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A Survey on the Uplink Capacity in the Cellular System

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Abstract*— LTE and LTE-A uses Single Carrier (SC) uplink transmission because of its large inclusion and low Peak to Average Power Ratio (PAPR) when compared to multi-carrier (MC) transmission. In any case, the wireless channel turns out to be frequency selective as the information rate increments because of delay at different times. In such a case, Inter Block Interference (IBI) and Inter Symbol Interference (ISI) are created and corrupt the transmission fundamentally. To combat ISI, Frequency Domain Equalization (FDE) strategy is used in SC transmission. In cellular framework, neighbouring cells utilize a similar carrier frequencies to effectively utilize bandwidth. But there is existence of Co-channel Interference (CCI) and the CCI power is controlled by the separation between those cells. Moreover, the presence of various users inside a similar cell causes Multiuser Interference (MUI). Thus, cell limit is constrained by Multiple Access Interference (MAI i.e., both CCI and MUI). Adaptive Array Antenna (AAA) is an amazing technique to battle MAI. In this manner, so as to battle the MAI, it is normal to implement in both FDE and AAA. However, the performance of antenna array will depend on the angle of arrival of the received signals and the antenna placement which determines the radiation pattern and coupling between antennas. Then again, cell limit is dictated by the available bandwidth and its efficiency. By expanding the Frequency Re-use Factor (FRF), the separation between co-channel cells will increment, and the CCI power decreases. However, the accessible data transfer capacity decreases. Subsequently, cellular capacity turns into a trade-off between data transfer capacity effectiveness and bandwidth availability, which is dictated by FRF. But, the ideal FRF relies upon the channel propagation model and transceiver structure. This paper gives an overall review on how to choose the optimal FRF based on the different methods that has been implemented by various authors.

Index Terms*— *OFDM, Frequency Re-use Factor (FRF), Direction of Arrival (DoA), MUSIC algorithm, LMS algorithm.

I. INTRODUCTION

Numerous cellular applications utilize the technique of OFDMA that transmits data on M carriers that are orthogonal to each other at a bit rate of 1/M times the information signal. OFDMA waveform likewise shows envelope fluctuations bringing about a high peak-to-average power ratio (PAPR). High PAPR signals require linear power amplifiers to avoid intermodulation distortion that can cause frequency offset and thereby decreasing the efficiency. To beat these impediments, the modified version of OFDMA has been proposed – Single Carrier Frequency Division Multiple Access (SC-FDMA) that utilize orthogonal subcarriers sequentially to transmit information symbols and has lower PAPR than OFDMA signals [3].

Eventually, cell frameworks reuse same carrier frequency in spatially separated cells for powerful usage of the available bandwidth. But, there is an existence of Co-Channel Interference (CCI) from the adjacent cells. All together to lessen the CCI, Frequency Re-use Factor (FRF) is acquainted to modify the separation between the cells. Higher the FRF, larger is the separation and lesser is the CCI. But, there is degradation in the spectral efficiency. To improve the spectral proficiency of the cell frameworks, space division multiple access (SDMA) utilizing adaptive antenna array (AAA) has been acquainted which permits various users to access the carrier simultaneously using the same bandwidth. However, because of the existence of the frequency selective nature of broadband channels, inter symbol interference (ISI) occurs and corrupts the exhibition of SC transmission [4]. It is essential for the removal of this interference. It is shown that the SC-FDAAA viably removes MAI from a channel that is highly frequency selective in nature [5].

However, as information rate increases, enormous transmit power is necessary to understand information rate if cell coverage remains unchanged. To beat this issue, W Peng and F Adachi [5] proposed the implementation of Distributed Antenna Networks (DAN) where a number of antennas are

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spread across in each cell, and each of the antennas are connected with the DAN central processor via optical links. But, the performance of this array in a cellular network depends on the antenna placement and the angle of arrival (AOA) of the signal that is received which further decides the coupling and radiation pattern between antennas. Thus Hybrid FRF has been proposed to upgrade the capacity of the cellular frameworks. M H Asti, W Peng *et. al.* [6] have structured a framework model of linear adaptive array antenna system with FDAAA receiver that implements hybrid FRF calculation. It executes FRF = 1 and FRF = 3 adaptively i.e., as per the area and channel status of the user, algorithm utilizes FRF=1 for region close to the center of cell and FRF=3 for region close to the edge of the cell. Accordingly, two different data rates exist together inside the cell.

