Research and design of resource allocation algorithm in wireless communication system

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Abstract. Although communication has been a topic of research since the 1960s, the last decade or so has seen a boom in research in this area. This is mainly due to the influence of several comprehensive factors, such as spectrum, power. We research the method Integer Fractional Frequency (IFR) and Fractional Frequency Reuse (FFR). We research some equations in a wireless system. And we calculate the capacity under different channel numbers. We also research the optimal power in a cell system, and the best suitable user number in the system. In a real environment, such a method can optimize the system capacity or performance and we can use a suitable model.

1. Introduction

With the fast development of wireless communication technology, we have higher requirements for wireless transmission speed. Now 4G networks have achieved full coverage, while 5G networks also have only certain coverage regions. 5G technology, an extension of 4G technology development, is a high-frequency and high-speed wireless communication technology. Now 5G networks have become another new stage of mobile communication development. Among 5G network technologies, the most important and precious thing is wireless Communication resources, 5G network wireless communication resource allocation technology is a key technology in the development of 5G networks [1, 2]. In terms of the wireless communication system, the amount of data information is constantly increasing. The appearance of this situation has created new contradictions between people's requirement for traffic and the frequency of useless resources. The unsatisfactory demand for communication technology results in a mismatch between wireless resources and actual requirements. For 5G network technology, user demands are higher. To ensure that there are sufficient frequency resources, resources need to be green and environmentally friendly [3]. In view of the scarcity of 5G spectrum resources, limited power resources, and intricate network construction, how to efficiently allocate limited frequency resources and maximize network performance is an urgent issue to be solved in the development of 5G. Therefore, the research of 5G-oriented network resource allocation is of great significance to the development of 5G [4].

The frequency reuse technology under the cellular concept can well work out the problem of frequency resources. In the 21st century, the sharp development of mobile communication technology, the limited spectrum resources gave birth to the development of frequency reuse technology, the concept of cellular is proposed to solve the issue of insufficient frequency. The core idea of the cellular concept is that cells (base stations), which are remote from each other, share the same frequency. It was not until...
1979 that the first cellular system became a reality in the United States. Cellular technology has greatly increased the capacity of the system, at the cost of increasing the overhead of the system construction and making the mechanics of communication more intricate. The specific manifestation is more complex implementation protocols, complex facility technology, and wireless resource management and mobility management [5].

But the mechanics of communication can really go to the masses, and the solution to the increase of its system capacity is the key, and the proposal of the cellular concept solves the fundamental factor limiting the improvement of capacity [6]. The development of mobile communication technology is to continuously expand capacity and improve spectrum utilization. The evolution of frequency reuse technology has witnessed the continuous improvement and progress of mobile communication technology [7]. The system allocates different subsets in the sequence space to different areas of the sector. By means of power control, the coverage of the specified sequence in different sectors (or cells) is different, and the signal to interference ratio is improved, so as to improve the spectral workpiece ratio of the system. It can improve the spectrum efficiency of the system to a greater extent, and realize the frequency reuse coefficient of 1, which greatly reduces the complexity of frequency planning in cell deployment [8]. This paper briefly analyzes the characteristics of 5G network wireless communication, and then summarizes the principles of 5G network wireless communication resource allocation in terms of guaranteeing service quality and fairness. Then, on the basis of low-frequency spectrum allocation and high-frequency spectrum allocation, this paper analyzes and expounds the allocation mode of 5G network wireless communication resources in detail [9]. 5G network wireless communication in the use of the process, the most significant feature is fast and stable, which compared with the previous modes of mechanics of communication, the advantages can be shown from many aspects [10, 11]. The biggest challenge for future wireless communication systems is to provide users with a quality of service (QoS) guarantee and efficient spectrum resource utilization [12]. Flexible and effective wireless resource management and scheduling plays an important role in the design of wireless network [13, 14].

