Further Research on Frequency Allocation (19-Cell System) Method based on IFR and FFR

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Abstract: Many of the most advanced technology has a basic need for efficient telecommunication. In order to achieve this goal, the team should allocate those frequency channels in an intelligent way so that the interference can be reduced to the maximum extent. Here the team introduced a new method based on IFR3&IFR1 (Integer frequency reuse) in a 19-cell network, but also apply the FFR (fractional frequency reuse) method to reduce the interference ulteriorly. In the pure IFR situation, the integer frequency reuse factor and the cellular network specification collectively decide the network capacity. While in FFR only a fraction of the whole bandwidth is used by the users in the edge. By contrast, the users near the BS can make use of the total bandwidth. The cell is divided into an outer and an inner part in this effective way. Fractional Frequency Reuse (FFR) and its derivative method are accepted widely in the downlink (DL) inter-cell interference coordination(ICIC) schemes. The team also optimized the FFR method by measuring the distance in a more precise way. The team utilized Matlab to make a simulation of the system applying the new method and come to a couple of reasonable conclusions by comparing the FFR+IFR3 with FFR+IFR3. FFR+IFR3 has a better performance against FFR+IFR1 in a system whose distance between each cell is with more accuracy. While the average number of users per cell and transmission power for cell edge have little impact on average capacity. When the SNR increases, the network capacity starts steep but later flattens. Our method is more intelligent and can minish interference efficiently.

Keywords: IFR, FFR, Frequency allocation.

1. Introduction

In the past few decades, the tremendous development of telecommunication has contributed vastly to the ever-increasing number of people who are concerned about the development of 5G networks [1]. Compared to the 4G network which connects people with cloud and streaming, the 5G network has made the connection between people and things possible. The advancement of the 5G network compared [2-3]to 4G is its higher speed, larger bandwidth (BW), more direct signals, and shorter range. 5G networks can confront the difficulty faced by 4G in the realms of delay, network quality, energy consumption, and throughput [4-5]. One method to achieve these characteristics above of a 5G network is to densify the mobile network by deploying base stations. The team used the hexagon model to represent the spectrum of those base stations. The capacity of the cell is decided by the interference between cells. There is an interference management method called Fractional Frequency Reuse (FFR) featuring the partition of the cells' BW. In this way, the difference between the edge and center of a cell is considered. While another interference management method called Integer Frequency Reuse (IFR) groups the cells and gives different weights to the cell in the particular position of each group. In a pure IFR network, the capacity is mainly decided by the cellular network specification and the integer frequency. This deployment has a high interference among users in adjacent cells using a particular frequency, especially those users located near the cell's edge [6].In this paper, the team combined the IFR 3 network(the IFR network whose frequency reuse factor is three) with the FFR network. The team simulated the capacity in three circumstances (FFR, IFR3,

and IFR3+FFR) and compare their performance in different situations with different pass loss exponent alpha and different Signal to Interference plus Noise Ratio (SINR).

2. Related work

2.1 Frequency Reuse

When it comes to distance communication. There are various of problems. The distance (Pathloss), the block for the single (Shadowing), multipath and so on. Having a general model is relatively difficult. To better analyze the Frequency Allocation situations. A path loss plus shadowing plus small-scale fading model is introduced:

$$P_r = P_0 d^{-\alpha} \Psi \tag{1}$$

P_r in the formula represents the received power of noise or signal; P_0 represents the power of the base station; d demonstrates the distance between the base station and the users; α represents the path loss exponent, and Ψ is the shadowing. Ψ_{dB} follows the normal distribution with mean value of 0 and variance of σ^2:

$$\Psi_{dB} \sim \mathrm{N}(0, \sigma^2) \tag{2}$$

When it comes to the interference Signal-to-Interference Plus Noise Radio ($SINR$) is determined by Noise-limit (N) and Interference-limit (I):

$$SINR = \frac{S}{N + I} \tag{3}$$

where S stands for signal power. The Formula can degenerate, if Interference-limit (I) is far less than Noise-limit (N):

$$SINR = \frac{S}{N} \tag{4}$$

while if Noise-limit (N) is far less than Interference-limit (I):

