Intercell Interference Mitigation Techniques

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Abstract :- *To address the demands for high speed data keeps on increasing, LTE systems face the potential issues related to Intercell interference due to increased network traffic density, thereby affecting the spectral efficiency. Interference in cellular networks can be categorized as Intracell Interference and Intercell Interference. The orthogonality amongst the subcarriers diminishes the effect of Intracell interference as LTE downlink systems employ OFDMA technology. However, Intercell interference that is produced as result of using the same frequency by the serving and the neighboring cell greatly reduces the cell throughput, hence reducing the spectral efficiency. This type of interference is highly pronounced in case of cell edge users (CEU). Thus, in order to improve the efficiency of the existing LTE systems Intercell interference mitigation is of paramount importance. In this paper we discuss the principle of orthogonality among the various adjacent symbol streams. We also give a brief review about some of the interference mitigation techniques.*

Keywords: OFDMA, Inter-Cell Interference, Partial Frequency Reuse, Fractional Frequency Reuse, Soft Frequency Reuse, Soft Fractional Frequency Reuse, Spatial Filtering (SF), User Equipment (UE).

1. INTRODUCTION

LTE, a 4G wireless technology regulated by 3GPP (3G Partnership Project) that is being employed by the telecom companies all-around the Globe to tackle the issues encountered earlier with regards to speed and multimedia services. To enable the user's access high speed network, as the LTE network propagates, it augments the traffic density, thus facing interference. As the spectrum is limited, Interference is the major hurdle in achieving high data rates. Though filters have been employed to mitigate interference but the fact still remains that it cannot be completely eliminated [3].

LTE-A or LTE Release 10 further puts an impetus on increasing the data rate in a cost efficient manner with increased capacity and improved spectral efficiency. To achieve the objective of LTE-A, component upgrading is required [11]. These components include Femtocells and Pico cells that bring network closer to the users. A Femtocell can be regarded as a low power base station employed either in home or a small business establishment. It provides coverage to the cell edge users or indoors where service is otherwise unavailable. On the other hand, to deal with the coverage issues of a dense population or to extend coverage of a Macrocell, a Picocell is used. It usually covers a small area as in buildings, trains and now in aircrafts as well [3].

To further enhance the transmission efficiency and to expand the coverage area of a base station (BS), LTE is implemented as MIMO, Relay Station, and Carrier Aggregation, CoMP [2]. LTE systems utilize OFDMA technology that offers immunity against frequency fading by bifurcating bandwidth among sub carriers [12]. Thus, OFDMA is employed in LTE-A systems with the aim of achieving high Throughput and Spectral Efficiency.

In order to increase the system capacity, Frequency Reuse technique is used. In FRF-1, user can access the entire bandwidth at once but must deal with interference caused by neighboring cells [8] [13]. In FRF-3 scheme, bandwidth is split into three sub channels so that the adjoining cells use different frequencies. In FFR, bandwidth is split as Majority Group and Minority Group; each provided a part of bandwidth [14]. Majority group covers the outer regions surrounding the users in the inner region, thereby increasing the throughput in the cell edges while as throughput is reduced among cells center users than that in FRF-1 scheme [15]. Another technique PFR also called FFR with full Isolation isolates the external regions from inner regions leading to reduced interference between the two regions [16]. In case of SFR, One third ($1/3^{rd}$) of the available bandwidth is allocated to cell edge users with amplified power and the rest of the bandwidth is utilized by the cell center users with low power [2]. This technique proves to be efficient as the cell center users can utilize the entire bandwidth and the cell edge users can access only the allocated sub band with higher priority.

