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# Interference Control in OFDM-base Mobile Networks

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**Abstract.** In this paper, we are considering the implementable frequency allocation schemes (in OFDM-base systems as LTE or WiMax) performance, to support maximum capacity and least outage probability. Meantime, techniques combining strategy that called pre-produced code in LTE standard with a frequency allocation scheme, called cell region division, in perspective of interference control, especially in marginal areas of the cell will be considered. Simulation results indicate that rank 1 pre-code scheme base on MISO channel (according to what mentioned in the LTE standard) along with cell region division (to OFDM frequency carriers allocation) lead to the substantial gain in the total network capacity, under the different traffics.

**Keywords:** LTE, interference control, pre-coding, capacity in OFDM.

## 1. Introduction

The long-term evolution (LTE) standard is a radio interface with a very high flexibility which review by the 3rd Generation Partnership Project (3GPP) starting from early 2005 and was completed in 2009 [1,2,3]. However, this system that provided with aimed to support peak data-rate 100 Mbit/s and 50 Mbit/s for downlink and uplink respectively, require a broad bandwidth and also effective productivity of this bandwidth. Hence, one important target in designing a LTE network, is improve performance cell edge to the maximum capacity and thus the frequency resource management in these systems is very important. The LTE downlink radio transmission using OFDM modulation is performed, but in uplink radio transmission because the problem PAPR (Peak to Average Power Ratio) using SC-FDMA (Single Carrier-FDMA) has been proposed [3,4].

Know that the frequency reuse leads to efficiency of resources in the cellular system. However, this technique leads to increase interference especially in the cell edges and reduce SINR and thus reduce the capacity in these areas [5]. Although proper use of cluster and sectorization in current cellular systems (eg GSM), partly resulting in increased channel capacity and reduce interference between cells, but according to the high rate sending in new systems, more needs to reuse frequencies is felt to can be support increased traffic, high rate and desired quality of service. Therefore it is necessary to study new schemes of the OFDM frequency carriers allocation in different regions of a cell and also the effect of new measures predicted in a OFDM-based system such as LTE or WiMax on the performance of these schemes be examined more carefully [6,7]. An example of these arrangements, is support MIMO channels in above systems that in this paper will be studied from aspects its effect in controlling of the inter-cell interference.

MIMO using one of the most important technological advancements in modern digital communication field . MIMO system that first introduced by Telatar in 1995 was widely today is considered in OFDM-based standards such as LTE and WiMax, and to increase the transmission rate, coverage and capacity of cell [8,9].

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A major technique in these systems, send data simultaneously with proper weights (pre-coding) on multiple antennas that lead to radiation beam forming antenna (Beam-Forming) [9,10]. If this method done by of antennas weighting with appropriate coefficients (to the location the user depend on the cell) can cause to increase signal strength, especially at the edges of the network cells, however, may be increase interference effects on adjacent users. The main aim in this paper study effect of different frequency allocation schemes in combination with rank 1 pre-coding, on the place capacity cell (capacity in terms of distance from the center of the cell) and also average capacity supported and the outage probability in a OFDM-based cellular network such as LTE.

The remainder of this paper is organized as follows. In Section II, we will be introduce sectoring and cell division schemes [6,7] and also technique Beam-Forming antenna with rank 1 (according to the standard LTE). In Section III, we will formulate the criteria to compare study schemes such as SIR, outage probability and location and average capacity. In Section IV, using the simulation results produce to compare the frequency allocation schemes introduced in previous sections and their combination with rank 1 pre-coding and finally conclusions are presented in Section V.

## 2. Frequency Allocation Schemes

Radio transmission downlink, in systems such as LTE and WiMax is done by data transmission on a large number of parallel and narrow-band subcarriers, in OFDM configuration. Due to the use of relatively narrowband subcarriers in combination with a cyclic prefix (CP), OFDM transmission is inherently resistant against time dispersion on the radio channel without requirement to advanced and potentially complex receiver. This feature cause simply baseband processing in receiver and thus reduce terminal cost and power consumption [1, 2, 3, 4]. Since the CP in each region, in order to compensate time dispersion of the same design area and is injected in each OFDM symbol, available users in one area (cell or sector) despite overlap frequency do not interference on each other, but each frequency channel belonging to a specified frequency category from each area can interfere on all of the frequency carriers of the same category in other areas, unless this interference is controlled with the proper design area shapes or coverage antenna patterns.

