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M. S. Thesis

Resource management in heterogeneous cellular systems with small moving cells

이동셀이 포함된 이종 셀룰러 네트워크에서 자원 관리 연구

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Abstract

Deployment of small cells has received a great attention as one of feasible technologies to support explosively increasing traffic demands in cellular communication systems. However, it may involve technical issues, including the management of handovers and cross-tier interference near the cell boundary.

In this thesis, we consider deployment of small moving cells (SMCs) in a heterogeneous cellular communication system that employs fixed small cells such as femto- and pico-cells. SMCs can have mobility while providing services for a small number of users in a very short transmission range. We assume that SMCs can make communications among them through a side-haul link for their cooperative operation and make communications with the macro cell through a wireless back-haul. We also assume that the macro cell and SMCs orthogonally share resource to avoid cross-tier interference. We consider resource management for SMCs to maximize the transmission performance by exploiting the mobility of SMCs. For ease of implementation, we consider the resource allocation by coordination among SMCs without involvement of the macro cell. Exploiting that the peak-to-average load ratio (PALR) is larger than 1, we can minimize the resource utilization for SMCs, while allowing them to utilize the resource orthogonal to each other. Thus, the proposed scheme can make SMCs operate without experiencing inter-cell interference. It also virtually reduce the PALR of cells, which is one of major concerns for resource saving operation. Finally, the performance of the proposed scheme is verified by computer simulation.

Keywords: Small moving cells, peak-to-average load ratio, side-haul, cooperative resource management

Student number: 2012-23215

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1. Introduction

Recently, demand for wireless multimedia services has dramatically increased with the use of smart phones and wireless devices. As a consequence, the number of mobile-connected devices has exceeded the global population in 2013, requiring advanced technologies for future demands [1]. There have been extensively on-going research works to this end, including the improvement of spectrum efficiency and network density [2]-[6].

Deployment of small cells has received a great attention in advanced cellular systems [7]. 3GPP LTE-A systems adopt additional deployment of small cells, referred to heterogeneous network (Het-Net). Overlaying small cells on a macro cell can improve spectrum utilization through cell-splitting, increasing the capacity in hot spot areas while reducing energy consumption. However, deployment of small cells may involve technical issues, including the management of frequent handovers and cross-tier interference near the cell boundary. Co-tier interference among small cells densely deployed in a small area cannot easily be handled.

Recently deployment of small moving cells (SMCs) has been proposed for 5G wireless communication systems [8]. The SMC base station (SBS) in an SMC serves a small number of users, referred to SUEs, located within a short distance from itself. It can have mobility and make communications with a macro cell base station (MBS) through a wireless backhaul. It can also make communications with its neighboring SMCs through a side-haul link for cooperative operation.

However, deployment of SMCs may cause co-tier and cross-tier interference in a heterogeneous cellular system. The interference problem can be alleviated by means of fractional frequency reuse (FFR) in frequency domain or by using almost blank sub-frame (ABS) in time domain [9, 10]. The FFR allows the macro cell and small cells to use different frequency resource, referred to frequency assignment (FA), enabling to avoid the cross-tier interference [11]. Enhanced inter-cell interference coordination (eICIC) in LTE-A [10], an ABS scheme, makes the macro cell to disuse certain subframes for small cells. Since these schemes only consider the use of resource in frequency or time domain, they may suffer from low efficiency of resource utilization. A selfish optimization scheme was proposed to improve the resource utilization [12]. However, it may not be able to fast manage the co-tier interference in the presence of heavy data traffic with mobility.

In this thesis, we consider resource allocation in a heterogeneous cellular communication system with SMCs. We assume that the macro cell and SMCs share the same resource, but utilize it orthogonally to minimize the interference between the macro cell and SMCs. For ease of implementation with reduced complexity, we consider the resource allocation by means of cooperation among SMCs without involvement of the macro cell. Exploiting that the peak-to-average load ratio (PALR) of a cell is always larger than 1 in addition to SMC mobility, we can make SMCs share a same FA resource in an orthogonal manner. This allocation can virtually reduce the PALR by maximizing resource utilization. As a consequence, it can improve the spectral efficiency of the cell. Finally, the performance of the proposed resource allocation scheme is verified by computer simulation.

The rest of the thesis is organized as follows. Chapter 2 describes the system model of a heterogeneous cellular system with small moving cells in consideration. Chapter 3 briefly reviews previous works on resource management in heterogeneous cellular networks. Chapter 4 describes the proposed resource management scheme. Chapter 5 evaluates the performance by computer simulation. Finally, Chapter 6 concludes the thesis.

2. System model

We consider additional deployment of SMCs in a heterogeneous cellular system that deploys a number of small fixed cells such as femto- and pico-cells. SMCs can have mobility and services a small number of users in a very small transmission range. For ease of description, we define the parameters of a heterogeneous cellular system with SMCs by:

- $\mathbf{M} = \{1,...,m\}$: A set of macro cells.
- $\mathbf{N}_n = \{n_1,...,n_K\}, \forall n \in \mathbf{M}$: A set of MUEs in macro cell *n*.
- $\mathbf{S} = \{1,...,s\}$: A set of SMCs.
- $\mathbf{u}_i = \{i_1,...,i_K\}, \forall i \in \mathbf{S}$: A set of users in SMC i.

We assume that SMCs make communications among them through a side-haul link and make communications with the macro cell through a wireless backhaul. We also assume that the macro cell and SMCs utilize resource orthogonally to avoid cross-tier interference, and that SMCs serve users in a closed subscriber group (CSG) mode [13].

2.1. Resource allocation for SMCs

Fig. 1 illustrates a typical operation scenario of SMCs in a heterogeneous cellular system, where the color represents the spectrum allocated to each SMC. Although the macro cell and SMCs share the same resource, the macro cell and SMCs utilize resource orthogonally to avoid cross-tier interference. But the co-tier interference between SMCs may still remain.

Minimizing the co-tier interference among SMCs without involvement of the MBS, SMC can get resource for signal transmission in a cooperative or non-cooperative mode according to operation environments. The operation environment can be measured by SMC and its users. For example, SMCs can estimate the operation environment by means of energy detection and determine a set of neighboring SMCs operating in each FA. Let $\mathbf{S}_i$ be SMC i's set of interfering SMCs, defined by

$$\mathbf{S}_i = \left\{ j \in \mathbf{S} \mid P_{j,i_k} > P_0 \text{, for } \forall i_k \in \mathbf{u}_i \right\} \tag{1}$$

where P_{j,i_k} denotes the received signal power from SBS j to user i_k and P_0 is a threshold to be determined [14]. Here, i_k denotes the *k*-th user of SBS i. From the received signal, users of SMC i can figure out the cell identification (cID) of adjacent SMCs

The SBS can make decision on its operation mode, non-operative or cooperative operation, after estimating the operation environment. The SBS may adopts the non-cooperative operation mode when no SMC exists nearby or resource is achievable without consideration of neighboring SMCs. It determines the resource for signal transmission by itself in the non-cooperative mode. Otherwise, it can get resource for its operation through cooperation with neighboring SMCs. When it cannot find resource available for itself, it may request the MBS for the allocation of an additional

FA for SMC operation or temporary data-offloading through the utilization of resource used by the MBS. The MBS can adjust the amount of resource allocated to the SMC operation in response to the change of SMC operation environments, maximizing the resource available for itself.

