Performance Analysis and Evaluation of Deployment in Small Cell Networks

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Abstract

Small cells are deployed in Heterogeneous Networks (HetNet) to improve overall performance. These access points can provide high-rate mobile services at hotspots to users. In a Small Cell Network (SCN), the good deployment of small cells can guarantee the performance of users on the basis of average and cell edge spectrum efficiency. In this paper, the performance of small cell deployment is analyzed by using system-level simulations. The positions of small cells can be adjusted according to the deployment radius and angle. Moreover, different Inter-Cell Interference Coordination (ICIC) techniques are also studied, which can be implemented either in time domain or in frequency domain. The network performances are evaluated under different ICIC techniques when the locations of Small evolved Nodes (SeNBs) vary. Simulation results show that the average throughput and cell edge throughput can be greatly improved when small cells are properly deployed with the certain deployment radius and angle. Meanwhile, how to optimally configure the parameters to achieve the potential of the deployment is discussed when applying different ICIC techniques.

Keywords: Small Cell Network, Inter-Cell Interference Coordination

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1. Introduction

With the population of smart phones and other mobile devices increasing drastically, there is a rapid growth of wireless traffic expected over the coming few years [1]. In order to meet the demand of ubiquitous network access and high rate wireless services, wireless operators are finding new ways to provide seamless coverage and improve the network capacity. Small Cell Network (SCN) is come up with by Third Generation Partnership Project (3GPP), as an effective solution to accommodate the traffic need of high-density user equipments (UEs) in Long Term Evolution Advanced (LTE-A) networks [2]. The main motivation of deploying SCNs is based on the idea of cell densification [3]. The evolved Node B (eNB) in a SCN can be called Low Power Node (LPN) or Small eNB (SeNB), which usually has a lower transmit power compared with Macro eNB (MeNB) [4]. The introduction of SeNBs can provide high data rate in hotspots and offload the data traffic from the congested macro cell. However, the increase in network capacity is achieved at the expense of the deployment cost and interference issues [5].

Various techniques have been adopted to explore the potential capacity of SCNs. For example, Inter-Cell Interference Coordination (ICIC) is effective when small cells are overlaid with macro cells [6]. In frequency domain, Fractional Frequency Reuse (FFR) is commonly applied including strict FFR and Soft Frequency Reuse (SFR). The usable spectrum is partitioned into equal sub-bands and then the sub-bands are assigned to different sectors or areas in a macro cell. This can feasibly cancel the interference at the cost of spectrum efficiency [7]. Almost Blank Subframe (ABS) is a typical ICIC scheme in time domain, aiming to decrease the interference from MeNB [8]. In ABS, a MeNB only transmits reference signal to decrease the interference. This technique is always combined with Cell Range Expansion (CRE) to further improve the performance of the users in the expanded range of small cells [9].

Some existing literature focused on the deployments or the positions of the SeNBs in SCN. In [10], the authors analyzed the system performance of random SCNs compared to that of the perfectly regular topology. While in [11], algorithms that utilize interference and physical environment knowledge to assist LPN deployment are proposed. The authors also evaluate planning complexity, capital expenditure and energy consumption of the network. However, the scope of this paper is to examine how to deploy SeNBs in SCN from the viewpoint of the system throughput and ICIC, which is not well-investigated so far. In our study, SeNBs are deployed on a circle whose center coincides with the sector's center of MeNB. Based on extensive simulations with different radius and central angle of the deployment circle, average throughout and cell edge throughput are evaluated. Moreover, different ICIC techniques in LTE-A are also combined with the deployment of SeNBs to achieve the best configuration of the network.

The rest of the paper is organized as follows: Section 2 presents the system model and ICIC techniques. The topology of SCN and the parameters when deploying SeNBs are given. It also addresses basic resource partitioning schemes in frequency domain ICIC and Almost Blank Subframe (ABS) combined with Cell Range Expansion (CRE) in time domain ICIC. Section 3 gives the simulation methodology in SCN. Section 4 demonstrates that ICIC techniques and suitable positions of SeNBs can greatly improve the system performance via extensive simulations. The appropriate configurations are provided according to the results. Section 5 concludes the paper.