2. Method
In this section, we will show our research in detail.

2.1. IFR3
The cellular wireless system model is as follows:

![19-cell wireless system model](image)

Figure 1. 19-cell wireless system model

In the model, we use such calculation:

\[ N = k^2 + k^1 + l^2 \]  

(1)

where \( N \) is the number of cells on the same frequency. To switch from a cell to a cell with the same frequency, we need to go clockwise \( K \) grid, then turn clockwise 60 degrees, and go \( L \) grid. Take figure 1 as an example. When \( N=3, k=1, l=1 \), then cell 1, 9, 11, 13, 15, 17, 19 share one frequency, cell 2, 4, 6, 10, 14, 18 share another frequency, cell 3, 5, 7, 8, 12, 16 share the other frequency. In the system model, only the cells sharing the same frequency have interference before, and the size of the interference coefficient is positively correlated with the distance between the two cells. The signal power \( S \) is
calculated as follows:

$$S(c,u) = P \cdot |h(c,c,u)|^2$$  \hspace{1cm} (2)$$

Where P represents the power allocated to a cell, \( h(c,c,u) \) is the channel gain of the Rayleigh distribution. The interference power I between cells is calculated as follows:

$$I(c,u) = \sum_{c\neq c} \rho(c,c) \cdot P \cdot |h(c,c,u)|^2$$  \hspace{1cm} (3)$$

Where c_ is a cell that shares the same frequency as the currently used c, u is the number of users in a current cell, P is the power allocated by the channel, and \( \rho \) is the interference coefficient between the two cells. \( h(c,c,u) \) is the channel gain from the signal generated by c_ to the signal received by c.

The signal-to-noise ratio SINR is calculated as follows:

$$SINR(c,u) = \frac{S(c,u)}{I(c,u) + \sigma^2}$$  \hspace{1cm} (4)$$

Where I(c,u) is the noise which comes from other users. \( \sigma^2 \) is the power of Gaussian White Noise.

$$\sigma = \sqrt{\frac{P}{SNR}}$$  \hspace{1cm} (5)$$

Where SNR represents one user’s signal to noise, P represents the power.

Then the channel capacity is calculated as follows:

$$C = \sum_{c=1}^{19} \log_2 (1 + SINR(c,u))$$  \hspace{1cm} (6)$$

2.2. FFR+IFR3

The FFR model is as follows:

![Figure 2. FFR +IFR3](image)

In the model, part of the frequency is reused, the central area of each cell is allocated the same frequency, so there is interference in the central area of each cell. Take a 19-cell system as an example.
for the edge area. We also assume \(N=3, k=1, l=1\). Then cell 1, 9, 11, 13, 15, 17, 19 share one frequency; cell 2, 4, 6, 10, 14, 18 share another frequency; cell 3, 5, 7, 8, 12, 16 share the other frequency. The interference coefficient is determined by the distance between cells sharing the same frequency. The calculation of the signal power \(S_{\text{center}}\) in the center area is as follows:

\[
S_{\text{center}}(c, u) = P_1 \cdot |h(c, c, u)|^2
\]  

(7)

Where \(P_1\) is the power of the channel allocated to the central area of the cell. \(h(c, c, u)\) is the channel gain of the Rayleigh distribution. \(c\) is the cell where the user is currently located. \(u\) is the number of users in the current cell. The interference power \(I_{\text{center}}\) between the central areas of the Cell is calculated as follows:

\[
I_{\text{center}}(c, u) = \sum_{c_1=1}^{19} \rho(c, c_1) \cdot P_1 \cdot |h(c_1, c, u)|^2
\]  

(8)

Where \(c_1\) is a cell that shares the same frequency as the current cell \(c\), \(u\) is the user number in cell \(c\), \(P_1\) is the power of the channel allocated to the center of the cell, and \(\rho\) is the interference coefficient between the centers of the two cells. \(h(c_1, c, u)\) is the channel gain from the signal generated by \(c_1\) to the signal received by the cell \(c\).

