

An Overview of Techniques for Reusing Fractional Frequency

Prakash Kumar H R¹, Madhurya B R²

Lecturer, Department of Electronics & Communication, Government Polytechnic, Hosadurga, India¹

Lecturer, Department of Electronics & Communication, Government Polytechnic, Chitradurga, India²

ABSTRACT: The traffic burden on network capacity is increased by the recent development of smart phones and multimedia applications; this can be mitigated by employing solutions with low high capacity and latency. Conventional frequency reuse plan satisfies the need for large system capacity but falls short of give cell edge users better Quality of Service (QoS). To resolve this issue, coordination of intercellular interference (ICIC) method produced a fractional solution. methods for frequency reuse (FFR). This paper provides a thorough analysis of several FFR strategies, such as stringent FFR, sectored FFR, multi-level, soft frequency reuse (SFR) FFR: advantages and disadvantages. This survey offers methods and strategies to enhance cell edge user performance, spectral efficiency, likelihood of an outage, and the system's throughput, etc. This paper's primary goal to quickly go over the development of FFR schemes and how it works the researchers' future definition of the FFR problem statement technology

KEYWORDS: Fractional Frequency Reuse (FFR), Soft Frequency Reuse (SFR), Inter-cell interference Co-ordination (ICIC) Techniques, Heterogeneous Networks, Long-term Evolution Advanced (LTE-A), Resource allocation.

I. INTRODUCTION

Rapid advancements in internet-connected mobile devices lead to a notable increase in network traffic burden. This prompts the network operator to investigate cutting-edge techniques for cellular network high data rate [1]. One of the more advantageous rivals of next-generation networks is LTE technology, which uses the orthogonal frequency division multiple access (OFDMA) approach to give users higher data rates while maintaining better spectral efficiency [2]. Individual orthogonal carriers are used by each user in the cell when using the OFDMA technology. Thus, inter-cell subcarriers are the primary cause of interference [3]. Because of the substantial frequency reuse in OFDMA-based cellular networks, managing ICI is a key difficulty [4]. The ICI lowers system bandwidth efficiency, diminishes fairness of service, and lowers channel link quality [5].

Many strategies for averaging, coordinating, and avoiding interference have been proposed; of these, coordination of interference is the preferable option in terms of spectrum efficiency [6]. System capacity increases as resources are reused effectively. Because the frequency reuse factor (FRF) value in the typical frequency reuse system is minimal, there is greater bandwidth available per cell. In contrast, the reuse-1 strategy has a high level of interference, particularly for cell edge users, which increases the likelihood of a cell outage while simultaneously reducing system capacity. When using the old technique, bandwidth available per cell is substantial for small cluster sizes; however, data rate and spectrum efficiency are limited because of the huge number of ICI. Various solutions are presented to improve the spectrum efficiency and cell edge performance. The FFR scheme, a non-traditional frequency planning technique for the multicellular network, is one of the better options to increase user gain in the cell edge zone. The FFR scheme implementation [7] offers a balance between increasing throughput, improving spectral efficiency, and expanding coverage.

The goal of 3GPP-LTE release 8 and later (Sophia, 2011) was to boost the cellular network's gain by distributing resources (such as power, frequency, and time) in a way that would lower ICI. Because of space constraints and governmental limitations, base station density is limited in metropolitan areas. Heterogeneous networks (HetNets), which comprise overlapped diverse size cells like microcell, microcell, and femtocell, enable an increase in network

International Journal of Innovative Research in Science, Engineering and Technology

[A High Impact Factor, Monthly, Peer Reviewed Journal| Impact Factor: 6.209| UGC Approved]

Vol. 5, Issue 12, December 2016

capacity. HetNets have an alternative in the form of optical wireless (OW) communication, which has recently advanced. Uncontrolled light, either infrared or visible, is used in OW communication. The transceiver employs photodiodes and an affordable incoherent light emitting diode (LED) to reduce the cost of the communication network.