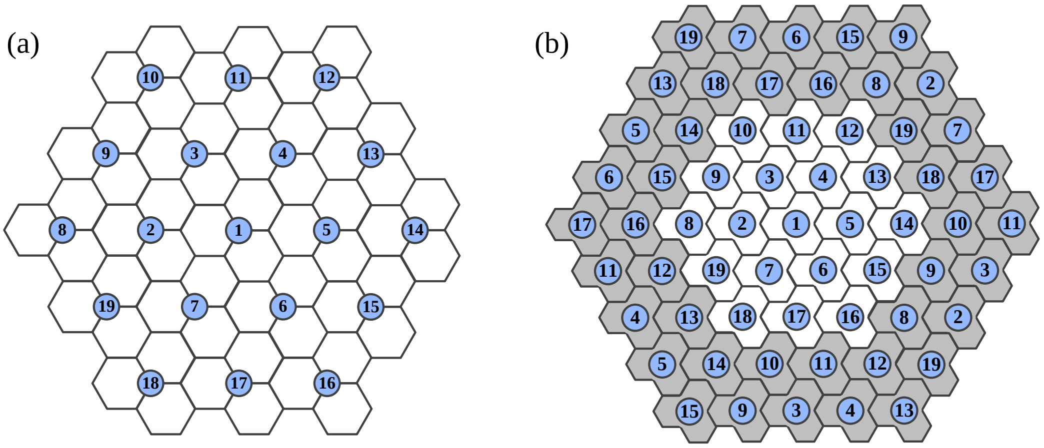
2. System Model and ICIC techniques

2.1 Topology of Small Cell Network (SCN).

SCN mainly consists of two components, i.e., macro cells and small cells, where the former provide mobility while the latter boost coverage and capacity. For comparison purpose, we discuss the topology of network with only macro cell as well as that of SCN.

For macro-only network, it only consists of several macro cells (e.g., 4, 7 or 19 cells), each of which has a MeNB serving a few Macro UEs (MUEs). Usually, there are two typical scenarios for MeNB deployment, i.e., urban and suburban. The major difference between these two scenarios is the radius of macro cell and the density of MUEs. In this paper, the urban scenario is considered because it is more necessary to introduce the small cells for better coverage and capacity.

As shown in **Fig. 1 (a)**, the network is composed of 19 macro cells. Each MeNB is located at the center of macro cell with three regular hexagon sectors. The cells are numbered outward from the center with small blue circles.



(a) Topology of cellular network

(b) Wrap-around deployment

Fig. 1. Macro-only network and wrap-around deployment.

Apart from the downlink signal from the serving MeNB, each MUE receives interferences from other neighboring MeNBs. In this paper, interferences from two layers of cells outside the serving cell are considered. Since only Cell 1 has the completed interference environment, the wrap-around technique is adopted to remedy this flaw [12], as presented in **Fig. 1 (b)**. To complement the interference sources, two layers of cells are virtually added outside the 19-cell network. These two layers are used only to calculate the interference and do not exist ‘physically’. From another point of view, these 19 cells can be viewed as placed on a sphere. The concrete number of cells is marked in the figure and omitted here. The technique of wrap-around guarantees the completed interference environment in the premise of not introducing new cells. MUEs can select the serving MeNB according to the Reference Signal Received Power (RSRP). It is noted that the MUE may not locate at the same macro cell as its serving MeNB. These MUEs are usually situated in the edge of the cell.

User distribution has a large effect on system performance. In macro-only cellular network, MUEs are usually assumed to be uniformly distributed. Also, MUEs cannot be too close to their serving MeNB [13].

Consider a two-layer SCN with small cells in this paper. The topology of each macro cell is presented in **Fig. 2**. In a macro cell, SeNBs are deployed together with their donor MeNB. The positions of the SeNBs are one of the important factors determining the system performances. In our simulation, two SeNBs are deployed in each sector. Let the SeNB be situated on the circle whose center coincides with the sector's center and be symmetric in regard to the bore-sight of the MeNB antenna. There are two variable parameters, α and θ_p , which represent the radius of the circle and the central angle of the deployment circle, respectively.

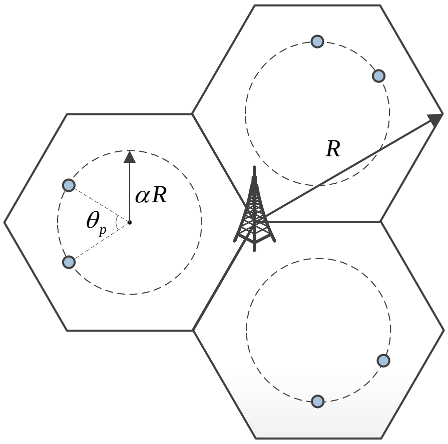


Fig. 2. Topology of a two-layer SCN.

2.2 Inter-Cell Interference Coordination techniques in SCN.

In this section, ICIC techniques applied in frequency domain and time domain are analyzed. In frequency domain, FFR including strict FFR and SFR are widely used. The spectrum partitioning scheme is also discussed in this section. In order to offload the users of macro cells to small cells, CRE can be applied in time domain. In certain subframes, MeNBs mute the transmission to decrease the interference to Small Cell UEs (SUEs).

A. Frequency Domain ICIC.

Deploying SeNBs at the same or different frequency layer as the MeNB presents different interference situations. As shown in **Fig. 3**, orthogonal and full reuse are usually two basic resource partitioning schemes when a SCN is deployed [14], coming from the concept of classical clustering technique [15-16]. The former scheme means that users from macro cells and small cells do not share the same radio resource. Hence, there is no co-channel interference between MUEs and SUEs. However, the spectrum efficiency of this scheme is relatively low. Oppositely, MUEs and SUEs can share the entire bandwidth in the latter scheme. The improvement of spectrum efficiency is achieved at the cost of the introduction of more interference. In SFR scheme, the spectrum is partitioned into three equal sub-bands. Each sub-band is assigned to edge users in different sectors in the same macro cell. The center users are allowed to share sub-bands with edge users in other sectors. Because center users share the spectrum with neighboring cells and sectors, they typically transmit at a lower power level. For the edge users, the reuse frequency factor may be three. Detailed analysis can be found in [17]. In this way, the cell edge throughput is improved. For the underlaying small cells, they operate on the whole band without partitioning to maintain the performance at hotspots.

