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Multi-level Soft frequency reuse using improved Okumura-Hata path loss model

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***Abstract* – Frequency planning is the most important concern in modern cellular system. In this paper, we have discussed different types of frequency reuse schemes such as Fractional Frequency Reuse (FFR), Soft Frequency Reuse (SFR) and Multi-Level Soft Frequency Reuse (ML-SFR), which are preferred in modern communication system. These schemes are mostly preferred for orthogonal frequency division multiple Access (OFDMA) networks where available bandwidth is used in single cell by splitting it to the orthogonal sub-carrier signals. In this paper a 8-level SFR technique is discussed for three different path loss models and results shows that improved Okumura Hata path loss model has better spectrum efficiency than other two model for an urban environment.**

***Index Terms*- Fractional Frequency Reuse (FFR), Soft Frequency Reuse (SFR), Multi-Level Soft Frequency Reuse (Multi-Level SFR), Orthogonal Frequency Division Multiple Access (OFDMA), Inter Cell Interference (ICI).**

I. INTRODUCTION

Next generation cellular systems are developed to increase the overall throughput of the system. Focus of these systems is to get maximum performance from the limited resources that are available. Orthogonal frequency division multiple Access (OFDMA) is the one of those technique in which available spectrum can be utilized efficiently.

In OFDMA available spectrum is divided in large number of sub carriers which are orthogonal to each other. Data is transmitted simultaneously over these low data rate sub carriers which increases the efficiency and scalability of system [1]. In OFDMA sub carriers are orthogonal to each other so that intra cell interference is minimum that will increase the efficiency but also introduce co-channel interference that is also called inter-cell interference as frequency bandwidth of neighbouring cell is same [2] which mainly degrade the performance of system at cell edge area. It is known that by reusing the resources efficiently in the cellular system it can greatly increase the capacity of the system and can reduce the effect of the ICI in the system.

II. CONCEPT OF FREQUENCY REUSE

Frequency reuse is an important concept of cellular communication system which allows the user in different geographical area to use the same frequency band. By reusing the frequency bands over and over again a cellular network provider can serve a large number of users simultaneously, therefore increasing the capacity of the system. While reusing the frequency, proper planning is required to overcome the effect of interference which is caused due to same frequency used in neighbouring cells.

Efficient frequency allocation techniques have been developed now to minimize the interference in neighbouring cells and maximize the benefits of frequency reuse.

III. TRADITIONAL FREQUENCY REUSE

Traditional frequency reuse is the basic technique to allocate the frequencies in cellular network, [3] in traditional frequency reuse technique frequency planning can be done in two ways.

A. Frequency Re-use 1

Main objective of cellular network is to achieve high spectral efficiency [4] for which whole available spectrum is allocated to each cell in the network as shown in the Fig.1.

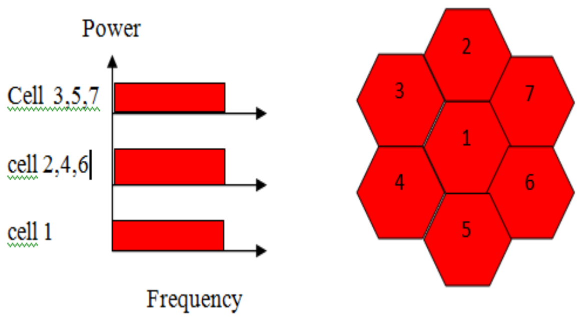

Fig.1 Frequency Re-use 1 [3]

Fig.1 shows the seven cell cluster in which same frequency is used in each cell. In re-use 1 scheme we observe high data rate with high interference at cell edges.

B. Frequency Re-use 3

In Re-use 3 technique whole available spectrum is divided into three equal sub bands and then these sub bands are allocated to cells such a way that no neighbour cell use same sub band [4] as shown in the Fig.2.

