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Analysis of 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 net-works, 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 impactof interference on system performance. This study 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 user distributions which is used to determine the most suitable ICIC technique to be used.

INTRODUCTION

LTE (Long Term Evolution)

Long Term Evolution is significant project defined by 3rd Generation Partnership Project (3GPP) in Toronto conference of 3GPP in 2004 and officially started as LTE work item in 2006[1]. LTE is the next generation 4G technology for both GSM (Global system for mobile communication) and CDMA (Code division multiple access) cellular networks. LTE as transition from 3G has achieved great capacity and high speed as compared to the previous generation cellular networks [12]. Hence LTE has to satisfy a set of high-level requirements as follows :

1. Reduced cost per bit
2. Simple architecture and open interfaces
3. Flexibility usage of existed and future frequency bands
4. Reasonable terminal power consuming
5. Enhanced user experience-more services with lower cost and high speed

LTE technology is important because it will bring up to 50 times performance improvement and much better spectral efficiency to cellular networks. It is an ideal technology to support high date rates for the services like Voice Over IP (VOIP), videoconferencing. It uses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) mode.

Frequency Reuse

In the wireless communication each cell has its own transmitter (Base Stations) and group of channels. Normally these channels are 8 to 10 channels in which some channels are used for voice control and some for data control. In this way if in a city there are 100 base stations then corresponding number of channels goes to 1000s but a fixed spectrum has been allocated by the TRAI (Telecom Regulatory Authority of India). If each channel has its own frequency bandwidth then spectrum will go to in gigabytes. That is beyond the control of TRAI. Therefore need to find a solution to manage these channels. The solution is Frequency Reuse or Frequency Planning [15]

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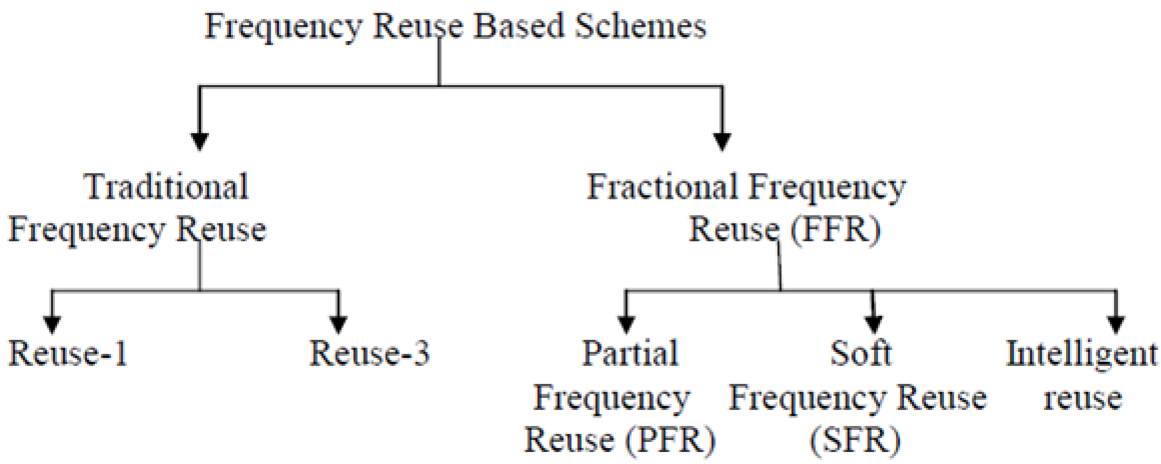

Conclusion from literature of LTE

	System Capacity	**Spectral Efficiency**	**Inter-cell interference**
Reuse-1	High system capacity is achieved.	Overall spectrum is not used So spectral efficiency degrades.	Interference is increased at cell edge users due to low SINR value.
Reuse -3	System capacity is low and resources are not fully utilized.	Spectral efficiency is high due to bandwidth divided into three subbands.	Inter-cell interference is decreased due to high SINR value.
Partial Frequency Reuse(PFR)	Resources are efficiently utilized with no sharing policy between cell center users and cell edge users.	Spectral efficiency is high as compared to reuse-1.	Interference is low at cell edge users.
Soft Frequency Reuse(SFR)	Overall cell capacity is degrades.	Low spectral efficiency.	Interference is low at cell edge users due to improvement in SINR value and high at cell-center users.
Intelligent Reuse	Cell capacity is increased.	Spectral efficiency is also increased.	Interference is avoidable at low traffic load.