In an acute setting when radio frequency (RF) communication is restricted, the OW system is used [8]. The paper's remaining portion is organized as follows: Section II explains the FFR kinds, Section III outlines the literature study on FFR methodologies, primarily stringent FFR, and Section IV provides a conclusion.

II. FRACTIONAL FREQUENCY REUSE

SFR and stringent FFR are the two main categories of FFR implementation strategies. Both uplink and downlink considerations are made for these FFR designs. Furthermore, when FFR schemes advance, new ones such as Sectorized FFR, Adaptive SFR, Multi-level FFR, and SFR are created. Fig. 1 depicts the classification of FFR schemes. The Intercell Interference Coordination (ICIC) technique distributes resources in a way that minimizes waste and maximizes spatial usage. The entire available bandwidth for each cell in the FFR scheme is split into primary and secondary segments. These frequency segments are assigned with the intention of minimizing interference for users in the cell interior region and taking into account interference among users in nearby cell edge regions [9].

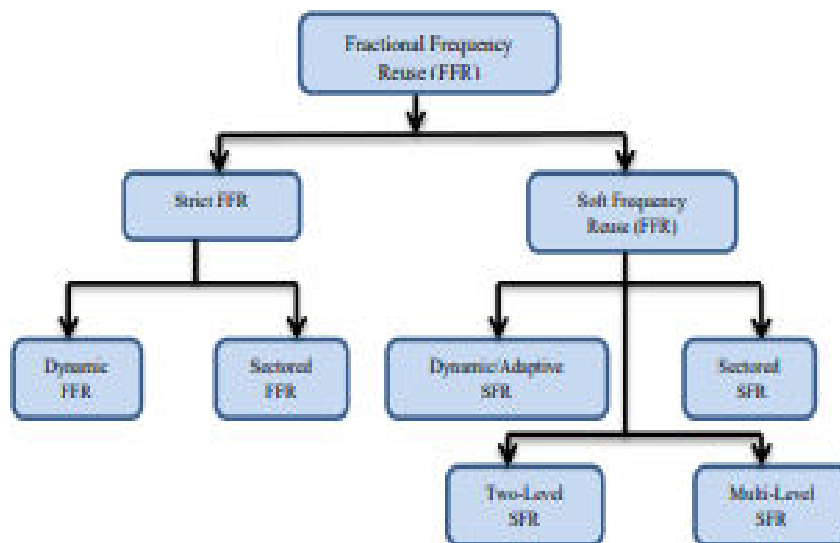


Fig. 1 Classification of Fractional Frequency Reuse Schemes

International Journal of Innovative Research in Science, Engineering and Technology

|A High Impact Factor, Monthly, Peer Reviewed Journal| Impact Factor: 6.209| UGC Approved|

Vol. 5, Issue 12, December 2016

(a) Strict FFR

A modification to the traditional frequency reuse method, strict frequency reuse (FFR) is mostly utilized in cellular networks (Begain et al., 2002; Sternad 2003). The deployment of tight FFR with reuse factor for cell edge region $\alpha=3$ is depicted in Fig. 2, using a hexagonal grid model. Each cell's cell center users are assigned a shared subchannel, whereas users in the cell edge regions have their bandwidth divided based on the frequency reuse factor (α). Therefore, $\alpha+1$ is the total number of sub bands needed in stringent FFR. This approach reduces interference between users of the cell edge and cell center regions by not sharing spectrum between the interior and outside sections of the cell (Novlan et al., 2010; 2011). In contrast to high and low power nodes, the transmission power levels in cell edge and core regions differ.

