공학석사학위논문

밀집된 펨토셀 네트워크를 위한 DTX 시간 할당 방법

Scheduling DTX Time for

Densely Deployed Femtocell Networks

2015 년 8 월

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이 논문을 공학석사학위논문으로 제출함

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Abstract

Scheduling DTX Time for Densely Deployed Femtocell Networks

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To reduce rapidly growing power consumption in wireless network infrastructure, cell downlink discontinuous transmission (DTX) has been considered as a promising candidate under discussion by standardization organization. DTX is also regarded as an ideal solution to avoid inter-cell interference, especially when the cell is under low load condition. We proposed a graph-coloring based scheme to mitigate the femto-to-femto interference of densely deployed femtocell networks with the goal of minimizing supply power consumption while they utilize the DTX operation. If femtocell access points (FAPs) choose different slots to transmit their data and leave the other slots in the DTX mode, then femtocells could reduce mutual interference to achieve high SINR thereby resulting in the reduction of power consumption.

FAPs report their interferers to femtocell management system (FMS), FMS then constructs an interference graph according to their reporting information. Based on the constructed interference graph, FMS determines which FAPs to include in which color groups (CGs) using our proposed graph-coloring algorithm. Then FMS allocates certain amounts of consecutive slots dedicated to FAPs in each CG and reusable slots to the unsatisfied FAPs by means of our proposed slots allocation algorithm.

The simulation results indicate that our proposed solution has better performances than existing schemes in terms of mean power consumption, mean SINR and mean outage probability with a little introduction of signal overhead. In particular, compared with the state-of-the-art scheme, our scheme conserves 15% of power consumption and diminishes almost 85% outage probability.

Keywords : Densely deployed femtocell networks, DTX, graph-coloring

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Chapter 1

Introduction

Since the smartphone was first introduced to the world, its popularity never stops growing. Now, we are living in a world where we cannot imagine a life without it. This phenomena brought some serious problems which we need to deal with carefully. One of them is increasing power consumption caused by densely deployed wireless networks infrastructure such as macrocells, access points, and FAPs. For example, base stations consume almost 60% of total power consumption of cellular networks [1].

We have already been familiar with the sleep mode of base stations. When there is little traffic, like in the late night, although base stations have no traffic to transmit, they still have to consume large amounts of power. In such a situation, base stations could go into sleep to save power. So researches on the sleep mode of base station have become a hot issue recently.

However, with the bursty nature of data traffic, it has become more and more important to reduce power consumption of base stations in short time scales. Researches to find potential solutions for reduction of power consumption in short time scales are currently under exploration. One of the potential solutions is DTX mode which is under discussion by standardization organization [2]. While the sleep mode of base station needs to deactivate many components of base station, the DTX mode just requires to deactivate the most power consuming part of base station, likes power amplifier. And it just takes 30μs [3] to activate power amplifier turning back to idle mode, while the sleep mode costs more than 1 second. So we could say that delay of the DTX mode is negligible even in short time scales. At the same time, the DTX mode could save a great deal of power consumption almost as much as that of the sleep mode, since power amplifier consumes almost 70% of total power consumption of base station.

In consequence, if base station utilizes the DTX mode in low traffic load, after transmitting required data, it could be in the DTX mode in the rest slots of frame. Since the DTX attracted researchers' attention, inter-cell interference has not been carefully considered. Especially, in densely deployed femtocell networks, femto-to-femto interference is a serious problem which cannot be ignored [4]. In a general sense, when femtocell networks use the DTX mode, it is easy to mitigate the femto-to-femto interference by differentiating transmitting slots of interfering FAPs as each FAP just occupies certain slots of frame.

There are a few precedent researches which try to deal with the inter-cell interference while using the DTX mode. In [5], they address the resource allocation problem for multi-user MIMO-OFDM with the goal of minimizing base stations' supply power. As we know, this paper is the first one which deals with the resource allocation problem in combination with the DTX mode. However, although it makes a fairly good contribution to considering the resource allocation problem with the DTX mode, it neglects the inter-cell interference. In this paper, that all base stations transmit their required data from the start of a frame will result in a considerable amount of the inter-cell interference. Consequently, due to the inter-cell interference, each base station needs more slots to transmit required data and leaves less slots in the DTX mode.

