Abstract— The Long Term Evolution (LTE) is defined by the 3rd Generation Partnership Project (3GPP) as the typical framework of beyond 3G or 4G systems. Spectrum efficiency is highly emphasized in LTE as it aims at providing higher data rates under the restriction that the radio resources are becoming scarce. Rather than the frequency reuse pattern applied on 2G and 3G systems (usually with higher reuse factors), LTE is expected to achieve the goal of frequency reuse of one or nearly close to one in practice. Due to the requirement of high spectrum efficiency, the frequency reuse of one is targeted for next generation OFDMA-based cellular networks. Such a frequency planning strategy can lead to unacceptable inter-cell interference levels experienced especially by users located at the cell edge area. However, due to transmit power limitations in mobile terminals, smaller cell size deployments are required in next generation networks in order to meet targeted higher data rates for users who are either near the base station or at the cell edge. For addressing this problem, many solutions have been proposed and the soft frequency reuse (SFR) is considered as the most representative approach due to its effectiveness of inter-cell interference coordination without compromising spectrum efficiency. Analytical method derived to calculate the performance measures of interest, i.e., new call blocking probability and probability of outage. Specifically an algorithm is developed using suitable model and will focus on a single cell, where cell-center mobile platforms occupying channels from the center band or the edge band will be distinguished. In algorithm, It is assumed that, via an appropriate power allocation, the data rate of each mobile platform with one channel is fixed regardless of its location within the cell.

Keywords—PRB, , call blocking probability, probability of outage,CAC,SFR.

I. INTRODUCTION

The CAC in wireless networks has been receiving a great deal of attention during the last two decades due to the growing popularity of wireless communications and the central role that CAC plays in QoS provisioning in terms of the signal quality, call blocking and dropping probabilities, packet delay and loss rate, and transmission rate. In the first and second generation of wireless systems, CAC has been developed for a single service environment. In the third generation and beyond wireless systems, multimedia services such as voice, video, data, and audio are to be offered with various QoS profiles. Hence, more sophisticated CAC schemes are developed to cope with these changes. Radio resource management (RRM) plays a major role in Quality of Service (QoS) provisioning for wireless communication systems. The performance of RRM techniques has a direct impact on each user’s individual performance and on the overall network performance. Arriving (new and handoff) calls are granted/denied access to the network by the call admission scheme (CAC) based on predefined criteria, taking the network loading conditions into consideration

One major problem in cellular systems is inter-cell interference that is caused by the frequency band overlapping of adjacent cells which eventually leads to severe performance degradation, particularly for users at the cell edge. The intercell interference issue was already noticed in traditional cellular systems and has been solved to a certain degree in several ways. For instance, in classical frequency and time division multiplexing (FDM/TDM) systems, like the global systems for mobile communications (GSM), a partial frequency reuse planning is employed to prevent neighboring cells from using the same set of frequencies. On the other hand, code division multiple access (CDMA)-based systems, such as the universal mobile telecommunications system (UMTS) or CDMA2000, use different scrambling codes in different cells, thus reducing inter-cell interference. However, these solutions may not work appropriately in future cellular systems (4G), which are based mostly on the orthogonal frequency division multiple access (OFDMA) transmission technique.

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targeted higher data rates for users who are either near the base station or at the cell edge. Therefore, it is reasonable to believe that the inter-cell interference problem will become more severe in next generation networks affecting significantly performance. with the assumption that the power level of a mobile platform is fixed regardless of its location within the cell. Second, via an appropriate power allocation, the power level for each cell-center channel will be lower than that for each cell-edge channel. Thus, the co-channel interference from adjacent cells will be minimized. Hence, the data rate of a cell-edge mobile platform will be guaranteed as shown in[13]. data rate of each mobile platform with one channel is fixed regardless of its location within the cell In this model focus is on a single cell, where cell-center mobile platforms occupying channels from the center band or the edge band will be distinguished. It is assumed that, via an appropriate power allocation, the data rate of each mobile platform with one channel is fixed regardless of its location within the cell. Analysis of Markov model is used and simulation results for Average new call blocking probability and probability of outage achieved.

