Frequency Allocation Based on FFR and SWF Algorithm Fusion of Large Trading Area Under the Condition of COVID-19

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Abstract: The highest level of epidemic prevention and control is precise prevention and control. That is to say, through rapid flow adjustment, we can track down all the close contacts and sub-close contacts, and only isolate them without affecting the work and life of others. Of course, it is difficult to achieve absolute precision prevention and control, so how to measure the degree of precision prevention and control in a region with a quantitative method. How to achieve the balance between security, efficiency, and economy under the abnormal background. From the perspective of safety, the prevention and control of the COVID-19 epidemic are still in a critical period. Once it is not carefully controlled, it may still cause secondary transmission, which will bring huge losses to the city's epidemic prevention work and the safety of residents' lives and property. Therefore, in order to immediately feedback on potential infectious sources, we created the fusion of FFR and SWF algorithms to expand the frequency capacity. The supervisors of large business districts can ensure that the frequency is distributed among as many groups as possible through the greater capacity to improve the information inspection mechanism.

Keywords: Network System, Interference, Fractional Frequency Reuse, Cellular Network.

1. Introduction

The outbreak of COVID-19 has been an essential and troublesome social issue in the past three years. However, most countries around the world have already implemented the most effective methods for epidemic prevention and control. China adopted a " scanning code " to ask the public to report risks voluntarily, so as to carry out more efficient prevention and control of the epidemic nationwide. And also, the outbreak of COVID-19 has also promoted the development of the telecommunications industry at the same time [1].

In various cities, there is no doubt that large business districts are one of the main places where people gather. With the rapid development of the economy, people's pursuit of material life is getting higher and higher, and the business circle is also growing, so as to the modern people's pursuit of material and economic [2]. Therefore, the frequency and range of crowd gathering will be improved, and the speed of crowd flow will also be faster. Methods such as "scanning code" will become limited and inefficient to a certain extent. Based on this problem, this essay will propose a new solution. Base stations can be established in large business districts for frequency distribution, directly associate with mobile devices of people entering and leaving business districts, query and back up the recent history of areas entering and leaving, timely count the flow of people, and control people with high risks. The network system will adopt the algorithm fusion between FFR and SWF to ensure the frequency distribution to more groups at the same time.

2. Basic fundamental of the FFR+SWF network system

2.1 Structure of the network system

2.1.1 Fractional Frequency Reuse in 19 Cell

Similar to Integer Frequency Reuse with Factor N (IFRN), the FFR solution is created to reduce the disturbance from other base stations and accept more effective capacity. Depending on where the user is positioned in the cell, two frequency reuse options are incorporated in the FFR solution [3]. Every cell is divided into two parts which are called cell center and cell edge. All the cell centers share the same frequency. So IFR1 scheme is used in the center of the cell. Cell edges choose IFRN scheme. The distinction between center and edge depends on human control. Engineers can set the radius of the center on the basis of the environment and structure.

