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Effective Energy Efficient Scheduling Scheme with Cancellation of Interference in Cellular System

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Abstract: In a multi cell scenario, co channel and adjacent channel interferences occur and degrade the performance of cellular networks particularly the edge users. In this paper, an algorithm is proposed for Inter cell Interference cancellation and resource allocation. This algorithm is based on Energy Efficiency and capacity. The main objective of this algorithm is to provide good energy efficiency to edge user. The algorithm is based on energy efficiency and it provides better cell edge efficiency and fairness. In this method, Inter Cell Interference (ICI) is cancelled by Frequency Reuse (FR) technique. After cancellation of ICI, the resources are allocated to the user equipment based on Transmitted Energy per Bit. The proposed method is compared with the previous techniques like Maximum Carrier to Interference ratio (MCI) and Round Robin technique (RR). This method is evaluated through simulations based on various performance measures such as spectral efficiency, Signal to Interference Noise Ratio (SINR), cell energy efficiency, capacity and fairness.

Key word: CoMP, energy efficiency, frequency reuse, SINR, India

INTRODUCTION

LTE-Advanced (LTE-A) specification on Release 11 is an enhancement of LTE and it supports 100Mbs and 1Gbsec for high mobility and low mobility (Pedestrian) users, respectively (Deruyck *et al*., 2013). Now a days, Orthogonal Frequency Division Multiplexing (OFDM) (Huq *et al*., 2015) is employed in cellular networks and is backward compatible with previous radio access technologies (Raza, 2013). Relaying, Coordinated Multipoint Transmission (CoMP), Heterogeneous Networks (HetNet), Device to Device Communication and Carrier Aggregation are an integral part of LTE Advanced Techniques. Important features of LTE Advanced are improving the Cell Efficiency for Edge Users and also improving Capacity even at high mobility. Frequency Reuse is the main task in Cellular Communication. When the same channel is assigned to different users in neighboring cells, the frequency bands overlap and ICI occurs. ICI degrades the throughput and capacity of cellular systems. OFDMA eliminates the Intra and Inter cell Interference due to orthogonal multiple carrier modulation. Cell edge user severely suffers due to Inter cell Interference (ICI) because it receives the signal from neighboring cells. Many techniques are Implemented to avoid ICI. Zhang *et al*. (2013) describes novel scheme for interference management to adaptively choose the best fractional frequency reuse. The study (Wany *et al*., 2011) develops Inter cell Interference Cancellation (ICIC) Method algorithm and this scheme allocates subcarriers among adjacent cells in a distributed manner. Generally radio resource management is differentiated into Distributed Radio Resource Management, Centralized Radio Resource Management and Self Organized Radio Resource Management. Distributed Radio Resource system management technique is explained in by allocating small base station to allocate its user equipment subcarriers based on received interference measurement (Chandrasekhar and Andrews, 2009). Centralized radio resource management (Pantisano *et al*., 2010a) uses central eNB to allocate subcarrier to users. Self-Organizing Network (SON) is an automation technology designed to make the planning, configuration, management, optimization and healing of mobile radio access networks simpler and faster. SON concepts are introduced in LTE Standards starting from the first release. Another method namely self organized radio resource management (Pantisano *et al*., 2010b) uses distributed and centralized radio resource management together to avoid interference. Dual Decomposition method is proposed for cancellation of ICI for LTE-A.

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Different types of scheduling are described in (Pateromichelakis *et al*., 2013). The most conventional scheduling algorithms (Park *et al*., 2005) in OFDMA systems are Maximum carrier to Interference Ratio (MCI) and Proportional Fairness (PF) based only on throughput. The algorithm of proportional fair modeling with network coding for Orthogonal Frequency Division Multiple Access (OFDMA) (Tang *et al*., 2013) proposes the Global Approach (GA) and Local Approach (LA) for scheduling in cellular network. The algorithm (Prasad *et al*., 2013) provides calculation of system throughput for the State of the Art (SoA) scheme. When the number of users increases, the energy usage of Base station also increases. Many Energy efficient techniques are described by Deruyuck *et al*. (2013). The method of energy efficient inter cell frequency small cell discovery schemes in (Prasad *et al*., 2013) achieves power saving in User Equipment (UE) and provides small loss in system level and User experience. The algorithm proposed for macro cells and femto cells in LTE-A consumes less power and is energy efficient (Deruyuck *et al*., 2013).

