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A Survey on Inter-Cell Interference Co-ordination Techniques of LTE Networks

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***Abstract:* -- The Long term evolution (LTE) is a latest technology standardized by 3rd generation partnership project (3GPP) to fulfill the growing demands of the users like high data rates in downlink and uplink, low cost, high spectral efficiency etc. Due to the growing demand for high data rate there is need to focus on frequency reuse i.e. reuse-1 so that we can get complete spectrum with in a cell. But the major problem is co-channel interference which increases due to the co-channel adjacent cells. So in frequency planning some co-ordination strategies should be considered to allocate the frequency bands in such a way that minimizes the inter-cell interference. There are different inter-cell interference coordination techniques for minimizing the interference like Frequency Reuse Distance scheme, Frequency reuse based schemes: Traditional/ Conventional Schemes, FFR and Dynamic channel allocation etc. This article represents an overview on LTE architecture and the inter-cell interference co-ordination techniques (ICIC).**

Index Terms: OFDMA, LTE, ICIC, SINR, SFR, FFR, REUSE.

I. INTRODUCTION

The LTE is a latest technology of cellular system which provides 50x better performance as compare to old cellular systems. The LTE adopted Orthogonal Frequency Division Multiple Access (OFDMA) technique for downlink and Single Carrier Frequency Division Multiple Access (SD-FDMA) for uplink and also called 4th generation technology (4G) a standard of 3GPP [3,9,14] in order to fulfill the growing demands of the users like high data rates for both magnitude i.e. the amount of data and variety i.e. the type of the data audio, video, image files, text file, multimedia files etc. in downlink as well as uplink, low cost for operation, low latency, backward compatible with previous generations, multi-antenna support and high spectral efficiency etc [9]. The LTE provides high data rate up to 300 Mbps on downlink and 75 Mbps on uplink for 20 MHz of bandwidth [8]. In 2004 the 3GPP conducted a workshop with many telecommunication industry players, and it was concluded that feasibility study for the new packet –only radio technology will be started on the basis of following requirements of the newer system [9, 13, 14].

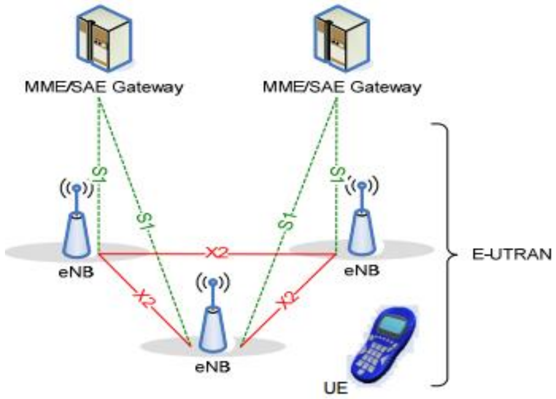
- High peak data rate (Uplink rate 75 Mbps and Downlink rate 300 Mbps).
- Backward compatible
- High spectral efficiency (Minimum Interference)
- Multi antenna support
- Delay must be very low (Low Latency)
- Flat or simplified architecture.
- Seamless Connection
- Plug and play

II. LTE ARCHITECTURE (HOW LTE WORKS?)

The higher level architecture of LTE is comprised of 3 main parts [14, 18]:

- UE: User Equipment.
- E-UTRAN: Evolved UMTS Terrestrial Radio Access Network.
- EPC: Evolved Packet Core.

Evolved packet core (EPC) made communication with packet data networks (PDN) of external world such as the internet, intranet etc. The interface between UE and E-UTRAN is represented by Uu, the interface between E-UTRAN and EPC is represented by S1 and the interface between EPC and PDN is represented by SGi through these interfaces these parts can communicates with each other.



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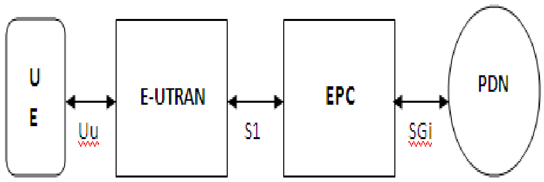

Figure 1.1

II.I User Equipment (UE)

As shown in figure 1.1 [14, 18] the user equipment for LTE is same as the UMTS and GSM which is actually a Mobile Equipment (ME) [14]. The mobile equipment comprised of the following important modules:

MT: Stands for mobile terminator, used to deals with all communication functions.