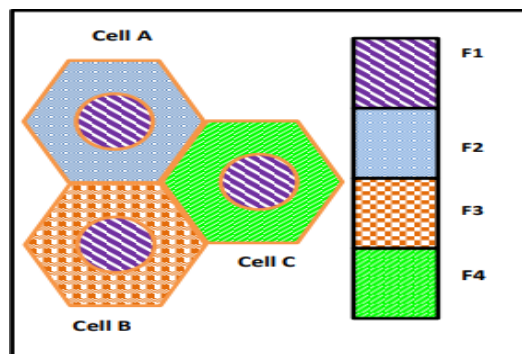


Fig.2 Strict FFR

(b) Soft Frequency Reuse (SFR)

Users in the cell exterior region of other cells share the sub-channel with users in the cell central region in the SFR system. In comparison to rigid FFR, the SFR scheme is a very spectrum-efficient technique; yet, more interference may arise as a result of bandwidth sharing between cell central and edge users (Doppler et al., 2009). Therefore, cell center regions are served by lower transmission power than cell edge regions in order to avoid interference (Shroff and Chong 1999). Three cell patterns for SFR in various SFR cells are displayed in Fig. 3.

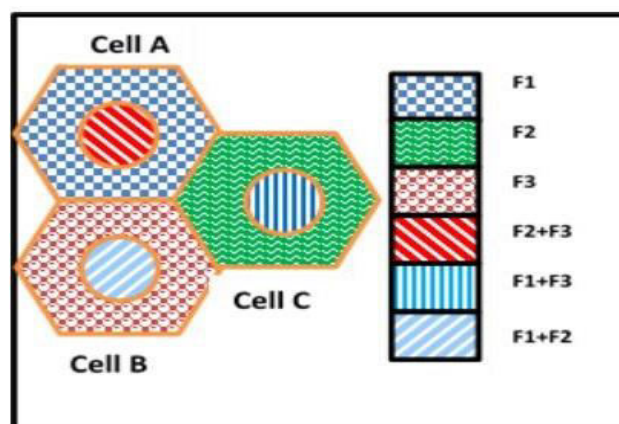


Fig. 3 Soft Frequency Reuse.

International Journal of Innovative Research in Science, Engineering and Technology

| A High Impact Factor, Monthly, Peer Reviewed Journal | Impact Factor: 6.209 | UGC Approved |

Vol. 5, Issue 12, December 2016

III. LITERATURE REVIEW ON FFR SCHEMES

In strict FFR scheme, frequency resources for inner regions of the cell are universally used with controlled transmission power so the effect of interference to central region is less. The authors [9] have found an optimal design parameters of the network by considering several parameter metrics like spectral efficiency, throughput, resource allocation and SINR of cell edge user. The strict FFR accomplishes high network throughput and high SINR to users in cell edge region. The outage probabilities for cell edge users are also calculated while designing the network. The simulation result shows strict FFR is less delicate to interior cell radius with less outage probability as compared to SFR.

The Fractional Frequency Reuse (FFR) Strict FFR Soft Frequency Reuse (FFR) Dynamic FFR Sectored FFR Dynamic/Adaptive SFR Sectored SFR Two-Level SFR Multi-Level SFR Cell A Cell B Cell C F1 F2 F3 F4 outage probability in SFR is improved by enhancing the user power control factors in exterior region of cell. The SFR balances both resource efficiency and interference reduction. In FFR schemes, based on the allocation of frequency, the system capacity is increased by reducing interference [10]. This method improves the spectrum efficiency by avoiding the problem of wastage of spectrum. To design optimal FFR system an advanced techniques like graph theory convex optimization [11] is used.

In LTE and LTE-A networks, to overcome the problem of low efficiency due to uneven distribution of user, the contention based FFR scheme is proposed. To optimize the network based on FFR schemes a cuckoo search (CS) algorithm is used and is easy to adopt due to need of limited arguments to tune the network. In this method, author proposed a mechanism to select the cell interior region optimum radius value. The optimal radius value in strict FFR helps to maximize the throughput as well as user satisfaction. The simulation result shows that the CS algorithm provides a maximum throughput for an inner cell radius of 128.6837m along with user satisfaction of 0.6. Authors derived an optimal signal to noise ratio threshold to maximize the probability of network coverage when base stations are located based on Poisson point process. In this procedure an exhaustive search algorithm is utilized to optimize the network. The authors [12] proposed an FFR mechanism and compared the result with conventional frequency reuse scheme. The results show that by strict FFR higher SINR is achieved for cell edge users but it will not reflect in terms of throughput due to lack of availability of small bandwidth.

