Power Control in virtualized Wireless Network

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Abstract

Wireless network virtualization is a promising technique to solve the increasing demand of mobile data services. Virtualization enables efficient resource utilization, isolation between service providers, and virtualization also reduces capital expenditures (CAPEX) and operational expenditures (OPEX). In this paper, we consider the transmission of virtualized wireless network where users of each service provider (SP) are served by an infrastructure provider (InP) who owns a set eNB through the orthogonal frequency division multiple access (OFDMA). We propose the problem of power allocation of each user that belongs to each service provider. Our objective is to minimize the power under the QoS constraint. Then we propose the iterative algorithm to solve the optimization problem.

Keywords – Virtualized wireless network, power allocation, iterative algorithm.

1. Introduction

The growth of wireless subscriptions is increasing exponentially with increasing mobile devices for Cyber–Physical Systems and Internet-of-Things applications. Network virtualization is a potential technology for next generation wireless network. In wireless network virtualization, the traditional mobile network operator (MNO) is decoupled into infrastructures providers and service providers. Infrastructure providers who own and operate the physical infrastructure and radio resources of physical wireless network, including licensed spectrum, RANs, backhaul, transmission networks and core networks. Service providers lease resources from multiple infrastructure providers (InPs) to create its own network to provide end-to-end services to end users. Thus, wireless network virtualization enables the coexistence of multiple virtual wireless networks in a shared infrastructure with flexible network operations. Although, there are still several research challenges before deploying wireless network virtualization, such as resource allocation, isolation, control signaling, mobility management, network management, security and so on[1][2][3][4].

One of the most important issues in network virtualization is an efficient allocation of resource. It will help to improve resource utilization, energy efficiency, quality of service (QoS) of each user and avoiding interference between service providers. There are two types of resource provisioning such as rate based and resource based provisioning, where the minimum rate and minimum resources are preserved for each service provider, respectively. In wireless network virtualization, isolation is also a basic issue that enable abstraction and sharing of resources among different service providers. While isolation is a bit easier in wired network, isolation in mobile cellular networks is challenging. Interfacing is also one of the most important issues of network virtualization. Infrastructure providers need to provide an interface so that service providers can communicate with InP and express their requirement. Basically there are two types of networks models. As shown in figure (1), two types of logical roles can be classified into infrastructure provider and service provider after virtualization.

![Fig. 1. Two–levels Business Model](image1)

Two–levels model can be decoupled into more specialized roles, such as Service provider (SP). Mobile virtual network operator (MVNO) and Infrastructure provider (InP).

![Fig. 2. Three–levels Business Model](image2)

- Service Provider : focuses to provide specific services to its subscribers.
2. System Model

![System Model Diagram]

As shown in Fig. 2, we consider a virtualized wireless network, which consists of an infrastructure provider (InP) who owns an eNB who owns a set of frequency bands, and a set of service provider (SPs). The total bandwidth of an eNB is divided into a set of sub-channels, denoted by \( K = \{1, 2, 3, ..., K\} \) and the serves a set of service providers, \( S = \{1, 2, 3, ..., S\} \) through orthogonal frequency-division multiple access (OFDMA). Each service provider has a set of users, \( N = \{1, 2, 3, ..., N\} \) and each user requests for a minimum served rate \( R_{s,n,k}^{\text{rev}} \), \( n = 1, 2, 3, ..., N \). So, \( \sum_{n=1}^{N} N_{s} \) is the total number of users served by the eNB. Let \( h_{s,n,k} \) and \( P_{s,n,k} \) be the channel gains on sub-channel \( k \) from an eNB to the user \( n \) of service provider \( s \) on sub-channel \( k \) and allocated power of eNB on user \( n \) of service provider \( s \) on sub-channel \( k \), respectively. Moreover, let \( P = [P_{s,n,k}]_{S \times N \times K} \) be transmit power allocation vector. We assume that one sub-channel is assigned to only one user and a user can assign to only one sub-channel. The received SNR (Signal to Noise Ratio) of the user \( n \) of the service provider \( s \) on sub-channel \( k \) can be expressed as:

\[
Y_{s,n,k} = \frac{P_{s,n,k} h_{s,n,k}}{N_{0} \omega_{k}},
\]

where \( N_{0} \) is the noise spectral density. And then, the transmit data of user \( k \) in service provider \( s \) is formulated as:

\[
R_{s,n,k} = \omega_{k} \log_{2}(1 + SNR),
\]

3. Problem Formulation and Algorithm.

The optimization problem can be expressed as:

\[
\begin{align*}
\text{minimize} & \quad \sum_{s=1}^{S} \sum_{n=1}^{N} \sum_{k=1}^{K} P_{s,n,k} \\
\text{subject to} & : \\
\sum_{k=1}^{K} R_{s,n,k}^{\text{rev}} & \geq R_{n}^{\text{rev}}, \quad \forall s, n \\
\text{Variables} & : P.
\end{align*}
\]

where the constraint is the QoS constraint. According to the constraint, the data rate on each sub-channel must be greater than or equal to the minimum required data rate of each user on each sub-channel. The optimization problem can be transformed into the following:

\[
\begin{align*}
\text{minimize} & \quad \sum_{s=1}^{S} \sum_{n=1}^{N} \sum_{k=1}^{K} P_{s,n,k} \\
\text{subject to} & : \\
\sum_{k=1}^{K} \omega_{k} \log_{2}(1 + SNR) & \geq R_{n}^{\text{rev}}, \quad \forall s, n \\
\text{Variable} & : P.
\end{align*}
\]

4. Simulation Results.

In our simulation, we consider the virtualized wireless network where SPs' users are randomly deployed within the coverage area of macro cell that belongs to the infrastructure.
provider (InP). We consider 3 service providers and each service provider has 5 subscribed users. We assume that infrastructure provider own 15 OFDMA sub–channels, each sub–channel has the total bandwidth of 180 KHz. We set the maximum power of macro cell is 40W. We set the noise power is $4 \times 10^{-21}$ W/Hz. So, the total noise power on each sub–channel is $0.72 \times 10^{-15}$ W.

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5. Conclusion

Wireless network virtualization is a promising technique to solve the scarcity of mobile data services. In this paper, we proposed power allocation in OFDMA based virtualized wireless networks. Then, we formulated the power allocation problem as an optimization problem, which maximize the data rate of each service provider. We solved the optimization problem by using the iterative algorithm. Simulation results were pretended to show the total data rate of users that belong to each service provider. Our future work is to consider multiple base stations in each infrastructure provider and we will also consider multiple infrastructure providers (InPs) and multiple service providers (SPs).