$$SINR = \frac{S}{I} \tag{5}$$

According to Boltzmann's model:

$$N_t = kTB \tag{6}$$

where N_t represents noise power; k represents Boltzmann's constant, which equals to $1.38 \times 10^{-23} JK^{-1}$; T stands for absolute temperature and B represents noise bandwidth. The capacity (C) is decided by the Signal-to-Interference Plus Noise Radio ($SINR$)and Bandwidth (W):

$$C = W \log_2(1 + SINR) \tag{7}$$

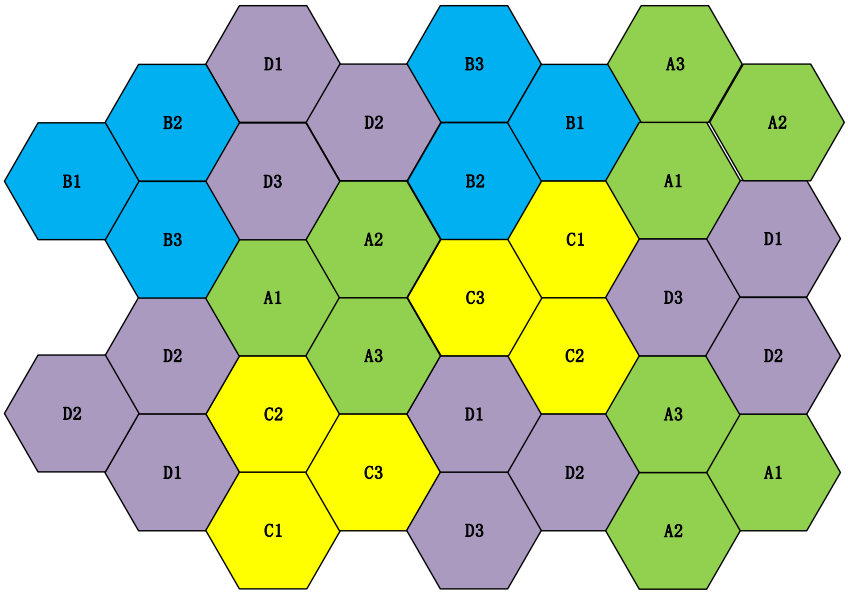


Figure 1. Frequency Reuse

Information can be communicated over different frequency channels simultaneously within a limited spectrum. Therefore, it's necessary to allocate and reuse the frequency. As shown in Figure 1.

2.2 Integer Frequency Reuse

According to hexagon's characteristics in the Fig 2-2, $R' = \sqrt{3}R$; and then can derive as follows:

$$N = \frac{A}{a} = \frac{D^2}{3R^2} \tag{8}$$

A represents area of the group; a represents area of the cell; D is the distance between two cells with the same frequency channels, and N represents reuse factor.

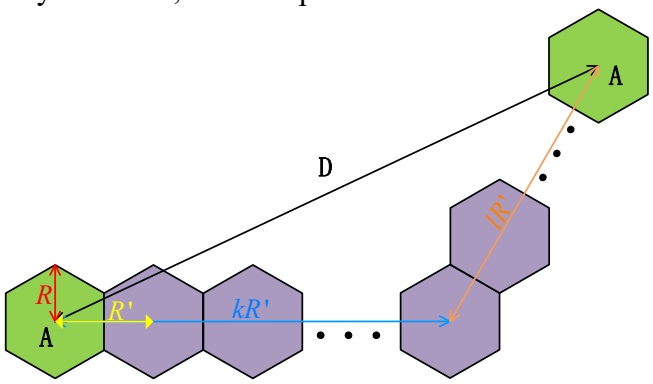


Figure 2. Distance between cells shares the same frequency channel

Furthermore, it's safely concluded that:

$$D^2 = 3R^2(k^2 + kl + l^2) \tag{9}$$

$$N^2 = k^2 + kl + l^2 \tag{10}$$

In a 19-cell system, examples can be listed as reuse factor N =1 (IFR1) and reuse factor N =3 (IFR3). To an IFR1 system, the quantity of channels with each cell is maximum at N_C. As shown in Figure 2.