Then again it is critical to estimate the AOA of the desired signal using AAA. AOA estimation help to change the weights in the adaptive beam former. Minimum Variance Distortionless Response (MVDR) and Multiple Signal Classification (MUSIC) are two mainstream methods that have been utilized for estimation of AOA the received signals in an Adaptive Array Antenna System. K H Lee [13] has proposed an algorithm that joins cost capacity and MUSIC calculation to decide the ideal weight value dependent on the estimation of desired signals correctly. Be that as it may, the outcomes that were gotten were not proficient.

The authors in [14] have given a comparision between Uniform Linear Array (ULA) and the Proposed Array (PA) models in solving sources of narrowband signal located at short distance to each other. The PA adds two components to the top and bottom of the array axis of the ULA. A numerical assessment is done on both ULA and PA geometries, in light of their resolution ability, on both MUSIC and MVDR algorithms. The results show that a slight change in the cluster geometry of ULA, there is an improvement in AoA estimation precision.

A Hakam et. al. [11] have introduced a comparative study of MUSIC and MVDR, and the simulation results have demonstrated that MUSIC has preferable performance over MVDR calculation since MUSIC produces an angular spectrum with low noise and clear and sharps peaks. Simulation results demonstrates that, expansion in the AOA spread diminishes the receiving antenna correlation, and thus to an expansion in the cellular capacity by utilizing FDAAA receiver.

II. RELATED WORK

Intra cell interference in OFDM cellular systems, inside the cell gets removed because of the orthogonality of subcarriers. In any case, inter cell interference (ICI) happens when FRF=1, in this manner resulting in decrease in system capacity for users at the edge of the cell (CEUs). Hence it is critical to stifle ICI in OFDM systems. In a conventional FRF=3 plot, the entire frequency band is equally isolated for every arrangement of three adjacent cells. Because of the removal of interferences from co-channels of the adjacent cells, there is an improvement in SINR. But the throughput diminishes due decrease in the availability of bandwidth. In the soft frequency reuse (SFR) plot, the FRF=1 is used in the center of the cell and the FRF=3 is used in the edge of cell. The cell initially appoints CEUs with high power band of frequencies, and later allocates CCUs rest of the bands. In the softer frequency reuse (SerFR) method, user based scheduling is made adaptable when compared to SFR plans. Contrast to SFR, SerFR accomplishes a CEU execution gain at a loss of total cell throughput corruption. But, the FRF remains static in all the above cases.

To overcome this issue, L Liu *et. al.* [1] have proposed Dynamic Fractional Frequency Reuse (DFFR) plot. This depends on Interference Avoidance Request (IAR) system to remove the ICI for OFDMA downlink cellular systems where the base stations trade IAR messages between each other, and control the transmit power as indicated by IAR messages. For the flexible data rate, this system mechanism along with Proportional Fairness (PF) scheduling algorithm, has accomplished both cell throughput and CEU throughput. Results show that the proposed DFFR plan outranks the previously used frequency reuse plots in terms of cell and CEU throughput.

In order to overcome high PAPR in OFDMA, SC-FDMA with lower PAPR is presented. SC-FDMA is proportional to a DFT-precoded OFDMA, in a frequency domain implementation, where the spreading of DFT re-establishes the low envelope variations of the received signal, in this way lessening the high PAPR of OFDMA (figure 1). The transmit antenna diversity under MIMO method as Space Time Block Code (STBC) and Space Frequency Block Code (SFBC) improves the uplink performance with SC-FDMA. Y Rui *et. al.* [2] have used the changed STBC and SFBC models for the above framework which maintain the SC property, based on which SINR values has been acquired that matches with that of AWGN channel alongside Block error rate (BLER).