In this study, a novel energy efficient algorithm with ICI Cancellation is proposed. The main target of this scheme is to improve cell edge performance. The performance of this scheme is evaluated by MATLAB Simulations and compared with the previous resource allocation methods. The performance indicators used for the comparison are cell throughput, fairness index and Signal to Interference Noise Ratio (SINR).

Overview of interference cancellation in of DMA: ICIC Techniques define coordination mechanisms to allocate orthogonal resources to their overlapping areas among neighboring cells. ICIC Techniques are divided into Mitigation and Cancellation/Avoidance techniques. In mitigation techniques, impact of interference is reduced in the intended signal. This mitigation technique includes Interference randomization, Interference cancellation and Adaptive beam forming. Interference avoidance represents the frequency reuse technique. The main characteristic of cellular network is the ability to reuse frequencies to increase capacity and coverage. Reuse Techniques is a static ICIC technique which mitigates the Inter Cell Interference (ICI) by applying different reuse factors in different regions in each cell. The frequency reuse is that whole frequency spectrum is divided into several sub bands: each sub band is assigned once to a cell of each cluster consisting of several adjacent cells.

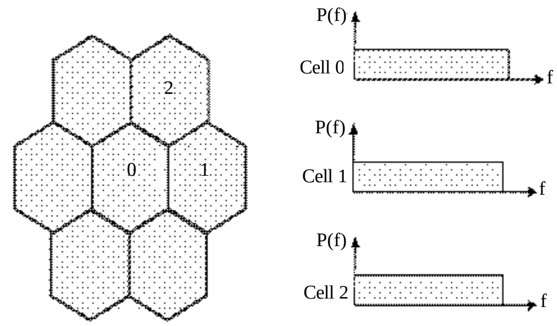

Fig. 1: Reuse-1(FR-1)

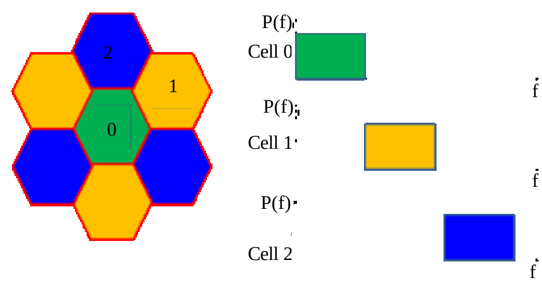

Fig. 2: Reuse-1(FR-3)

Reuse distance and frequency reuse factor are the parameters used to find frequency reuse-. Reuse-1 and Reuse-3 are also used in OFDMA based Cellular networks. In frequency reuse -1, the available frequency spectrum is reused in each cell. More Co Channel Interference will occur in reuse-1. In frequency reuse-3, the available spectrum is divided into three sub bands and each cell is given a sub band which is orthogonal to neighboring cell's sub bands. Reuse 1 and reuse 3 are shown in the Fig.1 and 2, respectively.

ICIC is divided into the following three types i.e. Static ICIC, Semi Static ICIC and Dynamic ICIC based on variations of traffic and channel environment. In Static ICIC, resource allocation is fixed and it does not depend on channel variations. In Semi Static ICIC, resource allocation is changed based on traffic environment. Static ICIC and Semi Static ICIC are not adapted to fast changing environment but dynamic ICIC is adopted to the fast changing environment. Static ICIC is divided into Partial Frequency Reuse (PFR) and Soft Frequency Reuse (SFR) (Tang, 2013). Users are divided into center users and edge users based on SINR.

Frequency sub bands β_{center} and β_{edge} are given to center users and edge users respectively. In PFR, spectrum is divided into many bands. Different power mode is given to the center and edge users. β_{center} is allotted to the center users and the remaining $\beta_{center}/3$ is