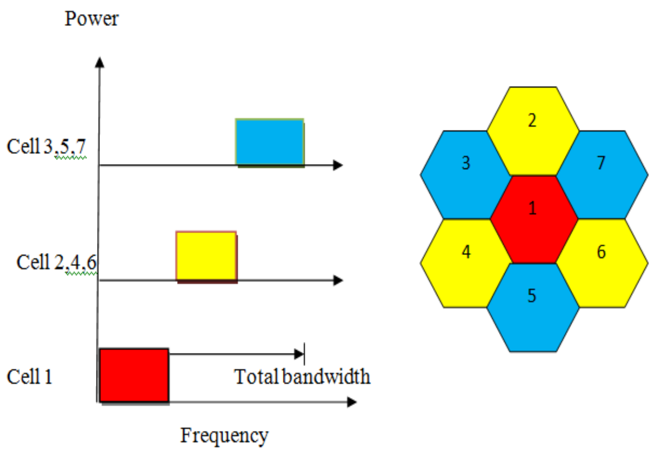

Fig. 2 Frequency Re-use 3 [3]

Fig.2 shows the seven cell cluster where neighbouring cells have different band of frequency. This technique reduces the interference but also decrease the capacity of the network.

IV. FRACTIONAL FREQUENCY REUSE (FFR)

In traditional frequency reuse (Re-use 1 and Re-use3) all user use the same frequency band in neighbouring cells. This technique can pick up the overall throughput of the system but users close to the cell edge will experience high level of interference resulting the degradation in system [5]

To overcome this interference fractional frequency reuse scheme is used.

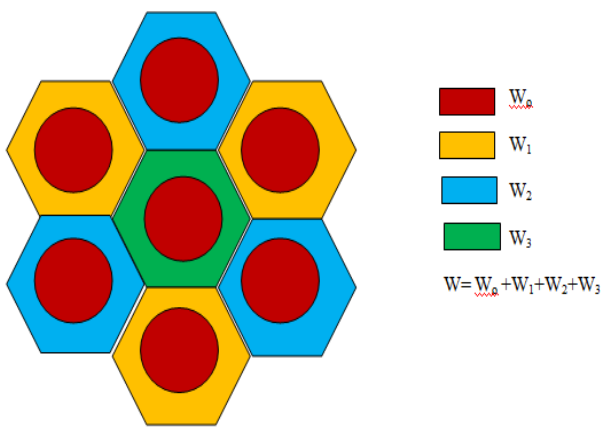

Fig.3 Fractional Frequency Reuse

In FFR cells are divided in two regions, inner and outer region as shown in fig.3. Circular region in Fig.3 is the inner region of the cell and rest of hexagon is outer region. Bandwidth allocated to these regions in such a way inner region uses frequency re-use 1 technique and outer region uses frequency re-use 3 technique [6].

V. SOFT FREQUENCY REUSE (SFR)

In the FFR scheme as discussed above, in the outer region Re-use 3 scheme is used by which cell edge throughput of system is increased but we lost the spectrum efficiency [7]. To increase the spectrum efficiency a soft frequency reuse scheme is used in which re-use 1 scheme is used in neighbouring cells with some power bounds at transmitter [8] [9]. In SFR, the overall bandwidth is shared by all base stations, but a power bound on certain sub-bands is introduced such that some sub-bands are transmitted with higher power in one cell and some sub-bands in other.

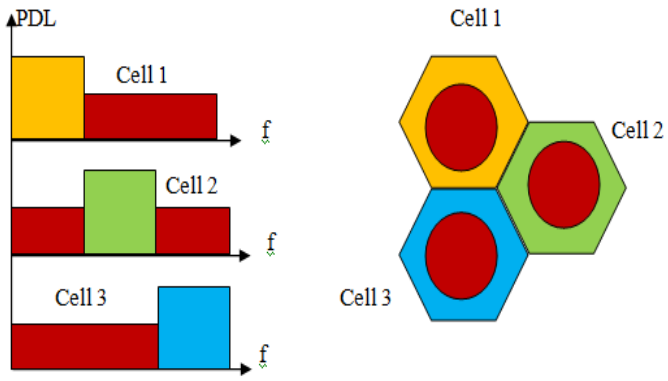

Fig.4 Power Density Upper Limit And Coverage of SFR [10].