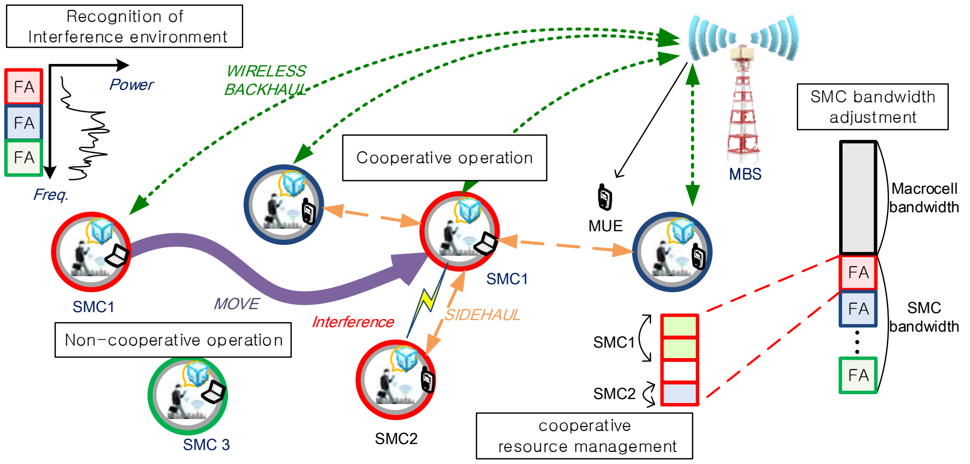


Fig. 1. SMCs in a heterogeneous cellular system

2.2. Resource structure

The macro cell manages the total amount of resource for SMC operation in response to the change of SMC operation environments. Fig. 2 illustrates the resource structure for optimal utilization of spectrum resource in a heterogeneous cellular network with SMCs. The MBS can allocate a total resource of up to N FAs for SMC operation, referred to $\mathbf{B}_{SMC}$, each of which comprises M sub-FAs. For example, each sub-FA comprises a number of resource block (RB) in the LTE-A system. For ease of analysis, we assume that each sub-FA comprises one RB. Each macro cell has a total amount of resource of $\mathbf{B}_{cell}$ and it can use a resource of $\mathbf{B}_{macro}$ for itself, where $\mathbf{B}_{macro} = \mathbf{B}_{cell} - \mathbf{B}_{SMC}$. The SMC resource $\mathbf{B}_{SMC}$ can be represented as

$$\mathbf{B}_{SMC} = \left\{ B_{FA_1}, B_{FA_2}, ..., B_{FA_{N-1}}, B_{FA_N} \right\}. \tag{2}$$

where B_{FA_n} denotes the *n*-th FA of $\mathbf{B}_{SMC}$, represented as

$$B_{FA_n} = \left\{ B_{FA_n^1}, B_{FA_n^2}, \ldots, B_{FA_n^{M-1}}, B_{FA_n^M} \right\}. \tag{3}$$

Here $B_{FA_n^M}$ denotes the *M*-th sub-FA of B_{FA_n}.

The MBS supports SMC by periodically broadcasting information including the FA size B_{FA} through a backhaul link. FA size can be adjusted in response to the change of the ratio of real time (RT) and non-real time (NRT) traffic load, and the signal-to-noise ratio (SNR). The FA size can be represented as

$$\begin{aligned} B_{FA} &= K\left(\eta \left\lceil \frac{b^{RT}}{f_{MCS}(\bar{\gamma})} \right\rceil + (1-\eta) \left\lceil \frac{b^{NRT}}{f_{MCS}(\bar{\gamma})} \right\rceil \right) \\ &= f\left(K, \eta, \bar{\gamma}\right) \end{aligned} \tag{4}$$

where K denotes the number of users in the SMC, b^{RT} and b^{NRT} respectively denote the amount of RT and NRT traffic load, η denotes the ratio of RT and NRT traffic load, $f_{MCS}(\bar{\gamma})$ denotes a function that calculates the highest achievable transmission rate in a RB at SNR $\bar{\gamma}$ associated with a given modulation coding scheme set (MCS), and $\lceil x \rceil$ denotes the smallest integer number larger than or equal to x. We consider the adjustment of FA size according to the SMC traffic load.

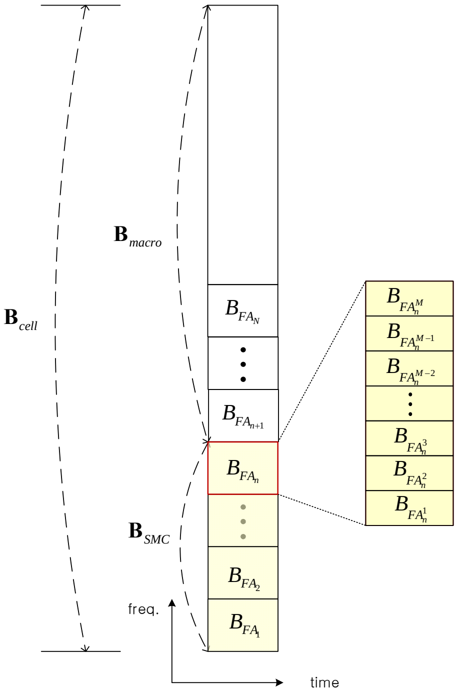


Fig. 2. Resource structure in a heterogeneous cellular system with SMCs

2.3. Signal-to-interference plus noise ratio

We consider the downlink transmission to SMC users, where the SBS is equipped with N_T transmit antennas and simultaneously serves K users with a single receive antenna. SMCs may initially have resource allocated orthogonally to each other, but they may experience inter-cell interference mainly due to the mobility.

The received signal of user i_k served by SMC i through RB f can be represented as

$$\mathbf{y}_{i_k}^{(f)} = \sqrt{\alpha_{i,i_k}^{(f)}}\mathbf{h}_{i,i_k}^{(f)}\mathbf{w}_{i,i_k}^{(f)}s_{i_k} + \sum_{\substack{i_{k'}=1,\\ i_{k'}\neq i_k}}^{K} \sqrt{\alpha_{i,i_k}^{(f)}}\mathbf{h}_{i,i_k}^{(f)}\mathbf{w}_{i,i_{k'}}^{(f)}s_{i_{k'}} + \sum_{\substack{j=1,\\ j\neq i}}^{|\mathbf{S}|}\sum_{j_k=1}^{K}\sqrt{\alpha_{j,i_k}^{(f)}}\mathbf{h}_{j,i_k}^{(f)}\mathbf{w}_{j,j_k}^{(f)}s_{j_k} + \mathbf{z}_{i_k} \tag{5}$$

where $\alpha_{i,i_k}^{(f)}$ and $\alpha_{j,i_k}^{(f)}$ respectively denote the path loss from SMC i and adjacent SMC j to user i_k, $\mathbf{h}_{i,i_k}^{(f)}$ and $\mathbf{h}_{j,i_k}^{(f)}$ respectively denote $(1\times N_T)$ channel vector from SMC i to i_k and from SMC j to i_k; $\mathbf{w}_{i,i_k}^{(f)}$, $\mathbf{w}_{i,i_{k'}}^{(f)}$ and $\mathbf{w}_{j,j_k}^{(f)}$ respectively denote $(N_T\times 1)$ beam weight vector from SMC i to i_k, SMC i to $i_{k'}$ and SMC j to j_k, s_{i_k}, $s_{i_{k'}}$ and s_{j_k} respectively denote the signal transmitted from SMC i to i_k, SMC i to $i_{k'}$ and SMC j to j_k, and $\mathbf{z}_{i_k}$ denotes zero mean complex circular-symmetric additive white Gaussian noise (AWGN) of user i_k.