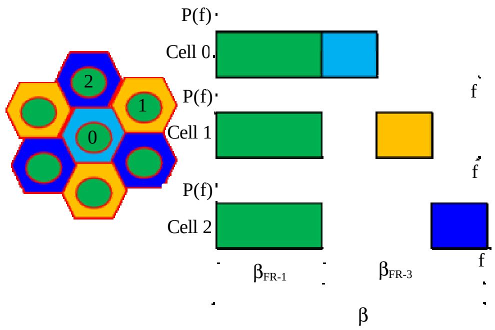

Fig. 3: Reuse partitioning

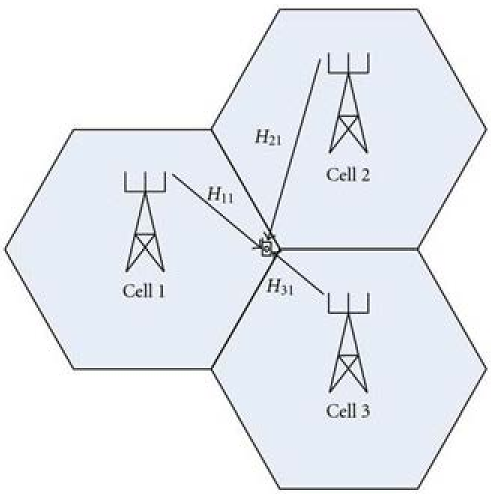

Fig. 4: CoMP Transmission

allotted to the edge users. This method is used to reduce the ICI. In SFR, the total spectrum is divided into S sub band. In SFR technique, S sub bands are allotted to Cell Center User (CCU) and 1/S sub bands are allotted to Cell Edge User (CEU). Unutilized band of Cell Edge users can be used by Cell Center users. Reuse partitioning which is applying different reuse factors to different regions in each cell. In this, the available spectrum is divided into two groups, frequency reuse-1 is given to cell center users and higher frequency reuse is given to cell edge users. It is given in Fig 3. The available spectrum â is divided into β_{FR-1} and $3\beta_{FR-3}$. The first group β_{FR-1} is used with reuse-1 and the second group $3\beta_{FR-3}$ is used with reuse-3. The available frequency spectrum in each cell is $\beta_{FR-1}+\beta_{FR-3}$. The effective frequency reuse factor is given by $\beta/(\beta_{FR-1} + \beta_{FR-3})$.

Resource allocation in LTE-A

Coordinated multipoint transmission: Coordinated Multipoint Transmission is developed in the LTE-A. CoMP enables the dynamic transmission and reception of geographically separated Base Stations (eNBs). The main feature of CoMP is to provide better system performance and effective usage of the resources but it keeps the system complexity low. Transmissions from the different cells to user equipment are given in the Fig. 4 In CoMP Technique, the coordination is done through X2 Interface (Lakshmana *et al*., 2010; Huq *et al*., 2014).

Scheduling increases the energy efficiency after coordinating the interference using CoMP. Schedulers like Round Robin makes decision based on throughput. The new criterion taken into account to improve the system performance is the energy per bit. In this resource allocation scheme, the scheduling metric chooses the users based on the ratio of transmitted energy to the number of transmission bits on resources m for users n. Users to be assigned in an order from lower scheduling metric. Scheduling metric is given by:

$$\text{Schedulingmetric} = \arg\min \frac{\xi\left(B_n^m\right)T}{h_n^m B_n^m} \tag{1}$$

Where scheduling metric denotes the index of the selected users and resources, respectively, Hm/n is the channel gain, Bm/n is the number of transmission bits and ξ (Bm/n) is the minimum transmitted power required for the number of transmission bits:

$$\xi\left(B_n^m\right) = \frac{\left(\sigma_n^m\right)^2}{3}\left[Q^{-1}\left(\frac{BER}{4}\right)\right]^2\left(2B_n^m - 1\right) \tag{2}$$

where σ^m_n is the noise variance. Eventually, the scheduling metric can be expressed as:

$$\text{Schedulingmetric} = \arg\max\left\{\frac{C_n^m B_n^m}{R_n^m}\right\} \tag{3}$$

Where excess channel gain:

$$C_n^m = \frac{1}{h_n^m\left(B_n^m\right)} - \frac{1}{h_{min}\left(B_n^m\right)} \tag{4}$$

$$\text{Received energy per bit } R_n^m = \xi\left(B_n^m\right)T \tag{5}$$

The scheduler allocates resources to the user with larger excess channel gain. At the condition of users having same channel gain, this mechanism allocates the resources to the users having lowest received energy bit.

MATERIALS AND METHODS

System model: The network model considered in this paper is downlink cellular systems. The reference cell is 0 for which interference is considered from all other eNBs transmitting in the same Transmission Time Interval (TTI) as eNB in the reference cell. The N number of users are randomly distributed through the layout. The path loss of the user N at distance d_n is discussed. For Line Of Sight (LOS):

PLdB (dn) = 22 log (dn) + 34.02 where 10m < dn <320m
PLdB (dn) = 40 log (dn)   11.02 where 32 0m < dn <5000m (6)

For Non   LOS (NLOS):
PLdB (dn) = 39 log (dn/1000) + 136.8245 (7)