### 2.1. Sectoring

The co-channel interference in a cellular system can decreased by replace an Omni-directional antenna at the base station by several directional antennas, each radiating within a specific sector. In this scenario, while practically every cell use of all frequency band, only with fraction of the adjacent cells will interfere. This technique that lead to reduced interference and thus increasing system performance is called *sectoring*. In this scheme, as shown in Figure 1, the total number of carriers available, divided into three parts and each part is allocated to one sector [5].

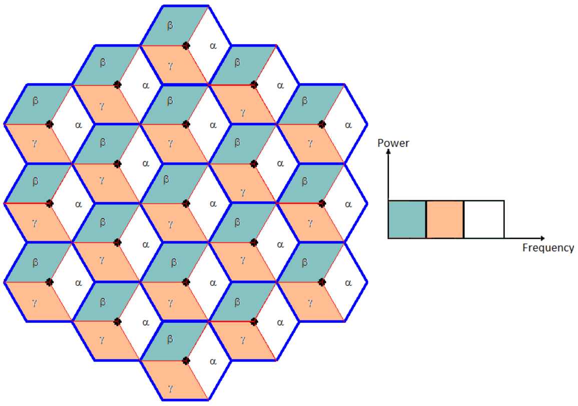

Fig. 1: $120^o$ Sectoring.

### 2.2. Cell Division Region

In this scheme [6,7], the area covered by each cell and the entire bandwidth (the total OFDM carriers) is divided into two outer and inner sections. As shown in Figure 2, the inner band is allocated to the inner region of each sector, but the outer band is divided into tree sub-bands, and each sub-ban is allocated to one sector. Depend on the location of each user is assigned one or more channels of the outer or inner band to it. For example, the network shown in Figure 2 is composed of 19 cells which such for inner region of the $\alpha$ sector in the $0^{th}$ cell (the reference cell), are interfere inner region $7\alpha$ sectors belonging to number of cells $\{5,6,14,15,16,17,18\}$, inner region $6\beta$ sectors belonging to number of cells $\{3,4,10,11,12,13\}$, inner region $6\gamma$ sectors belonging to number of cells $\{1,2,7,8,9,10\}$. Since cell centers in the network, are always away from each other, users in these areas will experience a high SIR, and therefore can be considered a set carriers for them to reuse factor 1. Also for outer region of the $\alpha$ sector in the $0^{th}$ cell (the reference cell), are interfere outer region $7\alpha$ sectors belonging to number of cells $\{5,6,14,15,16,17,18\}$ .

Geographical divide each area, is as function of the radius $r$ of inner region and also is done the bandwidth divided according to areas ratio. Then, $W_{in} = (W.Q)/3$ and $W_{out} = (1-Q)W/3$ is the bandwidth allocated to inner and outer region of each sector. In relation to the above $Q$ is area ratio inner region to total region.

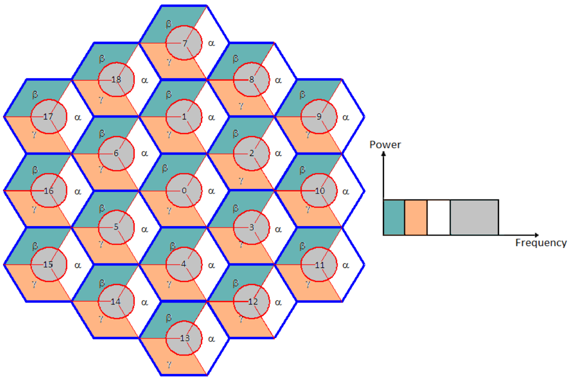

Fig. 2: Cell Division Region.

## 2.3. Transmit Beam – Forming with Rank 1

As was said, MIMO technologies widely to use in OFDM-based systems such as LTE and WiMax has been proposed. In LTE, the closed-loop spatial multiplexing (CLSM) includes sending one or two streams of data simultaneously by two antennas of the base station to mobile [9,10]. Sending 1 data stream is known as Rank1 CLSM and sending 2 data streams is known as Rank2 CLSM , which of course use each depends on the channel conditions. In this article we review only rank 1 CLSM as gain will create that in controlling SIR in each of these frequency allocation schemes.