Fig.4 shows that in SFR given bandwidth is divided in three parts, higher power density level frequency band, that is also called primary band which is used at cell edge and other two bands with low power density level are called secondary bands. At the cell centre whole available bandwidth is used and at cell edge high power density frequency bands are used. As primary bands are orthogonal to each other so interference at cell edge is minimum that will increase the overall throughput of system [10].

In SFR γ which is the ratio of PDLs of secondary to primary band, is an important factor.

$$\gamma = \frac{PDL\ of\ secondary\ band}{PDL\ of\ primary\ band}$$

It can be seen that when we increase the γ it will decrease the capacity of the cell edge user and increase the capacity of cell centre user and vise versa [10].

VI. MULTI-LEVEL SOFT FREQUENCY REUSE

In SFR capacity of the cell edge user depends on γ , the value of γ will be different for different kind of traffic distribution so it will depend on the user, how far he is from the base station based on this there should be many values for γ [10].

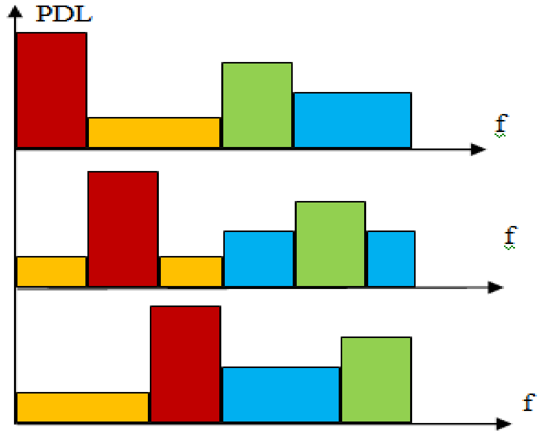

Fig.5 Power Density Upper Limit of SFR-4 Scheme [10].

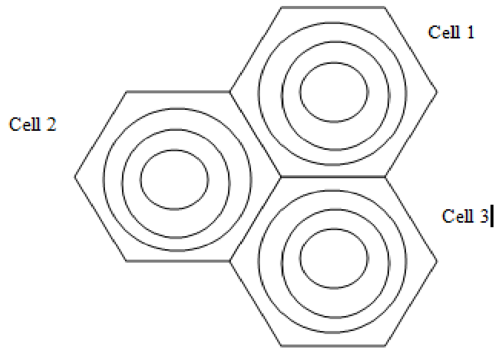

Fig.6 Coverage of SFR-4 scheme [10].

In Multi-level SFR whole bandwidth is divided in several parts and SFR-2 is applied to each part so there will be different values for γ at different level as shown in fig.5.

VII. 8-LEVEL SFR FOR IMPROVED OKUMURA-HATA PATH LOSS MODEL

A. System model

Consider a 13 cell cellular network with the radius r. In this, ML-SFR scheme can be used in which the primary band of the Cell 0 is also primary band of the Cell 7-12, and secondary band of Cell 1-6.

A UE is located in Cell 0 and their place is limited on straight line between base station and point A, intersection of Cell is 0,1, and 6. So, denote distance between UE and base station as

$$\beta o = \frac{do}{d}$$

where β_0 is coefficient in (0,1)

Consider the downlink and suppose p_n is the transmit power density of base station of the Cell n, which is expressed as

$$P_n = k_n N_o \qquad n = 0,1,2, \dots \dots 12$$

There, N_0 can be the power density of the white noise in UE receiver. Suppose bandwidth is B and power of noise in UE receiver is

$$\sigma_z = N_o B$$

Consider the distance between base station of the Cell n and UE as d_n and L(d) the path loss model, then received power of UE from serving cell is

$$\sigma_s = \frac{k_o N_o B}{L(d_0)} = \frac{k_o}{L(d_0)} \sigma_z$$

Interference power from the other cells is

$$\sigma_i = \sum_{n=1}^{12} \frac{P_n B}{L(d_n)} = \sum_{n=1}^{12} \frac{k_n}{L(d_n)} \sigma z$$