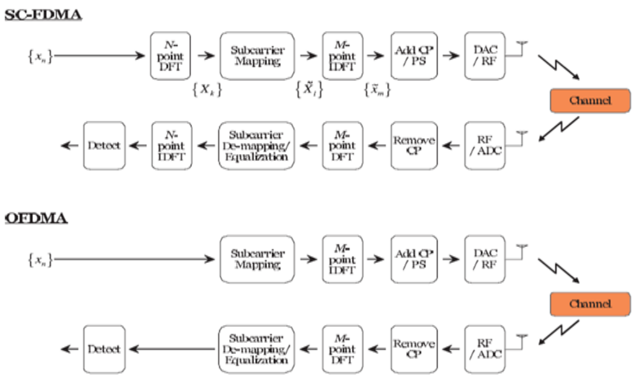

Figure 1: Transmit and Receive structures of SC-FDMA and OFDMA

H G. Myung *et. al.* [3] thought of two methodologies of SC-FDMA that are localised FDMA (LFDMA) where every terminal, to transmit its symbols, uses a set of adjacent subcarriers and Distributed FDMA where the subcarriers are spread over a band at a terminal. Interleaved FDMA (IFDMA) is one type of Distributed FDMA where subcarriers are at equal distance from one another. Distributed FDMA gives diversity in terms of frequency while LFDMA offers diversity in terms of

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multiple users. It requires Channel Dependent Scheduling (CDS) of subcarriers and adjust subcarrier assignments to changes in the channel frequency reactions of considerable number of terminals. The simulation investigation of SC-FDMA framework has been done on PAPR and model throughput. The PAPR examination demonstrates that SC-FDMA signal have PAPR that is lower than OFDMA signals. LFDMA brings about higher PAPR contrasted with IFDMA be that as it may, contrasted with OFDMA, it is lower. Regarding system throughput, it is better in IFDMA but LFDMA is better in high date rate users.

Upon more research, M H Asti *et. al.* [4] have proposed the arrangement of the utilization of Frequency Domain Adaptive Antenna Array (FDAAA), which is a blend of Frequency Domain Equalization (FDE) and Adaptive Antenna Array (AAA) that viably removes the ISI and Multiuser Interference (MUI). Additionally, there exist a trade-off between the CCI and spectral efficiency. So as to viably take into account both the prerequisites, the authors proposed the execution of Fractional Frequency Reuse Factor (FFRF) which can increase the cellular limit alongside the utilization of FDAAA. With the simulation results acquired, it was reasoned that hybrid FRF (figure 2) improves the trade-off among CCI and spectrum efficiency in cellular framework by utilizing FDAAA receiver.

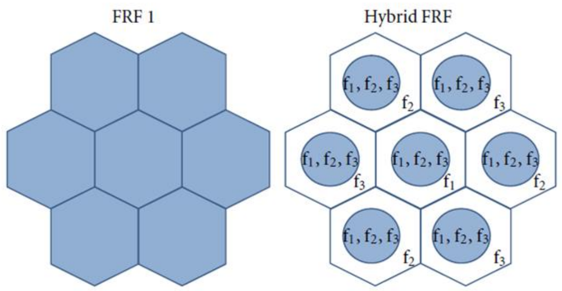

Figure 2: Structure of fixed FRF and hybrid FRF

As information rate increases, enormous transmit power is required to maintain the high information rate if cell coverage remains unchanged. To beat this issue, the usage of Distributed Antenna Networks (DAN) with SC-FDAAA has been proposed by W Peng and F Adachi [5] where a number of antennas are dispersed in every cell, and every one of them are associated with the DAN central processor via optical links. Hence a CEU can easily communicate with nearby located antennas. Thus, by expanding the coverage area of the cell, the transmit power in DAN can be kept low. The results have proven that the BER execution and Cellular Link capacity of DAN is superior to that of Centralized Antenna Network (CAN).