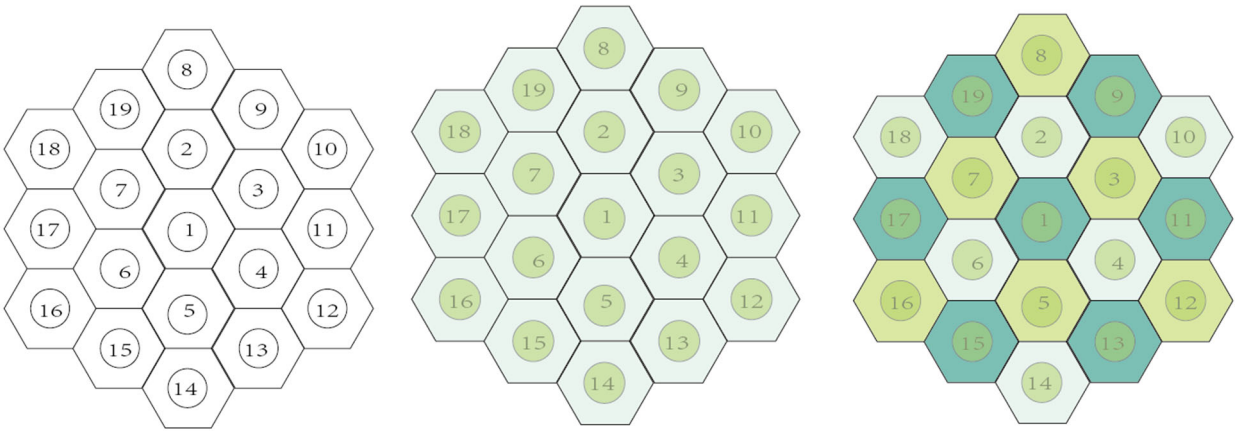


Figure 1. Images of 19-Cell Fractional Frequency Reuse in interference IFR1 and IFR3.

The typical FFR approach at the center of the cells uses Integer Frequency Reuse 1 (IFR1), which ensures that all inner cells utilize the same frequency. However, at the edge of the cells, IFRN is used to perform the computation. In Figure 1, IFR1 and IFR3 in cell edge are represented. Users can increase channel capacity by using this frequency reuse mechanism [4].

2.1.2 Simultaneous Water-Filling (SWF) in 19-Cell

Compared with the Water-Filling method, the Simultaneous Water-Filling solution is an application of the Water-Filling Solution into multiple user allocations. Because in the Water-Filling solution, there is only one user in the entire frequency channel [5, 6]. Basically, the space usually has multiple users. Therefore, SWF can relieve this problem and increase the capacity.

To carry out a Simultaneous Water-Filling solution, the initialization of the users' power allocation randomly is important. When one user starts applying the Water-Filling Solution, assuming that all other users' power allocations are fixed. When their power allocations are fixed, the user can be considered as a fixed interference pattern.

When the solution is used, the frequencies' channel is $|H[f]|^2$, the 19-cell's user capacity is determined by

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

where P_f is the transmit power at frequency f.

The users'capacity in general is offered by

$$C = \max \sum_{f=1}^{Nc} log_2(1+\frac{P_f|H[f]|^2}{\sigma^2}) \quad (2)$$

for $P_1 + P_2 + \ldots + P_{Nc} \leq P$.

The maximization which is presented priviously can be soved by the Lagrange multiplier method

$$L = \sum_{f=1}^{Nc} log_2(1 + \frac{P_f|H[f]|^2}{\sigma^2}) + \lambda(\sum_{f=1}^{N_c} P_f - P) \quad (3)$$

For N channels, the optimal power allocation is

$$\sum_{n=1}^{N}(\alpha - \frac{\sigma^2+I[n]}{|H[n]|^2})^+ = P \quad (4)$$

For the sake of water-level, we should introduce

$$p[n] = (\alpha - \frac{\sigma^2+I[n]}{|H[n]|^2})^+ \quad (5)$$

2.2 FFR and SWF algorithm fusion

2.2.1 Summary and Innovation in Different Frequency Reused Algorithms (19-cell)

Due to the calculating function in MALTAB, the comparation of Simultaneous Water-Filling (SWF) and Fractional Frequency Reuse (FFR) can be achieved through inputting the same data. Therefore, which method is more effective can be easily confirmed. The result shows that the SWF method can help users get more capacity. Because of some issues which cannot be ignored in the process, both IFR and FFR are still unadaptable and inflexible. The method cannot make a reasonable distribution in frequency capacity between cells on its own initiative[7, 8].From the limitations, this method will lead to inefficiency, unskillfulness, and many problems. During the innovation and practice, in the same condition and same inputted data, the method of FFR and SWF algorithm fusion will achieve larger capacity. Therefore, this method has a promising prospect in the reality.