2. RELATED WORK

Gerald Kelechi etal; in [3] makes use of heterogeneous networks (HetNets) and the technical issues faced by employing them so as to mitigate interference. Interference is one of the chief issues faced by LTE operators' and implementing solution techniques at terminal end can prove to be effective. The work has primarily relied on eICIC techniques for mitigation. V.Rekha in [2] has emphasized on the concept of frequency reuse and simulated a number of techniques amongst which SFFR has provided the highest throughput in comparison with other schemes. Basically it's based on power allocation and different categories of FFR schedulers. However, the future scope of FFR, that is; EFFR and DFFR have not been discussed. A. Daeinabi etal in [3] has compared a number of algorithms governing Intercell Interference Mitigation in terms of throughput in LTE Downlink Networks. The results obtained reveal that intercell coordination schemes have higher throughput as resources are allocated as per the information exchanged between the eNodeB's. Since dynamic schemes adjust instantaneously to the network changes, they display a better result in terms of cell throughput. However, they create new challenges to the system that impact the efficiency for implementation in the real world. Thus it suggests selecting an algorithm that may be suitable for achieving a particular goal rather that providing a general solution for mitigating interference. Muhammad Umair Ghori in [1] focuses on synchronization between the base stations using Dynamic Cooperative Base Station selection (DCBS). Here, SINR and Capacity of the system are evaluated when coordination is applied between the Cells. Three different situations; Coordinated Multipoint Transmission and Reception (COMP), Non-COMP and DCBS have been compared.

3. INTER-CELL INTERFERENCE MITIGATION TECHNIQUES

3.1 Inter-Cell Interference Coordination Technique

The basic frequency reuse schemes for OFDMA-based cellular systems with the diverse frequency reuse factor (FRF), signified by K. The FRF is characterized as the number of adjacent cells which cannot utilize the same frequencies for transmission. Its converse, 1/K, compares to the rate at which the same frequency can be utilized in the network or we can say 1/K is a factor to indicate how proficiently the bandwidth is utilized in the cellular framework. At the point when K=1, the whole bandwidth available for transmission is utilized in all cells. In this case, the clients near the cell center will encounter high Signal-to-Interference and Noise Ratio (SINR) because of the large path loss from adjacent cells[3][7]. Notwithstanding, the clients at the cell boundary will experience the ill effects of a small SINR, which may increase an outage rate at the cell boundary [6]. With the end goal to enhance the SINR all through the cell coverage area while diminishing the outage rate at the cell boundary, the entire bandwidth can be separated into three channels or subbands, each of which is allocated to adjacent cells in an orthogonal manner. It compares to K=3 and diminishes the usable bandwidth for each cell. Be that as it may, the clients at the cell boundary will encounter high SINR, diminishing inter-cell interference. Note that a subband is a subset of subcarriers, or, in other words whole subcarriers of each channel in the OFDM framework [14]. Unlike the multi-channel case of a solitary channel is partitioned into three subbands to be assigned to each cell regardless of whether the two cases compare to K=3. To enhance the performance at the cell boundary, an idea of fractional frequency reuse (FFR) has been proposed for the OFDMA cellular framework. By definition, FFR is a subcarrier reuse plan to allocate just a part of the total bandwidth, that is, a subset of subcarriers, to each cell with the end goal that 1 <K < 3. In FFR schemes, the entire bandwidth is separated into subbands, some of which are allocated to an alternate location in the cell [19]. Another sort of FFR conspire where an alternate frequency reuse is utilized, contingent upon the area in the cell [2]. Since the clients close to the cell center experience a high SINR, K=1 can be kept up for them. With the end goal to maintain a strategic distance from interference in any case, the higher frequency reuse factor should be utilized at the cell boundary. K=1 and K=3 are utilized at the inner locale and boundary, separately [14]. For this situation, the entire transmission capacity is separated into four diverse subbands, among which subband 0 is utilized by all cells (i.e., K=1), while whatever remains of them are orthogonally doled out to various cells, that is, K=3. The equivalent thought can be stretched out to various arrangements, for instance, K=1 for the inner area (center) and K=3/2 for the outer locale (boundary) [6]. With the true objective to upgrade the information transmission efficiency of the FFR designs K=1 can be so far acknowledged while decreasing the inter-cell interference in OFDMA cellular frameworks. Toward this end, we distribute unmistakable levels of power to the subbands, dependent upon the customer region. High power is dispensed to the subbands for the customers at the cell boundary, and low power is distributed to all unique subbands for the customers in the center (inner region), while orthogonally orchestrating the subband for those at the cell boundary of the adjacent cells as in FFR. This particular thought is insinuated as the soft frequency reuse (SFR).