UICC: Stands for Universal Integrated Circuit Card (SIM card for LTE devices). It runs an application known as USIM (Universal Subscriber Identity Module).

TE: Stands for Terminal Equipment. As the name suggest it terminates the data streams.

II.II E-UTRAN: Evolved UMTS Terrestrial Radio Access Network.

The E-UTRAN deals with radio communications between the mobile node and the EPC and just has one component, the evolved base stations, and called *eNodeB abbreviated as eNB*. Each eNB is called a base station of cells and an eNB communicating with any mobile node is known as its serving eNB (serves services to the mobile node) [13,14,18].

There are following two main functions of eNB:

The eNB (eNodeB) sends and receives the radio signals to all the mobiles nodes by using the (ADSP) analogue and digital signal processing functions of LTE interface.

- All the control operations of mobiles nodes are done by eNB by sending them control signal.
- Each eNB can be connected to EPC with the help of S1 interface [14].

Each eNB can be connected to nearby base stations with the help of X2 interface [14].

A home eNodeB (eNB) is a base station that has been purchased by a mobile user to provide femto cell coverage within the home region. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

II.III Evolved Packet Core (EPC):

The EPC is the core of the LTE networks because actual work is done by this. That contains multi components which provide all the needed services like the Earthquake and Tsunami Warning System (ETWS) etc. There are 5 main components of EPC [14,18]:

- The HSS is a centralized database which contains the complete information about all the subscribers.
- The MME (Mobility Management Entity) controls all the operations of mobile like control signaling etc.
- The serving gateway works as a router to forward information between Packet Data Networks and the base stations.
- The PCRF which is responsible for policy control decision making, flow based controlling etc.
- The PDN (Packet Data Networks) used to communicate with the outside world like internet and intranet.

III. FREQUENCY REUSE:

In Orthogonal frequency division multiplexing (OFDMA) [2] the frequency band is sub divided into sub-bands and these sub-bands or chunks are group of sub carriers are allocated to the cells for the users. But for the proper utilization of frequency spectrum in cellular systems the frequency reuse mechanism is used or if we don't use frequency reuse scheme than it is not possible to allocate a different set of channels for each and every cell throughout the world, that creates a very big problem in exploring the cellular network due to limited frequency band but frequency reuse solve this problem by reusing the same frequency channels among multiple cells by considering multiple parameters like frequency reuse distance, frequency reuse factors. But the frequency reuse also creates a problem called inter-cell interference. In this problem the frequency bands of adjacent cells will interfere with each other by overlapping [2,4,16,17].

The inter-cell interference problem leads to performance degradation of the cellular system. This problem also exists in traditional systems like in Frequency Division Multiplexing (FDM), Time Division Multiplexing based systems (TDMA), Global Mobile Systems (GSM) and Code Division

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Multiplexing Systems (CDMA). In GSM a frequency reuse distance technique is used to overcome this problem means those two cells which are using the same set of frequency should be at least this distance apart [7][16].

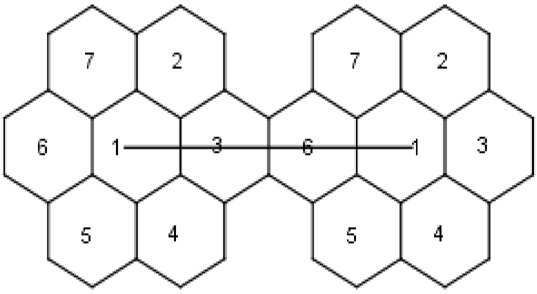

Figure 1.2

As shown in the Figure 1.2 [17] every cell having same number is using the same set of frequency bands (reuse of frequency bands) and all the cells are equally distance apart from each other and that distance is called Frequency reuse distance denoted by D and calculated by $D=R\sqrt{3N}$ [17]. That overcomes the problem of inter-cell interference [17].