2.2.2 Capacity Calculation in FFR and SWF algorithm fusion with Different Frequency Reused Factor (N)

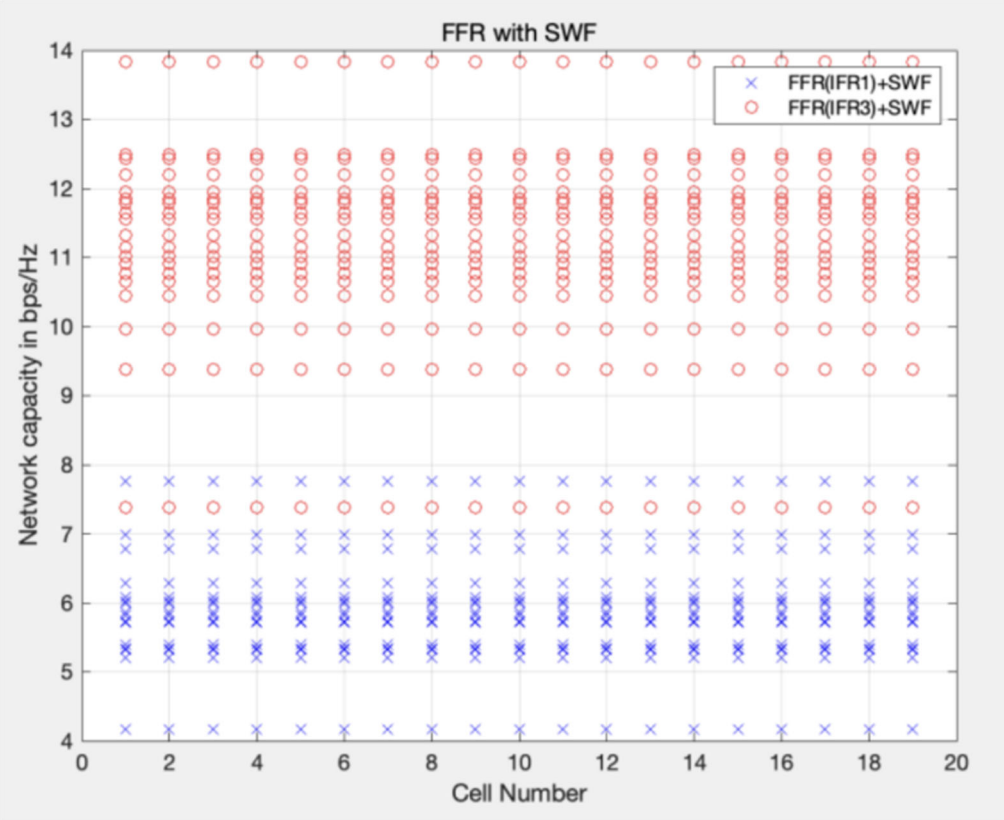


Figure 2. The Capacity of FFR(IFR1)+SWF and FFR(IFR3)+SWF Method with Small Input

In the experiment before, when the inputted data is the same but using the different frequency reused factor (1 or 3), the network capacities of the two solutions will be very close. Hence, if the

better method in FFR and SWF algorithm fusion wants to be selected, the further research and cooperation will be done.

In order to confirm the solution which can make more capacity in FFR and SWF algorithm fusion, the MATLAB carries out the code of FFR (IFR1) + SWF and FFR (IFR3) + SWF simultaneously and plots the figures of them to straightly observe the difference between them. The exmpriment is run in MATLAB R2021b, MacBook Pro (13-inch, M1, 2020).Through simulation and analysis of research, carrying out the function of FFR (IF3) + SWF can provide users with more channel capacity to ensure that the frequency is distributed among as many groups as possible. As shown in Figure 2.

3. Results

3.1 The establishment of the simulation model

The 5th generation (5G) and 6th generation (6G) communication technologies are intended to perform agile response services for user devices with high capability to provide new radio (NR) services for massive user terminals [9]. Future mobile services are based on cellular systems which a convergence of heterogenous radio gateway devices [10].