Ref. [6] shows that differentiating transmitting slots of interfering cells really causes less power consumptions by mitigating inter-cell interference. Notwithstanding that, it presents the necessity of differentiating transmitting slots, it fails to propose an efficient scheme. Ref. [7] proposes a distributed and heuristic algorithm which could improve the performances, namely cell power consumption and outage probability. In this scheme, each base station scores time slots of coming frame and transmits their data in the time slots with high scores. This heuristic algorithm is mainly about how to score the time slots. In short, it will enhance the score of the selected time slots of past frame and decrease the score of the unselected ones. In addition, it also improves the score of the time slot which has the best channel state in the past frame and expects that every base station will find their transmitting slots with good channel state in several frames. But when the required time slots of base stations and channel state are not static, this scheme is hard to converge and still arouses lots of inter-cell interference. Another issue which results in additional power consumption caused by on/off operations is that in this case the transmitting slots of base stations are not consecutive.

Hence, in this paper, we propose a graph-coloring based slots allocation scheme with the goal of minimizing power consumption of femtocell networks by mitigating the femto-to-femto interference when femtocell networks utilize the DTX mode to save power consumption. To achieve the goal, we guarantee consecutive and dedicated slots to every interfering femtocell. In our scheme, we first make an interference graph in where each node represents a FAP. Secondly, according to the interference graph, interfering FAPs are colored with different colors followed by our proposed graph-coloring algorithm. After interfering FAPs are included in different

CGs, we allocate consecutive and dedicated slots to different CGs and let unsatisfied FAPs reuse the allocated slots of other CGs based on our slots allocation algorithm. The simulation results show that our scheme outperforms the previous works in terms of mean power consumption, mean SINR and mean outage probability. By introducing a little more computational complexity and signal overhead, our scheme conserves 15% of power consumption and diminishes almost 85% of outage probability than does the state-of-the-art scheme.

The remaining part of this thesis is made up of the following sections. In Chapter 2, we will describe the details of system model and Chapter 3 addresses our proposed scheme which is based on the graph-coloring method. The simulation results will be presented and discussed in Chapter 4. Finally, we will reach a conclusion in Chapter 5.

Chapter 2

System Model

In this paper, we just consider the downlink of densely deployed femtocell networks and assume that there is dedicated resource for femtocell networks in the frequency domain. So we do not need to count interference from macrocells. N FAPs are randomly deployed in each apartment of business building and serve one active UE which are also randomly distributed in the same apartment as in Figure. 2.1. The set of FAPs is $S = \{1,2,\ldots,N\}$ $(N = |S|)$. We consider low traffic situation, so that FAPs can utilize the DTX mode to save power consumption. For the convenience of handovers, all these FAPs are timely synchronized and there is a FMC taking control of all these FAPs. The FAPs use an omni-directional antenna and take no interference from FAPs on different floors. System resources are shared via OFDMA by UEs on M subchannels and T time slots. And the set of subchannels is $K = \{1,2,\ldots,M\}$.

Each UE reports its channel state of previous frame, and FAP will transmit its data to the UEs according to the channel state. Further, due to the characteristic of femtocell networks, we ignore short-term fading effects, but focus on the propagation losses and shadowing. We denote P_{ij}^{k} as the strength of the received signal at subchannel k from FAP i to the UE j in the coverage of FAP j. P_{ij}^{k} can be written as