The instantaneous signal-to-interference plus noise ratio (SINR) of user i_k can be represented as [15]

$$\begin{aligned}\gamma_{i_k} &= \frac{\alpha_{i,i_k}^{(f)}P\left|\mathbf{h}_{i,i_k}^{(f)}\mathbf{w}_{i,i_k}^{(f)}\right|^2}{\sum\limits_{\substack{i_{k'}=1,\\ i_{k'}\neq i_k}}^{K}\alpha_{i,i_k}^{(f)}P\left|\mathbf{h}_{i,i_k}^{(f)}\mathbf{w}_{i,i_{k'}}^{(f)}\right|^2 + \sum\limits_{\substack{j=1,\\ j\neq i}}^{|\mathbf{S}|}\sum\limits_{j_k=1}^{K}\alpha_{j,i_k}^{(f)}P\left|\mathbf{h}_{j,i_k}^{(f)}\mathbf{w}_{j,j_k}^{(f)}\right|^2 + \sigma_{i_k}^2}\\ &= \frac{\bar{\gamma}_{i,i_k}\left|\mathbf{h}_{u_k^p}^{(f)}\mathbf{w}_{u_k^p}^{(f)}\right|^2}{\sum\limits_{\substack{i_{k'}=1,\\ i_{k'}\neq i_k}}^{K}\bar{\gamma}_{i,i_k}\left|\mathbf{h}_{i,i_k}^{(f)}\mathbf{w}_{i,i_{k'}}^{(f)}\right|^2 + \sum\limits_{\substack{j=1,\\ j\neq i}}^{|\mathbf{S}|}\sum\limits_{j_k=1}^{K}\bar{\gamma}_{j,i_k}\left|\mathbf{h}_{j,i_k}^{(f)}\mathbf{w}_{j,j_k}^{(f)}\right|^2 + 1}\end{aligned} \tag{6}$$

where $\bar{\gamma}_{i,i_k} = \alpha_{i,i_k}^{(f)}P/\sigma_{i_k}^2$, $\bar{\gamma}_{j,i_k} = \alpha_{j,i_k}^{(f)}P/\sigma_{i_k}^2$ and P is the transmitted power from SBS.

Thus, the spectral efficiency of user i_k can be represented as

$$\eta_{i_k} = f_{MCS}\left(\gamma_{i_k}\right). \tag{7}$$

2.4. Traffic load

We assume that the traffic load is statistically generated in a form of truncated Gaussian distribution. It can be shown that the probability density function (PDF) of traffic load X can be represented as

$$f_X\left(x;\mu,\sigma,a,b\right) = \frac{\frac{1}{\sigma}\phi\left(\frac{x-\mu}{\sigma}\right)}{\Phi\left(\frac{b-\mu}{\sigma}\right)-\Phi\left(\frac{a-\mu}{\sigma}\right)} \quad ; \; a < x < b \tag{8}$$

where $\phi(x) = \frac{1}{\sqrt{2\pi}}\exp\left(-\frac{1}{2}x^2\right)$ is the PDF of a normal random variable x and $\Phi(x)$ is the CDF of x. The average of traffic load can be represented as

$$E\left(X \mid a < X < b\right) = \mu + \frac{\phi\left(\frac{a-\mu}{\sigma}\right)-\phi\left(\frac{b-\mu}{\sigma}\right)}{\Phi\left(\frac{b-\mu}{\sigma}\right)-\Phi\left(\frac{a-\mu}{\sigma}\right)}\sigma . \tag{9}$$

Assuming a PALR range of 2~6, $a = 0$ and $b =$ peak traffic load, we can determine the value of the variance σ. Fig. 3 depicts the PDF of traffic load when the PALR is 2, 4 and 6, and b = 12. It can be seen that the traffic may have a high mean value when the PALR is high, and vice versa.

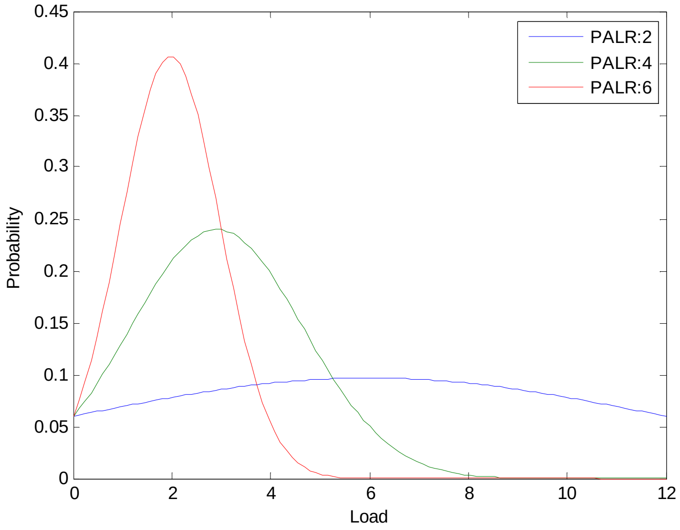


Fig. 3. PDF of traffic load according to PALR.

Fig. 4 illustrates an example of low and high PALR environments. When the PALR is low, the peak traffic load occurs in a form of uniform distribution. Since the PALR is normally much larger than one, it may be desirable to exploit opportunity for cooperation as the number of SMCs increases, which can be applied to the improvement of spectral efficiency and reduction of interference as well.

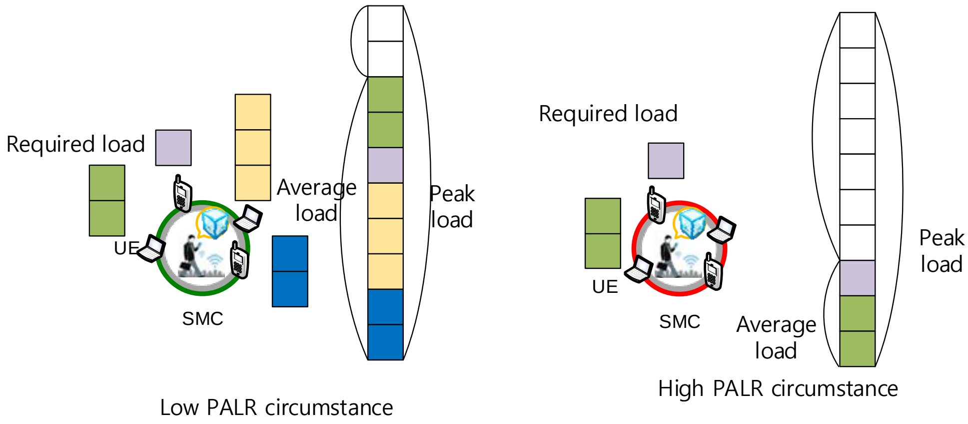


Fig. 4. An example of low and high PALR circumstances

3. Previous works

3.1. Conventional resource management

Small cell technologies can significantly improve the system capacity by exploiting various cell splitting techniques [10]. However, severe interference issues should be handled when they are densely deployed in a hot spot area to support extremely high data traffic. The FFR and ABS scheme can reduce the interference problems [10]. The FFR scheme divides the resource into a number of FAs in frequency domain. It allows neighbor cells to use different FAs, avoiding the interference among neighboring small cells. However, it may not be able to effectively manage co-tier interference since it uses limited frequency resource in a hot spot area, and it has much unused resource due to fixed FA size [16]. Also, resource partitioning in frequency domain may need an interference mitigation scheme, such as the coordinated beamforming and joint antenna processing technique [17]. But these techniques may not be feasible for a HetNet with SMCs mainly due to the mobility and high implementation complexity.

