Throughput Evaluation of Frequency Reuse Schemes in LTE

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Abstract: In the long term evolution (LTE) cellular network system, the frequency reuse schemes are utilizes to improve the overall network throughput and capacity. In this research the performance of two frequency allocation schemes; reuse 1 and reuse 3 in the downlink mode of an LTE FDD system is studied and compared. An analytical model limiting to frequency reuse schemes 1 and 3 along with an analytical model devised for interference is introduced to mathematically evaluate these schemes, then these schemes are proposed under different system dimensioning parameters by a program creating on MATLAB. The performance of the two allocation schemes is evaluated and compared in terms of the cell throughput for different transmit power level. Reuse 1 scheme shows to be very promising in terms of overall cell peak throughputs, but the highest expected regions for interference are on the cell edges. Reuse 3 scheme increases substantially user cell-edge performance due to the fact that interference is very limited, but promising lower cell peak throughputs because in reuse 3 used only one third of the available system bandwidth.

Keywords: Reuse 1, Reuse 3, Throughput, LTE, Cell-edge Performance.

I. INTRODUCTION

In recent years, the demand for mobile broadband services with higher data rates and better Quality of Service (QoS) is growing rapidly and this demand has motivated third generation Partnership Project (3GPP) to work on Long Term Evolution (LTE) [1].

LTE is developed by the third Generation (3G) technologies release-8 of the (3GPP) plan in order to make sure effectiveness of its standards in long term, and is considered a baseline and step towards the LTE-Advanced (LTE-A). The main challenges for LTE are to come up with new radio access technology so that high data rates, low latency can be offered [2].

The multiple access technologies on the air interface are different in downlink and uplink of LTE systems; Orthogonal Frequency Division Multiple Access (OFDMA) is the downlink multiple access technology, While for uplink a Single Carrier Frequency Division Multiple Access (SC-FDMA) is deployed. Moreover, LTE supports frequency division duplex (FDD) and time division duplex (TDD) as well as the wide range of system bandwidths which enables the system to work in a great number of different spectrum allocations [3].

Since the radio bandwidth is one of the scarce resources in wireless networks, new resource allocation algorithms need to be introduced to overcome radio resource limitation particularly when applications with high data rate are deployed. For this purpose, frequency reuse one has been used in cellular networks. However, the system performance is severely degraded due to increase of interference caused by neighboring cells. There are two major categories of interference for cellular mobile communication system; intra-cell interference and inter-cell interference [4].

Orthogonal frequency division multiplexing (OFDM) has emerged as a promising physical layer technology for LTE wireless networks. OFDM solves the problem of co-channel interference (CCI) in intra-cell to some extent because of the orthogonality of subcarriers. However, inter-cell interference (ICI) caused by using the same frequency in neighboring cells still exists, which leads to destroy the signal modulation of receiver and so restrict the LTE performance in terms of throughput and spectral efficiency, particularly for cell edge users (CEUs) [5].

Generally, inter-cell interference limits the spectral efficiency when a cellular network system aiming to use the full Bandwidth in all its cells like in the case of LTE in frequency reuse-1where ICI becomes more critical for the users present in the border area of a cell.

Inter-Cell Interference Co-ordination (ICIC) is one major alternative mitigation techniques to combat this problem in an OFDMA based system, which gives priority to cell edge performance under the restriction of maximizing system capacity. In ICIC, the coordination is done by using different frequency allocation schemes. This kind of approach has potential possibilities for improvement in Signal to Interference and Noise Ratio (SINR), thus in throughput and coverage of the users at cell borders [6].

Understanding the trade-offs associated with ICIC mechanisms is important, because it helps identify the architecture and protocol support that allows practical systems to realize potential performance gains.

The main goal of this research is to study and compare the analysis of two proposed radio frequency allocation schemes namely reuse-1 and reuse-3 in the LTE network cell and utilize these two schemes to minimize the inter-cell interference in the system.

The problem of obtained high throughput and large coverage in LTE Reuse-1 mode system is that there is a large inter-cell interference as adjacent cells have same frequencies to assign to their users, which lead to degradation of throughput and coverage.

After the investigation of reuse 1 and reuse 3 schemes, the results show that a mix of frequency-reuse 1 and 3 schemes in a cellular system is better to avoid interference and achieve high peak throughput and area coverage by allocate a frequency-reuse 1 in dense urban areas, and allocate a frequency-reuse 3 in a rural, less dense area and highways.
In this paper the MATLAB is chosen for the simulation of these analytical models and to analyze its performance under different power conditions to get a deeper understanding of what impact the cell throughput has on the cell radius increase, and the results obtained are going to be analyzed.