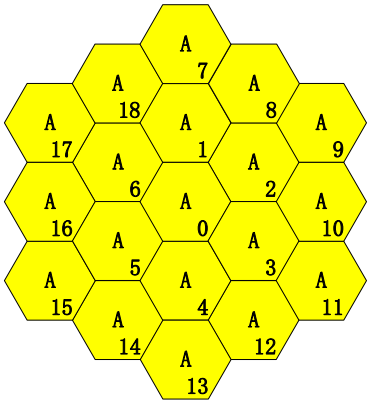


Figure 3. Single Reuse factor

For each cell, channel capacity C_n is calculated as: h is channel gain, and $h_{m,n}$ stands for base station m to user n; P_n represents transmit power from base station n; P_m demonstrates the transmit power from base station m; σ^2 represents the noise power. The capacity will be:

$$C_n = \log_2(1+\frac{\left|h_{n,n}\right|^2 P_n}{\sum_{m\neq n}\left|h_{m,n}\right|^2 P_m+\sigma^2}) \tag{11}$$

$$C_{\text{total}} = \sum_n C_n \tag{12}$$

IFR1 has obvious disadvantages that interference will be nearest and most severe. So it's better to increase the reuse factor N to 3. This will help reduce the interference [7].

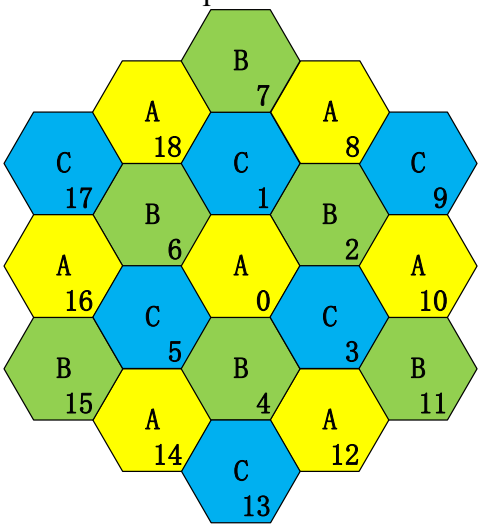


Figure 4. Reuse Factor

Now the capacity turns out to be: This time the number of channels per cell is cut down to $N_C/3$ and interference is weaker and farther away. However, increasing the reuse factor will make the system more complicated. Thus, the allocation of the frequency will be less flexible.

$$C_n = \log_2(1+\frac{\left|h_{m,n}\right|^2 P_n}{\sum_{m\neq n}\rho_{m,n}\left|h_{m,n}\right|^2 P_m+\sigma^2}) \tag{13}$$

3. Fractional Frequency Reuse (FFR)

To further improve the system performance and increase the capacity, introducing a FFR system can reduce the cell interference. Users will be divided into two groups according to their position.

There's IFR1 in the edge so that each user can use the same channel in the cell. Meanwhile, having IFR3 in the center can help increase the capacity. Se the capacity is calculated as:

$$C_n = P_1 \log_2(1+\frac{|h_{m,n}|^2 P_n}{\sum_{m\neq n}\rho_{m,n}|h_{m,n}|^2 P_m+\sigma^2}) + P_2 \log_2(1+\frac{|h_{n,n}|^2 P_n}{\sum_{m\neq n}|h_{m,n}|^2 P_m+\sigma^2}) \quad (14)$$

Transmit power is utilized to provide service for users in the inner area of the cell and outer area of the cell. Normally, a network can cut down the interference by providing the areas locating the inner part of the cell with a smaller power. Also, giving larger power to the outer area of the cell is necessary due to its longer distance. Otherwise, imagine that users squeeze to the edge for better signal performance. It's not going to be a good distance communication experience. In the FFR system, channel capacity will be higher and it will be less energy consuming.