3.2 Inter-Cell Interference Coordination Technique

As long as intra-cell and inter-cell synchronization can be maintained in the OFDM-based cellular systems, each sub channel can be considered autonomous because of the orthogonality among subcarriers. In any case, the interferences from adjacent cells may cause significant performance degradation; therefore the interference signal can be randomized for enabling the averaging effect of the inter-cell interference. More specifically, a Cell-Specific Scrambling code or Cell-Specific Interleaver can be utilized for randomizing the interference signal [6]. Let $X^{(m)}[k]$ and $C^{(m)}[k]$ indicate the transmitted signal and a scrambling code of the m^{th} cell for subcarrier k, m = 0; 1; 2; . ....;M-1. The received OFDM signal in the frequency-domain is given as;

$$Y[k] \approx \sum_{m=0}^{M-1} H[k]C[k]X[k] + Z[k]$$

Here, H[k] is the gain of channel, Z[k] is additive noise of the subcarier k. If m=0 denotes the serving cell, equation can be decomposed in manner as;

$$Y[k] \approx H^{(0)}[k]C^{(0)}[k]X^{(0)}[k] + \sum_{m=0}^{M-1} H[k]C[k]X[k] + Z[k]$$

Received signal Y[k] can be descrambled by the code as;

$$Y^{(0)}[k] \approx (C^{(0)}[k]) * Y[k]$$

Thus, interferences from neighboring cells can been whitened utilizing scrambling codes.

A cell-specific interleaving technique is often alluded to as Interleaved Division Multiple Access (IDMA) technique [6]. The IDMA technique is like the cell-specific scrambling technique for the case of single-user detection, where it whitens the interferences from contiguous cells. It whitens the inter-cell interference by utilizing a specific Interleaver at every cell, while the cell-specific scrambling technique performs a similar activity by utilizing a specific scrambling code. Particularly when the multi-user detection technique is utilized in IDMA, it can decrease inter-cell interference more adequately than the cell-specific scrambling technique by canceling interference iteratively with multiuser locator [6].

3.3 Inter-Cell Interference Cancellation Technique

To mitigate interferences from the adjacent cells, we have to distinguish the interfering signals first, so that we can remove them from the received signal. It is generally hard to identify the interfering signals from adjacent cells in practical circumstances. However Spatial Characteristics (SC) can be utilized to mitigate interference when multiple antennas are accessible at the receiver. One technique is the Interference Rejection Combining (IRC) technique, which exploits the interference statistics retrieved at various antennas. The IRC technique can be seen as a speculation of the Maximum Ratio Combining (MRC) technique that fuses the SC of the received signal for IRC at the receiver. In IRT, IDMA technique for a single user, interference at the receiver is viewed as noise. However with multi-user receivers, the execution is enhanced by demodulating the interfering signals and the desired signal, and thereby detecting iteratively with a Posterior Probability Decoder (PPD).

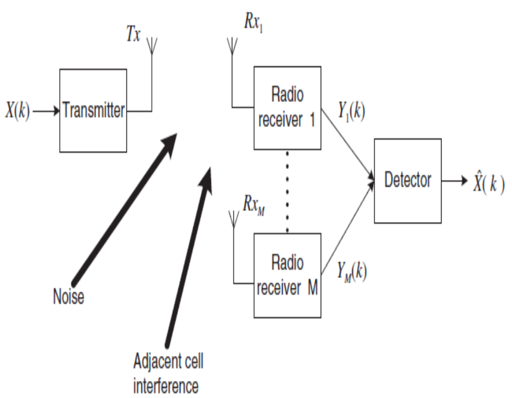

Fig. 3.1 IRC Technique

As shown in Figure 3.1, Consider the receiver with M antennas subjected to the neighboring cell Interference as well as Noise[6]. Let $H_i[k]$ and $Z_i[k]$ denote the channel Gain and Additive noise Interference for the k^{th} subcarrier of the i^{th} antenna in the receiver, respectively (i = 1; 2; . . . ;M. For the transmitted signal X[k] the obtained signal at the i^{th} Antenna is given by;

$Y_i[k]=H_i[k]X[k] + Z_i[k]$, I = 1,2,..,M

In Vector form,

Y[k] = H[k]X[k] + Z[k]

Interference Cancellation methodology is centered around Spatial filtering (SF) [7] and it requires the services of multiple antennas User Equipment (UE). Intercell interference Coordination method capitalizes on efficient radio resource management modus operandi to coordinate the channel allocation in nearby cells and minimize the interference level. Conclusively, Interference Randomization procedure spreads the user's transmission over a dispersed set of subcarriers with the end goal to randomize the interference situation and accomplish frequency diversity gain.

