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Improved Frequency Reuse Three Algorithm in LTE Networks

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Abstract: In mobile networks, frequency reuse techniques plays a crucial role in order to assure the exponential amplification of data demands. As an example, Long Term Evolution (LTE) network may be considered. In fact, at the cell-edge users, the simultaneous application of the similar frequency in neighboring LTE cells offers interference problems. As a consequence, the Inter-Cell Interference Coordination (ICIC) techniques for the system performance may be used for avoiding the alter impact of interference. This paper investigates the performance reuse-3, improved frequency reuse-3 as well as the existing interference techniques under various user distributions. Apart from the same, inspection of cell-edge users and cell-center users is performed. In addition to this, the overall spectral efficiency, throughput, interference and network load is evaluated in the proposed research work. System level simulations are performed in this work that shows the limitations and advantages of each of the examined schemes under varying user distributions and loads that are used to conclude the valued ICIC scheme for use.

1. INTRODUCTION

Long term evolution is a major scheme of 3rd generation partnership project (3GPP) that uses the Orthogonal Frequency Division Multiple Access (OFDMA) method for the purpose of downlink and single carrier frequency division multiple access (SC-FDMA) for uplink in Long Term Evolution (LTE) networks. These latest technologies are used to generate additional spectral efficiency and throughput [1]. In OFDMA technology, every sub-carriers are orthogonal to each other therefore no intra-cell interference is possible. But transmission between neighboring cells by way of same frequency causes inter-cell interference that confines the system performance. To avoid the impact of inter-cell interference, different types of frequency allocation schemes are deployed in cellular network [6].

The simplest frequency reuse technique is Frequency Reuse Factor 1 (RF1) in which whole available bandwidth is reused in every cell. But inter-cell interference is greater than before at cell edges which confines the performance of cell-edge users [3, 6,14]. In Frequency Reuse Factor 3 (RF3), the whole bandwidth is divided into three equal sub-bands and the sub-bands are allocated to cells in such a means that adjacent cells at all times use different frequencies that means each cell is using one-third of whole available bandwidth. This comes at the rate of very low bandwidth utilization but leads to lesser inter-cell interference at cell edges that overcome the limits of Reuse 1 [6, 14].

Fractional Frequency Reuse (FFR) scheme is designed to get a frequency reuse factor (FRF) between 1 and 3. FFR divides the whole available resources into two group *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 provided 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 bandwidth is divided into four sub bands. Cell center UEs are allocated the frequency of reuse factor 1. Cell edge UEs are allocated the frequency of reuse factor 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, edge users are allocated based on the 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].

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 Frequency Reuse techniques under various parameters are presented. Conclusion is given in section V.

2. 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 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. Based on the SINR model, comparison of two frequency reuse schemes is done. Reuse-1 in which overall 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). An improvement 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. 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.

The primary involvement of this work is a new systematic framework to estimate the coverage probability and average rate in Strict FFR and SFR systems. These two metrics are important metrics for cell edge users. 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.

3. SIMULATION ENVIRONMENT & 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 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.

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.

Table 1
Parameter Table

Parameters	*Parameters Value*
Number of Clusters	3
Number of cells in a cluster	19
Bandwidth	1.4,5,10,20,25,30(MHz)
Simulation carried out on cells	1
Start Users	0,5,20
Interval between users	5,10
Maximum users	20,50,80
Radius between cells	1000 m
Frame Structure type	FDD
User Speed	5 Km/h
Maximum Delay	0.1
Simulation Duration	46 s
Frequency Reuse Techniques	Frequency Reuse Factor One and Reuse Factor Three

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.

3.1. Improved Frequency Reuse Three Algorithm (IFR3)

In reuse factor three (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. This scheme leads to lower inter-cell interference. The RF3 algorithm is redesigned by proposed algorithm (IFR3) and implemented with own parameters values in LTE simulator.

Algorithm

Step 1: Initialize Cell, User equipments, frequently connected user and eNodeB.

Step 2: Load connectivity matrix from file.

Step 3: Compute the distance for each cell and compare with threshold value.

Step 4: randomly assign the frequency sub band for each cell.

Step 5: Find neighbors of each cell and compare the neighbor sub-band with assigned frequency sub band.