In CDMA technique the problem of inter-cell interference is reduced by the use of scrambling codes.

The OFDMA (Orthogonal frequency division multiplexing) also suffer from the problem of inter-cell-interference.

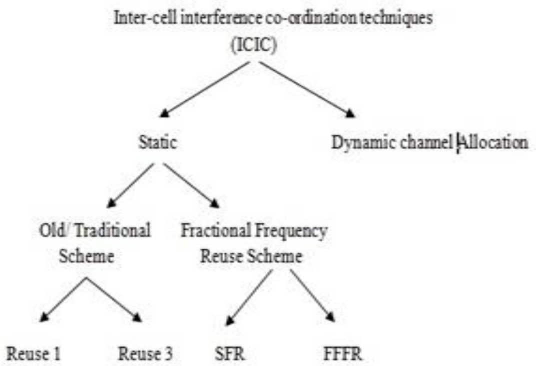

Figure 1.3

To solve this there are many inter-cell interference co-ordination techniques as shown in figure 1.3 [2,16].

III.I Static Schemes:

These schemes are also called frequency reused based schemes and as the name suggest in this the designer have to specify the best values for the parameters like power unit needed by a channel for its operation, set of channels used in a cell, the size of cluster, the area of the cell (cell center area and cell boundary area) in which the channels will be deployed at the structure design time statically and these parameters are fixed for that designed structure. There are two sub types of static scheme [2,17].

- Old/Traditional Scheme
- Fractional Frequency Reuse Scheme

III.I.I Old/Traditional Scheme:

This is the simplest and the basic scheme for the frequency reuse. In this frequency reuse is done on the basis of a parameter called Frequency Reuse Factor (FRF) denoted by K. The FRF is defined as the number of adjacent cells which can't use the same frequency for the transmission of the data and 1/K (inverse of K) defines efficient use of total bandwidth used in the cellular system [3][16]. There are two sub types of traditional scheme:

- Reuse 1
- Reuse 3

Before moving on Reuse 1 and Reuse 3 just have a look on these two parameters on the basis of the performance of the system is evaluated (there are so many other parameters also exist but in this review we will discuss about these two only).

Path Loss: Reduction in power density of the signal propagating through space. As shown in the figure1.4 if the path loss between any two adjacent cells is high then the interference of the signals will be low and the SINR will become high [3,16].

SINR: Specifies the theoretical upper bound for the rate at which information can be transferred in the cells [3,17].

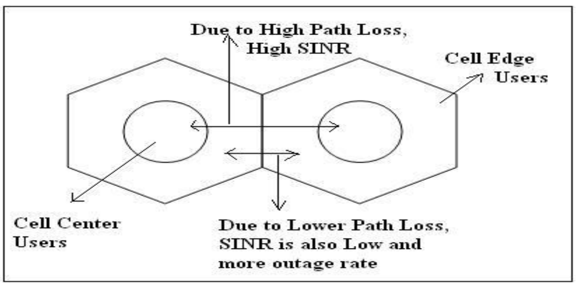

Figure 1.4

III.I.I.I Reuse 1:

Here Cluster Size is N=7 and K=1 that says the complete frequency is reused in each cell of the cellular system as shown in figure 1.5

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[16][17]. But there is problem of inter-cell interference between all the cells. In this case the users which are at cell center and its nearby boundary will experience large SINR [16] (Signal to Interference Noise Ratio) due to the large path loss. But the users at the cell boundary will experience low SINR due to small path loss that increases the outage rate at the boundary of the cell [2][16][17].

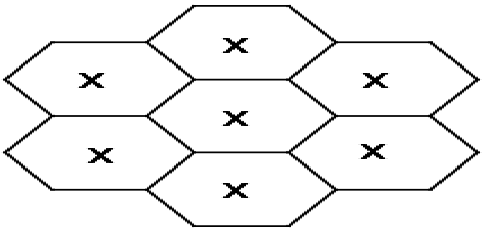

Figure 1.5
Reuse (K=1, N=7) Cell 1, 2, 3, 4, 5, 6, 7: use same frequency X.