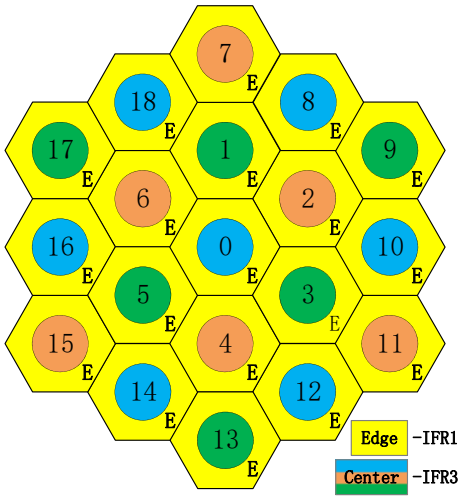


Figure 5. Fractional Frequency Reuse

4. Results

This experiment simulates the 19-cell network between FFR and IFR. This test sets 3 frequency channels for the inner area, and 5 frequency channels for the outer area. Furthermore, the transmit power for outer area is 1, and the transmit power for inner area is 0.5. Compared with figure 3-1, it is obvious that the figure 3-2 has the smoother curves. That because the number of random simulations increase. However, it does not increase linearly, but with the increase of SNR, the average power tends to be stable. Figure 3-3 can illustrate this result.

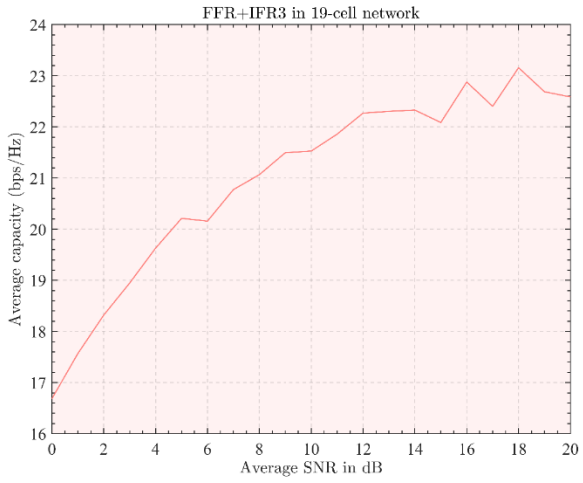


Figure 6. Results when Number of Simulations = 300

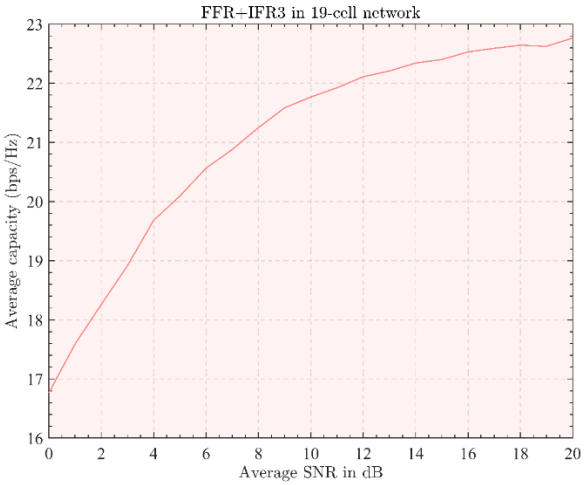


Figure 7. Results when Number of Simulations = 2000

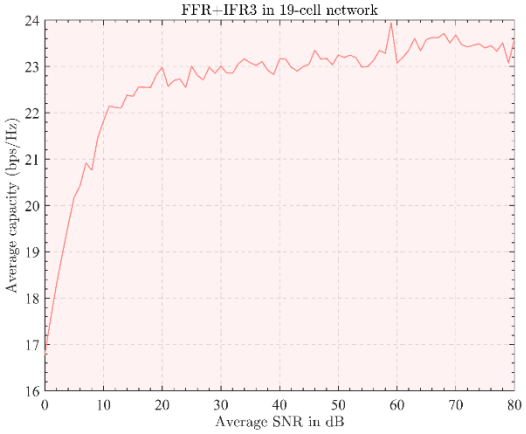


Figure 8. Results when SNR ranges form 0 to 80 dB

$$C = W\log_2(1+SINR) \tag{15}$$

The formula15 can understand it simply. Actually, at the beginning, idealizing the parameters ρ can show the interference. Where C is the capacity and W is the Bandwidth, $SINR$ is the Signal to Interference plus Noise Ratio.