$$P_{ij}^{k} = P_T \varphi \left(\frac{d_0}{d_{ij}}\right)^{\alpha} G_s$$

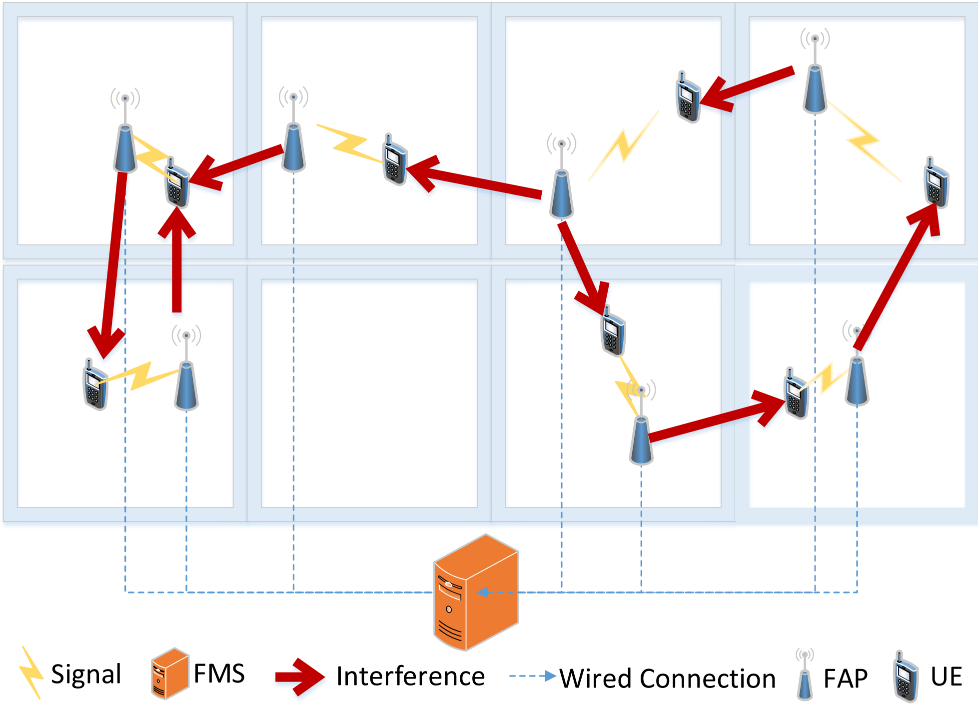

Fig. 2.1: Proposed system model

in which P_T and φ represent the transmit power and a unitless constant which depends on the antenna characteristics and the average channel attenuation, i.e., $\varphi = 20\lg((q/f_c)/(4\pi d_0))$ in dB, respectively. The parameters, q, f_c, and α are the speed of light, carrier frequency, and the path loss exponent, respectively. At last, d_0 means a reference distance which is generally 1m indoors and d_{ij} represents the distance between FAP i and UE j. G_s is used for modeling the lognormal shadowing. We can write the SINR of UE j, γ_j^k, at subchannel k as

$$\gamma_j^k = \frac{P_{jj}^k}{\sigma_N^2 + \sum_{\forall i \in I_j \setminus \{j\}} P_{ij}^k}, \qquad \forall j \in S$$

where σ_N^2 and I_j are the white noise power and a subset of S which is consisted of interfering FAPs in the same color with FAP j. I_j will be decided in the graph formation period of the following section.

For a given γ_j^k, the capacity of FAP *j* at subchannel *k*, C_j^k, can be expressed as

$$C_j^k = w \sum_{\forall k \in K} m_{jk} \log_2\left(1 + \epsilon \gamma_j^k\right)$$

where w is the bandwidth of a subchannel in Hz and m_{jk} is an indicator which represents if subchannel *k* is allocated to FAP *j*. What's more is that ϵ is equal to $-1.5/\ln(5P_e)$ with the target bit error rate P_e, which is 0.001. Finally, we assume γ_{max} and γ_{min} are the minimum and maximum SINRs in dB.

We refer to the general power consumption model of base stations which utilize the DTX mode. The power consumption $P_{supply}(P_t)$ is as follows,

$$P_{supply}(P_t) = \begin{cases} P_{const} + P_{subchn} N_t, & \text{if } P_t > 0, \\ P_{DTX}, & \text{if } P_t = 0. \end{cases}$$

where P_t and P_{const} are the transmission power in any time slot *t* and the minimum active power consumption. In addition, P_{DTX} and P_{subchn} are the power consumption of the DTX mode and the transmission power allocated to each subchannel. Since power control has little effect on the energy efficiency of femtocell networks, we assume that equal power is allocated to each subchannel. N_t is the number of subchannels in usage.

Chapter 3

Proposed Resource Allocation Scheme

In this section, we address a graph-coloring based resource allocation scheme with the goal of minimizing power consumption of femtocell networks by mitigating the femto-to-femto interference. We divide this scheme into two stages: first one is grouping FAPs followed by our proposed graph-coloring algorithm and the other one is to allocate time slots to FAPs by the means of our proposed slot allocation algorithm.

3.1 Proposed Graph-coloring Scheme

We try to group non-interfering FAPs with the same color and by this way, separate interfering FAPs in different colors. So, before coloring, we need to find out interfering FAPs of each FAP and show it by a $N \times N$ binary interference matrix, $B = [b_{ij}](i, j \in S)$. Here, b_{ij} is 1 if FAP i is interfering FAP of FAP j, or otherwise b_{ij} is 0. In addition, if either b_{ij} or b_{ji} is 1, then the other one is also 1. If γ_i^k of FAP i is smaller than γ_{th}, then FAP i will regard the neighboring FAP with the highest reference signal received power as a interfering FAP. And every FAP whose SINR is lower than the threshold repeats above process until its SINR become higher than the threshold.

Based on B, we form an interference graph where each node represents a FAP and every edge stands for an interfering relationship. As discussed before, we try to assign different colors to the interfering FAPs, hence the same color cannot be allocated to the connected nodes. In order to guarantee as much time slots as possible to each CG, we need to use as less number of colors as possible. So we design our graph-coloring algorithm based on the DSATUR (Degree of Saturation) algorithm.

