A Flower Tessellation for Simulation Purpose of Cellular Network with 12-Sector Sites

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Abstract— **This paper presents a novel network tessellation for 12-sector site deployment called "Flower" topology for use in cellular network simulations. The aim of this paper is to study the impact of higher order sectorization and perform a comparison of different network tessellations for Dual Cell HSDPA (DC-HSDPA) network. Throughput and Signal to Interference plus Noise Ratio (SINR) at different Intersite Distance (ISD) were used as merits of performance. It was found that at 1000m ISD, flower topology for 12-sector sites offers 7.2% and 210% relative throughput gain with respect to traditional hexagon layout for 12-sector and 3-sector sites deployment, respectively.**

Keywords— ***Dual cell high speed downlink packet access, Sectorization, Network tessellation, Network capacity, Intersite distance***

I. INTRODUCTION

In future, new advanced mobile services with different Quality of Service (QoS) and high data rate requirement will demand a high capacity from cellular network. Spectral efficiency of a system can be increased by employing spatial multiplexing through multiple antennas [1]. However, the successful reception of dual stream transmission requires good SINR condition, Performance of spatial multiplexing transmission is not homogeneous over the entire cell area in macrocellular environment [1]. Idea of Dual-Cell HSDPA (DC-HSDPA) was floated by 3GPP in Release 8, to provide homogeneous capacity gain for each user over cell dominance area. In DC-HSDPA, two single carriers of HSDPA each of 5MHz is aggregated, and simultaneously the resources of both carriers are allocated to single user with the help of joint scheduler [2].

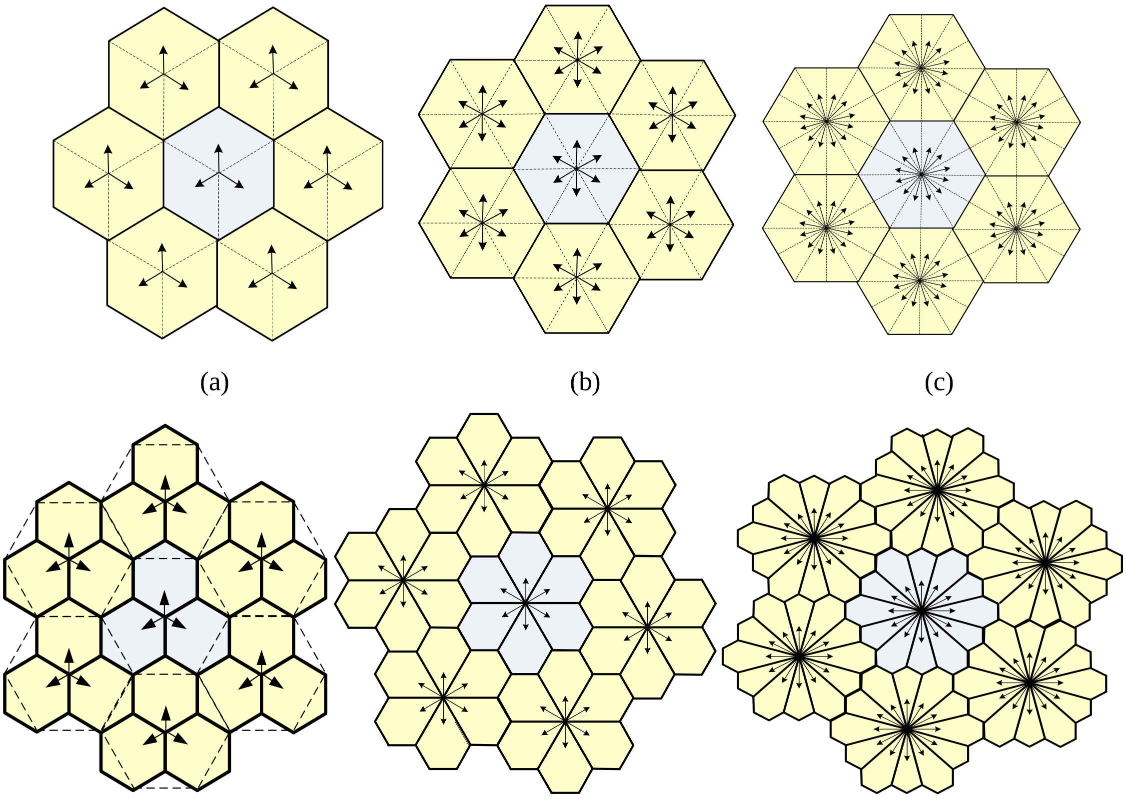
Mobile operators generally use macro cells with wide beam antennas for umbrella coverage, but future capacity demands cannot be fulfilled by using them only. The spectral efficiency of a system can be improved through "Sectorization", dividing the site coverage area spatially into multiple sectors and reusing the radio resources in each sector [3]. Normally, single site is divided into 3 sectors, having equally spaced antennas in azimuth plane with difference of 120^0. In this paper, 6-sector and 12-sector site deployment is referred as an example of higher order sectorization. In order to avoid the installation of new sites due to high operational costs, and to improve the capacity of cellular network, implementing high order sectorization within the existing site can be considered as a possible cost effective solution [4].