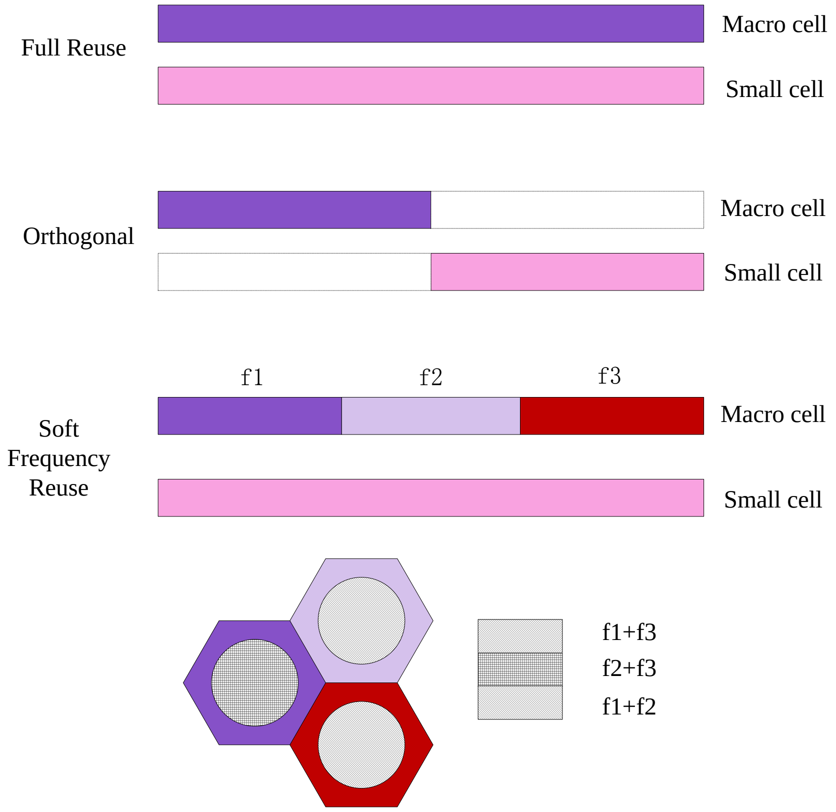


Fig. 3. Resource partitioning scheme.

The *Full Reuse* deployment of a heterogeneous network is attractive since the spectrum efficiency is higher and more feasible in case of the limited spectrum. SFR is also attractive due to the good performance tradeoff between cell edge users and central users. It can effectively eliminate the adjacent inter-cell interference at cell edge area. In the case of orthogonal scheme, although interference is totally avoided between layers, spectrum efficiency is not satisfied.

In SCN, a MUE receives the desired signal from its serving MeNB as well as the noise and interferences from other eNBs. In case of orthogonal scheme, the interference only come from N_1 neighboring MeNBs, called intra-layer interference. In our evaluation, N_1 =18, and they are distributed two circles outside the serving cell. The wrap-around technique is applied when the serving cell is not the center one. The received SINR of a MUE in the downlink can be expressed by

Orthogonal:

$$\eta_i^{MUE} = \frac{\alpha_{i,j} P_M}{\sigma^2 + \sum_{m \neq j} \alpha_{i,m} P_M}, \tag{1}$$

where P_M and $\alpha_{i,j}$ are the transmit power of sector *j* of MeNB and the channel gain from the serving MeNB to a given user *i*, respectively. $\alpha_{i,m}$ is the channel gain from other sectors of

MeNB in this network and σ^2 is the noise power of the Additive White Gaussian Noise (AWGN). When *Full Reuse* and *SFR* scheme are adopted in SCN, the interference from the SeNBs, i.e., inter-layer interference, have to be included in calculating the SINR of a MUE, i.e.,

Full reuse:
$$\eta_i^{MUE} = \frac{\alpha_{i,j}P_M}{\sigma^2 + \sum_{m\neq j}\alpha_{i,m}P_M + \sum_k \alpha_{i,k}P_S}, \tag{2}$$

SFR:
$$\eta_{i,edge}^{MUE} = \frac{\alpha_{i,j}P_M}{\sigma^2 + \sum_m \alpha_{i,m}\delta P_M + \sum_{m\neq j}\alpha_{i,m}P_M + \sum_k \alpha_{i,k}P_S},$$

(3)

$$\eta_{i,central}^{MUE} = \frac{\alpha_{i,j}\delta P_M}{\sigma^2 + \sum_{m\neq j}\alpha_{i,m}\delta P_M + \sum_m \alpha_{i,m}P_M + \sum_k \alpha_{i,k}P_S}, \tag{4}$$

where P_S and $\alpha_{i,k}$ are the transmit power of SeNB and the channel gain from the *k*th SeNB to a given MUE *i*, respectively, and there are N_2 neighboring SeNBs having the co-channel interferences, e.g., $N_2 = (6*19-1)$ is assumed in this paper. In *SFR*, δ is the factor of transmit power for center users. The interference of macro cell consists of two parts, the interference from the sectors with decreased power (with factor δ) and the interference from the sectors with normal power (without factor δ).