In our proposed graph-coloring algorithm, first we define a color pool *C* and initially there is just one color there. Following this, we order FAPs primarily by θ_i and then secondarily by δ_i. θ_i and δ_i denote the number of different colors to which FAP *i* is connected and the number of uncolored neighbors of FAP *i* respectively. Thus, we choose the FAP *k* with maximum θ_k and higher δ_k. If θ_k of the selected FAP *k* is equal to |*C*|, then add a new color to *C*, and color the FAP *k* with the new color. Otherwise, to minimize the total number of colors, we choose the color *c* which let $\omega_{k,c}$ of FAP *k* be the largest in *C* to color the selected FAP *k*. If there are more than one color which have the largest $\omega_{k,c}$, then find the color *j* whose S_j^{max} is most similar with the s_k of FAP *k*. $\omega_{k,c}$ denotes the total number of neighbors of FAP *k* and these neighbors have at least one neighbor colored with c. s_k and S_j^{max} represent the number of demanding slots of FAP *k* and the largest number of demanding slots of FAPs included in CG *j*. By doing this, we try to let FAPs with the similar s_i be in the same CG. This process continues until all FAPs in the interference graph are colored. The entire process is depicted in the following Algorithm 1.

3.2 Proposed Slots Allocation Scheme

Given that all FAPs are included in certain CGs, now we need to allocate time slots to these CGs and this is to allocate the same number of time slots to the FAPs belonging to the same CG. Furthermore, we plan to allocate dedicated and consecutive time slots to each CG. As far as the number of time slots allocated to the

CGs, we try to assign as much as possible to meet slots requirement of the FAPs included in each CG.

Because the number of active FAPs may be different in certain time and the density of deployment of FAPs are distinct in different environments, the number of CGs could be different. Moreover, if the number of CGs fluctuates, slots allocation scheme need to be different due to the fixed number of total time slots, S_{total}. Hence, we expect there are three cases. First case is that S_{total} is fairly enough, and second case is S_{total} is in shortage, but better than last case. The third case is that S_{total} is in a serious shortage. We tell these three cases by comparing S_{total} with two different sum of slots requirements of CGs. If the S_{total} is totally adequate, which means that S_{total} is smaller than S_{req1}, then we allocate the S_j^{max} to CG j (j∈C). Here, the first type of sum of slots requirements of CGs, S_{req1} is as follows,

$$S_{req1} = \sum_{j=1}^{N_g} S_j^{max}$$

where N_g is the total number of CGs. For the remnant slots, S_1^{rem}, we distribute them in a round robin way. The allocated number of slots of CG j, S_j^{alloc} is S_j^{max} plus the slots assigned from the distribution of S_1^{rem}.

If the S_{total} is less than S_{req1}, namely the second case, then we try to at least guarantee the required number of slots to the FAP with no reusable color. Once a FAP has reusable color, although the allocated number of slots may be less than its required one, it could reuse other time slots allocated to the reusable CGs. However, for those FAPs with no reusable color, it is better to allocate them as many slots as possible. Thus the second type of sum of slots requirements of CGs, S_{req2}, is as follows,

$$S_{req2} = \sum_{j=1}^{N_g} S_j^*$$

where S_j^* is either S_j^{avg} when there is no FAP with no reusable color in CG j or S_j^{req*} when there is a FAP with no reusable color and its demanding number of slots is larger than S_j^{avg}. S_j^{avg} and S_j^{req*} denote the average number of slots requirements of FAPs in CG *j* and the number of slots requirement of the FAP with no reusable color in CG *j*. If S_{req2} is less than S_{total}, we allocate S_j^* to each CG *j*. Next, distributing the remnant time slots, S_2^{rem}, is necessary. The allocated number of slots of CG *j*, S_j^{alloc} is S_j^* plus the slots assigned from the distribution of S_2^{rem}. For the unsatisfied FAPs, they divide their lacking slots to reusable CGs in proportion with the allocated slots of CGs. So FAP *i* requests for reusing CG *j* according to $r_{i,j}$ which is the number of slots that FAP *i* requests to reuse from CG *j*. And then, CG *j* decides the reusable number of slots, $R_{i,j}^{reuse}$ for FAP *i* in proportion with $r_{i,j}$.

In the third case, we have to allocate S_{total} to CGs in proportion to S_j^{avg}. Thus the allocated number of slots of CG *j*, S_j^{alloc} is as follows,

$$S_j^{alloc} = S_{total} \times \left(S_j^{avg} / \sum_{j=1}^{N_g} S_j^{avg} \right)$$

The reuse part is exactly the same with that of the second type. The entire scheme is shown in the following Algorithm 2.