Where dn is the distance between user and serving base station. In 3GPP LTE Standard, the available radio frequency spectrum is divided into M Resource Blocks (RBs) each RB consisting of 12 orthogonal subcarriers with total bandwidth of 20MHz. Scheduling is performed by eNB for every 1 ms TTI in order to allocate the RBs to User equipment (UE). One or more RBs are allocated to UE at a time. UE's interference within the reference cell is from all other eNBs transmitting in same TTI as for the eNB in the reference cell is referred as Signal to Interference Noise Ratio (SINR) (Li *et al*., 2014) and it is given by:

$$\Gamma^m_{c,n} = \frac{p^m_{c,n}\,|\,h^m_{c,n}\,w^m_{c,n}\,|^2}{\sum_{n'\neq n}^{N} p^m_{c,n}\,|\,h^m_{c,n}\,w^m_{c,n}\,|^2 + \sum_{c'\neq c}^{C}\sum_{n'}^{N} p^m_{c',n'}\,|\,h^m_{c',n}w^m_{c',n'}\,|^2 + \left|\eta^m_{c,n}\right|^2} \quad (8)$$

Where $p^m{}_{c,n}$ is the transmit power of mth resource block of n^{th} user of c^{th} CoMP cell, $h^m{}_{c,n}$ is the channel gain of resource block of n^{th} user of c^{th} Comp cell, $h^m{}_{c,n}$ is the channel gain of n^{th} user ${}^w{}_{c,n}$ is the precoding matrix.

In this scenario, the differentiation between cell edge users and cell center users can be made by received SINR at user side:

$$\Gamma^m_{c,n} < \Gamma_{Threshold} \quad (9)$$

Where $T_{thereshold}$ = predetermined threshold 3 dB. If Eq 9 is satisfied then the users are in cell edge otherwise they are in cell centre.

Proposed scheduling algorithm in LTE-A: The proposed algorithm is explained in this section. After mitigating interference by frequency reuse techniques, the resources are allocated based on scheduling technique. The main aim of resource allocation in cellular networks is to improve the spectral efficiency and capacity. The conventional schedulers like Maximum Carrier to Interference Ratio and Proportional Fair Scheduling allocates data based on throughput. In this paper, energy per bit is a new criterion taken into account to improve the performance. Large amount of datais conveyed day by day as the demand of networksincreases, which also needs more energy to betransmitted. The transmit energy remains lacking when the radio resources are fully used whereas the users have poor channel conditions. To put end to this, the ratio of the transmitted energy per bit to the number of transmitted bits are chosen and it is given in the Step 10 of algorithm. The steps of resource allocation are given in algorithm:

Algorithm:

- Step 1: Initialize the number of eNBs, number of User Equipments and Channel Bandwidth
- Step 2: Place the users randomly in network layout
- Step 3: eNB allocate β_{FR-1} to center and edge users respectively
- Step 4: Calculate SINR for all links between Base station and Users. If SINR value for user < 3 dB, then the user is in edge, else the user is in center
- Step 5: Count the total number of edge and center users. eNBs sends an information about the total number of edge and center users to the Central eNB.
- Step 6: Central eNB calculates the total number of edge and center users in cluster
- Step 7: Central eNB calculates the Frequency Allocation Variable (FAV) of edge user and centre users
- Step 8: Central eNB sends FAV to all eNBs. Then eNBs calculates the β_{FR-1} and β_{FR-3} based on FAV
- Step 9: After allocating the resources to cell, the transmission is done based on user priorities
- Step 10: Calculate the user priorities based on where is the transmit energy and is the number of transmission bits. User are allocated from lower to higher ratio of transmit energy over the transmission bits
- Step 11: Allocate the resources to users based on priorities
- Step 12: Check the Remaining Resource block for allocation
- Step 13: Stop the program

The number of eNBs and number of users are initialized. In this scenario, users are placed randomly in layout.