II. CHALLENGES REGARDING CALL ADMISSION CONTROL IN NEXT GENERATION WIRELESS NETWORKS

The next generation wireless networks will provide the capability to support a wide range of Services. No matter the traffic classes involved in those services, the network will allow an unconstrained user mobility while still being able to guarantee the quality of service (QoS) required for each one of the envisaged traffic classes. The admission control of new calls, the so called CAC, must therefore implement an algorithm that reacts to network condition variations in order to assure the best QoS management. The diverse QoS requirements for multimedia applications and the presence of different wireless access technologies pose significant challenges in designing efficient CAC algorithms for next generation wireless networks.

<table>
<thead>
<tr>
<th>REQUIREMENT``</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Heterogeneous environment</td>
<td>next generation systems will consist of several types of wireless access technologies, so CAC schemes must be able to handle vertical handoff and special modes of connection such as ad hoc on cellular.</td>
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<tr>
<td>Multiple types of services</td>
<td>next generation systems will need to accommodate different types of users and applications with different QoS requirements</td>
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<tr>
<td>Adaptive bandwidth allocation</td>
<td>With multimedia applications, system utilization and QoS performance can be improved by adjusting the bandwidth allocation depending on the state of the network and users QoS requirements</td>
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<tr>
<td>Cross-layer design</td>
<td>Both call- and packet-level QoS need to be considered to design CAC algorithms so that not only the call dropping and call blocking probabilities, but also the packet delay and packet dropping probabilities can be maintained at the target level.</td>
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III. INTER-CELL INTERFERENCE COORDINATION (ICIC)

In order to meet the rapidly growing demands on wireless networks to apply data services with higher throughputs and spectrum efficiencies, Orthogonal Frequency Division Multiplexing (OFDM) has to be introduced into 4G LTE-Advanced networks. Other advanced technologies also have been developed for better utilization of radio spectrum, including adaptive modulation and coding, hybrid automatic repeat request, fast channel-aware scheduling and multiple input multiple output techniques. Because of technologies aforementioned, Intra-cell interference is successfully cancelled in the 4G networks. A key objective with respect to deployment of OFDM 4G networks is to utilize a frequency re-use of one (denoted by $N = 1$) or as close to $N = 1$ re-use as is practical. A frequency re-use of $N = 1$ implies that the base stations in cells transmit on all available time frequency resource blocks (RBs) simultaneously. As a result, the bulk of interference problems which the interference originates from the neighboring cell called inter-cell interference (ICI) are emerged, especially at the cell-edge region. In a multi-cellular networks, ICI occurs when adjoining cells use the same RBs to different users. There are three main approaches to mitigate ICI, including inter-cell interference randomization, inter-cell interference cancellation and inter-cell interference coordination (ICIC). Considering the performance and the complexity of ICI mitigation schemes, ICIC is considered as the most promising proposal in next generation wireless networks.
Interference cancellation and mitigation techniques have been investigated and deployed with varying degrees of success in terrestrial mobile networks for more than 20 years. Traditional approaches to interference mitigation between transmitted signals have focused on either ensuring orthogonality between transmitted signals in time, frequency as well as spatially, or by actively removing and cancelling interfering signals from the desired signal if orthogonality between the desired signal and potential interferers cannot be achieved. In early 2G cellular systems such orthogonality was achieved primarily through static pre-planned allocations of radio resources. 3G systems introduced interference cancellation techniques based mostly on a combination of blind information gathering at a base station such as spectrum usage monitoring and coarse exchange of interference indicators such as the Rise over Thermal (RoT) indicator employed in the 3GPP2 1xEV-DO standard. Typically interfering signals have been estimated using blind detection and their estimates subtracted from the desired signals.

From a link perspective the downlink (DL) allows for a more tractable analysis since if the desired mobile terminal location is known, the distances to all potential interfering base stations can be easily determined based on the network geometry, and hence a probabilistic based estimate of the signal-to-interference-plus-noise ratio (SINR) can be calculated based on the channel fading conditions for the desired signal and the interfering signals. In addition to AWGN, both the desired signal and interfering signals will experience shadowing, which typically is log-normally distributed. Analysis of the uplink (UL) interference requires knowledge of not only the location of the desired mobile terminal under consideration, but also the relative locations of all potential interfering mobile terminals, for which both the locations of the interfering terminals, the number of potential terminals, and their spatial velocity will be random variables.

LTE offers the capability to provide a flexible dynamic inter-base station approach to interference coordination through the use of inter-base station signalling capabilities, including the use of UL reactive overload indicators (OIs) and proactive high interference indicators (HIIs) that provide bit maps of interference conditions on a per RB basis. DL inter-cell interference coordination (ICIC) is supported through the use of DL relative narrowband transmit power (RNTP) bit maps providing a coarse power indication on a per RB basis.