The ideal FRF additionally relies upon the channel propagation model and handset structure. M H Asti *et. al.* [6] have planned a framework model linear adaptive array antenna system with FDAAA receiver that adopts hybrid FRF algorithm. It executes FRF = 1 and FRF = 3 adaptively to improve the cell structure. As indicated by the area and channel status of a user, algorithm utilizes FRF=1 for cell center area and FRF=3 for cell edge area. Therefore, two information rates coexist inside a cell. Additionally, the cellular system capacity analysis has been done based on Signal to Noise plus Interference Ratio (SINR). Results have proven that expansion in the AOA spread, reduces correlation of antenna and hence an increase in the cellular capacity by using FDAAA receiver. Also, by increasing the separation between antennas to above 5λ reduces the correlation of the antennas to almost zero and increases the overall cellular capacity.

S Kaviani and W A Krzymien [7] have shown a Network Level Interference management system is required on downlink cellular networks that increases SINR without decreasing the FRF to remove the intra and inter-cell interference and increase the spectral efficiency in MIMO cellular networks. Because of its simplicity, linear precoding schemes, for example, Multiuser Zero Forcing (ZF) or Block Diagonalization (BD) for multi cells has been considered to eliminate the cluster interference where linear precoding of data is done for transmission of each user lies within the null space of transmission of other users' and increasing the throughput with increasing cluster size. Multi-user diversity is made conceivable with each user being planned for proper fairness.

As the speed of the users increase, the BD strategy is no more productive. So as to defeat this issue, T. Taniguchi *et. al.* [8] proposed a low computational structure approach dependent on BD consuming degrees of freedom smaller than or equivalent to the minimum required value, where just a subset of transmit loads are refreshed according to linearly extrapolated channel keeping the zero forcing (ZF) condition as possible. Simulation results of the received SINR have proven that the proposed methodology show great execution if the sufficient weight update parameters are chosen.

It is likewise essential to decide the AOA of the desired signal so as to isolate it from the interference/noise signals, subsequently expanding the capacity, information rate and coverage area of the framework and suppresses the multipath fading and CCI impacts. Additionally, numerous users can be handled at parallel by using multi-beam radiation pattern, thereby improving the efficiency of the spectral. For this reason, an Adaptive Array Antenna, additionally called as, Smart Antenna System is required that is a combination of a signal processing unit and an antenna array, which adaptively combines the incident signals using adjustment of the weights.

H.J. Chaloupka *et. al*. [9] have proposed to compensate the deviations brought about by changing the loads in DBF with the assistance of orthogonal property of Eigen vectors. Be that as it may, SNR degradation can't be remunerated through signal processing methods. Subsequently the authors thought of De-coupling the antenna ports. SNR improvement has been accomplished by diminishing the frequency bandwidth and an expansion in the sensitivity to the losses in the antenna and matching network structure.

So as to oblige the necessities of wideband signals, Dr B R Mohammed and N H Noori [10] proposed the plan of Linear AAA arrangement of transversal channel of J taps with a

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90degree phase shift between the taps and M sensors that utilizes Linearly Constrained Minimum Variance (LCMV) beam former algorithm. The outcomes proved that behind every sensor, with an appropriate number of taps, the framework was able to effectively compensate the effect of signals bandwidth and estimate AOA along with output SNR's of all the simultaneously received signals at high accuracy.

Direction vectors represent the steering vectors and are used to derive the sources of signal that are orthogonal to the subspace of the noise. The most popular algorithms used for determining the AoA are MUSIC and MVDR that is broadly used for narrowband signals. MUSIC algorithm is based on the Eigenvectors of thermal noise subspace that is related to the set of the equalized and smallest Eigenvalues of covariance matrix of orthogonalized received (desired) signals. On the other hand, MVDR finds optimum weight vector that maximizes the SINR of many antennas. A Hakam *et. al.* [11] have exhibited a comparative study for both the algorithms with respect to the effect of signal parameters, total number of mobile users, number of snapshots and spacing between adjacent elements. The results have proven that MUSIC performs better than MVDR algorithm since MUSIC produces an angular spectrum with low noise and clear and sharps peaks (figure 3).