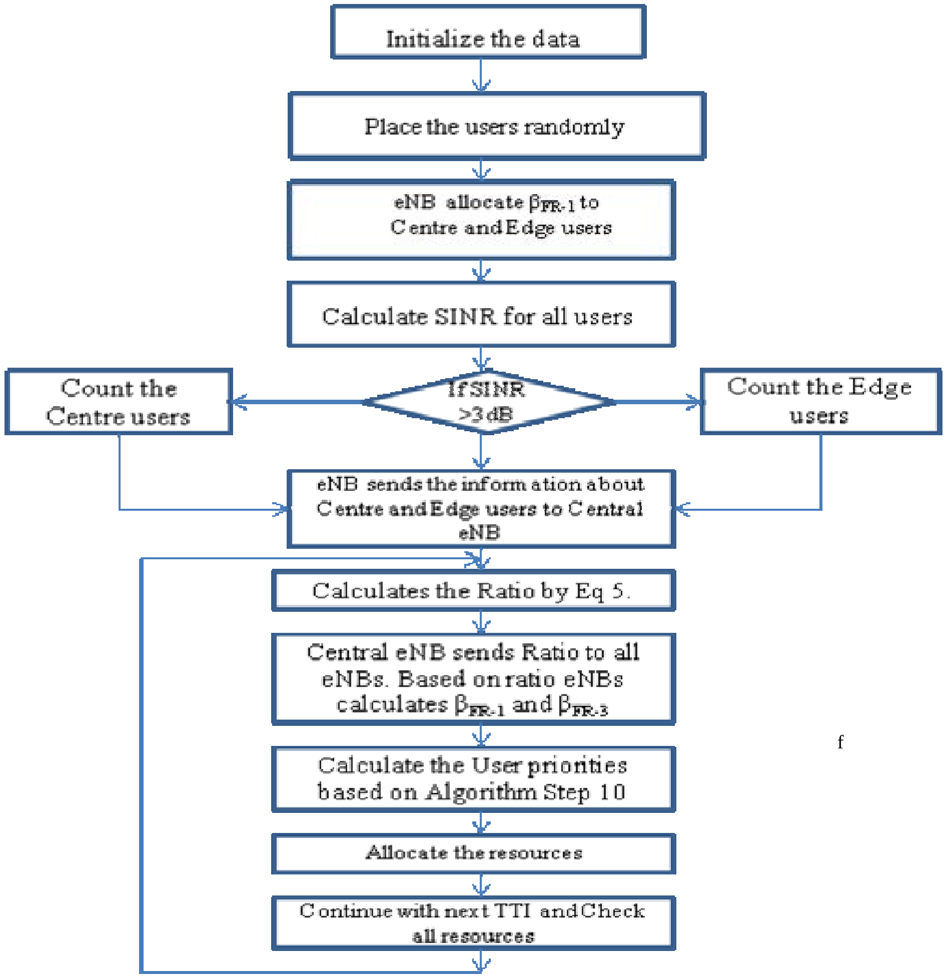

Fig. 5: Flowchart of the proposed algorithm

SINR of users are calculated by Eq 8. eNB allocates the initial value of Reuse-1 (β_{FR-1}) to center users and edge users, respectively.

SINR threshold value is set as 3dB to find out the users in cell center and cell edge. If SINR value is less than the threshold value then it is cell edge user else it is cell center user. Count the centre and edge users based on SINR values. eNB transfers the number of centre and edge users to their central eNB (CeNB) through X2 interface. CeNB Frequency Allocation Variable (FAV) is calculated to allocate the resources to users in an efficient manner. FAV is given by:

$$FAV = \frac{\text{Number of edge users for CeNB}}{\text{Number of edge users for CeNB}} \tag{10}$$

$$FAV = \frac{\beta FR - 3}{\beta FR - 1} \tag{11}$$

$$\frac{\text{AvailableBandwidth} -_{\beta FR-1}}{\beta FR - 1} \tag{12}$$

$$\beta_{FR-1} \frac{\text{AvailableBandwidth}}{3 \times FAV - 1} \tag{13}$$

$$\beta FR - 3 = \frac{\text{AvailableBandwidth} - \beta FR - 1}{3} \tag{14}$$

The resources are allocated in an organized manner to reduce ICI. This method increases the throughput and spectral efficiency, β_{FR-1} and β_{FR-3} are calculated based on FAV value. The remaining resources are to be checked and the algorithm to be continued for all the users in next TTI for available resources. Priorities are given to the user based on transmit energy per bit.

The flowchart of proposed algorithm is given in Fig. 5. After mitigating or coordinating the interference, scheduling is done based on energy efficiencies in bits/joules. Most of the conventional schedulers like MCI and PF are based only on Throughput. But, the other method of Round Robin (RR) allocates the resources to all users irrespective of channel conditions. This study is based on energy per bit to improve the system performance. Nowadays, more amount of data is used for the cellular applications and it is requiring more energy. When the resources are allotted, the transmit energy remains inadequate for users having poor channel conditions. To avoid this condition, the scheduling metric should be considered. Scheduling metric depends on the ratio of transmit energy per transmission bits. The resources are allocated to the user which is having lower ratio of transmit energy to a number of transmission bits. In scheduling scheme, the users are chosen based on scheduling metric in an order from lower to higher ratio. Suppose if the same users with same channel gain, resources are allotted to the lowest received energy bit.