According to the Cellular network, the area of the large business district can be evenly divided into independent areas, base stations are placed in the center of each area to transmit frequency signals (the base station is shown in the red icon). People carrying mobile devices in the business district are simplified as black circles. As shown in Figure 3.

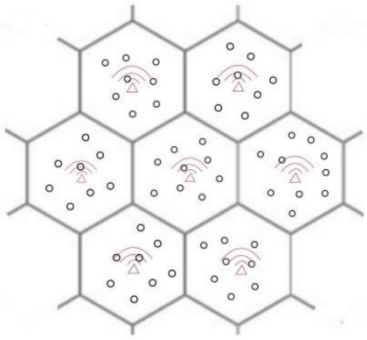


Figure 3. The diagrammatic drawing of the Cellular network.

Take a business district of about M square meters as an example while a base station covers a radius of about r meters.n order to get more frequency over the whole area we make *r* as close to *R* as possible we can. According to the regular hexagon area rule $S = \frac{3\sqrt{3}}{2}R$, we divide M into k peices (k=m/s). So we can get a Cellular network of k cells. As shown in Figure 4.

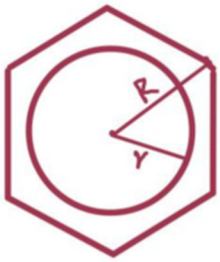


Figure 4. The diagrammatic drawing of each cell.

3.2 Analysis of experimental results and efficiency comparison

The user capacity will be expanded through the algorithm fusion. As shown in Figure 5. Find the highest efficiency method through comparing, which the frequency allocation is allocated to more

user groups in the same time. We can find that the network with both FFR and SWF has bigger frequencies. As shown in Table 1-2.

Table 1. A network with IFR and FFR.

Cell	1	2	3	4	5	6	7	8	9	10
Center capacity	2.4651	7.03624	/	/	7.6641	11.9364	12.5616	16.353	18.2612	18.7952
Edge capacity	0.0761	0.7575	2.7653	3.50434	4.75711	5.19704	5.23105	/	5.82583	11.5518
Total	2.5412	7.79374	2.7653	3.50434	12.42121	17.13344	17.79265	16.353	24.08703	30.347
Cell	11	12	13	14	15	16	17	18	19	
Center capacity	/	18.9506	19.9764	21.9038	23.5843	25.0544	28.2919	/	29.2419	
Edge capacity	11.5518	18.0926	21.5786	22.8707	23.1425	23.7102	24.4165	35.1255	35.5915	
Total	11.5518	37.0432	41.555	44.7745	46.7268	48.7646	52.7084	35.1255	64.8334	

Table 2. A network with IFR,FFR, and SWF.

Cell	1	2	3	4	5	6	7	8	9	10
Center capacity	74.1598	72.0637	78.1407	73.6396	60.1885	69.6558	69.4554	77.524	65.3663	70.6814
Edge capacity	8.61217	7.8343	7.41308	7.2243	5.1202	7.4003	6.62779	10.1794	6.9841	5.2913
Total	82.7699	79.898	85.5538	80.8639	74.3087	77.0561	76.0832	87.734	72.3504	75.9727
Cell	11	12	13	14	15	16	17	18	19	
Center capacity	81.0971	83.5789	83.4733	73.1308	63.7604	71.2062	77.9019	77.7396	66.9421	81.0971
Edge capacity	6.0173	6.6312	6.3327	7.0311	7.0831	8.4259	5.6543	7.6739	10.1237	6.0173
Total	87.1145	89.2101	89.806	80.162	70.8435	79.6322	83.5562	85.4135	77.0658	87.1145