Step 6: check weather all sub-bands are allocated to user equipments or not. If allocated then do nothing i.e. the last assigned sub-band is kept. If all sub-bands are allocated to user equipments then finish.

In IRF3 algorithm, first initialize cells, user equipments and eNodeB and load the connectivity matrix from file in which all parameter is set. Then calculate the distance of each user equipments with the evolved nodeB (eNodeB). For each user equipment, assign a random sub-band from the frequency sub-band f. Then identify the neighbor of each cell and check the frequency band of each neighbor. If neighbor has same sub-band allocated then assign another sub-band from the frequency sub-set f and check again. If the distance between frequently connected user and existing user is less than threshold value then this user equipments is registered with home eNodeB. If all sub-bands are allocated to users' equipments then the next user equipment is register with best eNodeB and share the bandwidth with the help of Frequency Reuse scheduler with center user and edge user. The Results of this algorithm is compared with the FR3 algorithm and explained in results section.

4. RESULTS AND DISCUSSIONS

Performance Metrics**:**

1) *Network Load* measures the traffic computed on the network based on different number of users on different Frequency Reuse Techniques.

2) *The Throughput* metrics measures the average rate of data transmission that is successfully transmitted. It is generally computed in terms of bits per second (bit/s or bps).

3) *Interference Noise Ratio* metrics calculates the interference noise ratio between the adjacent cells of different Frequency Reuse Techniques.

4). *Spectral Efficiency* measures how the spectrum bandwidth is efficiently utilized by these Frequency Reuse techniques.

5. RESULTS AND DISCUSSION

Result based on implementation of Frequency Reuse Techniques:

1. Network load: Fig. 1 shows the performance of RF3 (Reuse Factor three) and Improved RF3 by evaluating Network load with no. of users and their performance is given in Table 2. The overall performance percentage is calculated by using this formula:

$$Performance\ \% = \frac{(old\ \ value - new\ \ value)}{old\ \ value} * 100$$

where old value is RF3 and new value is improved RF3.

Table 2
Network load

Users	*RF3*	*Improved RF3*
5	0.0019	0.002205
10	0.00302	0.0022
15	0.00225	0.0027
20	0.00205	0.00195
25	0.0028	0.001802
30	0.00225	0.00215
35	0.0022	0.00175
40	0.0019	0.00195
45	0.00195	0.0019
50	0.0019	0.0019
	0.002222	0.0020507