III.I.I.II Reuse 3:
To overcome the problem of K=1, the whole frequency band is divided into 3 sub-bands (K=3 here X is subdivided into three sub-bands X_1, X_2, X_3) and the sub-bands are allocated to the adjacent cell in orthogonal manner as shown in figure 1.6 [16][17]. K=3 says the 1/3 part is usable for cells that reduces the bandwidth capacity of each cell but the cell edge user will get high SINR [16] due to the large path loss and reduces the inter-cell interference between the adjacent cells [16][17].

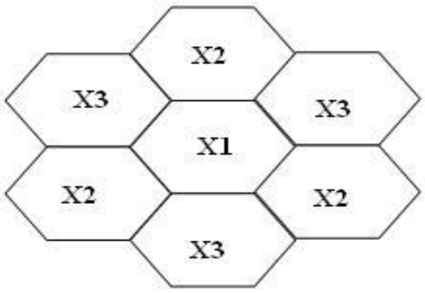

Figure 1.6
Reuse (K=3, N=7) Cell 1 use X1, Cell 2, 4, 6 use X2 and Cell 3, 5, 7 use X3.

III.I.II Fractional Frequency Reuse:

Generally interference affects the users at cell boundary and to improve the performance at cell boundary the FFR scheme is used. In FFR only a part (a fraction) of complete bandwidth is allocated to the cells so it is called fractional frequency reuse scheme. Here the complete bandwidth is divided into sub-bands and some of these sub-bands allocated to the cell at different positions (1<K<3). i.e. K=3/2 that means the bandwidth is sub divided into 3 sub-bands and 2 of the 3 sub-bands are allocated to a cell at different positions[2,3,6,8,16] as shown in figure1.7[16].

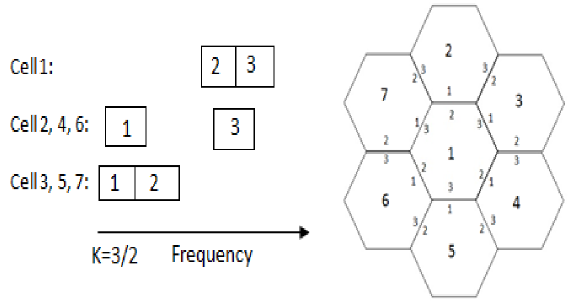

Figure 1.7

The FFR scheme can be applied on the basis of the location of the cell. In this the cell is divided into two regions:

- Cell Center Region
- Cell Boundary Region

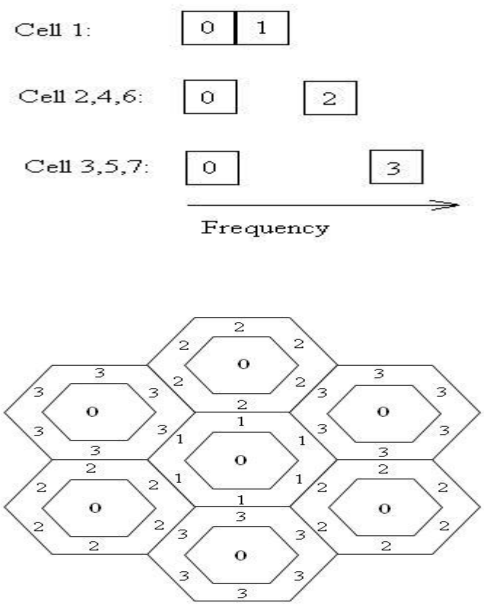

Figure 1.8

In this situation K=1 can be used for the cell center region because the SINR value of the cell center users is become high due to the large path loss but for the cell boundary users the SINR value become low due to low path loss so to improve that here we need a higher reuse factor like K=3, As shown in figure 1.8[16] the complete bandwidth is divided into 4 sub-bands and frequency band denoted by 0 is allocated to the cell center region of each and every cell and for Cell 1, Cell 2,4,6 and Cell 3,5,7;

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the sub bands 1, 2 and 3 are allocated in their boundary regions respectively [6,10,16].

There are 2 types of FFR scheme [2,16]:

- Soft Frequency Reuse.
- Fractional Frequency Reuse.