For initial site selection plan in cellular network system simulations, regular network tessellations are used. Regular network layout is based on geometric shapes, fulfilling the criterion of providing continuous coverage. Network tessellation is defined by the location of sites, order of sectorization, azimuth direction, and beamwidth of antenna. Earlier studies showed the network layouts based on hexagon for 3-, 6-, and 12-sector sites deployment [5-6]. The performance of cloverleaf layout for 3-sector site was found better than hexagonal layout [5]. However, for higher order of sectorization, cloverleaf layout cannot be used and new tessellation is needed to combat the problem of interference. The results presented in [5-6] indicate that 6-sector traditional hexagon tessellation offers better coverage and enhanced capacity compared to 3-sector site deployment. An optimum tessellation for 6-sector site is presented in [7], in which antenna of each sector is oriented in such a way that they are not facing each other. The authors of this paper call that layout as "Snowflake" layout.

The impact of higher order sectorization has been previously studied in [3-7], however no study on optimum network tessellation for 12-sector is available in open literature. This paper introduces a novel network layout called "Flower" tessellation for 12-sector site deployment, and also presents the performance analysis of enhanced tessellation for 6-sector site given in [7]. The target of this research work is to learn about the possible gain of using higher order sectorization in macrocellular environment. This paper highlights the advantage of adopting optimum network tessellation, and presents the performance comparison of traditional hexagonal layout with cloverleaf, snowflake and flower topology for 3-, 6-, and 12-sector sites respectively. The research work of this paper was done by performing simulations in MATLAB environment.

II. THEORY

This section deals with the theoretical aspects sectorization, network tessellation, and antenna selection for sectors.


(a) (b) (c)

(d) (e) (f)

Fig.1. Cellular network layouts. (a) 3-sector hexagon, (b) 6-sector hexagon, (c) 12-sector hexagon, (d) 3-sector cloverleaf, (e) 6-sector snowflake, and (f) 12-sector flower layout.

A. *High order sectorization*

For a macrocellular network without extensive capacity demand, 3-sector site is a practical solution. However, for the case of high capacity requirement, 3-sector sites are not able to fulfil the purpose and new sectors needs to be added. Adding another carrier in the same sector is not a viable solution for the mobile operators having only one carrier. High order sectorization is a promising technique for enhancing the site capacity without building additional sites and is therefore a good solution for hot spot areas [6]. Six-sector sites and 12-sector sites are example of high order sectorization. Performance of high sectorization depends upon the half power beamwidth of the antenna in horizontal plane, with optimum beamwidth antenna 6-sector site not only provide better coverage but also provide significant capacity enhancement compared to 3-sector sites [8].