Where

$$k_n = \gamma k_o, \qquad n = 1,2,\dots\dots\dots\dots 6$$

$$k_n = k_o, \qquad n = 7,8,\dots\dots\dots\dots 12,$$

It means transmit power of all the primary bands is P_o B, and all the secondary bands is $\gamma P_o B$, then

$$\sigma_i = \left[\gamma \sum_{n=1}^{6} \frac{k_o}{L(d_n)} + \sum_{n=7}^{12} \frac{k_o}{L(d_n)} \right]$$

Assuming the intra-cell interference which is effectively eliminated in OFDM systems, according to the Shannon's law of the channel capacity, the higher spectrum efficiency in flat fading channel that can be expressed as [10]

$$\eta(\gamma, \beta o) = Blog2\left(1 + \frac{\sigma_s}{(\sigma_i + \sigma_z)}\right)$$

The parameters is depicted $\eta(\gamma, \beta_0)$ as the function of $\beta_o^2 = 0$,0.25, 0.5, 0.75 for a flat fading channel. Moreover, see the curves go down if it increases due to enhancement of inter cell interference. In the engineering application, different options for parameter are available.

B. IMPROVED OKUMURA-HATA AS PROPOSED MODEL

The improved Okumura-Hata model takes into consideration that, buildings in the area also affect the path loss and hence the actual path loss should model the effect due to the buildings also.

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$$L_3 = A + B\ log_{10}R - E - 20*log_{10}(d_m)$$

Where d_m is the average height of the buildings in the areas in meters (here assumed to be 30m)

And

$$A = 69.55 + 26.16\ log_{10} f_c - 13.82\ log_{10}\ h_b$$

$$B = 44.9 - 6.55\ log_{10}\ h_b$$

$$E = 3.2\ \left(log_{10}(11.7554\ h_m)\right)2 - 4.97$$

In the results, the L_1 shows the spectrum efficiency using the path loss model as in [10] and L_2 shows the spectrum efficiency using the COST-231 Hata path loss model [11].

C. SYSTEM PERAMETERS

Different system parameters which have been considered for simulation are given in table 1.

Table 1. System Parameters for various path loss models

Power density of white noise 'N_o' in dBm/Hz		N_o = -169
Transmitter power 'P_o' in dBm/MHz		P_o = 50/20
Radios of cell 'd' in km		d= 1
Path loss in dB	Basic macro-cell model	L_1(dB)= 128.1+37.6 log_{10} (d)
	Cost 231 Hata model	L_3(dB)= F+Blog_{10} R-E+G
	Improved Okumura-Hata model	L_4(dB) = A + B log_{10}R – E – 20*$log_{10}(d_m)$
d_m		30 meter

Table 1 shows various system parameters for the simulation of various path loss models. In which N_o is the power density of the white noise at receiver end. P_0 is the transmitter power and bandwidth is given by B, in MHz and radius of the cell is denoted by d and value of d= 1.

For implementing 8-level SFR technique for each path loss model there will be different PDL value for each level which is predefined for each level as given in table 5.2.

Table 2. PDL levels for SFR-8 [10]

Level	1	2	3	4	5	6	7	8
γ	0	-2.4	-4.8	-7.3	-9.7	-12.1	-14.6	-17

In table 2 shows the value of γ for each level of SFR. Values of γ are considered between 0 dB to -17 dB for level 1 to level 8, approximately at interval of – 2.4 dB for each level.

VIII. RESULTS

In the Resulting section, consider the 8 positions as in Table 2.To reuse this scheme, high spectrum efficiency has been achieved at the cell edge (β_0 = 1) and at the center of the cell, SFR-8 using proposed method is realized more flat curve that increased cell over efficiency to the 0.19bps/Hz, which shows the improvement over the current ML-SFR.