The authors [13] have proposed generalized and optimal FFR scheme for broadband cellular radio access network. In typical FFR scheme, the reuse factor and OFDMA subbands are fixed and is suitable for ideal cell pattern but is not appropriate in practical irregular cell patterned networks. Authors [14] have identified an FFR scheme to achieve high capacity under certain fairness criteria. Based on normalized interior cell radius and border to center power ratio these FFR schemes are evaluated and analyzed the parameters like cell capacity, fairness constraints and outage condition. The authors [15] have determined optimal cell edge frequency reuse factor and optimal bandwidth assigned to cell interior and exterior region and outcomes of simulation justify that optimal inner cell radius is 0.63km and cell edge region reuse factor is 3. For optimum inner radius the throughput of system is maximum.

The trade-off among the cell partitioning radius and cell capacity is illustrated in [16] and the relationship between power efficiency of the cell and transmit power based on an optimal threshold of the radius of the cell is explained in [17]. The frequency reuse factor is fixed to 1.5 for exterior region of cell and generated results were analyzed to define optimum inner region radius and bandwidth of inner region [18]. The optimization of frequency subchannels in hexagonal and irregular pattern of the cell is discussed (According to for hexagonal cell pattern the optimum frequency reuse factor for users in exterior region cell is three and further, to define an optimum frequency reuse factor for irregular shape of cell a method is developed). To maximize the network throughput, an optimal distance threshold is derived. The parameters like SINR threshold and distance were adjusted to enhance average SINR to variance of SINR ratio [19]. The probability of coverage and average data rate for FFR schemes are derived and analysis is done with respect to optimum distance threshold to increase the cell capacity. The numerical result in [20] illustrates that SFR performs better than strict FFR in partially loaded condition and vice versa. Based on throughput an analytical optimization technique is developed to implement FFR schemes in LTE cellular system. In this method, average sector throughput is considered instead of cell edge user performance. The simulation results show that the normalized

International Journal of Innovative Research in Science, Engineering and Technology

[A High Impact Factor, Monthly, Peer Reviewed Journal | Impact Factor: 6.209 | UGC Approved]

Vol. 5, Issue 12, December 2016

switching radius declines from 0.8 to 0.3 and efficiency of spectrum for cell edge user increases from 0.23 to 0.35 b/s/Hz [21]. The authors [22] simulated two FFR schemes. One was based on user satisfaction and other was based on maximizing average throughput. The simulation outcome shows that the method developed by considering user satisfaction is superior and fairer in behavior. Authors [23] proposed a partial isolation scheme to enhance the gain of OFDMA based cellular network. The results of this scheme outperformance over reuse-3 and reuse-1 schemes in terms of cell total throughput and throughput of cell edge user.

IV. CONCLUSION

With the increase in growth of user and multimedia applications, the traffic load on network capacity increases. The LTE and LTE-A network came with a solution to meet high traffic capacity requirement. In wireless communication, bandwidth is more precious and limited, so appropriate frequency planning is essential in wireless communication networks. The conventional frequency reuse scheme increases the network capacity but could not satisfy the cell edge user needs due to the poor quality of service. To overcome this problem, inter-cell interference coordination technique came with a solution of FFR scheme. The implementation of FFR scheme provides improved SINR of cell edge user with respect to the reuse-1 scheme. The SINR in strict FFR is better than SFR due to high interference effect in SFR. Due to limited bandwidth in strict FFR, the throughput of cell edge users is reduced even though it has high SINR. The SFR scheme is highly efficient in terms of spectrum as related to strict FFR but the ideal value of power control factor (β) is selected to enhance both cell edge and center user performance. The SFR is better than FFR if the network is partially loaded and vice versa in fully loaded condition. The adaptive SFR scheme is used to increase the throughput of cell center as well as cell edge user by fine-tuning of power and subcarrier allocation.

