Comparison of Different Frequency Channel Allocation Methods in ultra-dense networks

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Abstract: The impact of information transmission on production and life under dense networking is self-evident. Dense networking application scenarios include airports, dense residential buildings, dense business districts and blocks, campuses, large gatherings, stadiums, subways, etc. However, with the increase of 5G frequency band, the 5G macro base station signal attenuates more when it penetrates the wall than 4G, which makes it difficult to cover indoor signals. The outdoor 5G macro base station signal can only provide shallow indoor coverage after penetrating obstacles such as brick walls, glass and cement, which cannot guarantee the good experience required for indoor deep coverage. This paper compares and discusses various channel allocation algorithms based on user scenarios in ultra-dense networks. By adjusting some parameters of 19 units, the integer frequency reuse (IFR) method (N=1,3), fractional frequency reuse (FFR) method, simultaneous water injection (SWF) method, and transmission interference temperature limit (TX-ITL) method are compared. In order to increase the capacity, a combination of several algorithms will also be used.

Keywords: Frequency Allocation, IFR, SWF, tx-ITL, FFR.

1. Introduction

Recent years have witnessed a rapid development of mobile communication networks from the 1G era to the 5G era. With the rapid development of wireless communication technology, the amount of broadband and user demands are increasing day by day, and when the limited network resources cannot meet the infinite market demand, the communication quality will decline. Several recent experiments show significant radio spectrum white spaces [1]. A more premium and effective frequency allocation strategy plays a significant role in resource allocation and improving utilization rates.

Previous frequency allocation methods have some limitations. In the IFR method, the frequency channel allocation is predefined and rigid. Therefore, the inter-cell interference coordination (ICIC) technique of the fractional frequency reuse (FFR) system has been proposed in OFDM-based fourth generation (4G) wireless standards [2]. However, both IFR and FFR methods are predefined and rigid. So, a more flexible algorithm called Simultaneous Water-Filling (SWF) has been introduced and Ling et al.s'(2013)study has optimized it as well [3]. Ren, Wong, and Khandaker [4] provide a more intelligent approach called the tx-ITL algorithm to manage the intensity of interference. Few people compare network capacity with different allocation methods or combine them. In addition to considering the channel capacity, the algorithm also needs to make flexible changes according to different environments. As a result, A better and smarter signal allocation needs to be analyzed. Aimed at the problem that the traditional frequency allocation method has poor performance in dense scenes that cannot meet people's daily life, the experimental results show that the performance is good, and has a good application prospect.

2. Method

The key to the method of this article is frequency reuse in hexagonal cell tessellation. The frequency reuse factor N is defined as the number of channel sets in the reuse pattern, depending on (k, l) Derive N:

$$\frac{D}{R} = \sqrt{3N} \tag{1}$$

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

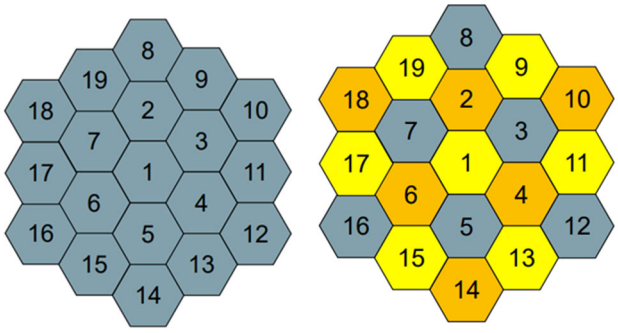
2.1 Integer Frequency Reuse

The channel capacity for each cell can be determined as follows:

$$C_n = \log_2\left(1 + \frac{|h_{n,n}|^2 P_n}{\sum_{m \neq n} |h_{m,n}|^2 P_m + \sigma^2}\right) \tag{3}$$

Where is channel gain from BS m to user n; P_n represents the BSn's transmit power.; P_m represents the BSm's transmit power; $\sigma^2$is the noise power.

$$C_{total} = \sum_n C_n \tag{4}$$



N=1 N=3

Figure 1. Principle in 19 network with Integer Frequency Reuse

2.2 Simultaneous Water-Filling (SWF)

A more flexible and intelligent algorithm will be introduced which considers multiple frequency channels for a user to best utilize the resources to maximize its capacity [5]. Water-Filling power allocation helps every user to select frequency by defining Channels for each frequency is$|H[f]|^2$, and then give the capacity for the user as:

$$\sum_{f=1}^{16} log_2 \quad (1 + \frac{P_f |H[f]|^2}{\sigma^2}) \tag{5}$$

Where P_f represents transmit power at frequency f and σ^2 represents noise power.