Rank 1 CLSM implements transmit by beam-forming. Two transmission symbols on each antenna and each channel OFDM are transmitted with certain phase difference to be together. Phase difference between two data sent can be 0, 90, -90 or 180 degrees. These phase differences can lead to the formation of four different beam in the base station, which each mobile depending on its position (angle than the main beam antenna) , can choose one of four radiation. This phase difference is created by selecting one of four precoder matrix as Table 1 [10].

Table 1 . Rank 1 precoder matrix in LTE [10].

| **Precoder Matrix** | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$ | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$ | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$ | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$ |
|---|---|---|---|---|
| **Phase Difference** $\varphi(i)$ | 0 | 180 | 90 | -90 |
| **Index** $i$ | 1 | 2 | 3 | 4 |

Can easily show that power received by the remote user, by vector sum the total published electric field by both antennas, and including the phase difference caused by published difference in signal path and also the phase difference caused by imposed precodes, defined with Eqn. (1).

$$P(i) \propto G^{2}(\alpha)\left(1 + Cos\ (2\pi kSin\ (\alpha) + \varphi(i))\right)^{2} \qquad (1)$$

In relation to the above $i$ type of precoder matrix, $k\lambda$ the distance between antennas ( $\lambda$ is transmission wavelength and $k$ is constant ) and $\alpha$ the angle between the main beam antenna and user location. Also,

$G(\alpha)$ show the antenna gain at angle $\alpha$ to the main beam and $\varphi(i)$ express the phase difference created by the precoder matrix.

As can be seen to be received power by each user on each OFDM carrier frequency is depend to the user location and also pre-coding type used for the user. Note that the beam pattern is very sensitive to the distance between two transmit antennas at base stations. If the inter-antenna distance is small (say $0.5\lambda$) then the transmitted signals are more correlated ($k = 0.5$) and the radiation pattern power can change depending on $\alpha$ will be slow. View of the angular power distribution pattern for a low distance between two transmitter antennas and introduced in four precoder in Table 1 is shown in Figure 3. Also, Table 2 , is shown number each precoder and angular range around the bisector of each sector that the radiation power it caused, is more from the other precoders. The mobile can select the best precoder matrix with calculate the SIR, and reporting pre-coding matrix desired and quality channel to base station.

If the best gain power region that achieved by a specific pre-coding, is high (As Table 2 for half the wavelength distance between two transmitter antenna), then a mobile even in high speeds also had the best coverage and will be received good strength. So the rank 1 closed-loop spatial multiplexing mechanism in LTE, is applicable in the high correlated environment (low distance between the transmitter antennas), in a wide range of user speed even with a low rate feedback.

Fig. 3: Transmit beam-forming depending on the angle of each user (Rank 1 CLSM).

Table 2 . Angular range for most power for each precoders introduced in Table 1.

| **Angular range to the middle beam (degree)** | -60 to -48 | -48 to -15 | -15 to 15 | 15 to 48 | 48 to 60 |
|---|---|---|---|---|---|
| **Precoder Matrix** | 2 | 3 | 1 | 4 | 2 |

# 3. Compare Performance Criteria

## 3.1. Signal – to – Interference Ratio (SIR)

The path loss between an mobile is located in “s” position of the base expressed as follows:

$$L = d^{-n} 10^{\xi/10} = d^{-n} \chi \tag{2}$$

Where $n$ is a path-loss exponent ($n \in [2,4]$), $d$ is the distance between the base station to user and $\xi$ is a Gaussian distributed random variable with zero mean and standard deviation $\sigma$ representing the shadowing, and therefore $\chi$ is a lognormal random variable.