II. Simulation Environments

Now that the used model and how it designed along with the assumptions have presented, it will move on by verifying the results of the entering data. It will begin by setting the parameter and finally display a couple of confirmation graphs. To evaluate the performance of the system and compare the different reuse schemes under different conditions, first it consider an LTE FDD cellular network, Also assume that one UE at a time in the target cell is connected to the BS using all available resources at BS. User locations are changed continuously to cover all possible locations within the coverage area of the cell, and at each location it is subject to interference pattern from cells of ring 1 and 2 according to the frequency reuse scheme used as illustrated in figure 1, where the interference is received at a UE from cells 4, 6 and 10.

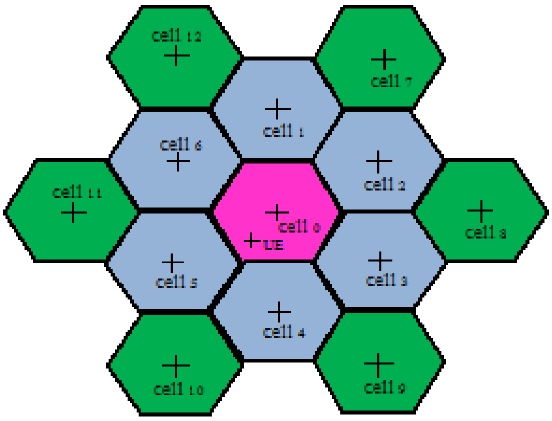

Figure 1 the target UE under analysis in cell (0)
Firstly the homogeneous LTE cellular system is simulated by setting the parameters summarized in Table 1, then the reuse 1 and reuse 3 overall cell throughputs are present after exploring different power levels of the system and plotting the curves for throughput against the increase of the cell radius.

Table 1 Simulation Parameters

Parameter	Assumptions
Cellular layout	Hexagonal grid, 13 cells
Cell radius	1 Km
Bandwidth	10 MHz in FDD mode
Radio frame chunk	30
Chunk bandwidth	0.3 MHz
BS Tx power	5, 10, 15, 20 dBm
Path loss coefficient (α)	3.75
FTP-like files size	4.5MByte
Background noise No	3 dB

III. Simulation Results for Reuse 1

The results for reuse-1in figure 2 illustrate the relationship between the cell throughput against the increase of the cell radius at different power levels, and figure 3 show the relationship between the service time and the transmitted power.

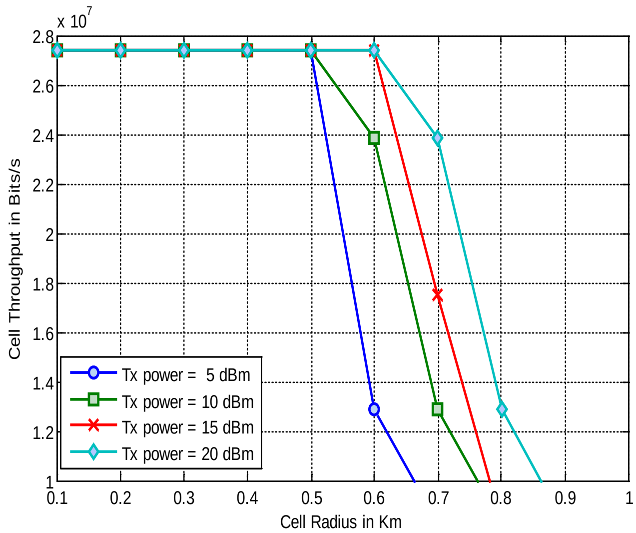

Figure 2 Cell throughputs against cell radius at different power levels for reuse1

From Figure 2, it is clear that the reuse-1 for different power levels has similar better throughput, but shows significant degradation in throughput after 0.5 Km from the cell center which varies from one power level to another.

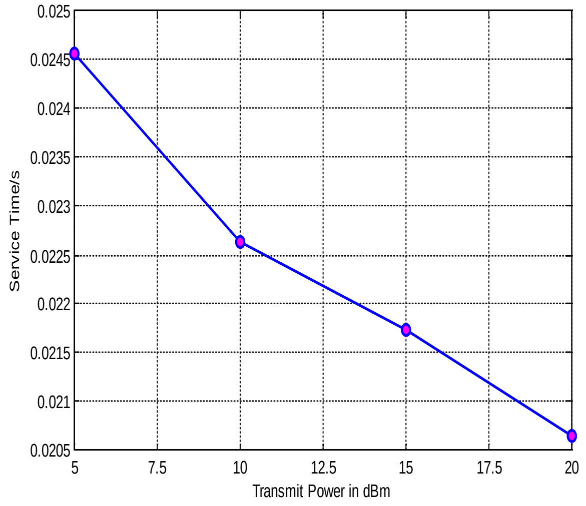

Figure 3 Average service time for re-use1 at different transmit power

This shows that, relative to reuse-1, the average service time values for different power levels are decrease slightly as long as power increased.