Similarly, the received SINRs of a SUE can be calculated, i.e.,

Orthogonal:
$$\eta_i^{SUE} = \frac{\beta_{i,j}P_S}{\sigma^2 + \sum_{k\neq j}\beta_{i,k}P_S}, \tag{5}$$

Full reuse:
$$\eta_i^{SUE} = \frac{\beta_{i,j}P_S}{\sigma^2 + \sum_{k\neq j}\beta_{i,k}P_S + \sum_m \beta_{i,m}P_M},$$

(6)

SFR:
$$\eta_i^{SUE} = \frac{\beta_{i,j}P_S}{\sigma^2 + \sum_m \beta_{i,m}P_S + \sum_m \beta_{i,m}\delta P_S + \sum_{k\neq j}\beta_{,i}P_k},$$

(7)

where $\beta_{i,j}$ is the channel gain from the *j*th SeNB to a given SUE *i*. The interference in SFR scheme is different based on the allocated resource block (RB), e.g. if RB in the first sub-band is allocated to this user, it will receive normal power interference (without factor δ) from

ID=1 macro sectors and decreased power interference (with factor δ) from ID=2 or 3 macro sectors.

B. Time Domain ICIC.

Although the deployment of SeNBs can effectively offload the data traffic from macro cells, channel condition of SUEs is not always perfect at hotspot areas. When applying a CRE bias for more users to associate to SeNB, the SINR of SUE in the expanded range is always below 0dB, as shown in **Fig. 4 (a)**. As illustrated in **Fig. 4 (b)**, in these Almost Blank Subframes (ABS), MeNB transmits only Cell-specific Reference Signal (CRS) and some cell-acquisition channels to decrease the severe interference to the SUEs, especially SUEs in the expanded area. As a matter of priority, expanded range SUEs are scheduled in ABS and center SUEs are scheduled in normal subframes. Note that the rate of ABSs to normal subframes can be adjusted to keep the balance of MUEs and SUEs. Combining CRE and the Time Domain Multiplexing (TDM) ICIC may optimally configure the network with perfect synchronization between MeNBs and SeNBs.

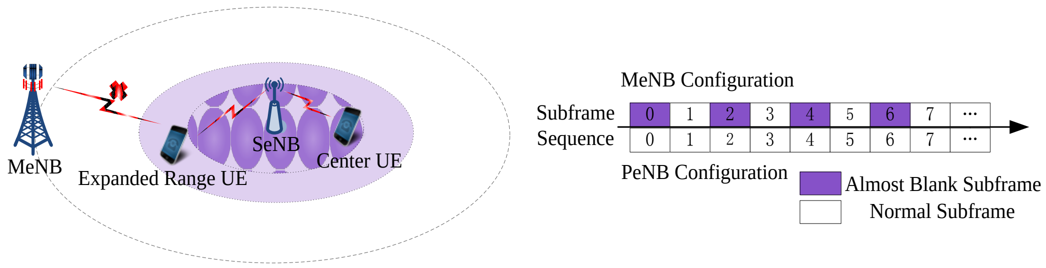

(a) (b)

Fig. 4. Cell range expansion and ABS configuration.

3. Simulation Methodology in SCN

3.1 Simulation Procedure

Monte Carlo simulations are carried out to analyze the system performance in SCN, where the results are collected through a large enough number of snapshots. In each snapshot, the locations of MeNBs and SeNBs are fixed, whereas the locations of UEs vary. The simulation converges as long as plenty of snapshots are carried out. The complete static simulation includes five processes, as shown in **Fig. 5**. Firstly, UEs are dropped in the network according to a variety of distributions, such as uniform distribution, Gaussian distribution and so on. In this paper, two-dimension uniform distribution is adopted. Secondly, the RSRPs of all the links are calculated with the consideration of channel propagation. Then, according to the given user association policy, e.g., the maximum received power, each UE associates to either MeNB or SeNB. Next, an important indicator of UE performance, i.e., the Signal-to-Interference-plus-Noise Ratio (SINR) is derived. Finally, SINR is mapped to Throughput (TP) by using Link-to-System (L2S) interface and the system performance is calculated.

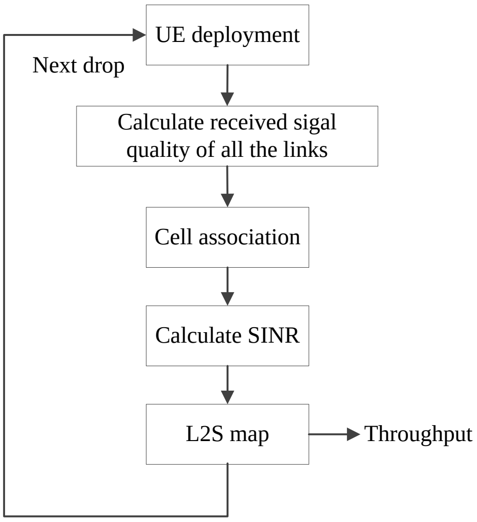


Fig. 5. Illustration of Simulation procedure.