REFERENCES

1. Himayat, N., Talwar, S., Rao, A.M., and Soni, R. (2010), 'Interference Management for 4G Cellular Standards [WIMAX/LTE UPDATE]', IEEE Communications Magazine, Vol. 48, No. 8, pp. 86–92.
2. Lee, P., Lee, T., Jeong, J., Shin, J. (2010), 'Interference Management in LTE Femtocell Systems using Fractional Frequency Reuse', in ACT 2009: Advanced Communication Technology Conference, Vol. 2, pp. 1047–1051.
3. Boudreau, G., Panicker, J., Guo, N., Chang, R., Wang, N., and Vrzic, S. (2009) 'Interference Coordination and Cancellation for 4G Networks', IEEE Communications Magazine, Vol. 47, No. 4, pp. 74–81.
4. Moretti, M., Todini, A., Baiocchi, A., and Dainelli, G. (2011) 'A Layered Architecture for Fair Resource Allocation in Multicellular Multicarrier Systems', IEEE Transactions on Vehicular Technology, Vol. 60, No. 4, pp. 1788–1798.
5. Society, I. C., Theory, M. and Society, T. (2006) IEEE Standard for Local and metropolitan area networks Part 16 : Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment 2 : Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands an.
6. Rahman, M., Yanikomeroglu, H., and Wong, W. (2009) 'Interference Avoidance with Dynamic InterCell Coordination for Downlink LTE System', in Proc. IEEE Wireless Communications and Networking Conference, pp. 1-6.
7. 3GPP; Technical Specification Group Radio Access Network (2007) 'Physical Channels and Modulation (Release 8)', TS-36.211, Version 1.2.0.
8. 3GPP; Huawei (2005) 'Soft Frequency Reuse Scheme for UTRAN LTE, R1-050507.
9. Kim, K.T., Oh, S.K. (2008) 'An Incremental Frequency Reuse Scheme for an OFDMA Cellular System and Its Performance' in Proc. of the 67th IEEE Vehicular Technology Conference, pp. 1504- 1508.
10. Bohge, M., Gross, J., and Wolisz, A. (2009) 'Optimal Power Masking in Soft Frequency Reuse based OFDMA Networks', in Proc. of the 15th European Wireless Conference 2009, pp. 162-166.
11. Xiang, Y., Luo, J. (2007) 'Inter-Cell Interference Mitigation through Flexible Resource Reuse in OFDMA based Communication Networks', in Proc. of the 13th European Wireless Conference, pp. 1-7.
12. Hashima, S., Elnoubi, S., Shalaby, H., Muta, O. and Mahmoud, I. (2013) 'Analysis of Frequency Reuse Cellular Systems Using Worst Case Signal to Interference Ratio', IEEE International Conference on Telecommunications, pp. 185-190.

International Journal of Innovative Research in Science, Engineering and Technology

[A High Impact Factor, Monthly, Peer Reviewed Journal| Impact Factor: 6.209| UGC Approved]

