Dual Decomposition Based Power Allocation in Virtualized Wireless Network

Yan Kyaw Tun, Choong Seon Hong
Department of Computer Science and Engineering, Kyung Hee University
Email: {ykyawtun7, cshong}@khu.ac.kr

Abstract
Wireless network slicing is one of the promising techniques to solve the increasing demand of mobile data services. Network slicing (virtualization) can achieve efficient resource utilization, isolation between each slice, and it can also reduce a large amount of capital expenditures (CAPEX) and operational expenditures for each mobile operator. In this paper, we consider a set of mobile operators are served by the infrastructure provider (InP) who owns a set of base-station (eNBs). We propose power allocation problem of each user that belongs to each mobile operator. Our objective is to maximize the sum rate under the QoS (quality of services) and power constraints. Then we use Lagrangian Dual Decomposition method to solve our objective problem.

Keywords – Wireless Network Slicing, power allocation, Lagrangian Dual Decomposition.

1. Introduction
Network slicing is the best way to solve the mobile data traffic growth in the future mobile wireless network. Although network slicing is a promising technique for next generation cellular network, there are still many significant challenges to be solved before the widespread deployment of network slicing in cellular network [1]. In network slicing, multiple mobile operators share the same infrastructure to provide services to their mobile users. The infrastructure provider who owns infrastructure and radio resources and allocate its radio resources to mobile operators according to agreements. As radio resources including channels and power are scarce resources in wireless network, the efficient allocation of resources among mobile operators is important to maximize utilization [2][3][4].

In this paper, we propose network slicing in wireless network with single infrastructure provider and multiple mobile operators and then we formulate down-link power allocation as an optimization problem. Moreover, we use Lagrangian Dual Decomposition technique to address our objective problem.

2. System Model
As shown in Fig.1, we consider a virtualized wireless network which consists of an infrastructure provider (InP) who owns a base-station (eNB) and a set of mobile operators. The total bandwidth of a base station is divided into a set of channels, denoted by $\mathcal{N} = \{1,2,3,\ldots,N\}$ and serves to a set of users, $\mathcal{U} = \{1,2,3,\ldots,U\}$. Each user requests the minimum reserved rate $R_u^{\text{rev}}, u = 1,2,3,\ldots,U$. 
Let $h_{u,n}$ and $p_{u,n}$ be the channel gains on channel ‘n’ from user ‘u’ and the allocated power of user ‘u’ on channel ‘n’, respectively. We assume that one channel is assigned to only one user and a user can assign to only one channel. The received SNR (signal to Noise Ratio) of the user ‘u’ on channel ‘n’ can be expressed as:

$$ Y_{u,n} = \frac{p_{u,n} h_{u,n}}{\sigma^2} $$

where $\sigma^2$ is the additive white Gaussian noise (AWGN) power then the transmit data rate of user ‘u’ is formulated as:

$$ R_{u,n} = \omega_n \log_2 (1 + Y_{u,n}) $$

The objective is to maximize the sum rate of users. The optimization problem can be expressed as:

$$ \max_{p_{u,n}} \sum_{u=1}^{U} \sum_{n=1}^{N} R_{u,n} $$

Subject to

$$ \sum_{n=1}^{N} P_{u,n} \leq P_{\text{max}} $$
$$ \sum_{n=1}^{N} R_{u,n} \geq R^\text{rev}_u, \forall u. $$
$$ p_{u,n} \geq 0, \forall u,n $$

where constraint (1) expresses the transmit power on all channels is below the maximum power of base-station. Constraint (2) means the QoS requirement of each user.

In this section, we propose Lagrangian Dual Decomposition method to solve power allocation problem [5]. The corresponding Lagrangian function is given by:

$$ L(p_{u,n}, \mu, \varphi) = \sum_{u=1}^{U} \sum_{n=1}^{N} R_{u,n} - \sum_{u=1}^{U} \mu_u P_{\text{max}} - \sum_{n=1}^{N} p_{u,n}) $$
$$ + \sum_{u=1}^{U} \varphi_u \left( \sum_{n=1}^{N} R_{u,n} - R^\text{rev}_u \right) $$

where $\mu$ and $\varphi$ are Lagrange multipliers (dual variables) for constraints 1 and 2. The Lagrangian dual function can be expressed as:

$$ D(\mu, \varphi) = \max_{p_{u,n}} L(p_{u,n}, \mu, \varphi) $$

The dual problem can be formulated as:

$$ \min_{\mu, \varphi \geq 0} D(\mu, \varphi) $$

We decompose the Lagrangian function into ‘n’ sub-problem. The Lagrangian function (7) can be written as:

$$ L(p_{u,n}, \mu, \varphi) = \sum_{n=1}^{N} L_n(p_{u,n}, \mu, \varphi) + \sum_{u=1}^{U} \mu_u P_{\text{max}} $$
$$ - \sum_{u=1}^{U} \mu_u R^\text{rev}_u $$

where

$$ L_n(p_{u,n}, \mu, \varphi) = \sum_{u=1}^{U} \sum_{n=1}^{N} R_{u,n} - \sum_{u=1}^{U} \mu_u p_{u,n} + \sum_{u=1}^{U} \varphi_u P_{\text{max}} $$

We solve the dual problem in (9) and update the dual variables according to the following equations:

$$ \mu_u(t + 1) = [\mu_u - \theta(t)(P_{\text{max}} - \sum_{u=1}^{U} p_{u,n})] $$
$$ \varphi_u(t + 1) = [\varphi_u - \theta(t)(\sum_{n=1}^{N} R_{u,n} - R^\text{rev}_u)] $$

where $\theta(t)$ is step size of the iterations.

Algorithm 1: Power Allocation Algorithm

1. Assign each channel to each user, and each user can access to only one channel.
2. Initialize the power vector $(p_{u,n})$ on each channel with the uniform distribution and the Lagrangian multiplier vectors $\mu_u$ and $\varphi_u$.
3. for $n = 1$ to $N$
4. for $u = 1$ to $U$
5. base-station updates the Lagrangian multipliers vectors $\mu_u$ and $\varphi_u$ according
to (12) and (13).
7. end
8. end
9. Run until convergence (Lagrangian multiplier vectors $\mu_u(t+1) = \mu_u(t)$ and $\phi_u(t+1) = \phi_u(t)$).

5. Simulation Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Power</td>
<td>-174dBm/Hz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5MHz</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>40Watt</td>
</tr>
<tr>
<td>fading</td>
<td>70kbps/user</td>
</tr>
</tbody>
</table>

![Fig. 2. Simulation Parameters](image)

6. Conclusion

In this paper, we have proposed Lagrangian Dual Decomposition based power allocation algorithm in virtualized wireless network. Our virtualized wireless network consists of only one base-station and multiple operators. We will extend this model into multiple base-stations.

![Fig. 3. Network Topology](image)

![Fig. 4. Sumrate of UEs](image)

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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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