B. *Introduction to cellular network layouts*

To learn about the system behavior in different radio conditions, preliminary cellular system performance is evaluated through link and system level simulation ns. For making a nominal plan of sites for simulation purpose, it is generally assumed that the sites have regular network layout. Tessellations use geometric shapes i.e. hexagon, triangle, square etc. to create a continuous plane and a regular grid like structure. These tessellations can be used as a basis for selecting the position of nominal sites [5].In literature, there are several definitions for the regular layout, but the most commonly used shape for cellular network is “Hexagon”. Hexagonal layout for 3-, 6-, and 12-sector site is shown in Fig.1 (a-c) respectively Cloverleaf layout for 3-sector site shown in Fig.1(d) was presented in [5], and was found better then 3-sector hexagonal layout. To enhance the performance of 6-sector site, an optimized network layout is presented in [7], in which sectors do not face each other and hence reduce the impact of other cell interference. Authors of this paper call the tessellation for six-sector site presented in [7] as “Snowflake” topology. Fig.1(e) shows the orientation of sectors and site location of snowflake topology. Finally, a novel tessellation for 12-sector site is shown in Fig.1(f). This layout for 12-sector site is named as “Flower” topology due to shape of the site dominance area.

C. *Antenna selection and its beamwidth*

Antenna configuration i.e. height, azimuth, beamwidth and radiation pattern has deep impact on cell capacity, and therefore selection of optimum antenna is of much importance [8]. Ideal sectored antenna has flat response within the sector and zero response outside the sector. For ideal sectored antenna there is no overlapping between the sectors of same site and hence there is no intersector interference [3]. Practically it is not possible to achieve ideal sector response,

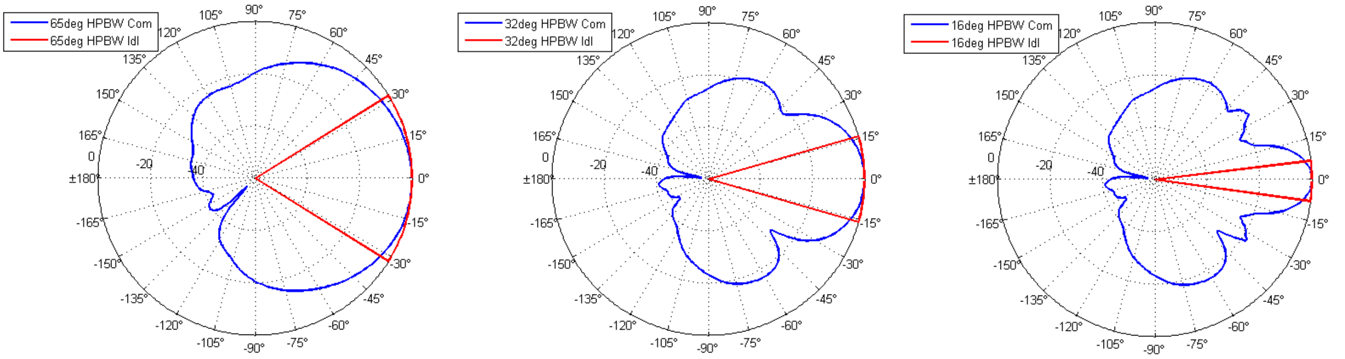


Fig.2. Radiation patterns of ideal and commercial antennas. (a) 65^0, (b) 32^0, and (c) 16^0 HPBW antenna

and each sector receives co-channel interference from the neighbour sectors of the same site as well as from other sites. Wide HPBW of antenna leads to large sector overlapping and will cause interference leakage to neighbour cell, which in turn will reduce the system capacity. Fig.2(a-c) depict the ideal sector response and the radiation pattern of commercially available 65^0, 32^0, and 16^0 HPBW antennas, respectively. For the research work of this paper, HPBW of antennas were scaled proportionally to the number of sectors per site i.e. 3-. 6-, and 12-sector sites were implemented with 65^0, 32^0, and 16^0 HPBW antennas, respectively.

III. SYSTEM SIMULATIONS AND RESULTS ANALYSIS

A single site in the middle interfered by two tiers of interferers i.e. 18 sites at equal intersite distance was considered for simulation purpose. All sites are assumed to have same antenna height and equal maximum transmit power. The scenario studied assumes macrocellular urban environment with data users having full traffic buffer, homogeneously distributed over the whole cell area. Flat terrain was assumed and Okumura-Hata path loss model was used for estimating the path loss between the user and NodeB, and lognormal distribution with 6dB standard deviation was used to model shadowing. Code orthogonality factor is modelled with Gaussian curve having maximum value of 0.97 at site location and 0.7 at cell edge, instead of average orthogonality factor value. Out of total 16 codes, maximum of 15 codes are available for allocating to the users at physical layer level. The simulator supports multiple users (5 users) per TTI with code multiplexing, and allocates equal number of codes to the active users in cell.