RESULTS AND DISCUSSION

Performance metrics

Capacity and throughput: Capacity is defined as the data rate for the user per unit bandwidth per cell in bps. The throughput is another metric used for an analysis of system and it is defined as the ratio of the number of corrected bits over the network divided by the time required to be transmitted.

Energy efficiency: Energy efficiency or Energy Channel Capacity is expressed in bits per joules. It is defined as successfully transmitted bits per total power consumed by network or how many bits per unit power are transmitted per second. The energy efficiency æ is given by:

$$\xi = \frac{TP}{PT} \tag{9}$$

Where TP is throughput (bps) and P_T is total power consumed by network (watts). P_T is addition of Transmission power and Circuit power. This metric is not directly related to throughput performance since their service is voice of the previous generation like GSM and it is for LTE-A because here all service are in data.

Fairness index: Fairness Index is given by:

$$FI = \frac{\left(\sum_{1}^{N} TP\right)^2}{N\sum_{1}^{N}(TP)^2} \tag{10}$$

Table 1: Simulation Parameters

Parameter	Value
Bandwidth	20MHz
Carrier frequency	2.6GHz
eNB power	46dBm
Channel model	LTE model
Circuit power	20dBm
Number of resource block	100 RB per slot, 7symbols
Modulation scheme	16 QAM
Total subcarrier	1200
Encoding and decoding	Convolutional encoding and turbo decoder

Where, TP is throughput of users. When resources are equally distributed among users, then FI equals 1. The value of Fairness Index decreases when the resources are not equally distributed among users. FI lies between 0 and 1.

Simulation results: The proposed scheduler is simulated using MATLAB and compared with other conventional schedulers. The performance metrics such as Throughput, Capacity and Energy Efficiency are compared. The simulation parameters are given in the Table 1.

In this simulation scenario, LTE-A Cellular system consisting of 19 CoMP cell is of six cells in first tier and twelve cells in second tier surrounding central CoMP cell is considered. Each CoMP cells includes 120^0 hexagonal sectors. All simulations are done in the central CoMP cell with remaining cells as interferers. Mobile nodes are placed in a scenario at various locations. In this scenario, the minimum distance between user and eNB is 30m. Noise density used here is -174dBm. The different performance measures like Average cell efficiency for Cell Center Users (CCU) and Cell Edge Users (CEU), Capacity, Throughput and SINR are compared with other techniques such as RR and MCI. In each TTI, the resource blocks are simulated based on available bandwidth. Data rate and SINR are calculated on each resource blocks. The achieved data rate according to SINR is divided by the total transmit power of eNB. Data rate of each resource block gives Energy Efficiency in bit per joule.

Figure 6 shows the Cumulative Distribution Function (CDF) of capacity for different schedulers. From Fig. 6, it can be observed that the proposed scheme provides higher capacity than the other types of schedulers. Due to the allocation of resources to all users, RR provides low capacity. In MCI technique resources are allotted based on channel gain and it provides lower capacity than proposed scheme. As proposed scheme is based on transmitted energy per bit and SINR, it provides high capacity to almost all users. In proposed scheme, the