Algorithm 1: Proposed graph-coloring scheme

while (there is an uncolored FAP){

sort all uncolored FAPs by decreasing order of θ;

if (there is one FAP k having θ_{max})

select the FAP k;

else (there are many FAPs having the same θ_{max})

among these FAPs, select FAP k having δ_{max};

if (there are available colors in *C*)

if (there is one color *j* making maximum $\omega_{k,j}$)

color FAP k with the color *j*;

else

color FAP k with color *j* which has most similar S_j^{max} with s_k of BS_k;

else

increase the size of *C* by 1 and color BS_k with the newly added color;

BS_k will be included in the CG *j* and s_j^{max} of CGs is updated; }

Algorithm 2: Proposed Slots Allocation Scheme

if ($S_{total} \geq S_{req1}$)

allocate S_j^{max} to CG *j* and then, distribute S_1^{rem} to CGs;

else if ($S_{total} \geq S_{req2}$){

allocate S_j^{*} to CGs, distribute S_2^{rem} to CGs;

unsatisfied FAPs divide lacking slots to reusable CGs in proportion with S_j^{alloc};

CG *j* allows FAP *i* to reuse $R_{i,j}^{reuse}$ in proportion with $r_{i,j}$;

else if {

allocate S_{total} to CG *j* in proportion with S_j^{avg};

unsatisfied FAPs divide lacking slots to reusable CGs in proportion with S_j^{alloc};

CG *j* allows FAP *i* to reuse $R_{i,j}^{reuse}$ in proportion with $r_{i,j}$;

Chapter 4

Performance Evaluation

In this section, we analyze our proposed scheme first and then compare it with the previous works with regard to mean power consumption, mean SINR and mean outage probability in different densities of FAPs. The two compared schemes are: sequential alignment [6] and memory-based alignment [7].

4.1 Simulation Environment

We set up our simulation environment using java language. We consider 50×50m business building [8] as a typical indoor environment and fix α accordinglly. There are 25 apartments in each floor of the building and we focus on one of the floors. In each apartment, the probability of existences of FAPs is φ and either FAP or the UE is randomly distributed. And we assume there is 3MHz bandwidth dedicated to the femtocell networks in the carrier frequency of 2GHz. P_{const}, P_{DTX}, and the on/off operation cost power consumption of 4.8W, 2.5W, and 1W respectively. Other parameters are listed in Table 4.1.

4.2 Simulation Results

Since the SINR threshold γ_{th} affects the formation of interference graph, it has an important effect on the performance of our proposed scheme. So, initially, we will check some measurements of our proposed scheme under different γ_{th} ranging from 0dB to 15dB in the following part. To see the effect of γ_{th} clearly, we try to deploy

Table 4.1: Simulation parameters

Parameter	Value
The number of subchannels	50
FUE fraffic load (γ Mbps)	$1 \leq \gamma \leq 5$
The number of FUEs/FAP	1
Min distance between FAP	5m
Min distance between FAP and	0.2m
FAP's transmission power	10dBm
α for business building	3.0
Min and Max SINRs	-10dB; 30dB
Shadowing standard deviation	4dB
σ_N^2	-174dBm/Hz
FUE's mobility (ω km/h)	$0 \leq \omega \leq 6$
Correlation distance	3m
Probability φ of FAP's existence	[0.5, 1.0]

FAPs densely and thus set φ =1.0.

Fig. 4.1 describes the results of mean SINR and mean number of colors as the γ_{th} increases. Because the higher γ_{th} causes the more interferers of FAPs, the mean number of colors increases as the γ_{th} rises. For interfering FAPs, as we allocate dedicated slots to FAPs, their SINRs become much better. So when the interference graph gets more complicated due to the growth of the γ_{th}, the mean SINR of FAPs is getting higher.

In Fig. 4.2, the mean power consumption and mean outage probability are depicted as the γ_{th} increases. As mentioned before, the mean SINR increases when the γ_{th} grows. Owing to the higher mean SINR, FAPs need less time slots to transmit their required data, resulting in less mean power consumption. In contrast, the mean outage probability decreases as the γ_{th} increases which is easy to understand. While the γ_{th} increases, we already know the number of colors grows. Then the amounts of time slots for each CG diminishes. So the mean outage probability of FAPs increases because of the shortage of time slots. We can found out