Inter-cell interference coordination techniques for next generation wireless networks systems with a specific emphasis on implementations for LTE. Viable approaches include the use of power control, opportunistic spectrum access, intra and inter-base station interference cancellation, adaptive fractional frequency reuse, spatial antenna techniques such as MIMO and SDMA, and adaptive beam forming, as well as recent innovations in decoding algorithms. Among them, Soft Frequency Reuse (SFR) scheme is most efficient compare to other approaches.

IV. FREQUENCY REUSE CONCEPT

Fractional frequency reuse (FFR) is an interference management technique well-suited to OFDMA based cellular networks wherein the bandwidth of the cells is partitioned into regions with different frequency reuse factors. There are two common FFR deployment modes: Strict FFR and Soft Frequency Reuse (SFR).

A. Strict FFR

Strict FFR is a modification of the traditional frequency reuse used extensively in multi-cell networks. Fig 1.1 illustrates a Strict FFR deployment with a cell-edge reuse factor of \( N = 3 \). Users in each cell interior are allocated a common sub-band of frequencies while cell-edge users’ bandwidth is partitioned across cells based on a reuse factor of \( N \). In total, Strict FFR requires a total of \( N + 1 \) sub-band. Interior users do not share any spectrum with exterior users, which reduce interference for both interior users and cell-edge users.

B. Soft Frequency Reuse

The soft frequency reuse (SFR) nowadays is considered as one of the most effective frequency planning strategies to mitigate inter-cell interference in cellular systems. It was first introduced in GSM, and then has been adopted under the 3GPP LTE framework with the aim of providing higher performance for users near the cell boundary. The basic idea of SFR is to apply a frequency reuse of one at the cell center area and a higher frequency reuse factor at the cell edge area.
Rather than the hard frequency reuse (HFR, where reuse factor = 3) and fractional frequency reuse (FFR) schemes, SFR is able to reduce the inter-cell interference without largely sacrificing spectrum efficiency due to its lower reuse factor (nearly equal to one).

In SFR, the available spectrum is divided into two reserved parts: a cell-edge band and a cell-center band. Users within each cell are also divided into two groups, cell-center users and cell-edge users, based on their distance to the base station or other differentiating factors. Cell-edge users are restricted to the reserved cell-edge band while cell-center users have exclusive access to the cell center band and can also have access to the cell-edge band but with lower priority. A frequency planning of SFR applied in a seven-cell hexagonal system layout is shown in Fig1.2 (left side), where the cell center users can use the entire frequency band but the cell-edge users only use partial frequency band non-overlapping with adjacent cells. The cell-edge users must transmit on a higher power level in order to improve their data rates, whereas the cell-center users can transmit with a reduced power level. Fig1. 2(right side) shows the power distribution of SFR. For SFR, the transmit power of cell-center users is limited to a lower level and the distance between a cell-center user and the adjacent eNodeBs is usually long enough to ensure large path loss, thus further reducing the received interfering power. Therefore, in SFR we only consider the mutual interference between cell-edge users and cell-center users from different cells while simultaneously using the same PRB.

V. SYSTEM MODEL

A. Model Description

A SFR-based single cell LTE system is considered. There is one eNodeB (base station) in the center of the cell. A number of mobile platforms can initiate multiple calls trying to occupy radio resources, where the basic unit of radio resources is referred to as Physical Resource Block (PRB). For simplicity, we assume that the eNodeB can only assign one PRB to a mobile platform at the time it initiates a call and, via an appropriate power allocation, the data rate of each call with one PRB is fixed regardless of its location within the cell. Additionally, we assume that all the mobile platforms will stay within the associated cell region all the time. Specifically, they are assumed to be stationary. For simplicity, we focus on an isolated cell without interference from other cells. Instead of depending on QoS criteria, it is assumed that cell-center calls are terminated, randomly, if necessary.