2.3 Transmit Interference Temperature Limit（tx-ITL）

On the basis of Game theory, SWF is highly inefficient due to CRs selfish compete [6]. As a result, almost all the user would like to occupy all the frequency channels which lead to inevitable interference. In order to solve this problem, tx-ITL will be shown in detail. A new constant called S_k will control the interference, which is compared with $c_k[n]$ so that user only occupies appropriate frequencies.

2.4 Fractional Frequency Reuse (FFR)

To service customers in the cell's inner and outer regions, different transmit powers are used [7-8]. A smaller P1 to service the cell's interior helps lessen interference with neighboring cells. Because of the greater distance, a larger power P2 is required to supply the cell's outside region [9].

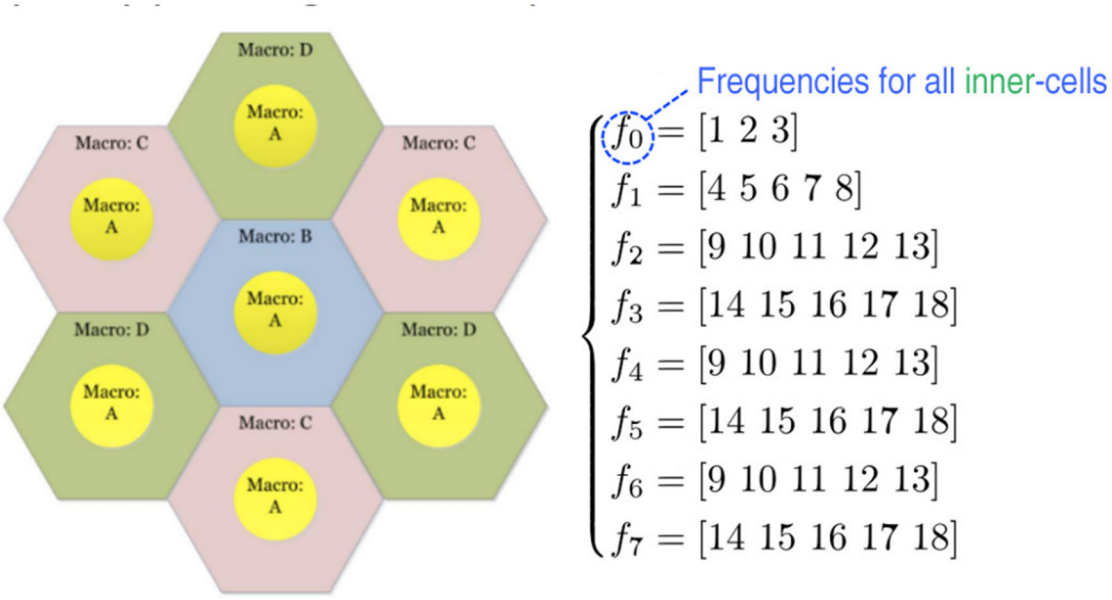


Figure 2. FFR method principle in 7 cell network

3. Results

In the parameter selection part, the reuse factor equals 1 or 3, within 500 random simulations, the number of frequency channels for inner area is 6, for outer area is 12, the average number of users in one cell is 9 and the range of SNR is 0:2:20.The simulation is implemented in the MATLAB R2018b software on Dell xps 13.