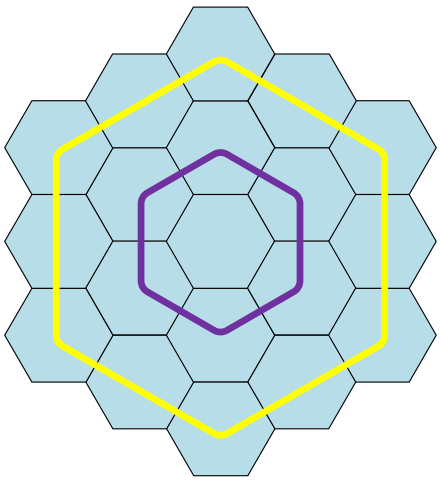


Figure 9. Hexagonal cell model

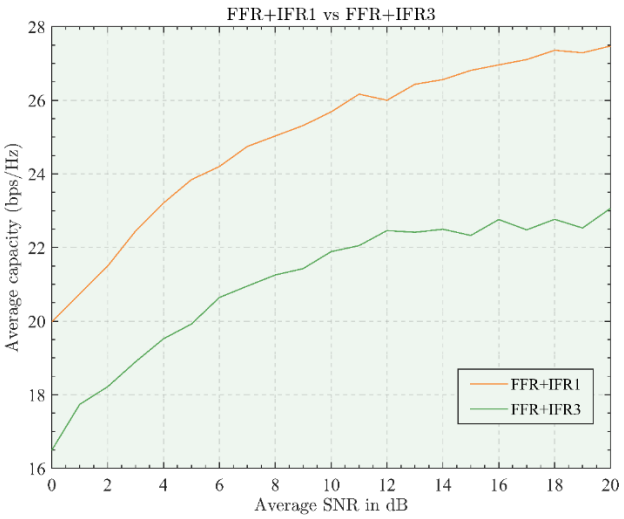


Figure 10. Comparation of FFR + IFR1 and FFR + IFR3

In the picture, ignoring the distance, this model shows that each hexagon has the same distance.This figure displays the comparison among the FFR + IFR with the reuse factor is 1 and 3 respectively. When the average SNR for each user increases from 0 to 20 dB, the FFR+IFR3 shows inferior performance [8].But in reality, each distance needs to be calculated in detail, so modifying some ρ can make the situation more realistic.

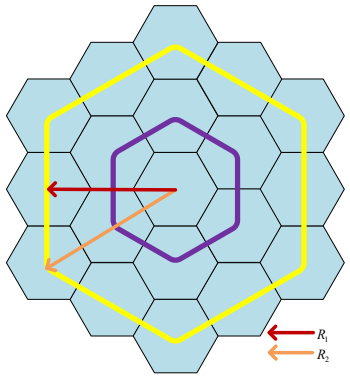


Figure 11. Hexagonal cell model (with R_1 and R_2 introduced)

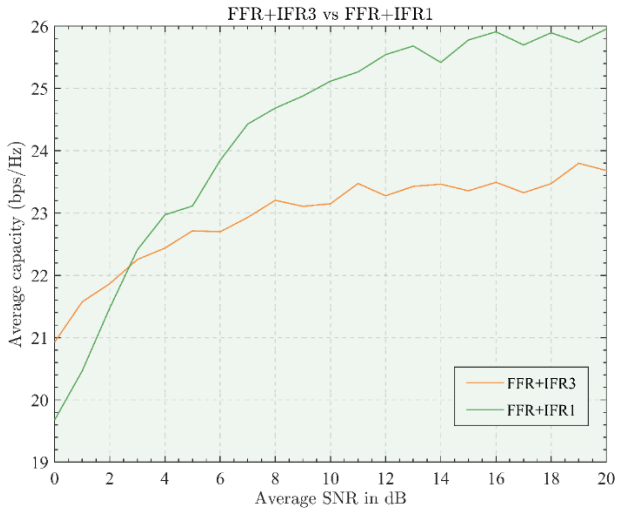


Figure 12 Comparation of FFR + IFR1 and FFR + IFR3

Afterwards, it depicts that every cell's distance should be considered when building the model.When the average SNR for each user is approximately lower than 3 dB, the performance of FFR+IFR1 is better than the performance of FFR+IFR3, when the Average SNR is larger, the performance of FFR+IFR3 is better than the performance of FFR+IFR1[9-10].