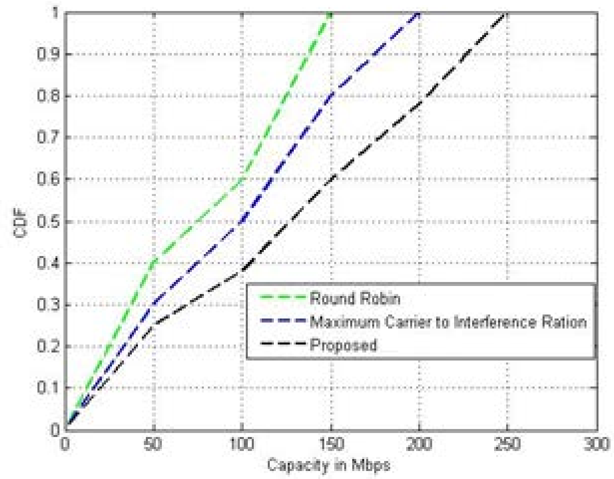

Fig. 6: Capacity comparison of proposed scheme with other schedulers

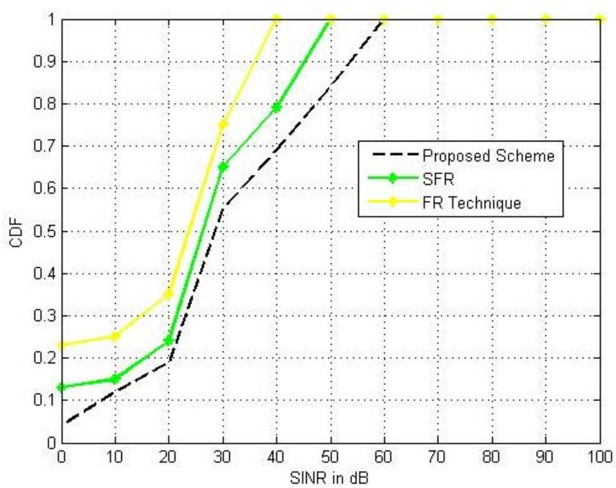

Fig. 7: Cumulative Distribution function of different scheme

resources are allotted to the edge users due to proper utilization of power in correct time which increases the overall capacity. Proposed scheme gives better capacity to users when compared to other techniques such as RR and MCI.

The SINR of different ICIC techniques are shown in Fig 7. The channel gain is used to calculate SINR. The channel gain is directly proportional to SINR. In this comparison, the proposed scheme is implemented with various ICIC techniques. In Fig 7, Frequency Reuse (FR) technique provides common frequency reuse factor 1 to CCU and CEU. Due to common reuse factor, it provides low SINR. SFR technique provides 3 Sub band to center user and one sub band to edge users. It gives better SINR values when compared to the FR technique because the ratio of frequency reuse is higher for edge users than center users. The proposed scheme provides better SINR values due to changing of resource allocation to the users at each time interval.

Comparison of Average Cell Energy Efficiency (AEE) is shown in Fig. 8. Average cell energy efficiency is calculated for the different types of scheduler assuming 100 users per cell. It shows that the proposed algorithm achieves best EE. For example, when the number of users is 50 proposed scheme achieves 35% AEE compared to MCI. This results indicates better EE with increasing users due to the transmit energy per bit. From Fig. 8, it can be observed that the proposed scheme gives better AEE when compared to other schedulers. Transmission through Relay node is done for edge users so energy will get increased. Energy Efficiency for all users is high in proposed system. MCI provides lower EE when compared