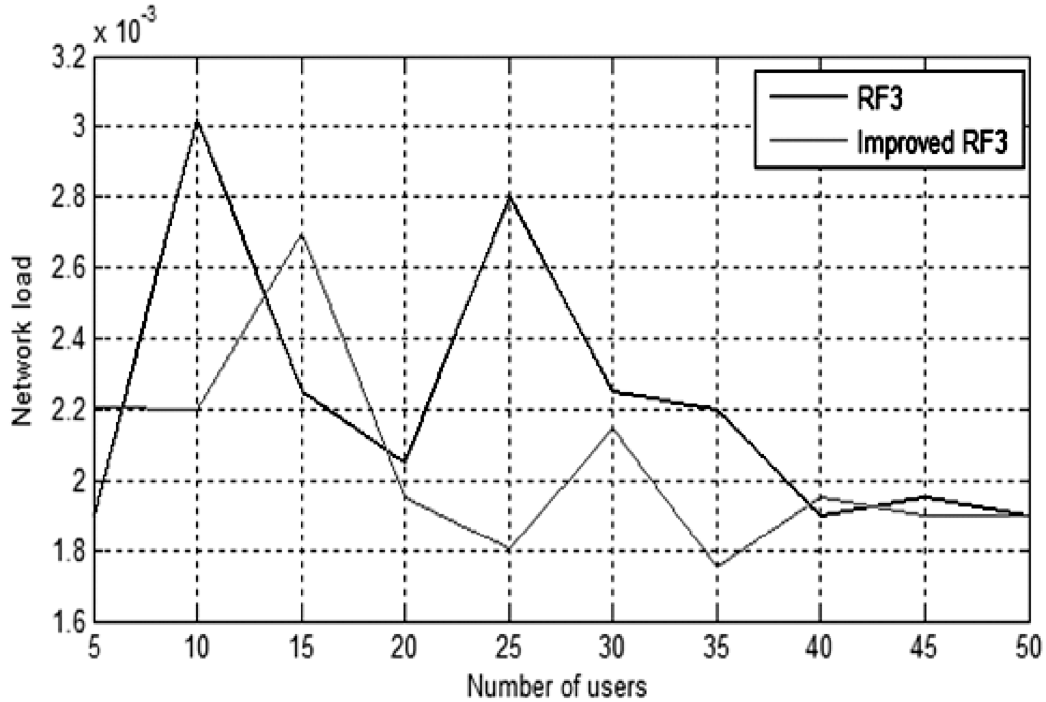

Figure 1: Network load

Result analysis shows that performance of Network load of Improved Frequency Reuse three is better than Frequency Reuse Three. After calculating the performance percentage, it is clear that network load of Improved Frequency Reuse Three is decreased by approximately 7% as compared to the Frequency Reuse Three. As shown in Fig. 1, when the number of users is 15, the network load is maximum and when the number of users is increases the network load is decreased as compared to the Frequency Reuse three. Therefore, in case of network load, Improved Frequency Reuse Three technique is better than Frequency Reuse three.

2). Throughput: Fig. 2 shows the performance of RF3 (Reuse Factor three) and Improved RF3 by evaluating Throughput with no. of users and their performance is given in Table 3. The overall performance percentage is calculated using the above formula.

Table 3
Throughput

Users	*RF3(e+06)*	*Improved RF3(e+06)*
10	7.53	7.951
15	7.46	7.673
20	7.341	7.53
25	7.392	7.621
30	7.501	7.92
35	7.679	7.9
40	7.812	7.95
45	7.701	8.21
50	7.51	8.235
Total	67.926	70.9

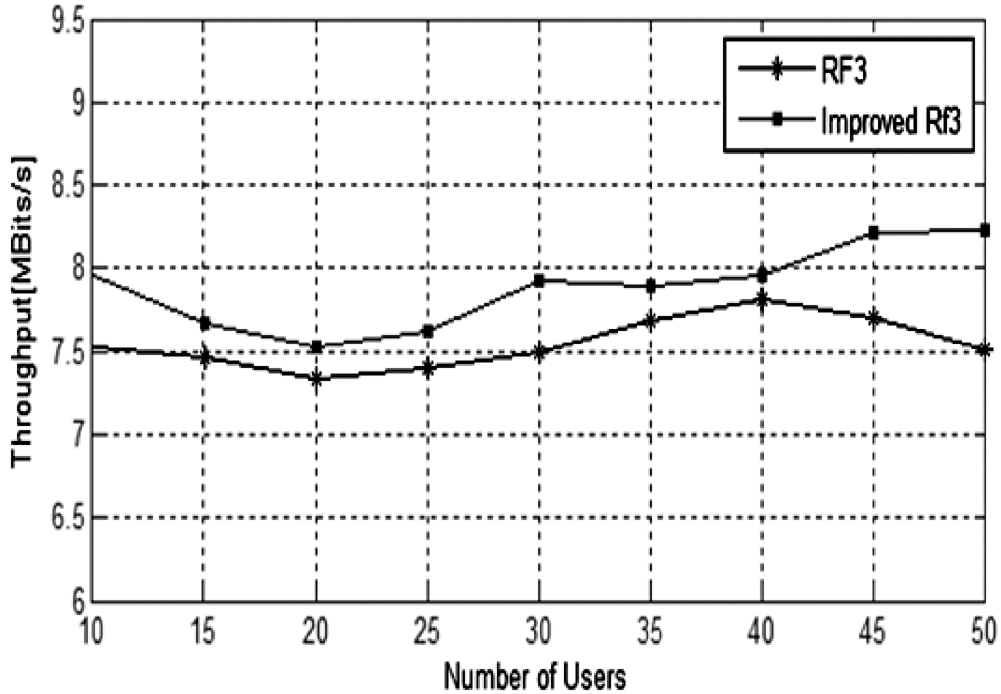

Figure 2: Throughput

Result analysis shows that performance of Throughput of Improved Frequency Reuse three is better than Frequency Reuse Three. After calculating the performance percentage, it is clear that throughput of Improved Frequency Reuse Three is increased by approximately 4% as compared to the Frequency Reuse Three.