4. CONCLUSION

The investigation has discovered that interference Coordination is powerful for moderate traffic load since coordination permits total Interference Rejection (IR). While as, the Interference Randomization demonstrates proficient execution in the event of heavily loaded systems since the random subcarriers scrambling stimulates fluctuations in the interference situation accordingly prompting a robust frequency Diversity Gain. Interference Cancellation method is based on SF and it employs a number of multiple antennas UE.

REFERENCES

1. Muhammad Umair Ghori etal, (2017), "Comparative Analysis of Intercell Interference Mitigation Techniques in LTE-A Network".
2. V. Rekha, (2016),"Inter-Cell Interference Mitigation Techniques in Long Term Evolution Networks: A Survey".
3. Ijemaru Gerald Kelechi etal,(2014) "Inter-Cell Interference Mitigation Techniques in a Heterogeneous LTE-Advanced Access Network".
4. A. Daeinabi etal,(2012) "Survey of Intercell Interference Mitigation Techniques in LTE Downlink Networks".
5. Frederic Lehmann,(2012),"Iterative Mitigation of Intercell Interference in Cellular Networks Based on Gaussian Belief Propagation".
6. "MIMO-OFDM Wireless Communications with MATLAB; Intercell Interference Mitigation Techniques" Volume 2, Chapter 8.R. Bosisio and U. Spagnolini,(2008),"Interference Coordination vs.

Interference Randomization in Multicell 3GPP LTE System".

7. MohamedA.Aboul Hassan,(2015),"Classification and Comparative Analysis of Inter-Cell Interference Coordination Techniques in LTE Networks".

8. Ijemaru, G.K., Udunwa, A., Ngharamike, E., and Oleka, E. (2014)"Evaluating the Challenging Issues in the Security of Wireless Communication Networks in Nigeria." International Journal of Innovative Technology and Exploring Engineering (IJITEE).Vol. 3.

9. Jinfei, S. (2009) "Mitigating Interference between LTE and 2G/3GNetwork." [online] available from http://www.huawei.com/en/static/HW-079472.pdf

10. Kummithe, R. (2012), "Interference Mitigation in 4G LTE-A Heterogeneous Network". University of Texas

11. Debbabi N, Kammoun I, Siala M. "Performance Optimization of Amplify- and-Forward Relaying Schemes for Uplink OFDMA Communications. Third International Conference on Communications and Networking, Hammamet". 2012. p. 1–7.

12. Afroz F, Sandrasegaran K, Kim H A. "Interference Management InLte Downlink Networks" International Journal of Wireless and Mobile Networks (IJWMN). 2015; 7(1):91–106.

13. Novlan TD, Ganti RK, Andrews JG, Ghosh A. "Comparison of Fractional Frequency Reuse Approaches in the OFDMA Cellular Downlink" Conference: Global Telecommunications. 2011 Jan. p. 1–5.

14. 4G++"Advanced Performance Boosting Techniques in 4th Generation Wireless Systems" Available from: http://4gpp-project.net/attachments/section/4/WP4_ICIC_v3.pdf.

15. Kwan R, Leung C. A Survey of Scheduling and Interference Mitigation in LTE Journal of Electrical and Computer Engineering. Journal of Electrical and Computer Engineering.

16. Selim MM, Khamy ME, Sharkawy ME. "Enhanced Frequency Reuse Schemes for Interference Management in LTE Femtocell Networks" International Symposium on Wireless Communication Systems (ISWCS), Paris. 2012.

17. M. C. Necker. Interference Coordination in Cellular OFDMA Networks. IEEE Network 22(6):12, December 2008.

18. S. Shukry, K. Elsayed, A. Elmoghazy, and A.Nassar." Adaptive Fractional Frequency Reuse (AFFR) scheme for multi-cell" IEEE 802.16 systems. In Proceedings of IEEE HONET,December 2009.