3.2 Simulation parameters in SCN.

The performance of the network under different SCN deployment and ICIC technologies is evaluated through system-level simulations. For each single user, the capacity of Multiple-Input Multiple-Output (MIMO) channel is deduced, assuming the channels to be static and power is equally allocated [18]. The parameters of SCN are presented in **Table 1**. More details can be found in [13].

Table 1. Parameters of small cell network.

Parameter	**Value**
Cell layout	3 sectors, hexagon
ISD	500 m
MeNB number	19
MUE number	20 per sector
UE distribution	Uniform distribution
Carrier frequency	2G Hz
Bandwidth	10M Hz
MeNB transmit power /antenna gain	46 dBm/14 dBi
Antenna system	2Tx, 2Rx, SU-MIMO
MeNB Antennal model	Tri-sector Directional Antennas
Penetration Loss	20 dB
Path loss (dB): MeNB to UE	$PL(\text{dB}) = 128.1 + 37.6\log_{10} R$, R in km
Path loss (dB): SeNB to UE	$PL(\text{dB}) = 140.7 + 36.7\log_{10} R$, R in km
Shadow fading	Lognormal distribution
Small eNB number	2 per sector
Small eNB location	Circle centered on the sector center

Minimal distance (UE-Small eNB)	3 m
Transmit power /antenna gain	30 dBm/5 dBi
SeNB Antennal model	Omni-directional
Noise density	-174 dBm/Hz

Although joint investigation on both deployment radius and angle may derive the optimized system performance, the complexity is too high to afford. Therefore, the study on deployment radius and angle are carried out separately. When deployment radius is fixed, the throughput may increase or reduce according to the variation of deployment central angle, and vice versa. Furthermore, the influences of time domain or frequency domain ICIC techniques are taken into consideration separately combined with variation of the deployment parameters.

4. Deployment Performance Analysis

In this section, the performances of SeNB deployment in SCN are evaluated from the viewpoint of the system throughput and ICIC techniques. The cell edge throughput, i.e., 5th percentile throughput, and average throughput are two key indicators to evaluate fairness and capacity, respectively. The compromise has to be made between them from the view of system design.

4.1 Effects of SeNB deployment radius on capacity performance.

We first evaluate average user throughput and cell edge throughput when α ranges from 0.2 to 0.5 in case of $\theta_p = 60°$. If two SeNBs are too close to each other, i.e., α is too small, the interference is unacceptable. When α equals 0.5, the circle is tangent to the hexagon sector.

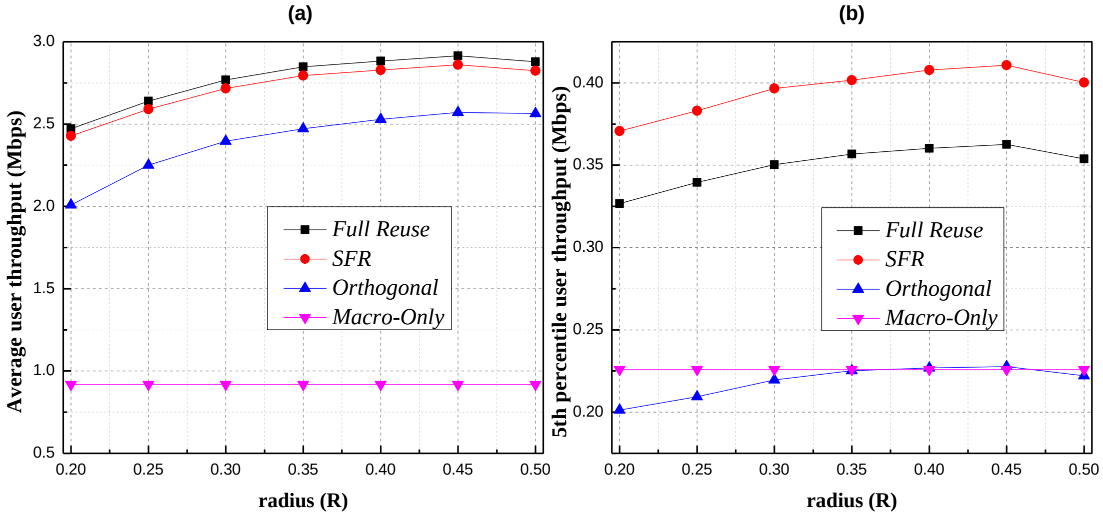


Fig. 6. Performance comparison with different spectrum reuse schemes ($\theta_p = 60°$).

As shown in **Fig. 6 (a)**, with different ICIC schemes, average user throughput of SCN is apparently higher than that of traditional cellular network. The indicator of improvement can even approximate 100% or more. Meanwhile, in **Fig. 6 (b)**, the increase of cell edge (5 percentile) user throughput is not so optimistic with the orthogonal spectrum partitioning scheme. The cell edge performance may be even worse than that of traditional network when α is too small or too large. The average and cell edge throughput both increase as α augments and then begin to decrease after the extreme value.