Problem :

In recent years, two major challenges for evolving LTE networks:

- How to achieve enhanced system capacity.
- How to improve cell coverage area.

To improve the capacity and cell coverage, frequency reuse techniques are used. But these techniques suffer from inter-cell interference at cell boundary when the complete frequency is reused. So for resolving the inter-cell interference problem we will implements these frequency reuse techniques and perform their performance analysis.

Objectives:

From the literature review it is concluded that Frequency Reuse Techniques have been studied by various researchers and there is lot of scope for research in this area. Therefore objectives for our Research are:

- To study the Frequency Reuse Techniques.
- Implementation of Frequency Reuse Techniques using LTE-Sim.
- Performance comparison of Frequency Reuse Techniques.

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Research Methodology TO achieve the object and to solve the problem :

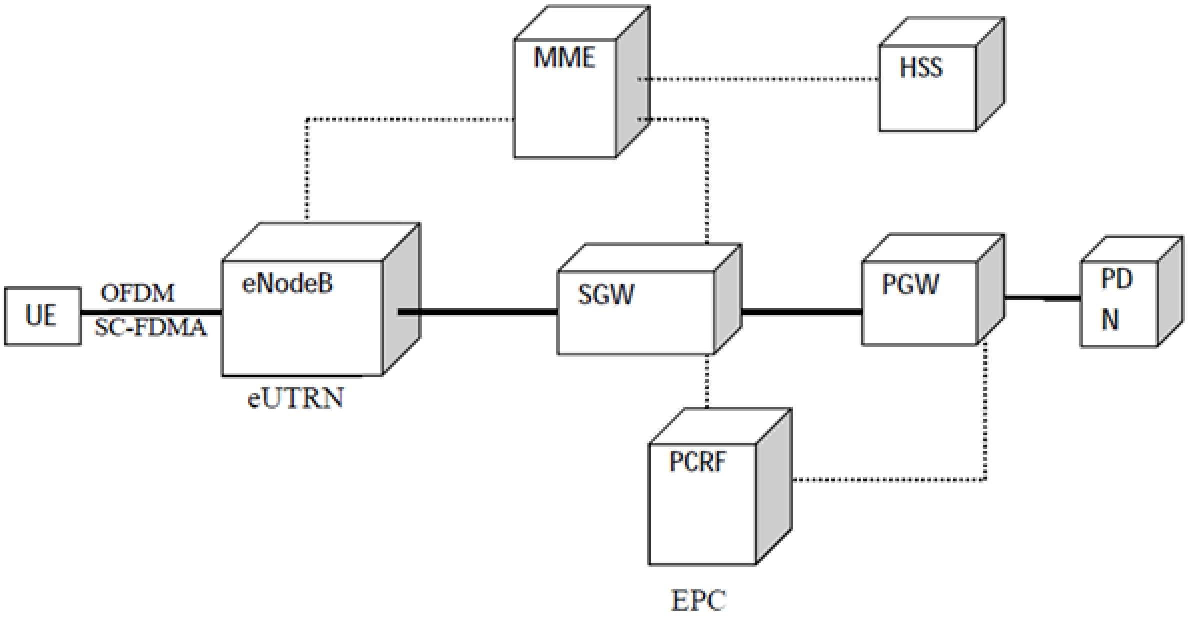
The following methodology will be followed to achieve the goals attached with research.

1. Background study of fundamentals of Frequency Reuse Techniques.
2. Understanding the architecture of LTE-Sim (Long Term Evolution- Simulator)
3. Implementation of Frequency Reuse Techniques in LTE-Sim.
4. Performance comparison of Frequency Reuse Techniques in LTE-Sim on the basis of multiple parameters like Throughput, Spectral Efficiency etc.

LTE Simulator : Long Term Evolution Simulator (LTE-Sim) is an open source framework is developed by Giuseppe Piro, Luigi Alfredo Grieco, Gennaro boggia, Francesso Capozzi and Pietro camarda which is used to simulate LTE networks. The developed LTE Simulator (LTESim) composed both the Evolved Universal Terrestrial Radio Access (E-UTRAN) and the Evolved Packet Core System (EPS)[1]. It supports both single and heterogeneous multi-cell environments, Quality of Service management, multi users environment, Frequency Reuse techniques, User mobility and Handover procedures. In this simulator, different types of network nodes are modeled: user equipment (UE), evolved Node B (eNB), Home eNB (HeNB) and Mobility Management Entity/Gateway (MME/GW)[2].

