An Improvement and Analysis of Horizontal Sector Offset Scheme for LTE Networks

Jianhua He, Zuoyin Tang, Wenqing Cheng, Keith Blow

I. Introduction

With rapid increase of smartphone shipments and increasing popularity of wireless multimedia applications cellular networks are driven to capacity limits. How to effectively increase network capacity and improve user quality of experiences (QoE) are the subjects of a large body of research. Heterogeneous network structure, small cell deployment, massive MIMO and advance frequency resource management technologies are some example hot research topics for LTE cellular networks [1].

Due to the increasing network capacity presssue mobile service providers wish to achieve a frequency reuse of factor 1 in modern cellular networks. However frequency reuse across all the sectors of a cite and across cites will result in strong interference and low SINR for users located at sector boundaries and cell boundaries. A widely used approach to address the above problem is using fractional frequency reuse schemes, which improve the throughput of cell edge users at the cost of reduced frequency reuse. Recently an interesting alternative approach of improving frequency reuse schemes by horizontal sector offset is proposed for 3 sector multi-carrier UMTS in [3] and LTE networks in [4]. The main idea is that the two sectors which point to the same direction associated with the two carriers in UMTS networks or the two groups of subcarriers in LTE networks are now offset with the highest gain direction of one sector pointing to an original sector boundary. With this new approach the frequency reuse is not reduced compared to the traditional 3 sectors configuration. Large improvements on user throughput and handover performances have been reported in [3] and [4].

In the sector offset scheme the horizontal half-power beamwidth of sector antennas was set to 65° [3] [4]. Such setting is unnecessarily wide and may generate extra interference. In this paper we propose an approach to improve the existing sector offset scheme by setting a better horizontal half-power beamwidth, which can largely reduce network interference and user outrage probability, and improve network throughput. In parallel to the above work a statistic model is proposed to analyse the LTE network performance with and without sector offset, in terms of interference, spectrum efficiency and outrage probability. Numerical results show that with a properly configured half-power beamwidth network performances could be largely improved. The analytical model is also verified by simulations, which can be used as an effective tool for estimation of user QoE and network planning.

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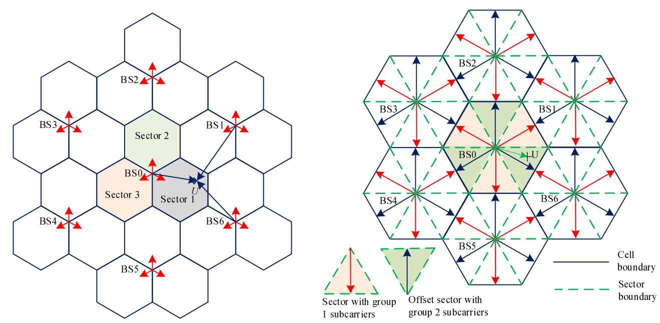
II. System model and performance

We consider a cellular network in a hexagonal grid layout. An example network layout with 7 BSs is shown in Fig.1, with traditional 3 sectors configuration in Fig.1(a) and 6 sectors with horizontal sector offset in Fig.1(b).



(a) Traidtional 3 sectors setting (b) 6 sectors with sector offset.

Fig. 1. Network layout: a) Traditional 3 sectors and b) 6 sectors with offset.

Let P_t denote the transmit power for the signal transmitted from the jth sector of BS i to a general user u located in sector 1 of BS 0. Let $\mathcal{P}_{i,j,u}$ denote signal power received by the target user u, which is calculated as the product of the transmit power P_t, path loss $G_{PL}(i,u)$, antenna gain $G_A(i,j,u)$ and shadow fading $\psi_{i,u}$:

$$\mathcal{P}_{i,j,u} = P_t G_{PL}(i,u) G_A(i,j,u) \psi_{i,u} \tag{1}$$

$G_{PL}(i,u)$ represents the path loss between BS i and user u, which is modelled according to [2] for outdoor line-of-sight communications:

$$G_{PL}(i,u) = -34.02 - 22log_{10}(D_{i,u}) \ (dB), \tag{2}$$

where $D_{i,u}$ represents the distance between BS i and user u.

The antenna gain $G_A(i,j,u)$ models the gain obtained by focussing the signal beam towards one direction, which is calculated according to [2] [3] by:

$$G_A(i,j,u) = G_{A,max} G_{A,h}(\vartheta_{i,j,u}) G_{A,v}(\theta_{i,j,u}) \tag{3}$$

where $G_{A,max}$ represents the maximum antenna gain, which is set to 3 dB in this paper, $\vartheta_{i,j,u}$ and $\theta_{i,j,u}$ are the horizontal and vertical angles between the sector antenna and the user u. $G_{A,h}(\vartheta)$ and $G_{A,v}(\theta)$ models the normalized horizontal and vertical radiation patterns of sector antennas, respectively, which is calculated according to [2] [3] by:

$$G_{A,h}(\vartheta) = -min(12(\frac{\vartheta}{\vartheta_{3dB}})^2, 25) \ (dB) \tag{4}$$

where ϑ_{3dB} represents the horizontal half-power beamwidth. $G_{A,v}(\theta_{i,j,u})$ models the vertical radiation pattern, which is calculated according to [2] by:

$$G_{A,v}(\theta) = -min(12(\frac{\theta - \theta_{down}}{\theta_{3dB}})^2, 20)\ (dB), \quad (5)$$

where θ_{down} is the down-tilt angle, and θ_{3dB} represents the vertical half-power beamwidth. With the above channel and antenna models, the user and network performances could be obtained by simulation and analytic model, which are not presented due to the limited space.