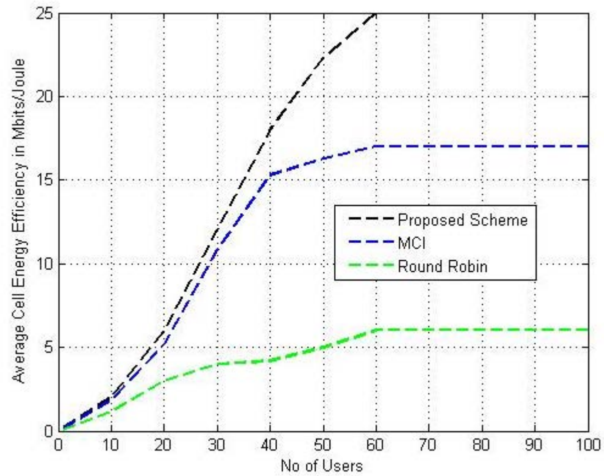

Fig. 8: Comparison of Average cell EE for users in scenario

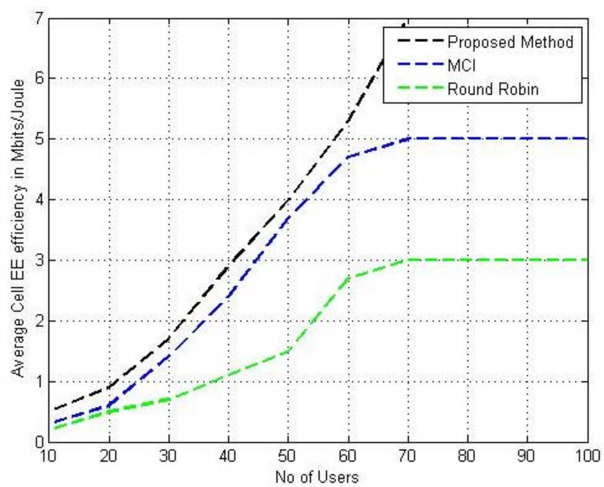

Fig. 9: Comparison of Average cell edge energy efficiency for edge users

to the proposed scheme because it provides low channel gain to edge users. RR techniques provide fairness to all users, so it provides less efficiency to all users. Figure 9 shows the variation of Energy Efficiency with the number of edge users. In this 20% of users are located in the cell edge. For example, when the number of users is 50 proposed scheme achieves 10% AEE compared to MCI. The improved efficiency occurs in proposed scheme because it considered the scheduling metric. In MCI, channel gain of edge users is low so it gives low EE when compared to combined EE of cell center and edge users. AsRR provides equal fairness to allusers, irrespectiveof channelconditions, itgives low EE. The comparison of fairness is shown in Fig. 10. From Fig. 10, it shows that the fairness increases when the number of users also increases. In this comparison, fairness of the proposed scheme is better because it provides efficient throughput to CCU and CEU when compared to MCI. For MCI it provides low fairness to users, because it provides good fairness to center users not to edge users. In this scenario, 20% are edge users. RR provides good fairness to all users but throughput is low. The comparison of average energy efficiency vs Transmission power is given in the Fig. 11 where the maximum transmit power is 50W as given in the 3GPP LTE-A Specification. From the results, the proposed algorithm sustained 1Mb/J for 1W. Figure 11 explains that when transmission power gets increased, then throughput increases. Due to increase of throughput, energy efficiency gets increased. In this comparison, proposed method provides good efficiency. Due to low efficiency of edge users, MCI and RR provide lesser efficiency when compared to proposed method.

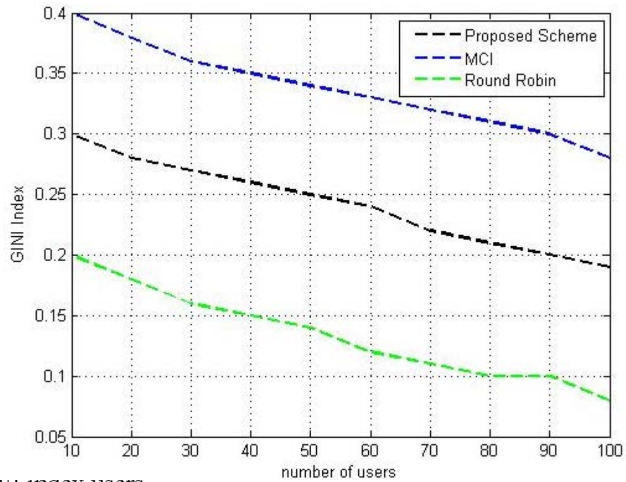

Fig. 10: Comparisonof GINI index users

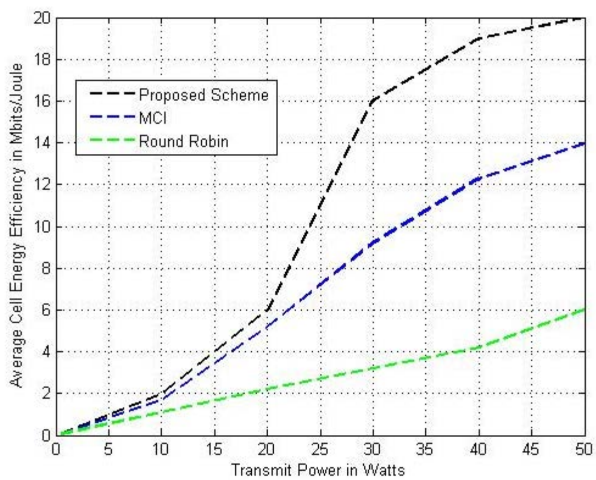

Fig. 11: Comparison of average cell energy efficiency for various transmission power

CONCLUSION

The challenges of LTE Advanced are providing resources to cell edge users and cell center users in balanced manner and also to provide high SINR and low ICI in LTE-A. In this study, an algorithm is proposed to provide better performance to edge users as good as center users. In this algorithm different frequency reuse factor is allotted for edge and center users. So ICI is minimum in edge users. This scheme balances efficiency to cell edge and cell center users. The system level simulation suggests that the proposed scheme provides best cell edge energy efficiency and cell center energy efficiency. Inter cell interference is avoided by use of FR technique in the proposed scheme. After cancellation of ICI, scheduling is done based on the transmitted energy per bit as well as channel gain. The proposed scheme is compared with the previous schedulers like MCI and RR. From the simulation results, proposed algorithm offers good EE to cell center users and cell edge users. This algorithm is developed to provide better performance to edge users identical to center users.

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