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Comparative Analysis of Traditional Frequency Reuse Techniques in LTE Network

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Abstract: Frequency Reuse Techniques are required to satisfy the exponential increase of data demands in mobile networks, such as the Long Term Evolution (LTE) network of Universal Mobile Terrestrial radio access System (UMTS). However, the simultaneous usage of the same Frequency in adjacent LTE cells that creates inter-cell interference problems at cell-edge users. Inter-Cell Interference Coordination (ICIC) techniques are deployed to avoid the negative impact of interference on system performance. This paper classified the existing ICIC techniques and investigates the performance of reuse-1, reuse-3 schemes under various user distributions. Performance of cell-center and cell-edge users is inspected, as well as the overall spectral efficiency, throughput and network load. System level simulations are performed that shows the advantages and limitations of each of the examined techniques under different network loads and user distributions which is used to determine the most suitable ICIC technique to be used.

Keywords: LTE, OFDMA, Reuse 1, Reuse 3.

I. INTRODUCTION

Long term evolution is a significant project of 3rd generation partnership project (3GPP) that uses the Orthogonal Frequency Division Multiple Access (OFDMA) technique for the downlink and single carrier frequency division multiple access (SC-FDMA) for uplink of the radio interface in Long Term Evolution (LTE) networks. These new technologies are used to generate more spectral efficiency and throughput [1]. In OFDMA technology, each subcarriers are mutually orthogonal to each other therefore there is no intra-cell interference. But transmission between neighbouring cells with same frequency causes inter-cell interference that limits the system performance. To improve the system performance, carefully management of inter-cell interference is important in LTE. To avoid the impact of inter-cell interference, different types of frequency allocation schemes are deployed in cellular network [6].
The simplest frequency reuse scheme is Frequency Reuse Factor 1 (RF1) in which total available bandwidth is reused in each cell. But inter-cell interference is increased at cell edges which limits the performance of cell-edge users [3, 6,14]. In Reuse Factor 3 (RF3), the total bandwidth is divided into three equal and orthogonal sub-bands and the sub-bands are allocated to cells in such a way that adjacent cells always use different frequencies that means each cell is using one-third of total available bandwidth. This comes at the cost of very low bandwidth utilization but leads to lower inter-cell interference at cell edges that overcome the shortcomings of Reuse 1 [6, 14].

Fractional Frequency Reuse scheme is introduced to achieve a FRF between 1 and 3. FFR divides the whole available resources into two groups i.e major group and the minor group. The major group which uses the FRF 3 is used to serve the cell-edge users, while the minor group that uses the FRF 1 is used to cover the cell-center users [1, 7]. In this scheme only a part of complete bandwidth is allocated to the cell so it is called Fractional Frequency Reuse scheme. The FFR scheme can be applied on the basis of the location of the cell. FFR scheme can be divided into three parts: Partial Frequency Reuse, Soft Frequency reuse, Intelligent Reuse. The basic concept of PFR is to put restrictions on a portion of the resources are not utilized by some user. In PFR Scheme, total available bandwidth is divided into four sub bands. Cell center UE are allocated the frequency reuse factor of 1. Cell edge UEs are allocated the frequency reuse factor of 3. This scheme is also known as the FFR-FI (Fractional Frequency Reuse with full isolation) because cell edge users are fully isolated [12].

Soft Frequency Reuse scheme aimed to avoid inter-cell interference associated with reuse factor 1. For each sector, cell edge users are allocated in the fraction of bandwidth with highest power level and cell center users are allocated with lower power in the rest of frequency band [8]. RF1 is used in the cell center region and RF greater than one is employed at the cell edge users. When the traffic load increases, SFR perform better than FR 1 by achieving higher throughput at cell edge users [8, 13, 14]. Intelligent Reuse aimed to overcome some of the limitations of SFR like increased inter-cell interference at low traffic load, low spectral efficiency etc. [6]. In this scheme, frequency band allocated to different cell increases or decreases based on their traffic loads. If workload is low, reuse factor 3 is used while with the increase of workloads it uses PFR, SFR or even Reuse 1[3].

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In this paper, the existing Frequency Reuse techniques for multiuser OFDMA networks are classified such as LTE. Specially, the performance of reuse1 and reuse 3 under various user equipment distributions are studied. Here particularly focus on throughput, spectral efficiency, and signal to interference noise ratio for each of Frequency Reuse techniques. LTE simulator is chosen for simulation of comparison between frequency reuse techniques. In section II describe the related work of frequency reuse techniques. Simulation Environment and Setup of LTE-network is given in section III. In section IV, simulation results for the compared Frequency Reuse techniques under various parameters are presented and discussed. Conclusion is given in section V.

II. RELATED WORK

In recent years, LTE network have become rapid growing technology in 4th generation cellular wireless broadband technologies. With the aim of providing better quality of service and universal connectivity to end users there are several frequency reuse schemes [4]. The author categorized these techniques into groups and identified the advantage and drawback for each of these techniques. All these frequency reuse schemes are possible to provide the solution for interference issues in 4G networks with proper frequency reuse planning. A new classification model was used to explain frequency reuse based schemes that is conventional frequency reuse and fractional frequency reuse schemes [5].