B. Call Admission Control

When a cell-center new call is originated, the cell-center new call will attempt to occupy a cell-center PRB. At this time, if one or more cell-center PRBs are available, it will be admitted. If no cell-center PRBs are available, then it will attempt to occupy a cell-edge PRB. It will be blocked once no cell-edge PRBs are available. In contrast, when a cell-edge new call is originated, it will attempt to occupy a cell-edge PRB. At this time, if all cell-edge PRBs are in use by cell-edge ongoing calls, it will be blocked. If at least one cell-edge PRB is available, it will be admitted. If no cell-edge PRBs are available but one or more cell-edge PRBs are occupied by cell-center ongoing calls, it will still be admitted. This is because the eNodeB(base station) will randomly terminate one of the cell-center calls occupying cell-edge PRBs. The probability that the cell-center call is forcefully terminated is referred to as Probability of outage.

C. New Call Arrival Processes

Assume that the new call arrival process within a cell is Poisson with the mean request rate $\lambda n$, and is uniformly distributed over a cell, where $\theta r$ is the ratio of the area of cell-edge region to the total area of a cell. The cell-center and the cell-edge new call arrival processes are given as $\lambda nC = \lambda n(1 - \theta r)$ and $\lambda nE = \lambda n\theta r$, respectively.

VI. METHODOLOGY

It is proposed that analysis for Call admission control will be done by using suitable model e.g. Markov Model, algorithm will be generated using SFR concept for CAC and predicted parameter will be presented with the help of Simulation using Matlab Software.
VII. ANALYSIS OF CALL ADMISSION CONTROL (CAC) USING SOFT FREQUENCY REUSE (SFR)

Fig. 3. The 3-dimensional Markov chain model of a single cell

PRB = Physical Resource Block (Basic Unit of Radio Resource)

We consider 1 call = 1 PRB
Hence spectrum is divided in 1) Cell edge PRB = Accepts edge calls & cell centre calls
2) Cell centre PRB = It will admit only cell centre calls

That is basically service provider decides the region of cell centre and how much region consider as cell edge i.e. area for edge & centre calls decided and available PRBs are assigned to total edge and centre areas for best Qos or CAC.
i.e. Blocking of calls should be as less as possible and more calls need to be accepted with chosen PRBs and total area of a cell (Divided for cell centre and cell edge calls). This is achieved and termed as Call Admission Control.

A. Important Assumptions and Terms for Analysis
Assuming that new call arrival process within a cell is Poisson with the mean request rate
\( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell \( \lambda_n \) and is uniformly distributed over a cell

\[ W_r = \frac{\text{No. of cell edge PRB}}{\text{Total No. of PRB}} \quad \text{(2)} \]

\[ \theta_r = \frac{\text{Area of cell edge region}}{\text{Total area of cell}} \quad \text{(3)} \]
2) **Analysis to find the equation of Aggregate new call Blocking Probability**

\[ \text{Probability} = \frac{\text{Individual}}{\text{Total quantity}} \]

Here in this case we consider SFR i.e.

Aggregate new call blocking probability = Individual cell centre new call blocking probability + Individual cell edge new call blocking probability -------- (4)

Let’s assume → \( P_b \) = Aggregate new call blocking probability

\[ P_{c,b} = \text{Cell centre new call blocking probability} \] -------- (5)

\[ P_{e,b} = \text{Cell edge new call blocking probability} \] -------- (6)

From (4), (5), (6) & (7) we get

\[ P_b = P_{c,b} + P_{e,b} \] -------- (8)

Let’s assume → \( N=\)Total no. Of PRBs

\[ N_c = \text{No. Of PRBs allocated to cell centre region} \] -------- (9)

\[ N_e = \text{No. Of PRBs allocated to cell edge region} \] -------- (10)

i.e. \( N = N_c + N_e \) -------- (12)  

b) **To find Cell centre new call blocking probability \( P_{c,b} \)**

i.e. we have to consider call arrival process at cell centre. As mentioned in (1)

Assuming that new call arrival process within a cell is Poisson with the mean request rate \( \lambda_n \) and is uniformly distributed over a cell

**Cell centre call arrival process(\( \lambda_{nc} \))**

Cell centre call arrival process= mean request rate x \( (1 - \frac{\text{Area of cell edge region}}{\text{Total area of cell}}) \) -----(12)

i.e. By substituting (1) and (3) in Eqn (12) we get

\[ \lambda_{nc} = \lambda_n (1 - \theta_r) \] -------- (13)

Hence by using probability concept we get,

Cell centre new call blocking probability = \[ \frac{\text{Cell centre call arrival process}}{\text{Total no.Of PRBs}} \] -------- (14)