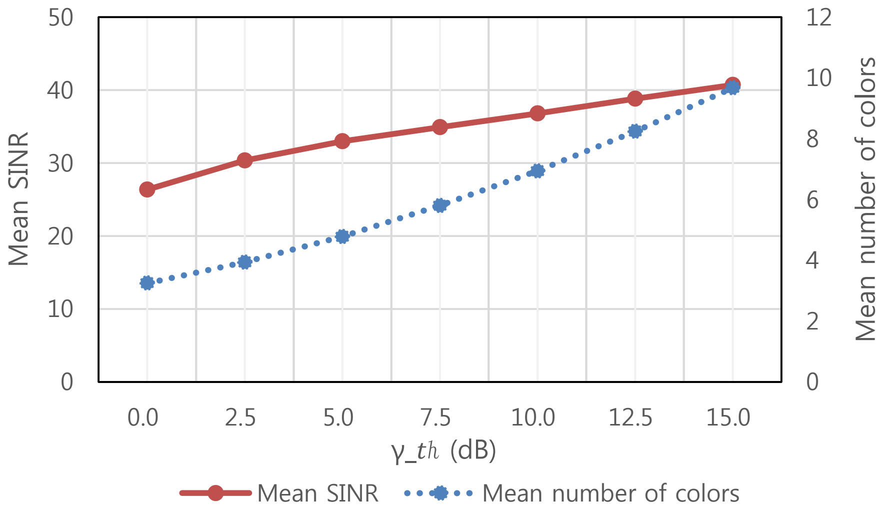

Fig. 4.1: Mean SINR and mean number of colors vs. γ_{th}

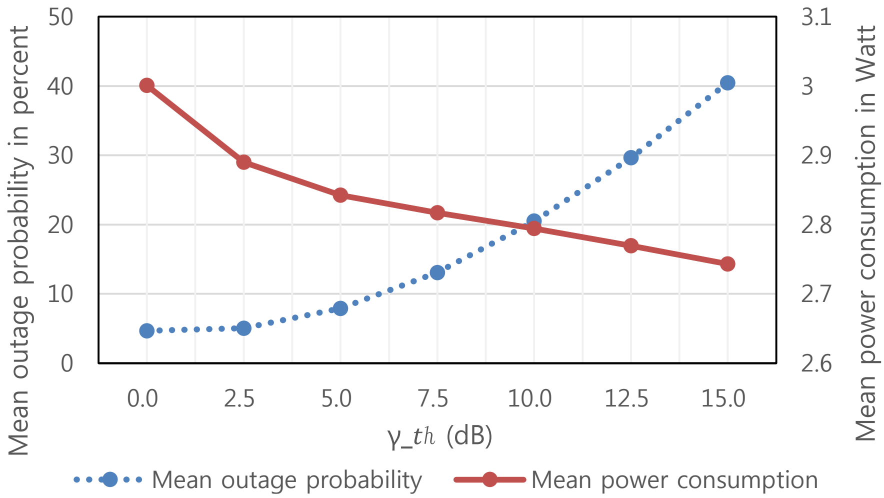

Fig. 4.2: Mean power consumption and mean outage probability vs. γ_{th}

that there is a tradeoff between the mean power consumption and the mean outage probability. By considering that the mean power consumption decreases slowly and the mean outage probability increases sharply when the γ_{th} is more than 5dB, 5dB is the best for the value of γ_{th} in our scheme. Thus, afterwards, we set γ_{th} as 5dB.