The 3rd Generation Partnership Project (3GPP) LTE-advanced systems adopt an ABS to control the interference [18]. To avoid the interference without additional transmission of control signal, macro and small cells have an ABS pattern exchanged through x2 interface which is shown in Fig. 5 [10]. However, it still cannot manage the interference in a hot spot area due to much delay and it has much unused time resource depending on an ABS ratio of macro and small cells.

An enhanced dynamic spectrum sharing (EDSS) scheme was proposed for interference management, which combines FFR and ABS schemes [19]. It can reduce the scarcity of orthogonal resource for managing the interference by adjusting the transmission power of macro cell in cell center region. However, it cannot fully utilize whole frequency spectrum due to the use a fixed frequency reuse factor. Fig. 6 illustrates interference management by EDSS, where the macro cell area is divided into the center and the edge region, and the edge region is further divided into three sectors. The whole frequency band is partitioned into three portions and the center region is operating with a reuse factor of one. When applied to a HetNet with SMCs, the macro cell may find it difficult to allocate the resource because of the SMC mobility. Moreover, EDSS may require high signaling overhead and computation complexity to manage all the co- and cross-tier interference in hot spot areas, where a large number of small cells may exist.

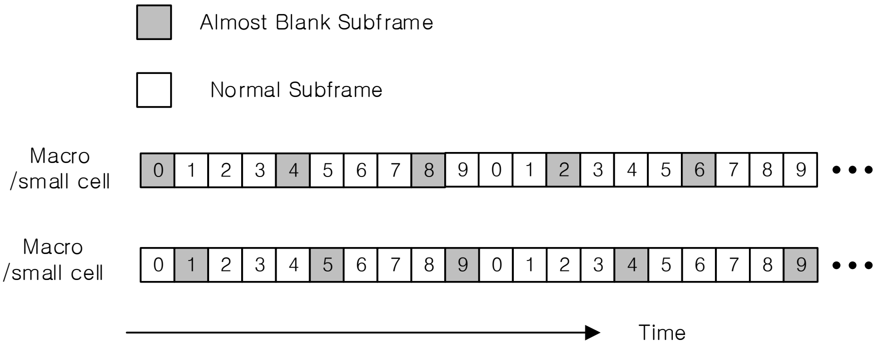


Fig. 5. Interference management with ABS

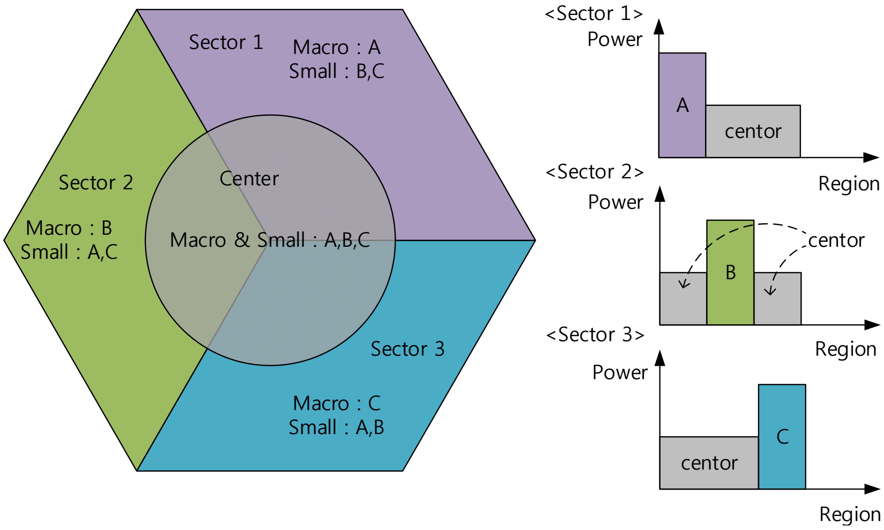


Fig. 6. Interference management with EDSS

3.2. Dynamic radio resource allocation

Dynamic resource allocation schemes have been proposed in consideration of the change of operating environments. A graph coloring based operating scheme can adjust the spectral resource by constructing interference graph for FFR scheme [20]. However, it may require high signaling overhead and unacceptable time delay since it allocates resource to users in a centralized manner. A similar scheme considers fractional frequency reuse, where a cell surface is virtually partitioned into two regions according to interference [21]. Although it can reduce interference, it may suffer from low reuse factor. A modified version of these two schemes considers the resource allocation in a decentralized manner [22]. It employs a selfish resource allocation that independently minimizes the transmit power to neighbors. However, it may not effectively manage the co-tier interference in the presence of SMCs.

In this thesis, we design a decentralized cooperative resource allocation algorithm for heterogeneous networks with SMCs. The proposed scheme reduce the signaling overhead because each SMC can independently and dynamically allocate resource by itself considering its neighbor SMCs. It can avoid interference through cooperative operation among SMCs and may achieve improved spectral efficiency by exploiting the PALR and SMC mobility.

4. Proposed resource management

We consider a HetNet with SMCs, where the macro cell and SMCs share the same resource but utilize it in an orthogonal manner to avoid cross-tier interference. However, co-tier interference among SMCs still remains. In order to avoid the co-tier interference and improve the spectral efficiency, we consider the resource allocation by means of cooperation among SMCs without direct involvement of the MBS.

4.1. FA size

We assume that the FA size is determined in consideration of the average or the peak traffic load. Let $\bar{B}_{FA}$ and $\hat{B}_{FA}$ be the FA size determined in consideration of the average and the peak traffic load, respectively.

With the use of $\bar{B}_{FA}$, when no SMC exists nearby, sudden change of its traffic load can easily be handled by increasing the number of FAs in $\mathbf{B}_{SMC}$. However, when SMCs using a same size of FA are located nearby, the resource should be reallocated to avoid interference with interfering SMCs. Therefore, it may be desirable to use $\bar{B}_{FA}$ only when the number of SMCs is small. With the use of $\hat{B}_{FA}$, SMC has much less burden than the use of $\bar{B}_{FA}$ because the peak FA size can easily handle sudden increase of the load. When an SMC has interfering SMCs, it may have to use other FA just like the use of $\bar{B}_{FA}$, or it can use its FA by exploiting the unused resource of interfering SMCs.

Therefore, it may be preferable to use $\hat{B}_{FA}$ when the number of interfering SMCs is not small.

When the MBS determines the FA size, the average FA size can be calculated by averaging (4), while the peak FA size is the largest value of (4). The FA size information can be transmitted to SMCs with periodical information to SMCs.

4.2. Resource management

In order to adapt to dynamic operation environments, SMCs should operate depending on the result of estimation for its environment. Using energy detection, each SMC determine the available resource and determines the set of interfering SMCs. We assume that SMCs can recognize the resource used by neighbor SMCs by the estimation of the operation environment with different measurement times [23].

The operation of SMCs for resource management can be divided into three steps. Fig. 7 depicts a flow chart for the operation. The first step is initial processing, including the access process of users in SMC and the registration process of users to MBS.