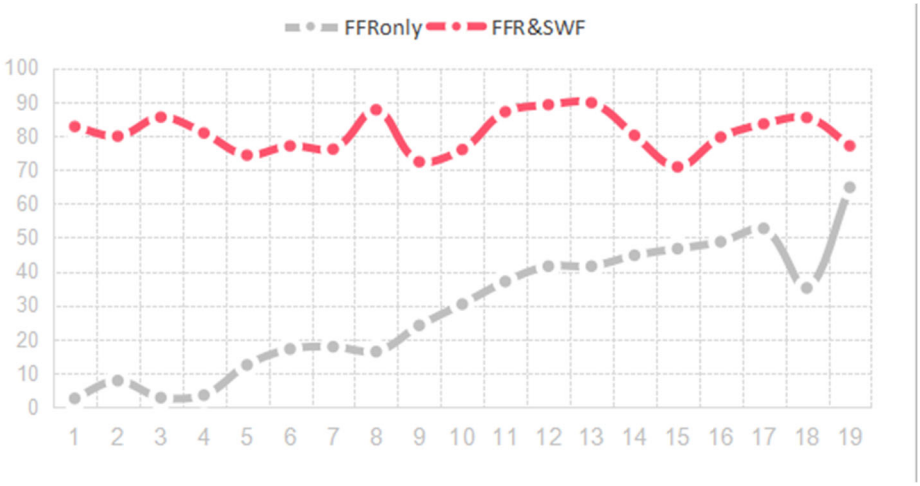


Figure 5. A comparison of the total frequencies.

4. Conclusions

After the research process and simulation experiments, the FFR and SWF algorithm fusion make a better performance than using the single method. The reason of this is that the measure of SWF will select the channels which are able to carry the stable signals and make a relative average distribution in frequency capacities between each cell. What's more, frequency planning can be improved by FFR. Therefore, combining FFR with SWF can improve the network capacity to some extent.

References

[1] J. C. Lin, "Telecommunications health and safety: The Covid-19 pandemic and 5G cellular telecommunication systems," in URSI Radio Science Bulletin, vol. 2020, no. 372, pp. 56-59, March 2020.

[2] Jie Shen, Jing Xie, Hua Kuan and Peisi Shi, "Discussion about sustainable development of country economic development zone in northern Jiang Su with industrial transferring," 2011 International Conference on Remote Sensing, Environment and Transportation Engineering, Nanjing, China, 2011, pp. 3974-3977.

[3] H. Chen, B. Huang and C. Wu, "Simulation and Analysis of Simultaneous Water-Filling Allocation Based on Fractional Frequency Reuse for 19-Cell Network," 2021 International Conference on Electronics, Circuits and Information Engineering (ECIE), Zhengzhou, China, 2021, pp. 240-244.

[4] T. I. Giovany, U. K. Usman and B. Prasetya, "Simulation and analysis of interference avoidance using fractional frequency reuse (FFR) method in LTE femtocell," 2013 International Conference of Information and Communication Technology (ICoICT), Bandung, Indonesia, 2013, pp. 192-197.

[5] O. Popescu, D. C. Popescu and C. Rose, "Simultaneous Water Filling in Mutually Interfering Systems," in IEEE Transactions on Wireless Communications, vol. 6, no. 3, pp. 1102-1113, March 2007.

[6] O. Popescu, D. C. Popescu and C. Rose, "Simultaneous Water Filling in Mutually Interfering Systems," in IEEE Transactions on Wireless Communications, vol. 6, no. 3, pp. 1102-1113, March 2007.

[7] S. Liu, X. Zheng and B. Wang, "Analysis of the Capacity of Different Frequency Channel Allocation Method in the Simulated Amusement Park," 2021 International Conference on Wireless Communications and Smart Grid (ICWCSG), Hangzhou, China, 2021, pp. 168-178.

[8] Song Wei et al 2021 J. Phys.: Conf. Ser. 1871 012082

[9] Frederic Launay, "5G-NR Radio Interface – Operations on the Frequency Bands," in NG-RAN and 5G-NR: 5G Radio Access Network and Radio Interface , Wiley, 2021, pp.141-160.

[10] Sa Math ,Prohim Tam ,Seokhoon Kim, "A Lightweight Software-Defined Routing Scheme for 5G URLLC in Bottleneck Networks",J. Internet Comput. Serv.,ISSN 1598-0170