure, when one virtual network arrives and there is no enough spectrum for it, it has to wait. But, for cross-infrastructure, it can share spectrum from more than one physical network and that makes the spectrum sharing more efficient.

2. System Model

In Fig. 1, there are three base stations and seven users in the area of these base stations. Assume that each base station is owned by different InPs and InPs want to sell their spectrum resources to SPs because SPs do not own any physical spectrum resources. SPs want to serve their users in these areas by buying spectrum resources from InPs.

In terms of virtualization, SP can provide one VN which is as a collection of spectrum resources from InPs for their users. Here, one PN is as the total physical spectrum resource of one particular InP.

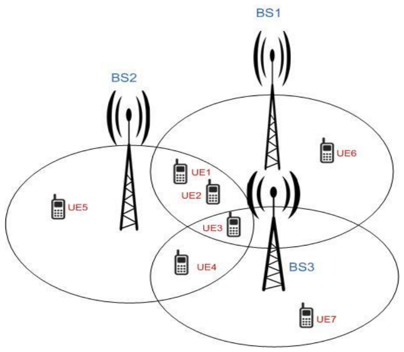

Fig. 1. Cross-Infrastructure Virtualization

For user 1,2 and 3, they are in the range of BS1 and 2 so that they can share the spectrum from both BS 1 and 2. As shown in Fig 2, VN1 can share the spectrum resources from PN1 and PN2 which are the spectrum resources of BS1 and 2 respectively. So, the SP can serve the user 1,2 and 3 with VN1. It is the same for other users.

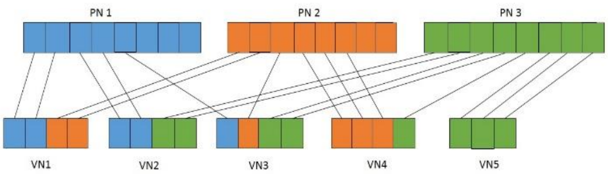

Fig. 2 Spectrum Sharing in Cross-Infrastructure Virtualization

3. Problem Formulation

Physical network (PN) is indexed by j and virtual network (VN) is indexed by i. A concave pricing strategy is used to charge the VN which is proposed in [4].

$$p = a\log(1 + x_{i,j}) \qquad (1)$$

where a is a constant and $x_{i,j}$ denotes whether VN i shares the spectrum from PN j and how much spectrum it shares or not. Then, the problem is formulated as an optimization model as follows. The objective is to maximize the revenue of the system.

$$\max \sum_{i=1}^{n_v}\sum_{j=1}^{n_p} p \qquad (2)$$

s.t.

$$\sum_{i=1}^{n_v} x_{i,j} \le c_j \qquad (3)$$

$$\sum_{j=1}^{o_p} x_{i,j} = d_i \qquad (4)$$

$$0 \le x_{i,j} \le d_i \qquad (5)$$

where n_v is the number of VNs, n_p is the number of PNs, o_p is the number of PNs in the area in which user can share spectrum simultaneously. For example, in Fig.1, UE 3 can use the spectrum resources from BS 1,2 and 3 simultaneously. In this case, o_p is 3. Moreover, For UE 5, he can use the resources from only BS 2 so o_p is 1 $x_{i,j}$ is the number of spectrum resources allocated to j BSs by i user so it can be between 0 and the user's demand First constraint is capacity constraint for PN. Second is the user demand constraint. The above problem is the convex problem and it can be solved by convex optimization solver easily.

4. Evaluation

To perform evaluation, convex optimization solver for Julia is used for the optimization problem. First, simulation is set up. For PNs, the number of PNs (n_p) follows a uniform distribution from 8 to 12. Furthermore, the capacities of each PN (c_j) follow a uniform distribution between 80 to 120. For VNs, the demand of each VN also follows a uniform distribution from 15 to 30. The figure 3 shows the revenue of the system in terms of virtual network numbers.

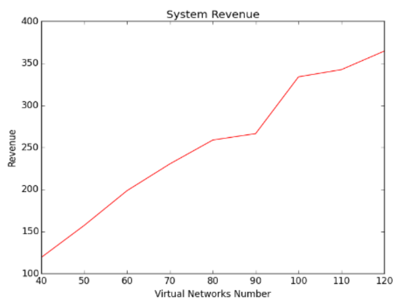

Fig.3 Revenue of the system

5. Conclusion

In this paper, spectrum sharing in cross-infrastructure is proposed in which one virtual network can share the spectrum from multiple infrastructures at the same time. This makes the spectrum sharing more efficient. Future work will consider how to virtualize in cross-infrastructure environment in details by taking the interference and other factors into account.

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References

[1] Mahmoud I. Kamel, Long Bao Le, André Giraard, "LTE Wireless Network Virtualization: Dynamic Slicing via Flexible Scheduling", 2014 IEEE 80th Vechicular Technology Conference, September 2014, pp. 1-5

[2] 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

[3] Xin Wang, Prashant Krishnamurthy, David Tipper,"Wireless Network Virtualization", 2013 International Conference on Computing, Networking and Communications (ICNC), January 2013, pp. 818-822

[4] Mao Yang, Yong Li, Jiaqiang Liu, Depeng Jin, Jian Yuan, Lieguang Zeng, "Opportunistic Spectrum Sharing for Wireless Virtualization", 2014 IEEE Wireless Communications and Networking Conference (WCNC), April 2014, pp 1803-1808