The second step includes service request by SMC to the MBS, and reception of load, FA size and $\mathbf{B}_{SMC}$. Here, we assume that the MBS periodically broadcasts the FA size information. When SBS requests services to the MBS, it transmits channel information including the SNR.

The third step includes resource management process which is configured by non-cooperation or cooperation after estimating the operation environment. The SBS may adopt the non-cooperation mode when no SMC exists nearby or sufficient resource is achievable. In this case, the SMC simply determines the resource by itself. Here, if the number of available FA is more than one, SBS should use the lowest FA index and it transmits information of FA index in use for MBS to recognize reducing FA number. However, if interfering SMCs exist nearby, the SBS first checks the available resource for the transmission of traffic. When it cannot find resource available for itself, it requests the MBS the allocation of an additional FA or temporary data-offloading through the utilization of MBS resource. When the SBS requests an additional FA to the MBS, it transmits information including a set of interfering SMCs with FA index in use. If the MBS cannot offer an additional FA, it allocates its available resource being non-overlapped with SMCs in the set. When the SMC receives request for temporary off-loading, it can allow the requesting SBS to utilize its resource temporarily. When the SMC receives request for an additional FA, it may allocate an additional FA to SMCs.

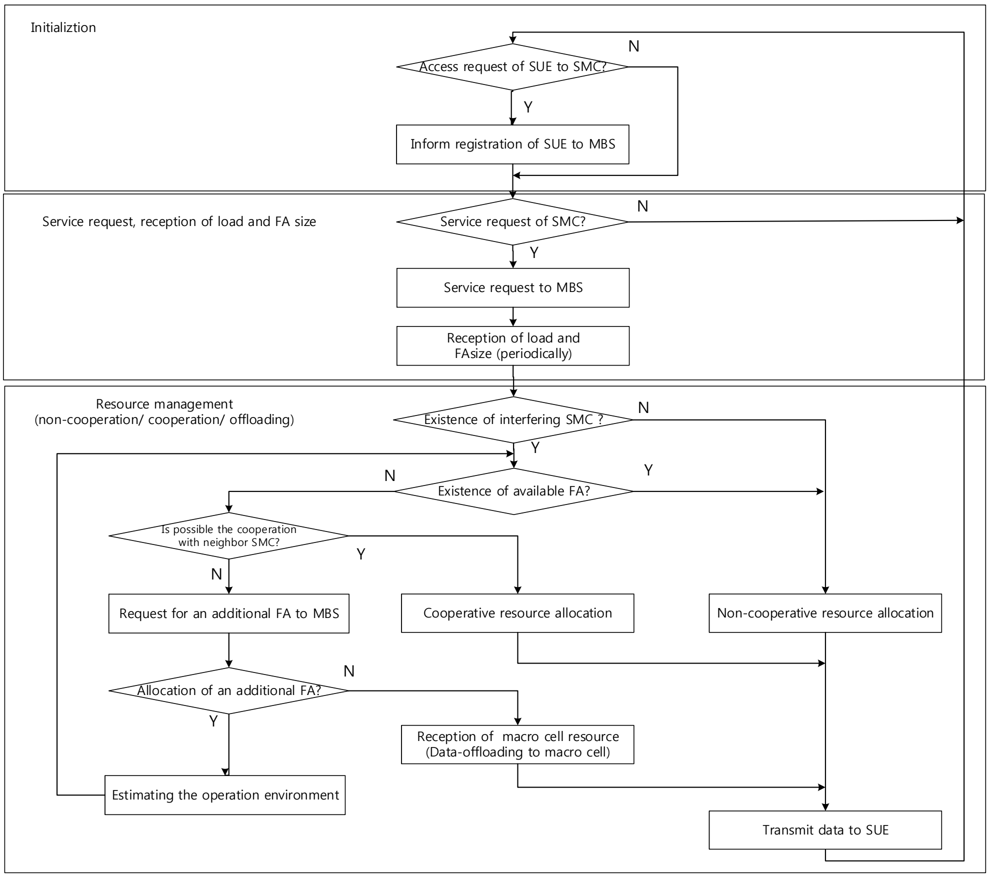


Fig. 7. The flow chart of SMC operation for resource management

4.3. Cooperative resource allocation

In cooperative resource allocation with using the peak FA size, SBS can make request neighboring SMCs for cooperation through a side-haul link. The cooperation process is summarized in Fig. 8. The cooperation primarily considers the traffic type (i.e., RT or NRT). Let $\mathbf{R}_i$ denote available resource for SMC i, which can be represented as

$$\mathbf{R}_i = \{\mathbf{r}_{i,1}, \mathbf{r}_{i,2}, \dots, \mathbf{r}_{i,z-1}, \mathbf{r}_{i,z}\} \qquad (10)$$

where $\mathbf{r}_{i,z}$ denotes available resource in the z-th FA and z denotes the maximum number of recognized FA indices. To use the resource efficiently, when the total load of SMC can be transmitted using $\mathbf{R}_i$, the SBS chooses an SMC having the lowest FA index in $\mathbf{R}_i$ as the cooperating SMC. Then, the SBS can use this FA together with the cooperating SMC through a request for cooperation.

Let $\hat{\mathbf{r}}_i$ be the available resource in a chosen FA, which can be represented as

$$\hat{\mathbf{r}}_i = \min\left\{\mathbf{r}_{i,n} \in \mathbf{R}_i \mid \left|\mathbf{r}_{i,n}\right| \geq N_i \right\} \tag{11}$$

where $\left|\mathbf{r}_{i,n}\right|$ denotes the size of available resource $\mathbf{r}_{i,n}$ in the n-th FA, and N_i denotes the resource for the transmission of the load of SMC i.

On the other hand, when only RT load can be transmitted through $\mathbf{R}_i$, the SBS may select an SMC having the largest available resource in $\mathbf{R}_i$ as the cooperative SMC. Then it can also use this FA together with the cooperating SMC through a request for cooperation. The available resource $\hat{\mathbf{r}}_i$ in a chosen FA can be written as

$$\hat{\mathbf{r}}_i = \max\left\{\mathbf{r}_{i,n} \in \mathbf{R}_i \mid \left|\mathbf{r}_{i,n}\right| \geq N_i^{RT}\right\} \tag{12}$$

where N_i^{RT} denotes the required resource to transmit RT traffic of SMC i.

In cooperative resource allocation with using average FA size, when SBS can transmit its total load in an available resource, it determines different resource for transmitting the load from interfering SMCs. Otherwise, SBS determines the resource for transmitting RT traffic load in an available resource, and then it determines remaining resource in an available resource for NRT traffic load as far as possible.