When α is small, two SeNBs are deployed closely. Hence the users associated to one SeNB may receive strong interference from the other. These users will definitely achieve low SINR value, and will possibly have a low throughput value. As α gradually increases, the distance between the two SeNBs becomes larger. More users will associate to small cells when small cells don't overlap with each other much. This can balance the load of macro cell and can improve the throughout performance. In orthogonal scheme, the cell edge throughput outperforms the traditional one-layer network when α=0.4 or α=0.45. The reason to this poor performance is that the spectrum allocated to macro cells and small cells is limited. Moreover, in full reuse and SFR schemes, the distance between the two SeNBs becomes larger as α increases. SUEs receive weaker interference power from MeNB. This also contributes to the throughput gain. Combine these two factors above, the average throughput and cell edge throughput are both improved. When α is equal to 0.5, the circle is tangent to the hexagon sector. SeNBs in different cells get much closer. Also, the SUEs receive heavier interference from MeNB in other cells, which will obviously impact the SINR value.

From the above analysis, the optimized system throughput performance can be achieved when α equals 0.45 in the condition of $\theta_p = 60°$ with all the three resource partitioning schemes. The average throughput of all UEs is 2.914, 2.860, 2.570 Mbps for *Full Reuse*, *SFR* and *Orthogonal* scheme, respectively; and the cell edge user throughput is 0.363, 0.411, 0.228 Mbps, separately. Although the average throughput of *SFR* is 1.9% lower than that of *Full Reuse* scheme, cell edge throughput can be much better with a 13.2% gain.

The performance of TDM-ICIC is also evaluated when deployment radius varies. The ABS rate is configured as 1/4 which means the MeNB mutes the transmission in one fourth of the subframes. θ_p is fixed to 60° as well. Average user throughput and cell edge throughput are evaluated when α ranges from 0.2 to 0.5 under different CRE bias.

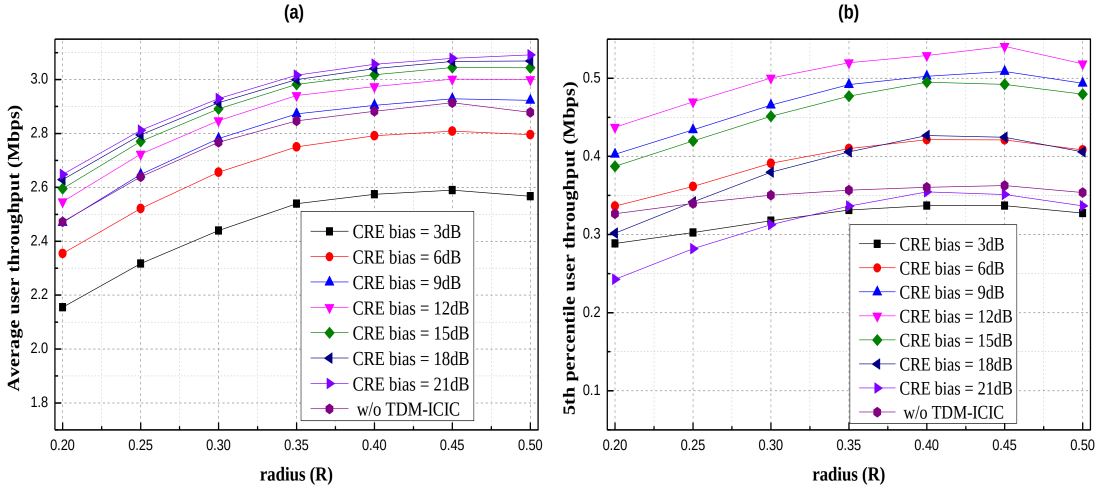


Fig. 7. Performance comparison with different CRE bias (θ_p = 60°).

As illustrated in **Fig. 7 (a)**, when CRE bias value is equal to or higher than 9dB, the average user throughput performance is better than that without TDM-ICIC scheme. However, when bias value exceeds 15dB, the gain of average throughput is limited, which is lower than 1.5% as bias value grows 3dB. As for cell edge users in **Fig. 7 (b)**, their performance is affected seriously whether bias value is too high (above 18dB) or too low (below 6dB). In TDM-ICIC, with the increase of deployment radius, cell edge throughput changes more quickly than that without ICIC.

CRE technique (RSRP plus bias based cell selection scheme) can certainly offload more macro cell traffic to small cell. Thus, with bias value increasing, more MUEs associate to SeNBs in the expanded range of SeNBs. Although the average throughput benefits from this change, the cell edge throughput increases and then drops after 12dB. This is because when bias value is high, a large amount of users are located in the expanded range and few users are served by MeNBs. The imbalance load between SeNBs and MeNBs diminishes the cell edge users throughput.

As shown in **Fig. 8**, i.e., CRE bias is 6dB, 12dB or 18dB as examples, the access rates of users are depicted. When CRE bias is high, the rate of central range user increases with deployment radius increases. However, the number of expanded range user first decreases then increases. This is because during the radius range 0.2~0.4, more expanded range users will be grouped into central area of SeNBs because most of them are in the vicinity of SeNBs. During the radius range 0.4~0.5, more MUEs are grouped into the expanded range of SeNBs.