Vol. 5, Issue 12, December 2016

13. Sophia-Antipolis 'UTRAN architecture for 3 GHome Node B (HNB); Stage 2', France, TS25.467(Rel. 10), 2011.
14. Boudreau, G., Panicker, J., Guo, N., Chang, R., Wang, N., Vrzic, S. (2009) 'Interference Coordination and Cancellation for 4 G Networks', IEEE Communication Magazine, Vol. 47, No. 4, pp. 74–81.
15. Damnjanovic, A., Montojo, J., Wei, Y.B., Ji, T., Luo, T., Vajapeyam, M., Yoo, T., Song, O., Malladi, D., (2011) 'A Survey On 3GPP Heterogeneous Networks' Qualcomm Inc in IEEE Wireless Communications, Vol. 18, No. 3, pp. 10-21.
16. Armstrong, J., (2009) 'OFDM for Optical Communications' Journal of Lightwave Technology, Vol. 27, No. 3, pp. 189–204.
17. Haas, H., (2013), 'High-speed Wireless Networking using Visible Light' SPIE Newsroom.
18. Novlan, T.D., Ganti, R.K., Ghosh, A. and Andrews, J. G. (2011) 'Analytical Evaluation of Fractional Frequency Reuse for OFDMA Cellular Networks', IEEE Transactions on Wireless Communications, Vol. 10, No. 12, pp. 4294-4305.
19. Begain, K., Rozsa, G., Pfening, A., and Telek, M.. (2002) 'Performance Analysis of GSM networks with Intelligent Underlay-Overlay', in Proc. International Symposium on Computers and Communications, pp. 135-141.
20. Sternad, M., Ottosson, T., Ahlen, A., and Svensson, A. (2003), 'Attaining both Coverage and High Spectral Efficiency with Adaptive OFDM Downlinks', in Proc. IEEE Vehicular Technology Conference, Vol. 4, pp. 2486-2490.
21. Novlan, T., Ganti, R., Ghosh, A., and Andrews, J., Sohn, I. (2010) 'Comparison of Fractional Frequency Reuse Approaches in the OFDMA Cellular Downlink', IEEE Global Telecommunications Conference, pp. 1-5.
22. Li, J., Shroff, N., and Chong, E. (1999) 'A Reduced-Power Channel Reuse Scheme for Wireless Packet Cellular Networks', IEEE/ACM Transaction on Networking, Vol. 7, No. 6, pp. 818–832.
23. Doppler, K., Wijting, C, and Valkealahti, K.(2009) 'Interference-Aware Scheduling for Soft Frequency Reuse', in Proc. IEEE Vehicular Technology Conference, pp. 1-5.
24. Bilios, D., Bouras, C., Kokkinos, V., Papazois, and Tseliou, G. (2012) 'Optimization of Fractional Frequency Reuse in Long Term Evolution Networks' 2012 IEEE Wireless Communications and Networking Conference: Mobile and Wireless Networks, pp. 1853-1857.
25. Chang, R., Tao, Z., Zhang, J., and Kuo, C.(2009) 'A Graph Approach to Dynamic Fractional Frequency Reuse (FFR) in multi-Cell OFDMA networks' in Proc. IEEE International Conference on Communications, pp. 1-6.
26. M. Assad. (2008), 'Optimal Fractional Frequency Reuse (FFR) in Multicellular OFDMA System' in Proc. IEEE Vehicular Technology Conference, pp. 1-5.
27. Zhan, H. Y., Hu, B. J., Wei, Z. H., Liu, W. J. and Li, B. (2016) 'Contention-based Fractional Frequency Reuse Scheme in LTE/LTE-A Network', pp. 663-666.
28. Abushabab, E. S., Khodier, M. and Ismail, S.S. (2016) 'Performance Optimization of Fractional Frequency Reuse In Long Term Evolution (LTE) Systems Using Cuckoo Search Algorithm', International Conference on Electronic Devices, Systems and Applications, pp. 1-6.
29. Fang, L., and Zhang, X., (2008) 'Optimal Fractional Frequency Reuse in OFDMA based Wireless Networks' in Proc. 4th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1-4.
30. Elfadil, H. E. E. O. M., Ali, M. A. I., Abas, M.(2015) 'Fractional Frequency Reuse in LTE Networks', 2 nd World Symposium on Web Applications and Networking, pp. 1-6.
31. Chen, L., Yuan, D. (2012) 'Generalizing and Optimizing Fractional Frequency Reuse in Broadband Cellular Radio Access Networks', EURASIP Journal on Wireless Communications and Networking, Vol. 15, No.20, pp. 115-130.