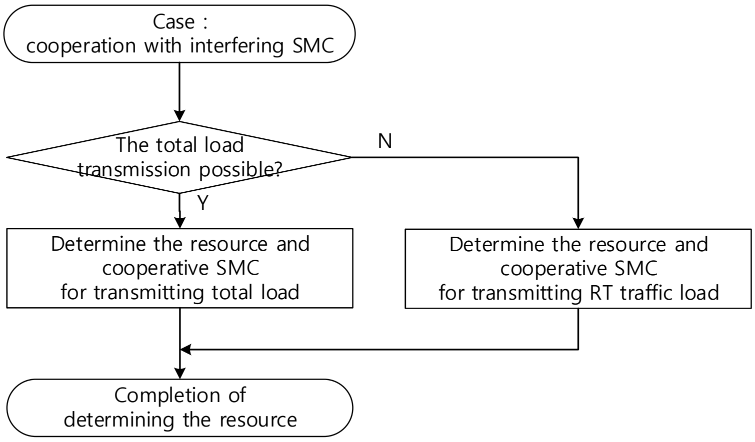


Fig. 8. Cooperative resource allocation at peak FA size

5. Performance evaluation

Table 1. Simulation parameters

Simulation parameters	**Settings**
Total Bandwidth	20Mhz (100RBs)
Simulation coverage radius	50 m (Coverage of set of interfering SMCs)
Side-haul link coverage	70m
Channel	Rayleigh fading channel (0,1)
Average SNR of SMC	20 dB
Traffic load model	Truncated Gaussian distribution
FA size	Max 20 RBs
SMC bandwidth	Max 10Mhz (50RBs)
Number of users of SMC (K)	0~4 (uniform distribution)
SMC PALR	2,4,6
Number of interfering SMCs	0~7
Mobility	3km/h

In this section, the performance of the proposed scheme is verified by computer simulation. Simulation parameter is summarized in Table 1. For the evaluation, we consider one macro cell network including SMCs which are uniformly distributed. MCS set is summarized in Table 2. We determine the FA size by components of Table 3, and K is number of users and η (ratio of RT and NRT traffic load) as 0.5. Therefore $\overline{B}_{FA}$ and $\hat{B}_{FA}$ become respectively 6, 16. Macro cell updates the FA size in 40ms period with broadcasting information on operation SMC [10]. To analyze the total throughput, we assume that macro cell uses all of the remaining resource including unused resource of SMCs. We evaluate spectral efficiency, the total throughput, and PALR performance when SBS with single transmit antenna has up to 4 users. We compare our proposed scheme with the other resource management schemes of FFR with reuse factor 3, referred to FFR-3, according to the number of interfering SMCs under various density of SMCs.

Table 2. Modulation and Coding Set (MCS) Table

Index	SINR(dB)	Modulation	Code rate	Bit rate
1	-5.57<SINR< -4.08,	QPSK	1/12	1/6
2	-4.08<SINR< -0.96	QPSK	1/8	1/4
3	-0.96<SINR< 2.07	QPSK	1/4	1/2
4	2.07<SINR< 5.29	QPSK	1/2	1
5	5.29<SINR< 7.62,	QPSK	3/4	3/2
6	7.62<SINR< 12.63,	QPSK	1/2	2
7	12.63<SINR< 16.27	16QAM	1/2	3
8	16.27<SINR< 17.25,	64QAM	2/3	4
9	17.25<SINR< 19.0	64QAM	3/4	9/2
10	SINR>19	64QAM	5/6	5

Table 3. FA size components

	RT traffic load	NRT traffic load	Total load
Peak load [bits/ms]	64 (Video streaming)	4000 (FTP 0.5Mbits/sec)[24]	K(64 ~ 4000)
Avg. load [bits/ms]	64	680 (FTP source rate 680 kbps)[25]	K(64 ~ 680)

Fig. 9 depicts the spectral efficiency according to the number of interfering SMCs. It can be shown that the proposed scheme can achieve better performance than FFR-3. the proposed scheme with $\mathrm{SMC} = 7$ can provide spectral efficiency about 3 times higher than that of FFR-3. The spectral efficiency of peak and average FA size are cross over at about 3~4 SMCs. It can be seen that when the number of SMC is somewhat small, a relatively small average FA size is better for resource management in terms of spectral efficiency. On the other hand, peak FA size is better when there are many interfering SMCs. This is mainly due to the fact that as the number of SMCs increases in an area, the possibility of a chance to use unused resource of interfering SMCs increases. This characteristics has the same effect on total throughput.

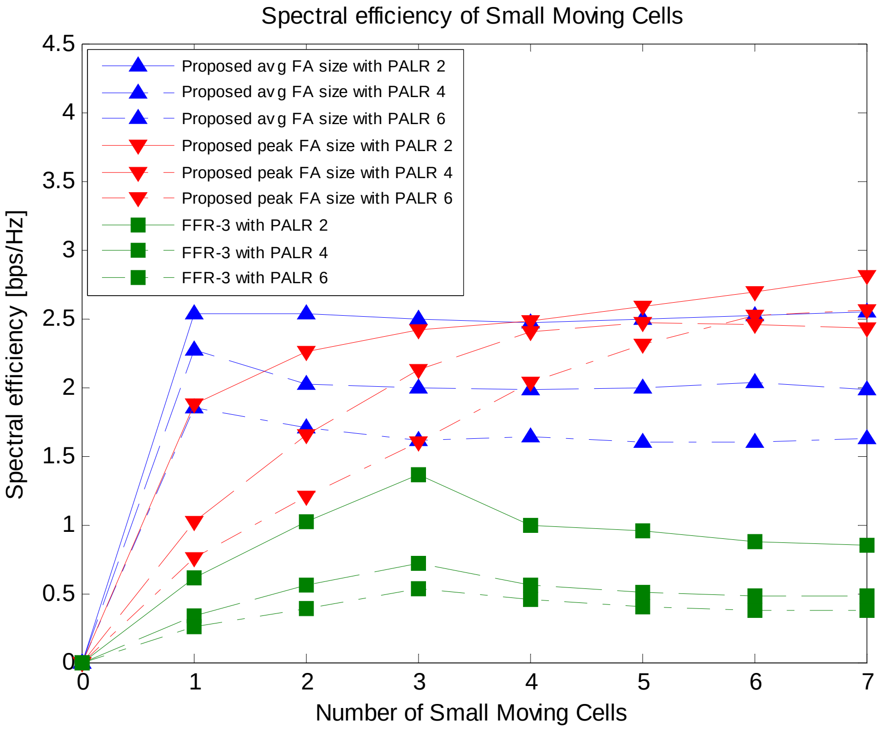
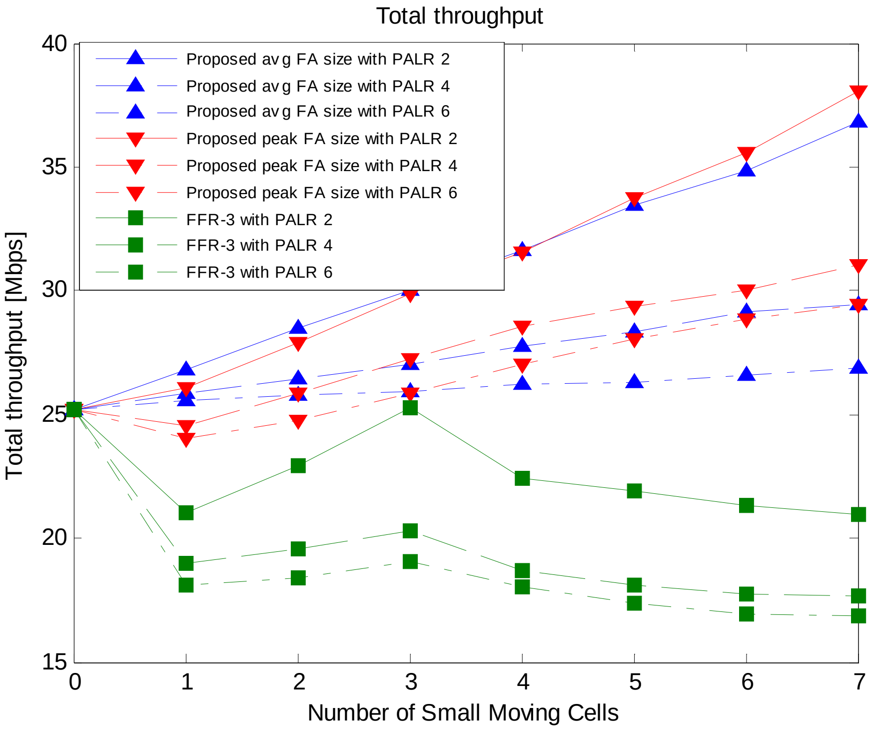