Based on the evaluation, it is concluded that if number of user increases then throughput of the Improved Frequency Reuse Three is little bit increase than Frequency Reuse Three.

3). Interference Noise ratio: Fig. 3 shows the performance of RF3 (Reuse Factor three) and Improved RF3 by evaluating Interference Noise ratio with no. of users and their performance is given in Table 4.

Table 4
Interference Noise ratio

Users	*RF3*	*Improved RF3*
10	0.00234	0.00264
15	0.00232	0.00245
20	0.00226	0.00235
25	0.00212	0.00222
30	0.00198	0.00212
35	0.00199	0.00196
40	0.0020	0.0018
45	0.00215	0.00181
50	0.00225	0.00182
Total	0.001941	0.001917

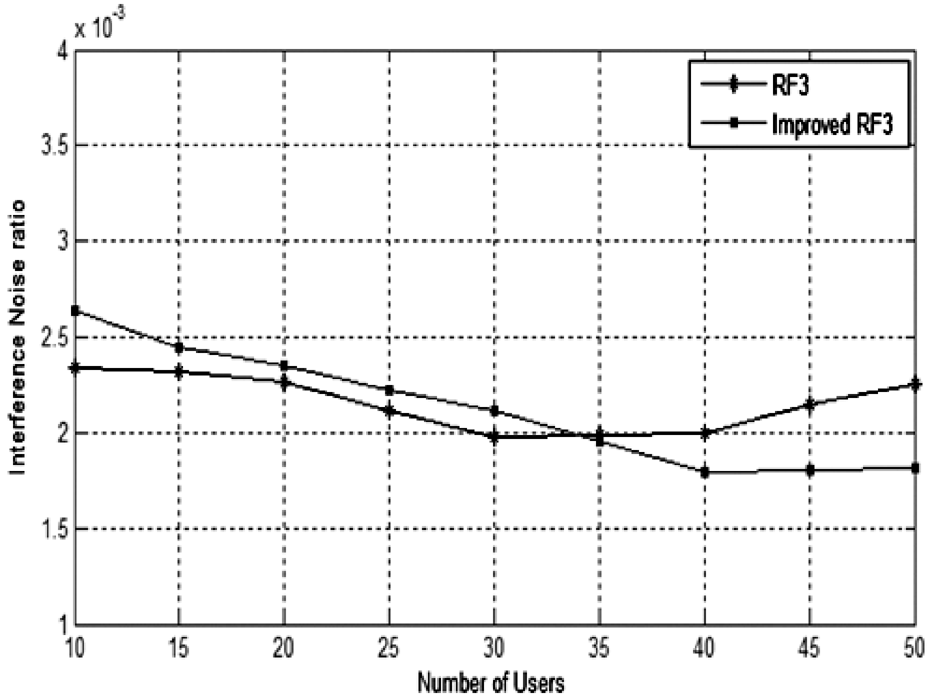

Figure 3: Interference Noise Ratio

From result analysis it is concluded that as the number of users increases the Improved Frequency reuse three interference noise ratio decreases as compare to Frequency Reuse three. The overall performance percentage is calculated using the above formula. After calculating the performance percentage, it is clear that Interference-noise ratio of Improved Frequency Reuse Three is decreased by approximately 2% as compared to the Frequency Reuse Three. Therefore, Improved Frequency Reuse three algorithm decreases the interference noise ratio generally which is present on cell-edge users and performs better than Frequency Reuse Three.

4). Spectral Efficiency: Fig. 4 shows the performance of RF3 (Reuse Factor three) and Improved RF3 by evaluating spectral efficiency with no. of users and their performance is given in Table 5.