Substituting (6), (13) & (9) in Eqn (14) we get

\[ P_{c,b} = \frac{\lambda_n (1 - \theta_r)}{N} \] -------- (15)

*Here N i.e. Total no. Of PRBs are consider since in SFR as specified that cell centre calls can occupy cell Edge PRBs also.

c) **To find Cell edge new call blocking probability \( P_{e,b} \)**

Similarly we have to consider

**Cell edge call arrival process(\( \lambda_{ne} \))**

Cell edge call arrival process= mean request rate x \( (\frac{\text{Area of cell edge region}}{\text{Total area of cell}}) \) -----(16)

By substituting (1) & (3) in Eqn (16) we get

\[ \lambda_{ne} = \lambda_n (\theta_r) \] -------- (17)

Hence by using probability concept we get,

Cell edge new call blocking probability = \[ \frac{\text{Cell edge call arrival process}}{\text{No.Of PRBs allocated to cell edge region}} \] -------- (18)

Substituting (7), (17) & (11) in Eqn (18) we get

\[ P_{e,b} = \frac{\lambda_n (\theta_r)}{N_e} \] -------- (19)

Hence Aggregate New Call Blocking Probability Can be Given as
From Eqn (8), (15) & (19)

\[ P_b = P_{c,b} + P_{e,b} \]  (8)

Substituting we get

\[ P_b = \frac{\lambda_n(1-\theta_r)}{N} + \frac{\lambda_n(\theta_r)}{N_e} \]  (20)

Analysis to find the equation of Aggregate new call Blocking Probability is complete.

3] **Analysis to find out the probability of outage** \( P_o \)

When a cell edge new call is originated, if there are no cell edge PRBs are available but there is at least one cell-centre calls occupying cell edge PRB, then one of the cell-centre calls occupying cell-edge PRBs will be terminated randomly. This is termed as probability of outage.

Hence

\[
\text{probability of outage}= \frac{\text{Area of cell edge region}}{\text{Total area of cell}} \times \text{Cell edge new call blocking probability}
\]

Hence Probability that new call arrival can be successfully admitted = 1 - \( P_b \)  (22)

By substituting (3), (7) & (22) in (21) we get

\[ P_o = \frac{\theta_r P_{e,b}}{1-P_b} \]  (23)

This completes the analysis for finding Aggregate new call blocking probability and Probability of outage for CAC using SFR.

VII. **SIMULATION RESULT**

Assumed ratios for analysis are as follows.

1] \( W_r \) constant = \( \frac{1}{4} \) and \( \theta_r \) constant = \( \frac{1}{4} \)

2] variable ratio \( W_r \) and \( \theta_r = \frac{1}{4} \cdot \frac{1}{3} \cdot \frac{1}{12} \)

For these particular ratios now by inserting various number of PRBs and call arrival rates in GUI we achieve following results for blocking and outage probabilities.

I] case1 \( \rightarrow \) call arrival rate = 0.01 to 1 PRB’s = 10
II] case 2 $\Rightarrow$ call arrival rate $= 0.1$ to $1$, PRBs $= 15$

III] case 3 $\Rightarrow$ call arrival rate $= 0$ to $1$, PRBs $= 50$

IX. CONCLUSION

Markov “s model is most accurate analytical method for examining and analyzing the soft frequency reuse (SFR) method in LTE based system. main approach of model is to find out probability of outage and probability of blocking. As SFR the analysis done in two parts of cell named as cell-center and cell-edge. It shows that decreasing of $\theta_r$ eventually decreases the cell-edge region to total area ratio i.e. decreases the cell-edge area where the interference occurs so in turn improves probability of blocking and probability of outage. Whereas $W_r$ increases gives us more no. of PRBs in the edge region such that there is no need to terminate the cell–center arrival to cell-edge. Which again helps in improving probability of blocking and probability of outage.

The cases we presented above verifies markov’s estimation using SFR. here importance of SFR is because in SFR, the power ratio between the cell-edge band and the cell-centre band can be an operator-defined parameter, thereby increasing the flexiblity in system tuning, the performance of the SFR with partial frequency reuse at the cell centre for large scale networks in realistic radio environments and with irregular cell patterns is investigated.

Therefore, it was suggested that the SFR is better used for resolving interference issues at some specific areas, at which the performance reduction at the center zones is much significant compared to the improvement in the cell edge, rather than being used in the entire network.
REFERENCES