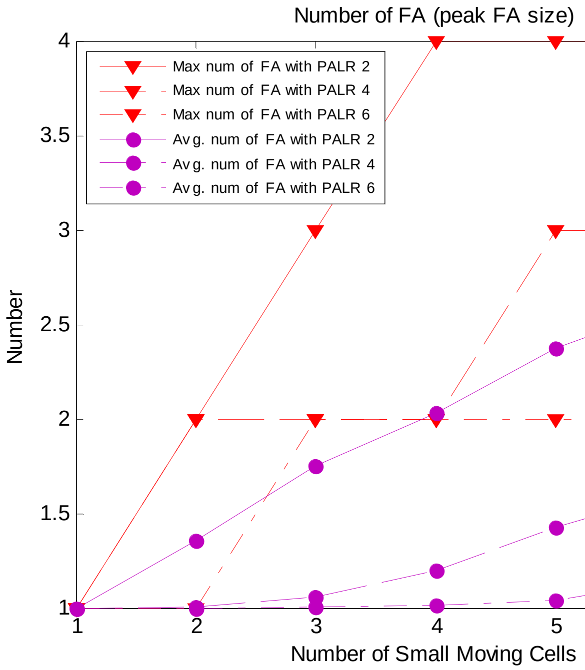
Fig. 9. Spectral efficiency of SMCs with respect to interfering SMCs

Fig. 10 depicts the total throughput and the required number of FAs according to the number of interfering SMCs. The total throughput is the sum of effective transmitted data of macro cell and SMCs. It can be seen from Fig. 10 (a) that the total throughput of proposed scheme is always better than that of FFR-3 regardless of the number of SMCs. The proposed scheme can achieve higher spectral efficiency and it can avoid co-tier interference through allocating dynamically orthogonal resource allocation by means of cooperation and adjustment of the FA size/FA number depending on operation environment. However, FFR-3 with fixed peak FA size 16 RBs cannot avoid the co-tier interference when interfering SMC is larger than 3. Additionally, it can be shown that the scheme with peak FA size has steeper slope than that of the scheme with average FA size. It is because that as the possibility of interference between SMCs increases, there is more chance to cooperation of the interfering SMCs.

When PALR reduces, the average of loads may be higher and required resource for service also increase. Therefore, data-offloading of SMC is carried out when required resource is higher than limitation of SMC resource 50 RB. It can be seen from Fig. 10 (b) that as the number of interfering SMCs increases, the required number of FA also increases. When the required number of FA is larger than 3, SMCs request data-offloading to macro cell. But the average of required number of FA cannot exceed three even through PALR two. Consequently, the proposed scheme rarely provides data-offloading to macro cell since almost only one or two FAs are needed even in hot spot areas.



(a) Total throughput



(b) Required number of FA

Fig. 10. Throughput and number of FA with respect to interfering SMCs

Fig. 11 depicts the PALR according to the number of interfering SMCs. From the figure, the proposed scheme gets the lower PALR than pre-configured load model when using peak FA size. Since the increase of PALR results in the higher chance of cooperation, the allocated resource of SMCs becomes compact and spectral efficiency is improved. Thus, we can get PALR about 1.5 when SMC is 6. Consequentially, the proposed scheme can virtually reduce the PALR, while improving the transmission performance in an energy efficient manner by simple implementation without complex mathematical calculation.

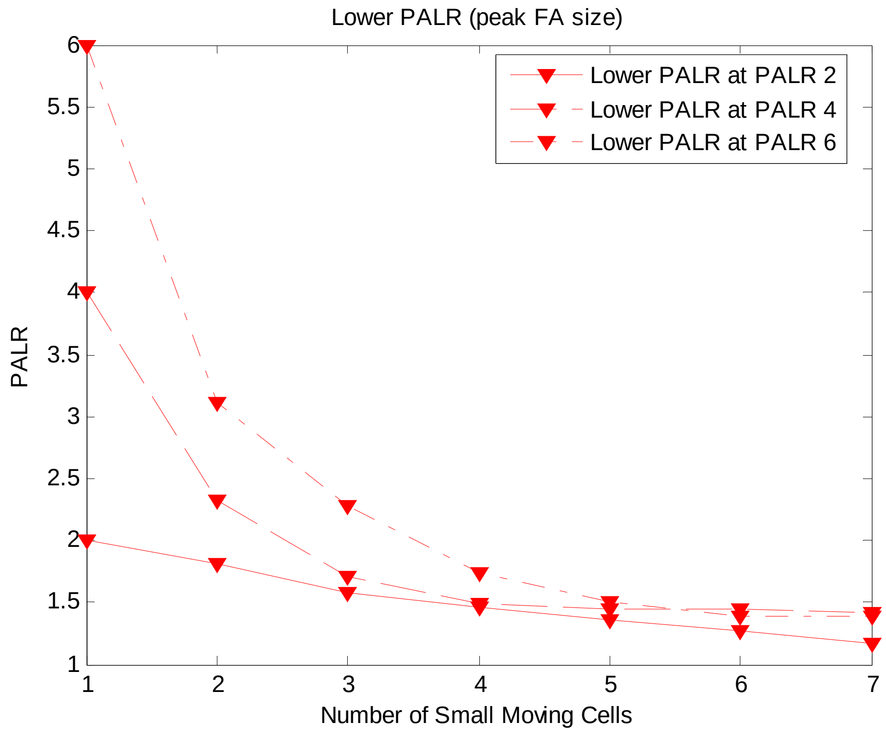


Fig. 11. PALR with respect to interfering SMCs

6. Conclusions

In this thesis, we have considered resource management for the deployment of SMCs in heterogeneous cellular systems. Although the macro cell and SMCs share the same resource, the macro cell and SMCs utilize resource orthogonally to avoid cross-tier interference. However, to solve the remaining problem of the co-tier interference between SMCs and to achieve high spectral efficiency, we propose simple resource management considering PALR by mean of cooperation of SMCs and adjustment of FA size/FA number in a decentralized manner. Exploiting the fact that PALR of a cell is always larger than one, the proposed scheme can provide SMCs enable to determine resource efficiently by means of cooperation with neighbors using the same FA. Additionally, the proposed scheme can satisfy users' quality of service by taking traffic types (real/non-real) into account in a distributive manner, and it outperforms conventional resource management scheme even in hot spot areas. The simulation result shows that when the number of SMC is somewhat small, a relatively small average FA size is better for resource management in terms of spectral efficiency, while peak FA size is better when many interfering SMCs exist. Consequently, the proposed scheme can make SMCs operate without experiencing inter-cell interference. It also virtually reduce the PALR of cells, which is one of the major concerns for resource saving operation.

References

[1] CISCO whitepaper, *CISCO Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017,* Feb. 2013.