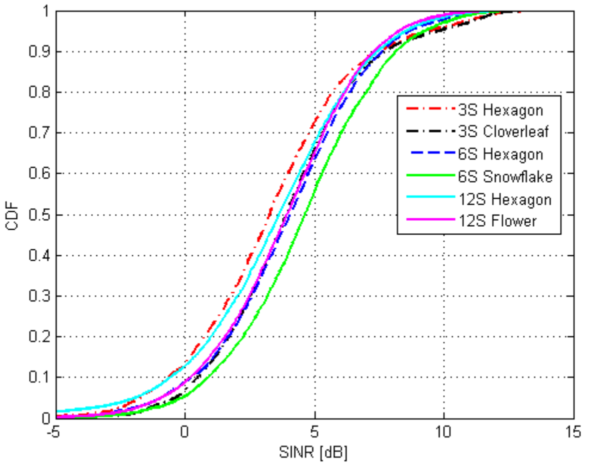


Fig.3. CDF of cell SINR at 1000m ISD with 5 users per TTI.

Fig.3 shows the CDF of cell SINR value for DC-HSDPA system with 5 users per TTI at 1000m ISD. In each iteration of Monte Carlo simulation, average SINR value over the cell is obtained by adding the linear SINR value of each user then dividing the sum by the number of users served per TTI. As seen from the results in Fig.4, the contribution of lower SINR level (less than 0dB) is over 13% by 3- and 12-sector hexagon layout, however with cloverleaf and flower layout it is brought down to 7% and 9%, respectively. It can be seen that improvement in cell SINR is not proportional to increasing order of sectorization. Migrating from 3-sector to 6-sector improves the cell SINR but shifting from 6-sector to 12-sector strategy deteriorates cell SINR. It was found that 6-sector deployment with snowflake topology outperforms and offers highest mean cell SINR of approximately 4.6dB and gives a gain of around 0.6dB compared to 6-sector hexagon tessellation. Similarly, improvement in cell SINR is also evident by cloverleaf and flower layout for 3- and 12-sector sites respectively, compared to traditional hexagon layout.

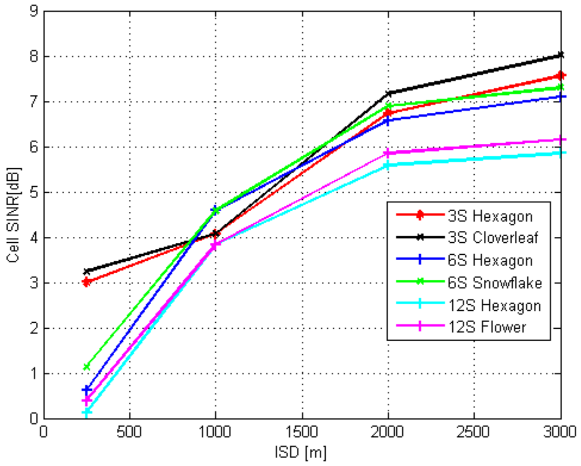


Fig.4. Mean cell SINR of different layouts against intersite distance.

Fig.4 shows the attained mean cell SINR for different network layouts against different intersite spacing. The trend of the curves shows that cell SINR improves by increasing the intersite distance. Small intersite distance corresponds to small cells, where high interference is caused by the near located neighbor cells and limits the user SINR. Irrespective of the ISD, 12-sector layout offers lowest cell SINR.

The results presented in Fig.5 highlights the gain of adopting proper network layout and spotlight the advantage of using higher order sectorization. It was found that at a small ISD i.e. 250m, impact of network layout is less significant, but the benefit of using optimum layout becomes prominent at large intersite spacing. Maximum gain of optimized network layouts for 3-, 6-, and 12-sector sites was found at 1000m ISD. It was learned that cloverleaf layout provides approximately 10.5%, snowflake offers 9% and flower layout tenders approximately 7.2% better throughout compared to hexagon layout for 3-, 6- and 12-sector sites respectively. Statistical analysis of sector and site throughput along with relative gain with respect to 3-sector hexagon layout is presented in Table I.