III.I.II.I Soft Frequency Reuse:

SFR is FFR with Power factor of sub-bands [6,16]. SRF works like same as FFR but a new thing is that here different power level density upper limit is defined for each cell and a power factor is applied to the sub-bands [1]. The sub-bands with high power level are used at the cell boundary and the sub-bands with lower power level are used at the cell center location as shown in figure 1.9 [7]. The cell center users can use only the frequency band allocated to it and the cell edge users can only use the frequency band allocated to it. Here in the figure Cell 1, Cell 2, 4, 6 and Cell 3, 5, 7 use higher power level sub-band orthogonally used for edge users and lower level sub-band used for cell center users [2,4,5,7,12].

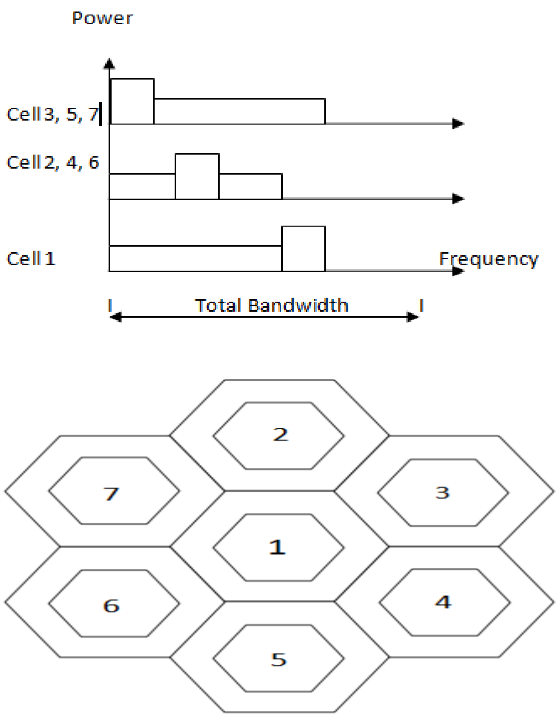

Figure 1.9

III.I.II.II Flexible Fractional Frequency Reuse:

In the flexible fractional frequency reuse the whole bandwidth is divided into groups of sub-channels and each group is allocated to cells adjacent to each other [16]. When the traffic load (incoming and outgoing traffic) is considered, if traffic is normal then it works normally but if the traffic is more, than a cell which have more traffic on demand can borrow sub-channels from the adjacent cells. The process of borrowing the sub-channels can also creates the problem of interference so the power level of the borrowed channel kept low so that the complete frequency band can be reused efficiently. For the borrowing process the resource allocation information of all the nearby cells must be known by the borrowing cell [8,11,16].

III.II Dynamic Channel allocation:

Generally for each and every cell, a fixed number of channels are allocated if the traffic is normal then it works efficiently but if there is an increase in the traffic it will result in shortage of channels and the system will not work efficiently. This problem can be resolved by this Dynamic channel allocation scheme (DCA). In this no any predefined channels are allocated to the cells if cell need a channel then it will request to its [16][17] Base Station DCA pool where channels resides then its BS allocate a channel to it when task of channel is complete it get released and sent back to the pool. This scheme provides a batter and efficient utilization of bandwidth. But it has some shortcomings like time delay (time consumed in channel request and channel allocation, can be very large in case of Distributed Dynamic Channel allocation scheme), the BS must be more power full, more intelligent and the implementation cost is very high. The DCA scheme can be Centralized Dynamic Channel allocation, Distributed Dynamic Channel allocation [16].

IV. Conclusion

Since last few years LTE has been the subject of exploration for researchers in the area of mobile communication. In this review paper we have studied about the LTE architecture, its working process and inter-cell interference co-ordination techniques of OFDMA cellular networks as scheduling strategies used to reduce the inter-cell interference for cell edge users basically. Its benefit is that the data rate increases in the cell coverage area and it improves the overall performance of the cellular system in many aspects like spectral efficiency, throughput, outage rate etc. Despite vast

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amount of research available in the field of LTE, a strong focus and redirection towards the specific needs of LTE architecture and research is required in future.

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