TABLE I
SYSTEM CONFIGURATIONS

Parameters	Value
Carrier frequency	2000 MHz
Bandwidth	5 MHz
Cell radius	500 m
Transmit power	26 Watt
Shadow fading (SF) std deviation	6 dB [2]
Inter-site SF correlation	0.5
Antenna height	25 m
Vertical half power bandwidth	θ_{3dB}=11.5°(3 sectors)
Antenna downtilt	$\theta_{down} = 10.57$
Colormap resolution	5 m

TABLE II
ID AND SETTINGS OF COMPARED FREQUENCY REUSE SCHEMES

Scheme ID	1	2	3	4	5
Number of sectors	3	6	6	6	6
Sector offset	N/A	No	Yes	Yes	Yes
Horizontal ϑ_{3dB}	N/A	N/A	35°	45°	65°

Typical results are presented for a cellular network with two tiers of BSs (19 BSs in total). System configurations are given in Table 1. Five frequency reuse schemes listed in Table 2 are compared, with schemes 1 and 2 being the traditional 3 and 6 sectors configurations, respectively. Scheme 5 is the one proposed in [4]. We propose to use smaller horizontal half-power beamwidth as with Schemes 3 and 4 (35°and 45°, respectively).

Network wide performances in terms of mean SIR, mean cell throughput and mean outrage probability are presented in Fig. 2. It can be observed that Scheme 4 (with ϑ_{3dB}=45°) outperforms the original sector offset scheme (Scheme 5) by 10% higher cell throughput and 25% lower outrage probability. Scheme 4 achieves 60% higher cell throughput and 58% lower outrage probability than the tradition 3 sector scheme (Scheme 1). Scheme 2 (traditional 6 sector configuration) achieves the highest cell throughput but also the highest outrage probability. It is also shown that both the analytical results consistently match simulation results closely. Fig.3 and Fig.4 show more details on the mean SIR and mean outrage probability of individual users in sector 1 of BS 0 in colormaps.

REFERENCES

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[3] H. Claussen, L. Ho, "Multi-carrier Cell Structures with Angular Offset," *in Proceeding of IEEE PIMRC'12*, 2012.

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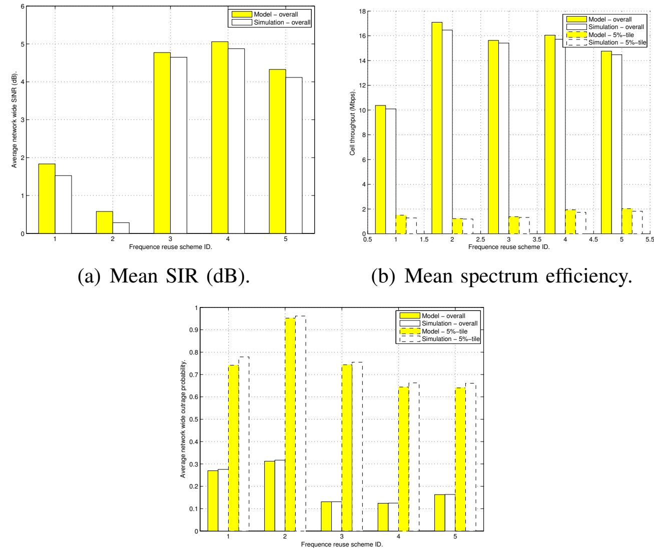
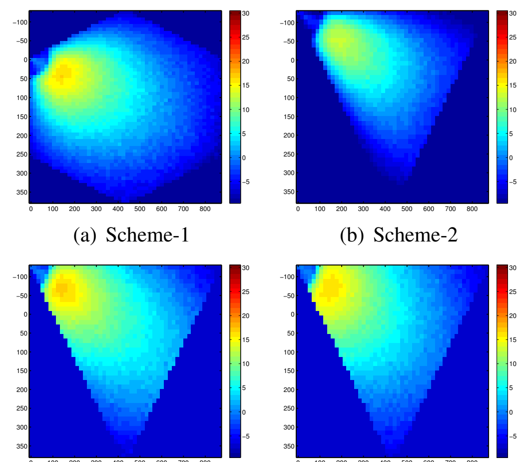


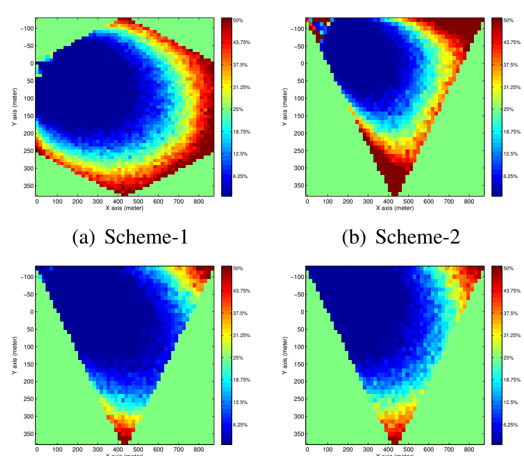
(a) Mean SIR (dB). (b) Mean spectrum efficiency. (c) Mean outrage probability.

Fig. 2. Network wide performances.



(a) Scheme-1 (b) Scheme-2 (c) Scheme-4 (d) Scheme-5

Fig. 3. Colormap of SIR (dB) for users in sector 1 of BS 0.



(a) Scheme-1 (b) Scheme-2 (c) Scheme-4 (d) Scheme-5

Fig. 4. Colormap of outrage probability for users in sector 1 of BS 0.