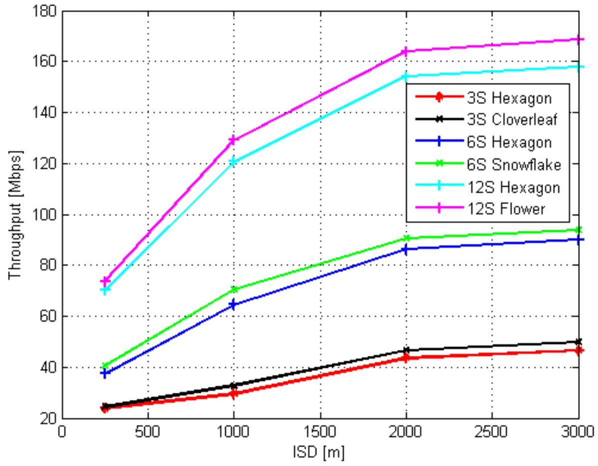


Fig.5. Mean site throughput for different layouts against intersite distance.

IV. CONCLUSION

This paper introduced a regular network layout called flower tessellation for 12-sector site deployment, and provides the performance comparison of cloverleaf and snowflake topology with hexagon layout. Post simulation analysis reveals that optimized network layouts offer better system throughput compared to traditional hexagon layout. For the purpose of cellular network simulations, flower topology can be considered as a basis for selecting a site location and sector azimuth direction, due to its enhanced performance in offering better SINR and throughput. The relative capacity gain of cloverleaf topology is about 2.5-10.5%, of snowflake topology 4-9%, and of flower layout is approx. 5-7.2% over hexagon layout, depending on intersite spacing. Simulation results show that adding a new sector at small ISD degrade the cell quality. To avoid the deployment of small cells, high order sectorization with optimized network layout can be considered as an alternate choice.

TABLE I. STATISTICAL ANALYSIS OF ACHIEVED THROUGHPUT

	Mean cell throughput (Mbps)	*Relative cell throughput gain (%)*	*Mean site throughput (Mbps)*	*Relative site throughput gain (%)*
ISD = 250 meter				
3S Hexagon	7.93	**0**	23.79	**0**
3S Cloverleaf	8.13	**2.52**	24.39	**2.52**
6S Hexagon	6.25	**-21.19**	37.50	**57.62**
6S Snowflake	6.74	**-15.06**	40.44	**69.99**
12S Hexagon	5.85	**-26.23**	70.20	**195.23**
12S Flower	6.15	**-22.44**	73.80	**210.21**
ISD = 1000 meter				
3S Hexagon	9.86	**0**	29.58	**0**
3S Cloverleaf	10.90	**10.55**	32.70	**10.55**
6S Hexagon	10.74	**8.93**	64.44	**117.85**
6S Snowflake	11.72	**18.86**	70.38	**137.93**
12S Hexagon	10.05	**1.92**	120.60	**307.7**
12S Flower	10.77	**9.23**	129.24	**336.92**
ISD = 2000 meter				
3S Hexagon	14.54	**0**	43.62	**0**
3S Cloverleaf	15.49	**6.53**	46.47	**6.53**
6S Hexagon	14.38	**-1.1**	86.28	**97.79**
6S Snowflake	15.10	**3.86**	90.60	**107.29**
12S Hexagon	12.84	**-11.7**	154.08	**253.23**
12S Flower	13.67	**-5.99**	164.04	**276.06**
ISD = 3000 meter				
3S Hexagon	15.48	**0**	46.44	**0**
3S Cloverleaf	16.58	**7.11**	49.74	**7.11**
6S Hexagon	15.01	**-3.03**	90.06	**93.92**
6S Snowflake	15.63	**0.97**	93.78	**101.93**
12S Hexagon	13.15	**-15.05**	157.8	**239.8**
12S Flower	14.06	**-9.17**	168.72	**263.31**

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