3.1 Analysis of experimental results in FFR section

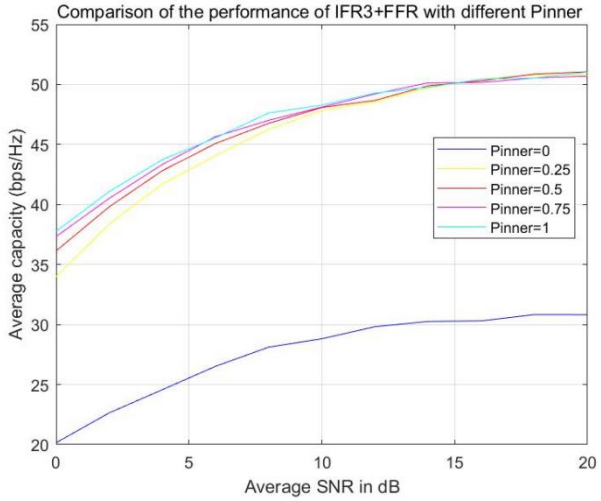


Figure 3. The capacity with different Pinner

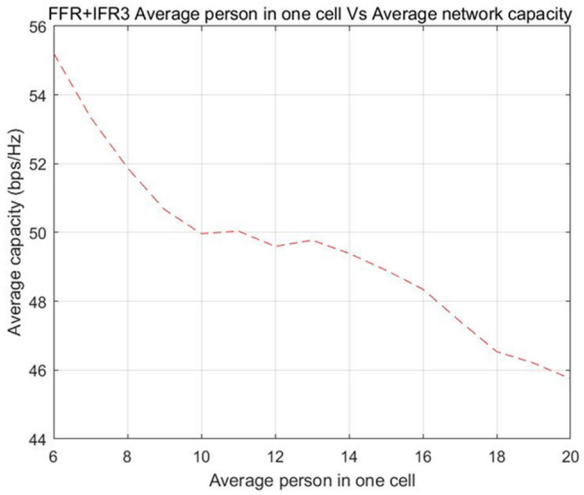


Figure 4. Capacity vs average person in one cell

In FFR method, it is crucial to choose a power budget ratio that is appropriate for both the inner and exterior areas. We experimented with different P values to determine which was the most effective. We then examined each value's performance in the network of 19 cells using the IFR3+FFR method. The simulation's output is shown in Figure 3 below, where P moves from 0 to 0.25, and the capacity rises significantly and then maintains. We can also find the capacity is very similar except when Pinner=0. In this instance, it is unnecessary to continuously raising the inner area's power budget. Consequently, 0.25 is the optimal option for the power budget ratio. Figure 4 shows that as the number of people in each cell increases, the capacity declines as the amount of user disturbance increases.In FFR method, I also tried to find the relationship between the inner or outer channel numbers and

capacity. As the figure 5 shows, when the inner frequency channel=3 and the outer frequency channel=15 is similar to the inner frequency channel =15 outer frequency channel=3. So in FFR+IFR3 method average capacity increase first and then decreases as the center users increases.
Through Figure 6 below, we could draw a preliminary conclusion

- IFR1 has the highest average capacity and IFR3 has the lowest capacity.
- FFR+IFR3 is smarter than FFR+IFR1
- FFR method improves the IFR3 capacity, but reduce IFR1 capacity.
- The fewer users, the lower the average capacity.