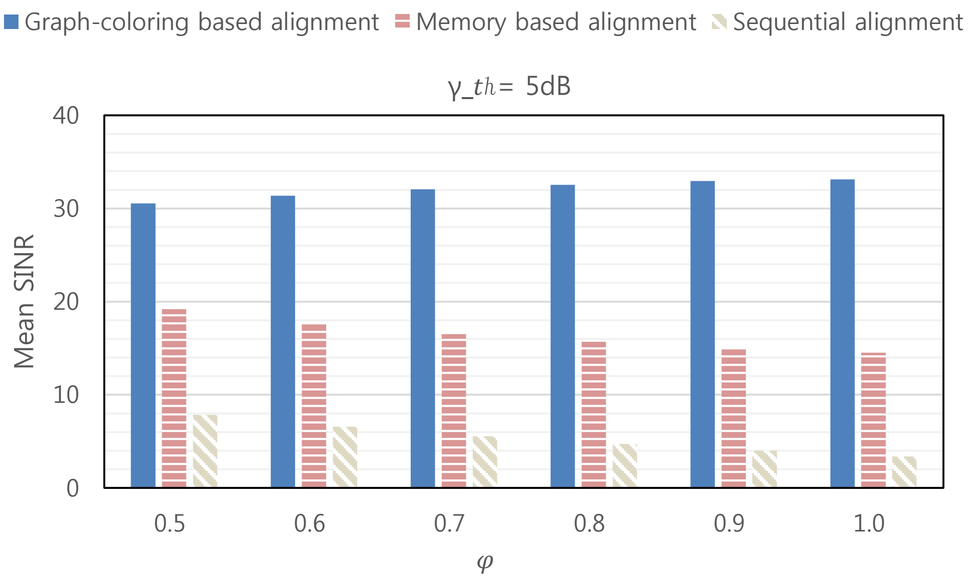

Fig. 4.3: Mean SINR vs. φ

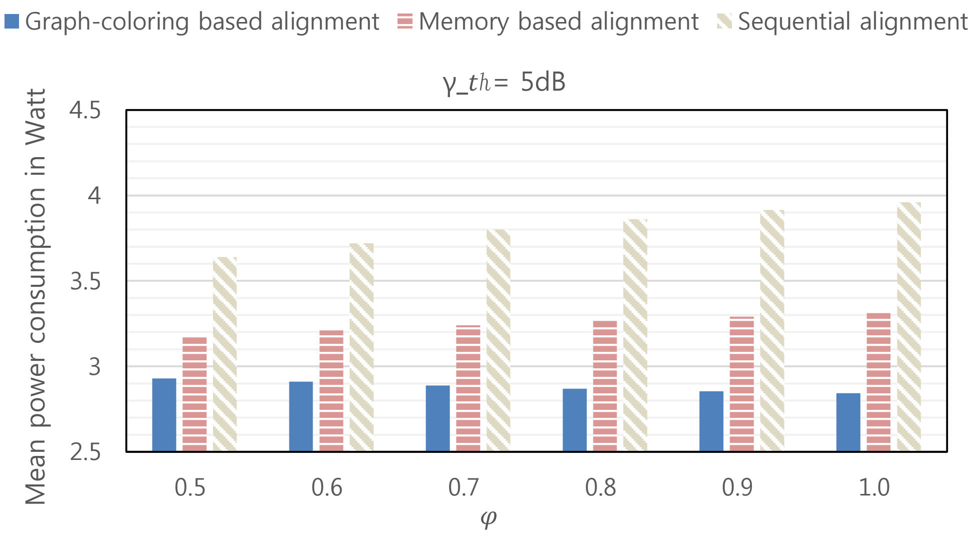

Fig. 4.4: Mean power consumption vs. φ

In the following part, we compare our proposed scheme with the previous works. Fig. 4.3 shows the mean SINR of schemes in different densities. In all different densities of FAPs, we can conclude that our proposed scheme has higher mean SINR

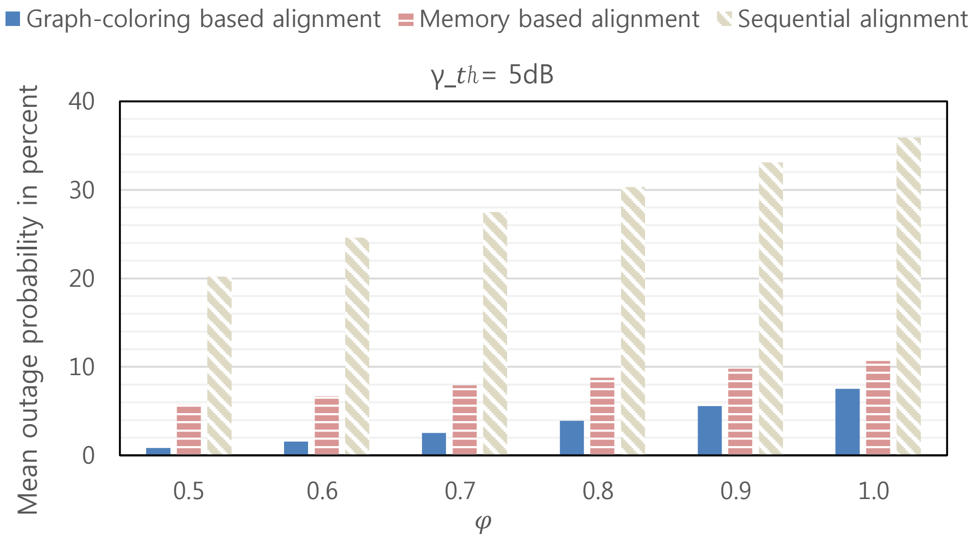

Fig. 4.5: Mean outage probability vs. φ

than the others. As expected in Chapter 2, sequential alignment has the worst performance, because all FAPs try to transmit their data at the same time which incurs the highest mutual interferences. For the memory based alignment, since the demanding time slots and channel state are fluctuant, the opportunity of collisions of transmit slots is still high. Thus its mean SINR is lower than our proposed scheme.