The SINR_{center} of the central area is calculated as follows:

\[
\text{SINR}_{\text{center}}(c, u) = \frac{S_{\text{center}}(c, u)}{I_{\text{center}}(c, u) + \sigma^2}
\]  

(9)

Where \(\sigma^2\) is Gaussian White Noise power.

\[
\sigma = \sqrt{\frac{P_1}{\text{SNR}}}
\]  

(10)

The channel capacity \(C_{\text{center}}\) of the central area is calculated as follows:

\[
C_{\text{center}} = \sum_{c=1}^{19} \log_2(1 + \text{SINR}_{\text{center}}(c, u))
\]  

(11)

The edge area signal power \(S_{\text{center}}\) is calculated as follows:

\[
S_{\text{edge}}(c, u) = P_2 \cdot |h(c, c, u)|^2
\]  

(12)

Where \(P_2\) is allocated to the power of the channel at the edge of the cell.

The interference power \(I_{\text{edge}}\) between the edge regions of the cell is calculated as follows:

\[
I_{\text{edge}}(c, u) = \sum_{c_1=1}^{19} \rho(c, c_1) \cdot P_2 \cdot |h(c_1, c, u)|^2
\]  

(13)

Where \(c_1\) is a cell that shares the same frequency as the currently used \(c\), \(u\) is the shared frequency, \(P_2\) is the power of the channel allocated to the central area of the cell, and \(\rho\) is the interference coefficient between the two cells.

The signal-to-noise ratio \(\text{SINR}_{\text{edge}}\) of the edge area is calculated as follows:

\[
\text{SINR}_{\text{edge}}(c, u) = \frac{S_{\text{edge}}(c, u)}{I_{\text{edge}}(c, u) + \sigma^2}
\]  

(14)

Where \(\sigma^2\) is Gaussian White Noise power.
The channel capacity $C_{edge}$ of the edge area is calculated as follows:

$$\sigma = \sqrt{\frac{P2}{SNR}}$$

The total channel capacity $C$ is calculated as follows:

$$C = C_{center} + C_{edge}$$

3. Results and Discussion

FFR+IFR3: Assuming that the power in the center area $P_1=0.5$ and the power in the edge area $P_2=1$, there are a total of 18 frequencies, the number of frequencies in the center area is 3, and the number of frequencies in the edge area is 5.

IFR3: Assuming the allocated power $P=1$, there are a total number of 18 frequencies.

Figure 3. FFR+IFR3 compared with IFR3

Figure 3 shows that when SNR increases, the capacity of the system also increases, that’s because $C=W \log_2(1+SNR)$. It also shows that under the same SNR, FFR+IFR3 has a higher capacity than IFR3, that’s because FFR can improve the efficiency of spectrum.
Figure 4 shows that the allocated power in a center user will affect the capacity, when power is 0.3, the capacity can achieve the highest. That’s because when the center user’s power increases from 0, SNR increases, this leads that capacity increases. When it reaches a suitable value, after that the power increases, the capacity will decrease. That’s because a high power will interfere with edge’s user, which leads to a decrease in capacity.

Figure 5. System with 5 channels
Figure 6. System with 15 channels

Figure 7. System with 25 channels
In Figure 5, the frequency channel number is 5, in Figure 6 the frequency channel number is 15, in Figure 7, the frequency channel number is 25. The blue line represents the average network capacity of FFR+IFR3 and the black line represents the average network capacity of IFR3. From these figures, we can conclude that the number of channels has little influence on capacity under some conditions. Figure 8 shows that the number of frequency channels is not the important element for capacity under some condition. That’s because, under the same user number, FFR can improve spectrum efficiency, which means that channel number does not play a decisive factor.

**Figure 8.** Variation trend of frequency channels

**Figure 9.** System with 10 users
Figure 10. System with 20 users

Figure 11. System with 30 users
The line above represents the capacity of FFR+IFR and the line below represents the capacity of IFR3 in Figure 9, 10, 11. In Figure 9, the system has 10 users, in Figure 10, the system has 20 users, in Figure 11, the system has 30 users. In these three figures, we can see that if the number of users increases, the capacity also increases. In Figure 12, we can see that under some condition, when the number of users increases, the capacity also increases, that’s because $C = \sum_{c=1}^{19} \log_2(1+SINR(c,u))$.

4. Conclusion
In this paper, we research the best value of P1 (the center user power) and the most influential factor for the capacity in a wireless system. In a real situation, adopting FFR can improve the performance of a wireless system. We also research that the number of users can affect the capacity of a system, so we should adjust the number of users.

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