For each scheme, perform the resource allocation to improve the sum data rate. The results for the two cases,

A. SPECTRUM EFFICIENCY AS A FUNCTION OF Γ.

In this way, spectrum efficiency of the system is simulated with respect to γ at each point in the cell as in this simulation, values of γ are not predefined. For the simulation, four points in the cell are defined which covers whole cell and are denoted by β_o^2. At every value of β_o^2, spectrum efficiency is determined.

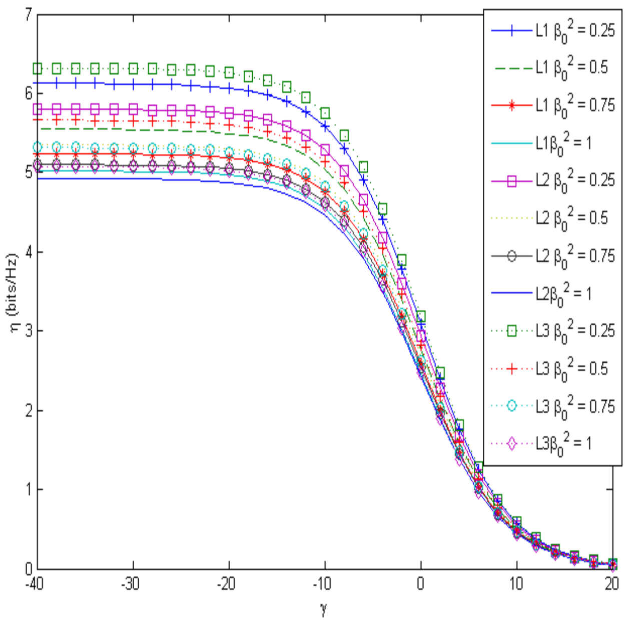

Figure: 6. Spectrum efficiency

B. SPECTRUM EFFICIENCY AS A FUNCTION OF B_0.

In this way, spectrum efficiency of the system is determined for predefined 8 levels of SFR with respect to the β_o where βo_o is the fractional distance of mobile equipment from the centre of cell. Predefined levels are given in table 1 with their corresponding value of γ.

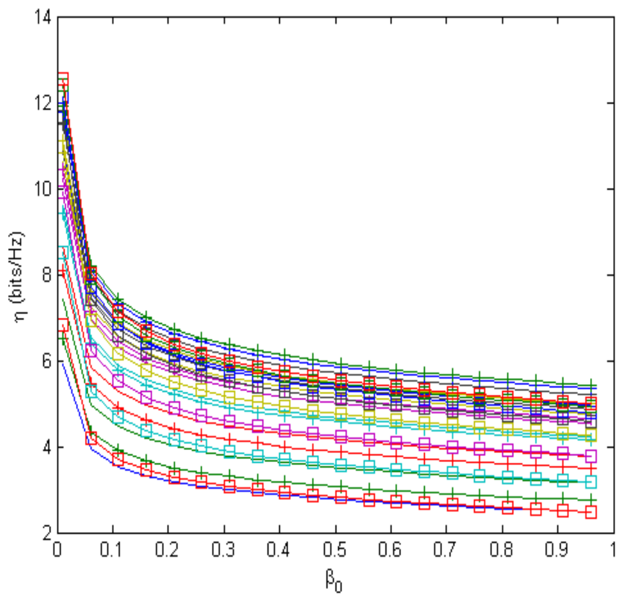

Figure: 7. Spectrum efficiency as a function of β_0 'square' shows COST-231 Hata model, '+' shows the proposed model & '-' shows the model in [10].

IX. CONCLUSION

The conclusion of proposed multi-level soft frequency reuse technique with the improved path loss model is an efficient method for realization of the ML-SFR scheme. ML-SFR and suggested resource allocation of the methodology along with the improved path loss model can be utilized to improve the overall data rate and cell edge as well as at its center. The proposed method can be used in current LTE system and can be a key technology feature for the upcoming generation of wireless communication.

The future work may involve reducing the complexity of the ML-SFR scheme in order to further improve its deployment cost as well as the operational cost.

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