Conventional frequency reuse is categorized into two types based on frequency reuse factor that is reuse-1 and reuse-3. Fractional frequency reuse is also divided into three parts: Partial Frequency Reuse, Soft frequency reuse and intelligent reuse. In recent research two major challenges for evolving LTE networks are to achieve enhanced system capacity and cell coverage compared with WCDMA. However, dense frequency reuse increases inter-cell interference which turns to limit the capacity of users in the system. This inter-cell interference restricted the overall system performance in terms of system throughput and spectrum efficiency, especially for cell edges users. Interference mitigation schemes for LTE downlink networks are described [6]. The impact of frequency reuses parameter settings while evaluating the interference model in LTE. An interference model based on SINR is developed to estimate the quality of signal received by UE [7]. Based on this model, comparison of two frequency reuse schemes is done. Reuse-1 in which full bandwidth is used in each cell and Reuse-3 in which the overall bandwidth is divided into 3 non overlapping groups and assigned to 3 co-site sectors within each cell. With respect to coverage, the number of users in outage or edge in LTE is sensitive to the choice of reuse pattern of the frequency band. That means reuse 3 gives better performance as compared to reuse 1.

A new approach for frequency assignment problem was introduced [20] that is called Dynamic Frequency Planning (DFP). This technique performed well when the traffic and channel conditions rapidly changed with the time. An enhancement of the DFP algorithm called vertical DFP based on the concept of Fractional frequency reuse schemes has also been presented. It increased the network capacity around by 15% compared to standard frequency reuse schemes. Experimental evaluation has been shown by system level simulation using realistic scenario. Recent research on FFR has focused on the optimal design of FFR system by utilizing advanced techniques such as graph theory [8] and convex optimization [9] to maximize the network throughput. Two types of the fractional frequency reuse- Strict FFR and Soft Frequency Reuse (SFR) were evaluated [10]. Poisson Point Process (PPP) model was used for the base station locations. One advantage of this approach is the ability to capture the non-uniform layout of modern cellular deployments due to topographic, demographic or economic reasons.

The primary contribution of this work is a new analytical framework to evaluate the coverage probability and average rate in Strict FFR and SFR systems. These two metrics are important metrics for cell edge users. In addition, by considering a special case relevant to interference limited network, the analytical expressions for the SINR distributions reduce to simple expressions. This analysis used to develop the system guidelines to show that Strict FFR provide better coverage for edge users than SFR users. System level simulations were performed under uniform and non-uniform UEs distributions to compare the frequency planning schemes [15]. Based on this simulation, reuse-1 model was better when majority of UEs has good radio conditions. Reuse-3 model outperformed in terms of UEs satisfaction and throughput when network load is low. SFR performance has shown the highest spectral efficiency for approximately all the UEs distribution. FFR technique model compromised between reuse-1 and reuse-3 models based on this simulation. However, some of them only reports comparison of the existing frequency reuse techniques. Other performs simulation under various user equipment distributions using LTE simulator.

III. SIMULATION ENVIRONMENT AND SETUP

The system model is based on the LTE network. It consists of several base stations (EnodeB), cells, user equipments (UEs). Here several cells make a one cluster and each cell is sectorized as hexagonal layout. In this model, 19 cells are used which form three clusters. Each cell is served as EnodeB which has its own scheduler, own bandwidth and has its own power allocation policy. When Frequency Reuse1 model is deployed, then the overall bandwidth is used in each cell of a cluster. But when Frequency Reuse 3 model is deployed, the one third of overall bandwidth is used in each cell.

The simulation parameters are shown in Table 1. In this user equipments are distributed between cell center zone

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and cell edge zone which is considered as important parameter on simulation because it impacts on system performance. So UEs position and its distribution between cell zones have a great impact on inter-cell interference and system throughput. This scenario is simulated and characterized by non homogenous UE distributions in which majority of active user are either in cell center zone or cell edge zone.

Table 1: Parameter Table

Parameters	Value
Bandwidth	5 MHz
Number of cells	19
Number of clusters	3
Cell radius	1000m
UEs distribution	10-50 users
Interval of users	10

LTE simulator is used in this work. In this frequency reuse 1 model is already embedded in the original version with user distribution but here, adjusted the original code of Frequency reuse with some parameter setup to implement the reuse 1 and reuse 3 models with non homogenous UEs distributions. In this simulation, basically focus on the implementation of Frequency Reuse1 and Reuse 3 models. As mentioned previous in the paper, geometry of cell is hexagonal and uses three clusters in which 19 cells are presented. In this each cell is served by its own EnodeB station. Each cell has radius equal to 1km, which is considered as a LTE network is deployed in an urban area. The operating bandwidth in each cell is 5 MHz and User equipment scheduling is performed after one millisecond.

IV. RESULTS AND DISCUSSIONS

In this paper, performance of Frequency Reuse 1 and Frequency Reuse 3 techniques are analysed based on these three parameters:

1) Spectral Efficiency: This parameter calculates the efficiency of overall usage of spectrum using the available bandwidth.