Table 5
Spectral Efficiency

Users	*Spectral Eff.(RF3)*	*Spectral Eff.(Improved RF3)*
5	0.056	0.0515
10	0.062	0.0583
15	0.059	0.063
20	0.0565	0.0576
25	0.054	0.0565
30	0.0525	0.053
35	0.0507	0.0529
40	0.0500	0.0516
45	0.0473	0.0535
50	0.0465	0.0531
Total	0.05345	0.05510

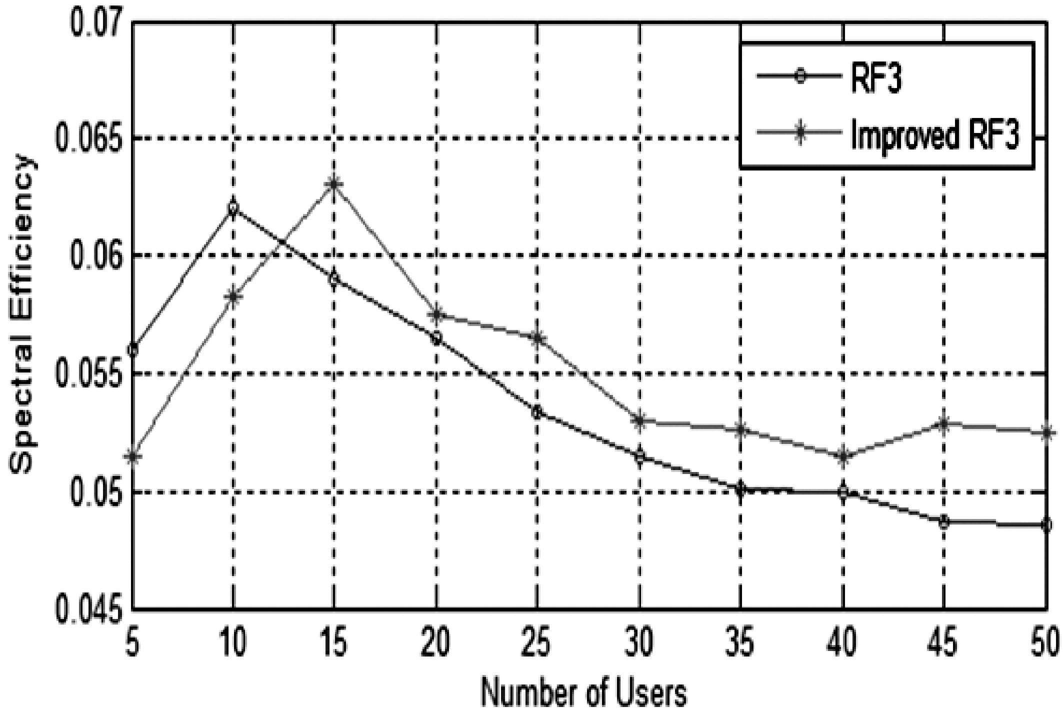

Figure 4: Spectral Efficiency

Result analysis shows that utilization of Spectrum is more in case of Improved Frequency Reuse three technique. After calculating the performance percentage, it is clear that spectral efficiency of Improved Frequency Reuse Three is increased by approximately 3% as compared to the Frequency Reuse Three. when the number of users is increases and Frequency Reuse three is less efficient to utilize the overall spectrum.

6. CONCLUSION

In this paper, the Performance of Frequency Reuse 3 and Improved Frequency Reuse 3 algorithm under system level simulations is analyzed. The Simulation is performed on the basis of user equipment distributions. Performance of these techniques is investigated through several parameters like Spectral Efficiency, Interference, Throughput and Network Load. Improved Frequency Reuse 3 shows 3% higher Spectral Efficiency as compared to Frequency Reuse 3. In case of Network load, it is decreased by approximately 7% when we used the Improved frequency reuse 3 algorithm. As the number of users increases, Network load on Frequency Reuse 3 is increases that are not good. After calculating the performance percentage, it is clear that throughput of Improved Frequency Reuse Three is increased by approximately 4% as compared to the Frequency Reuse Three. Based on the evaluation, it is concluded that if number of user increases then throughput of the Improved Frequency. Interference-noise ratio of Improved Frequency Reuse Three is decreased by approximately 2% as compared to the Frequency Reuse Three. Therefore, Improved Frequency Reuse three algorithm decreases the interference noise ratio generally which is present on cell-edge users and performs better than Frequency Reuse Three.

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