IV. Simulation Results for Reuse 3

Same as the previous case, the simulation repeated for the reuse-3, the results is a combination of figure 4 are introduced.

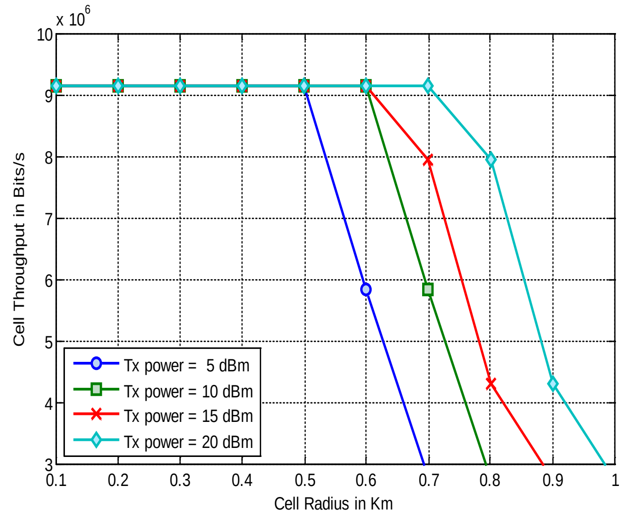

Figure 4 Cell throughputs against cell radius at different power levels for reuse3

In contrast to the results of the reuse-1, it is concluded from the figure 4 that a better coverage is actually achieved when the eNB power is increased taking the values 5, 10, 15 and 20 dBm. However, the curves showed a different in the peak throughput which decreases as power decrease.

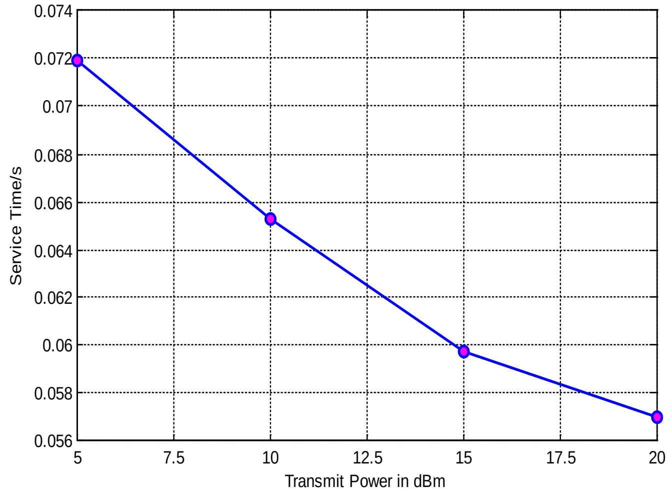

Figure 5 Average service time for re-use3 at different transmit power

Figure 5 shows that when using the reuse-3 schemes, the average service time is decreased as the transmitted power increased.

V. Comparisons between Reuse 1 and Reuse 3

The comparison between the two schemes results show that reuse 1 achieve more assign peak throughputs when compared to reuse 3, this is because in reuse 3 we used only one third of the available system bandwidth. However, reuse 3 shows almost all cell area coverage capability when compared to reuse 1. This is due to the fact that as cell radius increases, the amount of interference coming from the second ring, in the case of reuse 3, tends to become negligible.

It should be noted that as the radius increased, there was just a minor decrease in user throughput for both reuse schemes; this is because of the high power of the system, the system can accommodate larger cell area coverage than the 1 km radius set in the above evaluation curves.

VI. Conclusion

This paper studied two different frequency schemes in the forthcoming OFDMA-LTE system in FDD mode; these schemes are reuse 1 and reuse 3 frequency allocation schemes. It begins by calculating the expected number of collisions for an arbitrary number of users in a target cell.

The results have shown that a reuse 3 scheme when compared to a reuse 1 scheme increases user cell-edge performance, and is more immune to the increase of system loading, due to the fact that interference is very limited in the reuse 3 than in reuse 1, because in reuse 1 the highest expected region for interference are on the cell edges.

And a reuse 1 scheme shows to be very promising in terms of overall cell peak throughputs when compared to a reuse 3 scheme; this is due to the capacity limitation set by using only one third of the system bandwidth. However, reuse 3 has shown to be capable to achieve much greater cell area coverage, with a low power being able to cover a 1km cell radius.

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