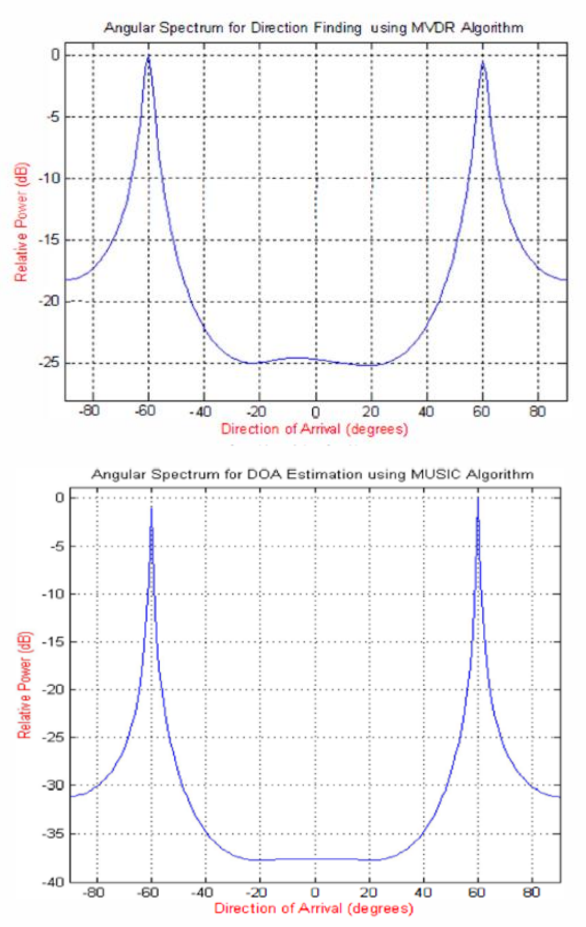

Figure 3: MVDR and MUSIC angular spectrum with elemental spacing d=0.25lamda

After the AOA estimation, the subsequent stage of processing the signal is beam forming. Beam forming is also called as spatial filtering because it removes some of the incoming signals from all directions of space, while amplifying the other signals. Based on the AOA of desired signals of the users, the main beam is adaptively moved towards the desired user and nulls are placed towards the interferers. M. Al-Sadoon *et. al.* [12] have investigated two fundamental kinds of adaptive processing algorithms: Least Mean Square (LMS) method and Sample Matrix Inversion (SMI) method. The results prove that SMI algorithm is faster than the LMS algorithm, but has computational complexity and creates singularities. LMS algorithm does not need direct matrix inversion or memory and is a less complex algorithm, but has a slow convergence time.

Based on the above survey, it has been found that capacity of cellular network can be enhanced with the help of a suitable frequency reuse mechanism.

III. CONCLUSION

In a cellular system, there is a limitation on the bandwidth available due to which the same carrier frequency is re-used by neighboring cells. As a result, the system performance gets limited due to interference from co-channel users. In order reduce CCI, Frequency Reuse Factor (FRF) is introduced to adjust the distance between the cells. The relation between the total number of RF channels available (Sf), number of channels per cell (So) and the re-use factor (K) is given by:

$$Sf = K(So)$$

Where K=1 maximizing the capacity. Thus, higher the reuse factor value, larger is the distance between cells using the same channel and lower is the interference between them. But there is degradation in efficiency of the spectrum.

Also, in order to overcome the disadvantage of having high PAPR in OFDMA, SC-FDMA with lower PAPR is introduced. But due to the frequency selective nature of broadband channels, ISI is produced and degrades the performance of SC transmission.

In context with the disadvantages of a fixed FRF calculation as well as capability of the cellular system, this paper has been reviewed to do the following:

1. Choose a frequency re-use factor for a desired SINR and BER.
2. Reduce the Interference and fading effects for large number of subscribers in a single area.
3. Use suitable algorithm to achieve the above with less computational complexity.

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