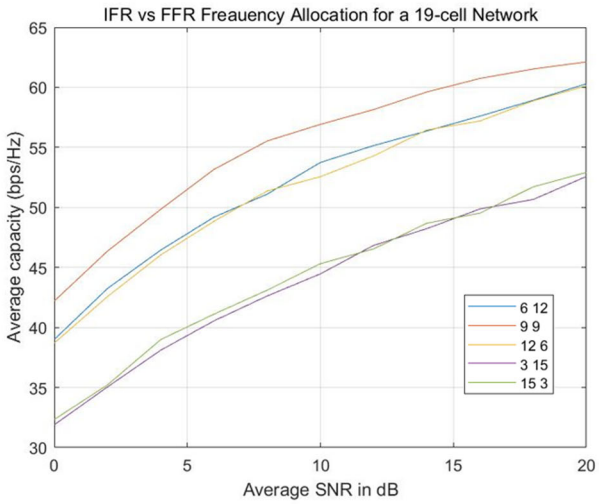


Figure 5. the capacity with different channel numbers

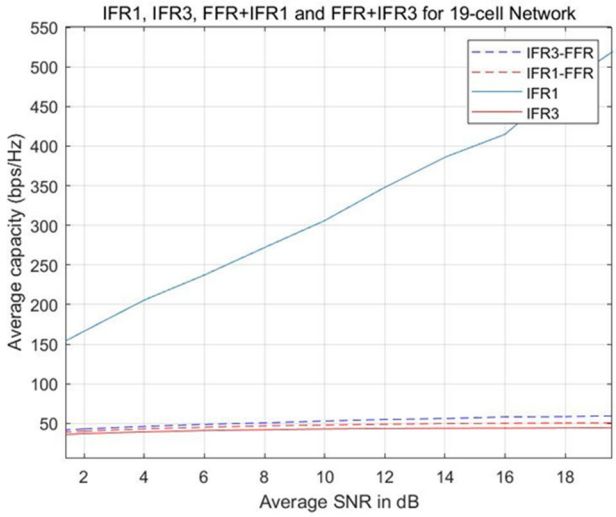


Figure 6.FFR vs IFR method

3.2 Comparison of four algorithms

It is critical to choose an appropriate Sk value for the tx-ITL algorithm. There is no advantage when Sk is set very high because the outcome is nearly identical to the SWF solution, and when Sk is to small it will not perform [10]. When Sk=100, the performance is at its best, as shown by the simulation result in Fig. 7. The four methods are comparison was shown though Fig.8. Obviously red line tx-ITL+IFR3 has the best capacity performance most of time, but when SNR range between 5.5-9 and 12-15.5 SWF+IFR3 is the best.

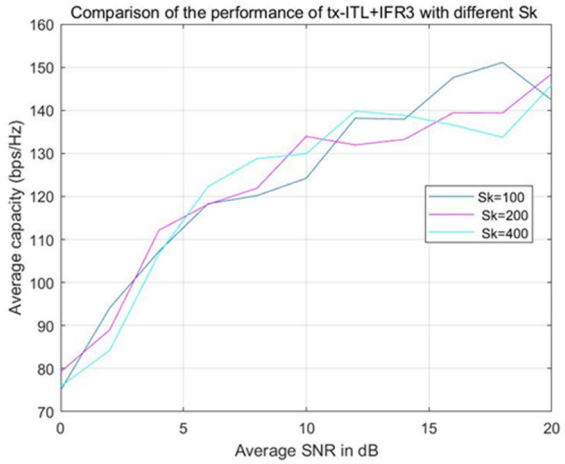


Figure 7. Cpacity with different Sk

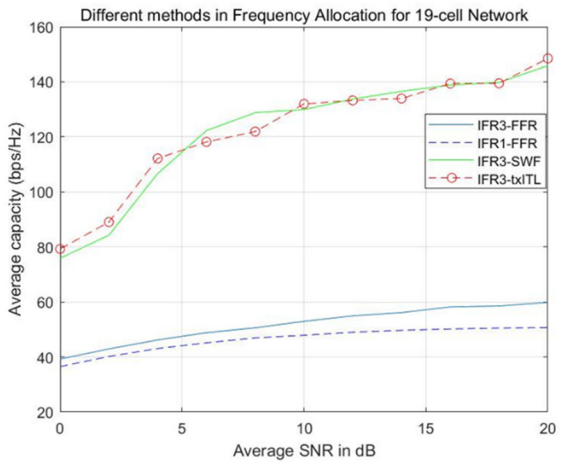


Figure 8. Capacity comparison with 4 algorithms

Although FFR has been applicated which improve capacity at first, yet compared with these two methods above, the capacity increases very slightly as SNR continues to increase. To conclude, their performance is worse means capacity is much smaller.

4. Conclusions

In this essay, the optimal channel allocation method have been examined based on the case of ultra-dense scenario. In extra dense situation, a smarter algorithm with higher capacity and less interference is our purpose. This essay has described 4 frequency allocation techniques which have also been combined with FFR and IFR method. Furthermore, it provides the formula used to calculate these variables for each approach. Moreover, the article has identified the most appropriate value for many parameters to optimise these algorithms. For example, It is critical to choose an appropriate Sk value for the tx-ITL algorithm. By evaluating the capacity under various SNR range of each method, a method with good performance has been chosen. The experimental results show that the txITL-IFR3 algorithm can meet massive user demands in ultra dense scenarios and has a good development prospects.

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