It provides a way to implement four different traffic generators at the application layer and the management of data radio bearer is supported. Frequency Reuse techniques implementation facility are provided to overcome the interference between adjacent cells.

SOFTWARE DESIGN - In order to ensure modularity, polymorphism, flexibility, and high performance, LTE-Sim has been written in C++, using the object-oriented language, as an event-driven simulator. At the present, the software is composed by 90 classes, 220 files, and approximately 23,000 lines of code. Fig. shows the UML (Unified Modeling Language) diagram of the most important classes implemented, highlighting their most important methods and variables [28].



There are four main components:

1. The Simulator
2. The Network Manager
3. The Flows Manager
4. The Frame Manager

Component	***Functionalities***	***Important Methods***	***Method description***
Simulator	Creates/Handles/Ends an event	1. Schedule() 2. RunOneEvent() 3. Run() / Stop()	Creates a new event and insert it into the calendar. Executes an event. Starts/ends the simulation.
FrameManager	1. Defines LTE frame of the LTE frame. 2. Schedules frames and sub-frames	StartFrame() and StopFrame() StartSubFrame() and StopSubFrame()	and Handles the start and the end structure of the LTE. Handles the start and the end of LTE subframe
FlowsManager	Handles applications	CreateApplication()	Creates an application
NetworkManager	1. Creates devices 2.Handles UE position 3. Manages the hand over 4.Implements frequency reuse techniques	CreateUserEquipment() CreateCell() UpdateUserPosition() HandOverProcedure() RunFrequecy Reuse()	Creates an UE device Creates a LTE Cell Updates the UE position Handles the hand over procedure Implements frequency reuse techniques

CHANNEL STRUCTURE AND RESOURCE MANAGEMENT

The LTE radio access is based on Orthogonal Frequency Division Multiplexing (OFDM) and provides a highly flexible bandwidth (from 1.4 to 20 Mhz). Both frequency division duplex (FDD) and time-division duplex (TDD) multiple access techniques are supported [33]. Radio resources are distributed among users in a time frequency domain. The eNB schedules radio resources among uplink/downlink flows at the beginning of each sub frame. LTE-Sim supports all six channel bandwidths (i.e., 1.4, 3, 5, 10, 15, and 20 MHz) available for the LTE system [32] and the cellular frequency reuse. Finally, TDD and FDD are handled by the Frame Manager.

- ***Bandwidth Manager***: All devices should know the operative bandwidth and available sub-channels for both uplink and downlink. Thus, a dedicated class, i.e., the Bandwidth Manager, has been developed to store this information.
- ***Frequency reuse:*** A fundamental implemented feature is the frequency reuse concept . As well known, the frequency reuse increases both coverage and capacity of the cellular network and reduces the inter-cell interference.
- ***Frame Structure:*** LTE-Sim supports two frame structure types proposed in [28] for the E-UTRAN. The first one is defined for FDD mode and it is called frame structure type 1. The second one is called frame structure type 2 and is defined for TDD mode.
- ***Radio Resource Scheduling:*** The most important objective of LTE scheduling is to satisfy Quality of Service (QoS) requirements of all users by trying to reach, at the same time, an optimal trade-off between utilization and fairness [32].

Performance Comparison of Frequency Reuse Techniques

- Result analysis describes Frequency Reuse Techniques performance based on different parameters over the network. The different Frequency Reuse Techniques namely Traditional Frequency Reuse and Fractional Frequency Reuse are analyzed. Basically, Traditional Frequency Reuse technique is again classified in two types : Frequency Reuse One and Frequency Reuse Three.
- These two different techniques are implemented in LTE-Simulator and their comparative analysis is carried out on the basis of different parameters namely Spectral Efficiency, Throughput, Network Load etc.

Performance Metrics

- **Spectral Efficiency** measures how the spectrum bandwidth is efficiently utilized by these Frequency Reuse techniques.
- **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).
- **Network Load** measures the traffic computed on the network based on different number of users on different Frequency Reuse Techniques.