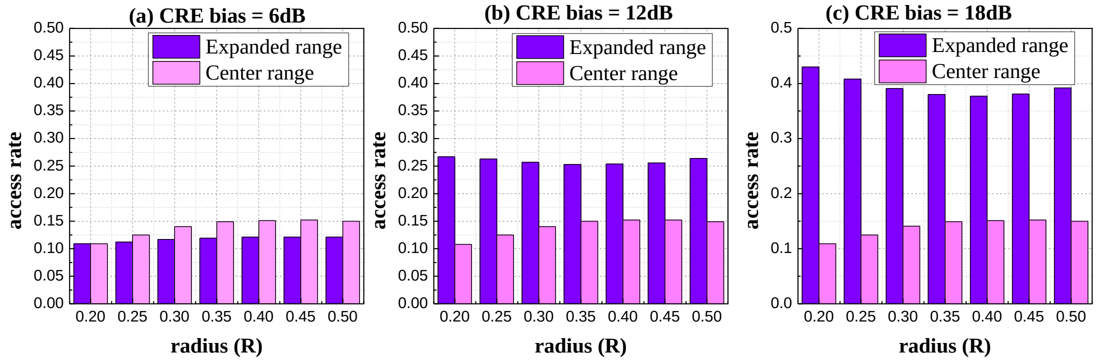


Fig. 8. Access rate under different CRE bias value.

As shown in the above TDM-ICIC results, the optimized performance is achieved when α equals 0.45 in the condition of CRE bias value equals 12dB. The average throughput of all UEs is 3 Mbps and the cell edge user throughput is 0.541 Mbps. If the bias value is higher, the cell edge users perform poorly with a 9.0% loss compared to bias value equals 15dB, and average throughput gains 1.5% compared to bias value equals 15dB.

4.2 Effects of SeNB deployment angle on capacity performance.

After the above analysis, we then set α=0.45 and discuss how the angle affects the average and cell edge throughput as shown in **Fig. 9**.

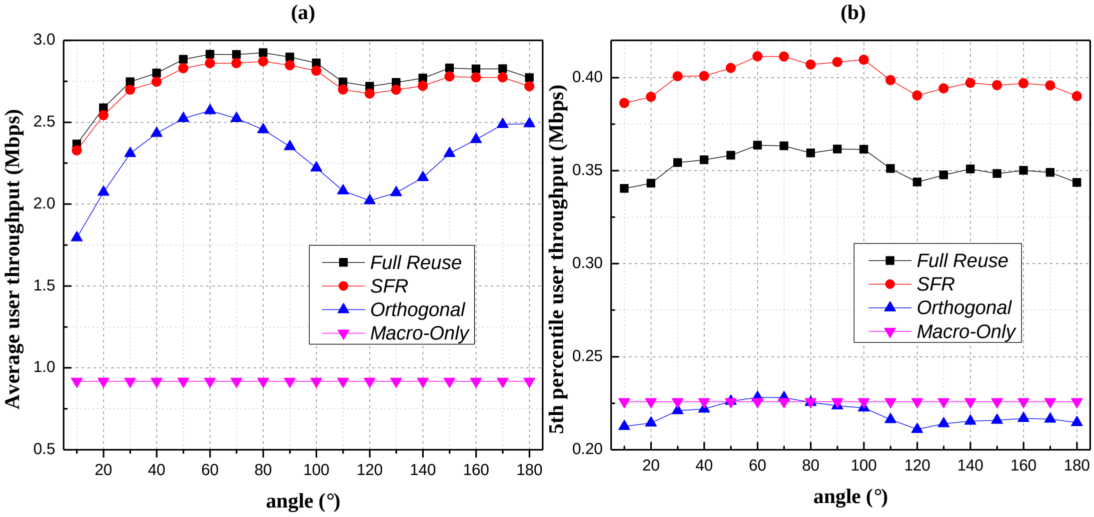


Fig. 9. Performance comparison with different spectrum reuse schemes (α=0.45).

Identical with the fixed-angle scenario, average user throughput improves a lot compared with traditional cellular network, but it has a dramatic vibration when θ_p varies. The cell edge throughput increases after the deployment of SeNBs in SFR and full reuse scheme. However, it performs not satisfying enough with orthogonal scheme.

Since the cell edge throughput investigates the 5% users who have the smallest throughput value. In traditional cellular networks, these users are usually located at the edge of macro cells. While in SCN, these users may be also located at the edge of small cells on account of the severe interference from MeNBs. When θ_p starts growing from zero, the users associated to one SeNB may receive strong interference from the other one, which is quite the same situation as α is small. The interference is mitigated as θ_p grows and the first peak is reached in case of $\theta_p = 60°$. As θ_p continually grows, the throughput starts to decrease. The reason is that users who are close to the farthest vector cannot obtain strong signal power. This may influence the cell edge users more so that the fluctuation is more obvious than average throughput. While the angle becomes much larger, SeNBs in neighbor cells get closer, which decreases the value of SINR especially in case of $\theta_p = 120°$. The third peak is when $\theta_p = 160°$ and the reason is that SeNBs in one cell and those in neighbor cells have approximately the same distance. Finally, when θ_p reaches $180°$, the distance between the SeNBs is quite large but the users of macro cells are not well served.