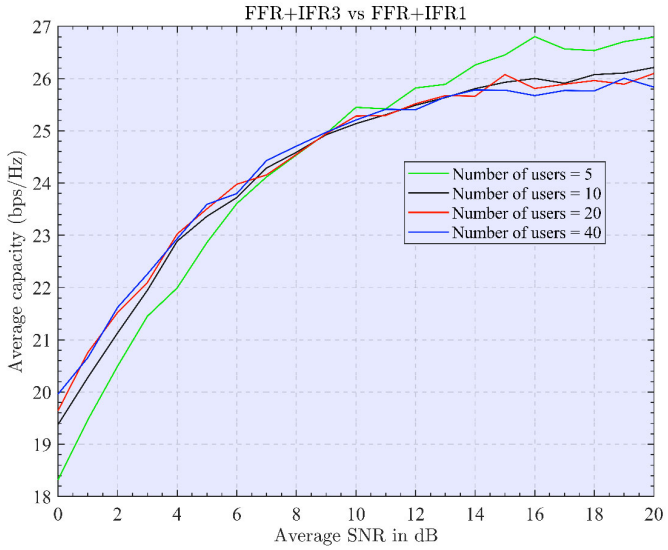


Figure 13. Results when Number of users increases

Relatively speaking, average number of users per cell has little influence on the average capacity. However, the average capacity will decrease when average number of users per cell is getting larger. T is center radius R is cell radius so T is smaller than R, P_1 is smaller than P_2. In fact, P_1 is the transmit power for cell center and P_2 is the transmit power for cell edge.

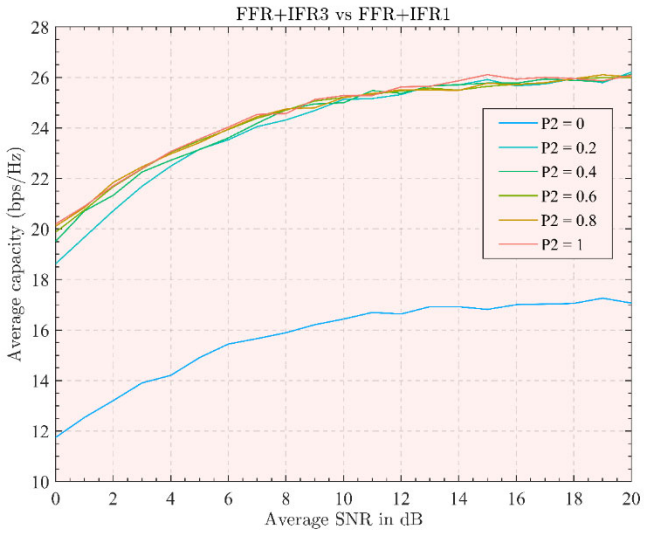


Figure 14. Frequency reuse performance with various range of Transmit power for cell edge.

$$P_1 = \left(T/R\right)^{\alpha} \bullet P_2 \tag{16}$$

T is center radius R is cell radius so T is smaller than R, P_1 is smaller than P_2. In fact, P_1 is the transmit power for cell center and P_2 is the transmit power for cell edge.

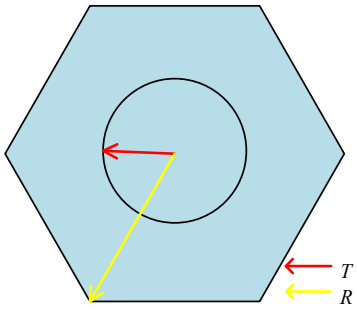


Figure 15. Single Hexagonal Cell Model

5. Conclusions

The article involves the change of average capacity in different SNR ranges and the comparison in different modes. To be exact, when the distance between each cell is more accurate, FFR+IFR3 performs better than FFR+IFR1. Average number of user per cell and transmission power for cell edge have little impact on average capacity. Once the SNR becomes infinite, the average capacity will hardly change.

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