[2] O. Yilmaz, S. Hamalainen, and J. Hamalainen, “System level analysis of vertical sectorization for 3GPP LTE”, in *Proc. ISWCS 2009*, pp. 453-457, Sep. 2009.

[3] T.L. Marzetta, “Non-cooperative cellular wireless with unlimited numbers of base station antennas,” *IEEE Trans. Wireless Commun*., vol.9, no. 11, Nov. 2010.

[4] Y. Ohwatari, N. Miki, T. Asai, T. Abe, and H. Taoka, “Performance of interference rejection combining receiver to suppress inter-cell interference in LTE-Advanced downlink,” *IEICE Trans. Commun*., vol.E94-B, no. 12, pp. 3362-3369, Dec. 2011.

[5] R. Cadambe and S. A. Jafar, “Interference alignment and degrees of freedom of the K-user interference channel,” *IEEE Trans. Inf. Theory*, vol. 54, no. 8, pp. 3425-3441, Aug. 2008.

[6] R Ratasuk, D Tolli and E Ghosh, “Carrier Aggregation in LTE-Advanced”, *in IEEE Proc. Vehicular Technology Conference (VTC-Spring)*, May 2010.

[7] S Parkval, *et al*., “Heterogenous Network Deployments in LTE” Ericsson Review 2, 2011.

[8] H. Noh, M. Lee, S. Kang, A. Park, Y. Song and S. Lee, “The Future of Mobile

Service: Case of 5G User-centric Individual Moving Cell,” in *IJAST*, Feb. 2014.

[9] M. Porjazoski and B. Popovski, "Contribution to analysis of intercell interference coordination in LTE: A fractional frequency reuse case," in *Proc. Global Mobile Congress (GMC)*, pp. 1-4, Oct. 2010.

[10] Sesia Toufik Baker, “LTE the long therm evoluation”, *Wiley 2nd, edition*. 2010

[11] R. Giuliano, C. Monti, and P. Loreti, “WiMAX fractional frequency reuse for rural environments,” *IEEE Wireless Commun*., vol. 15, no. 3, pp. 60–65, Jun. 2008.

[12] A. Stolyar and H. Viswanathan, “Self-organizing dynamic fractional frequency reuse in OFDMA systems,” *in Proc. IEEE INFOCOM,* pp. 691–699, Apr. 2008.

[13] Zhong Fan, *et al.*, “Access and Handover Management for Femtocell Systems”, *in IEEE Proc. Vehicular Technology Conference (VTC Spring)*, pp. 1-5, May 2010.

[14] Recommendation ITU-R P.1238-7, “Propagation data and prediction models for the planning of indoor radio communication systems and radio local area networks in the frequency range 900MHz to 100GHz”, Feb. 2012.

[15] K. A. Ali, H. S. Hassanein and H. T. Mouftah, "Directional Cell Breathing Based Reactive Congestion Control in WCDMA Cellular Networks", in *IEEE Proc. Symp. on Computers and Communications*, Jul. 2007.

[16] Meng Li, *et al.*, “Frequency and Time Resource Allocation for Enhanced Interference Management in a Heterogeneous Network based on the LTE-Advanced”, *Wireless Communications and Signal Processing (WCSP)*, pp. 1-5, Nov.

[17] Daewon Lee, *et al.*, “Coordinated multipoint transmission and reception in LTE-advanced: deployment scenarios and operational challenges”, in *IEEE communications Magazine*, vol. 50, no. 2, pp. 148 – 155, Feb 2012.

[18] J. Pang, J. Wang, D. Wang, G. Shen, Q. Jiang, and J. Liu, “Optimized Time-Domain Resource Partitioning for Enhanced Inter Cell Interference Coordination in Heterogeneous Networks”, *IEEE WCNC*, pp. 1613-1617, Apr. 2012

[19] M. Li, J. Li, W. Gao, A. Li, Z. Fei, and J. Kuang, “Enhanced dynamic spectrum sharing for multi-cell heterogeneous networks”, *International conference on Wireless Communications and Signal Processing (WCSP)*, pp. 1-5, Nov. 2011.

[20] R.Chang, Z.Tao, J.Zhang, and C.-C.J.Kuo, “A graph approach to dynamic fractional frequency reuse (FFR) in multi-cell OFDMA networks,” *in Proc. IEEE ICC*, pp.1–6, Jun.2009.

[21] S. Hussain and V. C. M. Leung, “Dynamic frequency allocation in fractional frequency reuse OFDMA networks,” *IEEE Trans. Wireless Commun.*, vol. 8, no. 8, pp. 4286–4295, Aug. 2009.

[22] Lei Huang et al, “Resource scheduling for OFDMA/TDD based relay enhanced cellular networks”, *Wireless Communications and Networking Conference(WCNC)*, pp. 1544 - 1548, Mar. 2007.

[23] 3GPP TR 36.133, “E-UTRA; Requirements for support of radio resource

management”, Jun. 2015

[24] 3GPP TR 36.814, “E-UTRA; Further advancements for E-UTRA physical layer aspects”, Aug. 2010.

[25] Afifi, A., *et al*, “Interference-Aware Radio Resource Management Framework for the 3GPP LTE Uplink with QoS Constraints”, *ISCC*, Jul. 2013

1. 초록

최근 셀룰라 시스템에서 급증하는 무선 서비스 부하를 지원할 수 있는 핵심 기술로 소형 셀을 이용한 기술이 주목 받고 있다. 하지만, 기존의 소형 셀 기술은 모바일 사용자의 잦은 핸드오버와 매크로 셀 경계 지역에서의 이기종간의 간섭에 의한 많은 문제를 아직 해결하지 못하고 있다.

본 논문에서는 상기 문제를 해결하기 위해, 기존 펨토 혹은 피코 셀 같은 소형 셀 시스템에 새로운 소형 이동셀 (SMC) 을 추가로 고려한다. 여기서, SMC 는 이동성을 가지고 근거리의 적은 수의 사용자를 서비스 할 수 있는 소형 셀이다. 그리고 SMC 는 인근의 SMC 와 서로 사이드 홀 링크를 생성하여 협조적 운용을 할 수 있고, 매크로 셀과는 무선 백 홀을 통해 통신한다. 매크로 셀과 SMC 는 이기종 셀간의 간섭을 제어 하기 위해 직교하게 자원을 사용한 시스템을 고려한다. 우리는 이와 같은 사용자 중심의 새로운 SMC 시스템에서 이동성을 이용하여 자원 효율을 극대화 시키고 전송 성능을 최대화 할 수 있는 자원 관리 방안을 제안하고, 변하는 환경에 유동적인 동작을 위해 SMC 간 매크로 셀의 도움 없이 협조적으로 자원 관리를 할 수 있는 방안을 고려한다. SMC 간에는 서로 직교하게 자원을 사용하나, SMC 간 사용하는 자원은 최소화 할 수 있도록 제안 기법에서는 PALR (peak-to-average load ratio)이 1 보다 큰 점을 함께 이용한다. 따라서, 제

안 기법은 SMC가 간섭에 대해 영향을 받지 않으면서도 PALR을 실질적으로 낮춰 에너지도 더욱 효율적으로 쓰는 효과를 갖는다. 제안 기법의 성능은 컴퓨터 시뮬레이션을 통해 검증하였다.

主要語 : SMC(small moving cell), PALR(peak-to-average load ratio), 사이드 홀, 협조적 자원 관리

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