The optimized system throughput performance is achieved when $\theta_p = 60°$ in the condition of α=0.45 with all the three resource partitioning schemes. The average throughput of all UEs is 2.914, 2.860, 2.570 Mbps for *Full Reuse*, *SFR* and *Orthogonal* scheme, and the cell edge user throughput is 0.364, 0.411, 0.228 Mbps, respectively. Although throughput of *SFR* is 1.9% lower than *Full Reuse* scheme, cell edge throughput can be much better with a 12.9% gain.

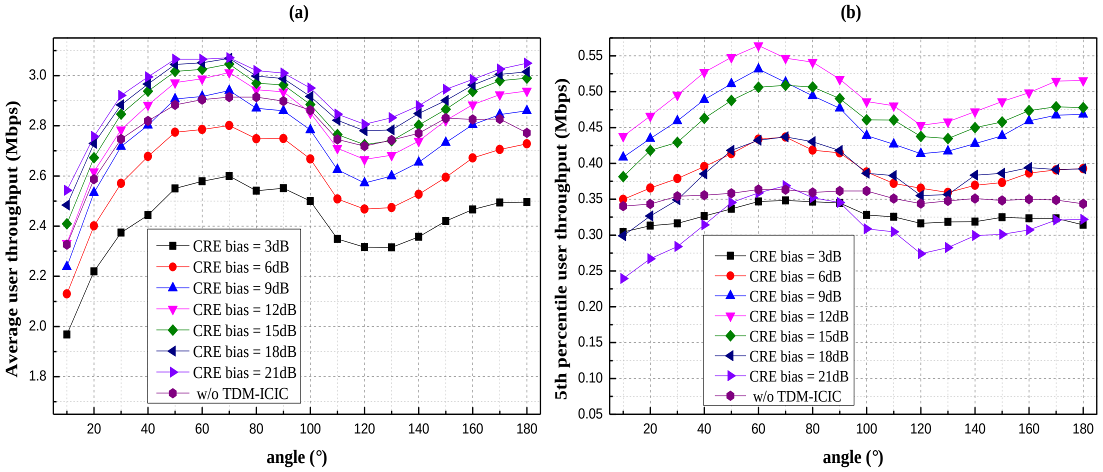


Fig. 10. Performance comparison with different CRE bias (α=0.45).

For TDM-ICIC technique, the ABS rate is configured as 1/4 as well when angle varies. It is illustrated in **Fig. 10 (a)** that in the range of 50° to 70°, when CRE bias value is equal to or larger than 9dB, the average user throughput outperforms the one without TDM-ICIC technique. The average throughput reaches its highest point at θ_p=70° because at this CRE bias value, two symmetric SeNBs will cover almost all the users that are between them. As is also true for deployment radius scenario, when bias value exceeds 15dB, the gain of average throughput will be less than 1.3%. The loss in the edge throughput outweighs the gain in the average throughput, which is shown in **Fig. 10 (b)**.

For cell edge users in **Fig. 10 (b)**, their performance is poorer that those without TDM-ICIC when the bias value is either too high (i.e., above 18dB) or too low (i.e., below 6dB). When the angle varies with TDM-ICIC applied, the cell edge throughput is also fluctuating. It is highly recommended to configure CRE bias value as 12dB combined with θ_p=60° as it has a 62.8% gain than without TDM-ICIC and has a 6.2% gain than CRE bias value equals 9dB. When bias value is higher, cell edge user throughput will be seriously affected. When θ_p=70°, there is a throughput loss of 3% compared to θ_p=60°.

Combined the cell edge and average throughput performances together, the optimized system throughput performance is achieved when α=0.45 in the condition of $\theta_p = 60°$ and CRE bias value configured as 12dB. The average throughput of all UEs is 2.987 Mbps and the cell edge user throughput is 0.564 Mbps.

Note that the above research is based on the condition of α=0.45. Although it is the optimized radius when $\theta_p = 60°$, it does not optimize all the angles. The optimized scenario can be achieved when the angle and the radius of the deployment are jointly studied.

5. Conclusion

This paper analyze the performances of different deployment cases of SeNB in SCN. When SeNBs are located on the circle whose center coincides with the center of cell sector, radius and central angle are two parameters that significantly influence user throughput. In our study, ICIC schemes either in frequency or time domain are also applied when evaluating the system performance with different radius and angle. In frequency domain, SFR and full reuse schemes outperform orthogonal scheme. Cell edge users benefit more from SFR scheme compared to full reuse scheme. In the time domain, when ABS ratio is configured as 1/4, CRE bias value = 12 dB is highly recommended. When the bias value is further increased, the average throughput is only improved a little while the cell edge throughput is much deteriorated. The above ICIC techniques can work well with central angle and radius are set to 60° and 0.45 of the cell radius, respectively.

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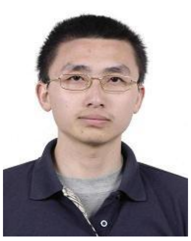

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