2) UE Throughput: In this parameter the impact of Frequency Reuse 1 and Frequency Reuse 3 on UE throughputs. This parameter find out how much throughput is modified in each zone.

3) Network Load: With the help of this parameter, network load on LTE network is analyzed based on increase or decrease the number of users.

RESULT

1) Spectral Efficiency Vs Number of Users

The effect of User Equipment distribution on spectral efficiency is analyzed for both Frequency Reuse 1 and Frequency Reuse 3 techniques. Their comparative result is shown in Fig 1.

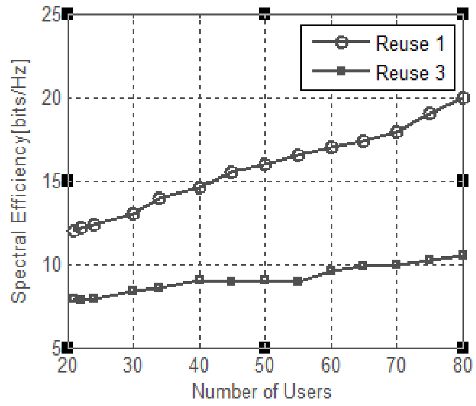

Fig. 1: Spectral efficiency Vs Number of users

From the Fig. 1 we noticed that Frequency Reuse 1 performance is better than Frequency Reuse 3. In Frequency Reuse 1, overall spectrum is divided among all the users therefore each cell is efficiently utilized the spectrum. As the number of users increases, spectral efficiency is improved but in case of Frequency Reuse 3, only one third of overall spectrum is used in each cell. In this when number of users is low the spectrum is efficiently utilized but as the number of users increases the spectral efficiency is low as compared to Reuse 1.

2) Network Load Vs Number of users

Based on the distribution of users, the Network load of Frequency Reuse 1 and Frequency Reuse 3 is analysed and shown in Fig. 2:

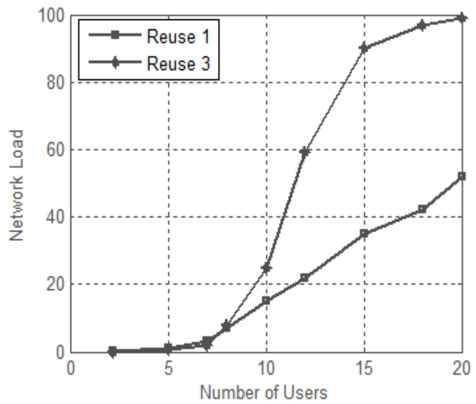

Fig. 2: Network Load Vs Number of Users

As shown in Fig. 2, it is concluded that when the number of users are less the Frequency Reuse 3 work better because it can handle the number of users according to their spectrum usage but however the number of user increases, the spectrum is not efficiently utilized and network load on cell center region is higher than Frequency reuse 1. As number of user's increases, Frequency Reuse 1 performance is better than Frequency Reuse 3. So it is concluded that when number of users are less then Frequency Reuse 3 model is better and when number of users increases then Frequency Reuse 1 model is better.

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3) Throughput

Throughput of Frequency Reuse 1 and Frequency Reuse 3 model is computed based on the Cumulative Distribution Function (CDF).

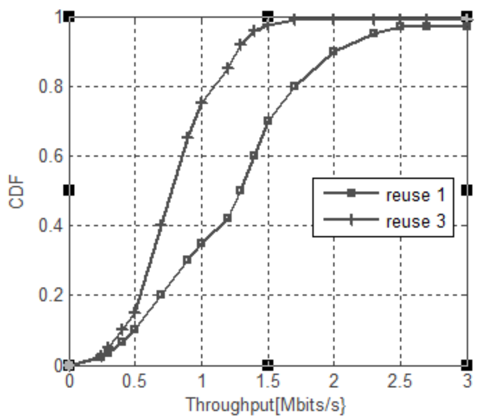

Fig. 3: Throughput

It is concluded from the Fig. 3 that Frequency Reuse 3 is first to reach the maximum throughput. Throughput of both techniques is analyzed on the base of Cumulative distribution function. As the achievable throughput increases, probability of bad region user's throughput is improved and bad region users are moved from bad region to good region. Cumulative Distribution Function of Frequency Reuse 3 works faster than Frequency Reuse 1 and this function works based on distribution of number of users. Therefore Frequency Reuse 3 has maximum throughput as compare to Frequency Reuse 1.

V. CONCLUSION

In this paper, the Performance of Frequency Reuse 1 and Frequency Reuse 3 techniques under system level simulations is analysed. The Simulation is performed on the basis of user equipment distributions. Performance of these techniques is investigated through several parameters like Spectral Efficiency, Throughput and Network Load. Frequency Reuse 1 shows higher Spectral Efficiency as compared to Frequency Reuse 3. In case of Network load, Frequency Reuse 3 works better when number of users is less. As the number of users increases, Network load on Frequency Reuse 3 is increases that are not good. Throughput of both Frequency Reuse 1 and Frequency Reuse 3 is analyzed on the base of cumulative Distribution Function. This function achieve maximum throughput in case of Frequency Reuse 3 as compare to Reuse 1.

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