Fig. 4.4 describes the result of the mean power consumption as φ increases. As shown before, sequential alignment needs more time slots due to its lowest mean SINR. Thus, the mean number of time slots allowed to be in the DTX mode is the minimum and thus the mean power consumptions is the maximum. For the memory based alignment scheme, it requires many time slots to transmit the requested data owing to its low SINR. In other words, it cannot allow many time slots to be in the DTX mode. As a result, it consumes lots of power consumption as well, although its performance is much better than the sequential alignment. In addition, because the transmitting time slots of this scheme is not consecutive, so it has to cost additional power for on/off operations. Our proposed scheme needs the minimum power consumption, since it just transmits their data in the allocated slots and SINR of the allocated time slots is fairly high in term of less interference.

Fig. 4.5 depicts the result of the mean outage probability as φ increases. In this thesis, we regard that outage will happen when UE's data rate requirement is not satisfied. For sequential alignment, because of its poor SINR, some FAPs cannot meet data rate requirement of their serving UE. So its mean outage probability is very high. Although the mean outage probability of memory based alignment is much better than that of sequential alignment, it still has worse performance than our proposed scheme. However, when FAPs become denser, the mean outage probability of our proposed scheme increases more sharply than others. The reason is that when the density of FAPs increases, the dedicated time slots for each CG get less.

As mentioned before, we need a central controller named FMS in our scheme while other two schemes do not need that. Additionally, FAPs report its interferers and slots requirements to FMS and then, FMS feedbacks the results of resource allocation to FAPs after the execution of our proposed algorithms. As a result, there is additional overhead in our scheme. Overhead of our scheme is shown in Table 4.2.

Table 4.2: Overhead of proposed scheme

Signal	Feedback
$N \times N$ bits/superframe	20 N bits/frame

Chapter 5

Conclusion

Because of its energy saving property, DTX mode of base stations attracts researchers' attentions and is regarded as one of the potential candidates to reduce power consumption in cellular networks. Furthermore, if base stations utilize the DTX mode, there is more room for further mitigating inter-cell interference, resulting in additional power saving. We need to take more consideration of the inter-cell interference which can be serious, particularly in densely deployed femtocell networks. So we propose a graph-coloring based scheme to mitigate femto-to-femto interference of densely deployed femtocell networks with the goal of minimizing supply power consumption.

The simulation results have shown that our proposed solution gives better performance than existing approaches in terms of mean power consumption, mean SINR and mean outage probability with only a little introduction of computational complexity and signal overhead. In precise, compared with the state-of-the-art scheme, our scheme saves 15% of power consumption and decreases almost 85% of outage probability.

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요약

대 규모의 무선 네트워크 인프라의 구축 및 사용으로 인한 파워 소모가 날로 많아지고 있다. 셀의 로드가 적은 상황에서 불필요한 파워 소모를 줄이고자 셀 비 연속 전송 (DTX)이 제안되어서 최근 표준화 조직과 많은 연구자들의 주목을 받고 있다. 그러나 DTX를 사용할 때의 인접 셀들의 간섭문제에 대한 선행 연구가 많이 이루어지지 않고 있다. 그래서 우리는 DTX를 사용하는 밀집된 펨토셀 네트워크 상황에서 그래프 컬러링을 기반으로 하여 인접한 셀들의 상호간의 간섭을 줄이는 방법을 제안했다. 우리가 제안한 방법으로 하면 펨토셀들이 서로 다른 슬롯에서 데이터를 전송하게 되는데 이렇게 함으로써 상호간의 간섭을 크게 줄여 결과적으로 적은 양의 슬롯으로 데이터를 전송하고 나머지 많은 슬롯에서 DTX 모드를 취하게 하여 파워소모를 줄일 수 있다.

본 논문에서 펨토셀 네트워크 관리자는 펨토셀들로부터 전달받은 정보에 의하여 펨토셀들간의 간섭을 나타내는 그래프를 만들어낸다. 그리고 얻어진 간섭 그래프를 제안하는 그래프 컬러링 알고리즘에 따라 서로 간섭을 주는 펨토셀들에게 서로 다른 색을 컬러링을 한다. 뒤이어 제안하는 슬롯 할당 알고리즘에 의하여 서로 다른 색의 펨토셀들에게 일정한 양의 슬롯을 할당한다. 부족한 펨토셀들은 재사용 가능한 색에 할당된 슬롯을 재사용한다.

시뮬레이션 결과에 의하면 저희가 제안하는 방법이 기존의 연구들에 비해서 평균 시그널 파워 대비 간섭의 비, 평균 소모하는 파워 와 평균 재전송 확률 등 면에서 더 좋은 성능을 보이고 있다. 특히 최근의 연구와 비교해보면 15%의 파워소모를 절약하고 85% 이상의 재전송 확률을 줄이고 있다.

주요어 : 밀집된 펨토셀 네트워크, DTX, 그래프 컬러링

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