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. The overall performance percentage is calculated by using this formula:

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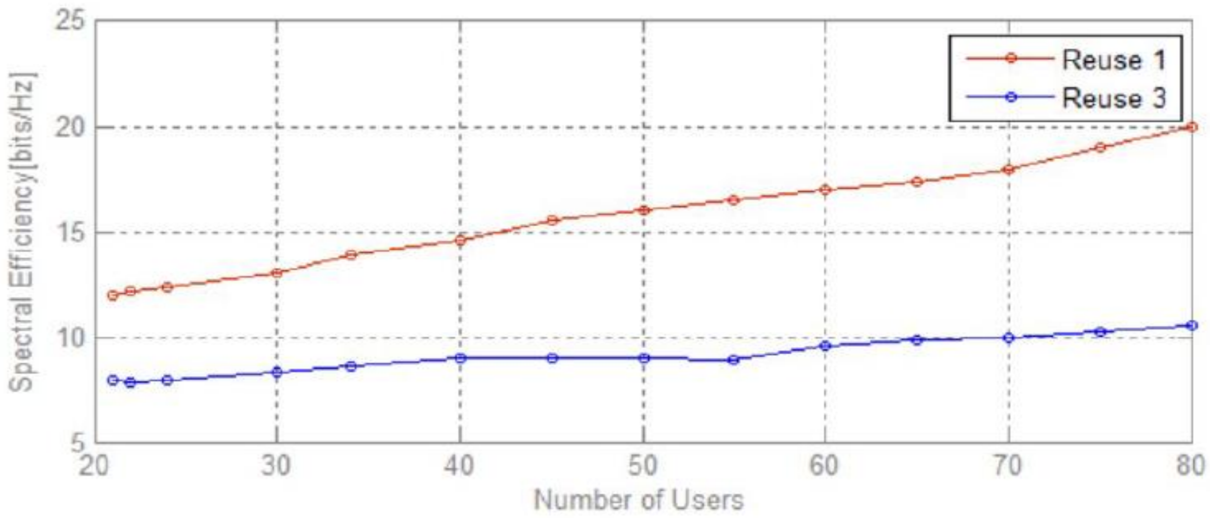
Performance % = ((Old valve – new valve) / old valve)* 100

Number of users	20	30	40	50	60	70	80	Total
RF3	12	13	14.6	16.02	17.01	17.95	20	110.58
RF1	7.9	8.35	9	9.1	9.6	10	10.5	64.45

Above Table : Spectral efficiency



Spectral efficiency Vs Number of users

From the result analysis 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. After calculating the performance percentage, it is clear that Spectral efficiency of Frequency Reuse One is increased by approximately 70% as compared to the Frequency Reuse Three.
As the number of user 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.

Performance Evaluation of Improved RF3

The implementation of proposed Improved Frequency Reuse Three and their setup or working conditions used during simulation. This chapter also explains all the results obtained through the experimental analysis. In the Result analysis, performance of Improved Frequency Reuse Three and Frequency Reuse Three is analyzed based on different parameters namely Spectral Efficiency, Throughput, Network Load and Interference Noise Ratio etc. over the network.

- ***Proposed 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.

Performance Metrics of IFR3

- **Spectral Efficiency** measures how the spectrum bandwidth is efficiently utilized by these Frequency Reuse techniques.
- **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).
- **Network Load** measures the traffic computed on the network based on different number of users on different Frequency Reuse Techniques.
- **Interference Noise Ratio** metrics calculates the interference noise ratio between the adjacent cells of different Frequency Reuse Techniques.

CONCLUSION

- Frequency Reuse Techniques are implemented in LTE simulator and their comparative analysis are carried out based on the different parameters like Throughput, Spectral Efficiency, Network load etc. Frequency reuse one and Improved Frequency reuse three algorithm are implemented in the LTE simulator. Then frequency scheduler is worked on these two algorithms and their performance is evaluated based on these parameters.
- 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. Results of implementation concluded that Improved Frequency reuse three are better than Frequency reuse three in spectral efficiency, interference-noise ratio, network load and throughput.
- After calculating the performance percentage, it is clear that performance of Improved Frequency Reuse Three is increased by approximately 4-5% as compared to the Frequency Reuse Three based on different parameters. This shows improved performance over Reuse three algorithm

FUTURE SCOPE :

There are several future directions for research:

1. There is need to improvise these techniques with respect to other parameters. As we have discussed different parameters for implement the frequency reuse techniques like reuse1 and reuse 3. We have only used frequency reuse algorithms for it. In future, we will improve any of these algorithms for reducing the intercell interference.
2. We will improve these algorithms to implement the other frequency reuse techniques like Fractional frequency reuse, Soft frequency reuse, Intelligent frequency reuse so that we improve the Spectral efficiency, Throughput, Network load, Inter-cell interference etc.
3. As we know these algorithms only used in the single-cell interference.h. These algorithms also be used in multi-cell interference.h, femto-cell etc.

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