As shown in Figure 2, two cases can be considered relying on the location of the user. In the first case, the user is located in the inner region of sector, for example $\alpha$ , and the second case, the user is located in the outer region of $\alpha$ sector. Quantity $E_b / I_0$ (bit energy to interference power for the $m^{th}$ user on the network) in two cases, are expressed by Eqns. (3) and (4), respectively.

$$\left(\frac{E_b}{I_0}\right)_m = \frac{P.L_{(s,i)} / R}{\left[\sum_{j=1}^{K} n_j P.L_{(s,j)}.Block\_Source\right] / W_{in}} \geq \delta \tag{3}$$

And similarly, for second case,

$$\left(\frac{E_b}{I_0}\right)_m = \frac{P.L_{(s,i)}/R}{\left[\sum_{j=1}^{K} n_j P.L_{(s,j)}.Block\_Source\right]/W_{out}} \geq \delta \tag{4}$$

In the above equations, $Block\_Source$ represents the number of allocated subcarriers to the user, $P$ is power allocation to each OFDM channel frequency, $n_j$ is the number of interfering users in the $j^{th}$ interfering cell, $L_{(s,i)}$ is the path loss between user at "s" position and the $i^{th}$ base station, and $L_{(s,j)}$ is the path loss between user at "s" position and the $j^{th}$ interfering base station. Also $R$ is the transmission rate on each OFDM channel and $\delta$ is threshold desired signal to interference ($E_b/I_0$).

### 3.2. Outage Probability

Considering the equations (3) and (4), the outage probability in the inner and outer region identified are as follows:

$$P_{\text{outage in}} = P\left[\left(\frac{E_b}{I_0}\right)_m \leq \delta\right] \times P\left[x \in R_i\right] \tag{5}$$

And

$$P_{\text{outage out}} = P\left[\left(\frac{E_b}{I_0}\right)_m \leq \delta\right] \times P\left[x \in R_o\right] \tag{6}$$

Where $R_i$ and $R_o$ represents inner region area and outer region area, respectively. Thus the total capacity and outage probability system are defined in Eqns. (7) and (8) respectively. In this equations, $C(r)$ and $P(r)$ represents the capacity place and outage probability place of the system based on the distance from the base station, respectively.

$$\begin{cases} C_i = \sum_{r \in R_i} C(r).\frac{2\pi r}{R_i}.\Delta r \\ C_o = \sum_{r \in R_o} C(r).\frac{2\pi r}{R_o}.\Delta r \end{cases} \Rightarrow \quad C_{\text{overal}} = C_i.\frac{W_{\text{in}}}{W} + C_o.\frac{W_{\text{out}}}{W} \tag{7}$$

And also:

$$\begin{cases} P_i = \sum_{r \in R_i} P(r).\frac{2\pi r}{R_i}.\Delta r \\ P_o = \sum_{r \in R_o} P(r).\frac{2\pi r}{R_o}.\Delta r \end{cases} \Rightarrow \quad P_{\text{overal}} = P_i + P_o \tag{8}$$

## 4. Simulation Results

We first consider a LTE cellular network with 19 cells and compare the methods Introduced in the frequency allocation and interference control. Assumed that all mobile phones are distributed on the cellular networks with a uniform probability density distribution and each base station assign a same power to all users . Also assumed that is available 1024 the OFDM channel and traffic load per cell is considered 50% of total traffic. In this simulation, we consider the frequency bandwidth of 10 MHz, transmission rate on OFDM each channel is $R = 15\,kbps$ , and threshold is $\delta = 4dB$ . we consider the radius normalized by the inner region and the antenna gain, $r = 0.5$ and $G(\alpha) = 1$ respectively. Also, is assumed that the standard deviation of $\xi$ is 8 dB for the interfering signals from adjacent cells and for the Reference cell signals is 2.5 dB.

Initially, we compared the sectoring scheme (Fig. 1), cell division region (Fig. 2) and cell division region with the transmit beam-forming (Fig. 3) according to the distance of the user to base station, and then will be evaluated the overall performance of each scheme according to the increased traffic load.

As shown in Figure 4, the cell division region scheme creates the less outage probability than the sectoring, especially in cell edge that the SIR is low. But considerably reduced the outage probability of cell division scheme with rank 1 CLSM technique. However, in areas close to the base station, the outage probability is practically zero, three schemes do not show significant difference relative to each other.

In Figure 5 is observed, that the cell division scheme, because of increased the interfering cells in the inner region support less capacity than the sectoring scheme in the same distances from the base station. In the outer region, since the reduction the number of interfering users in cell division scheme, effectively neutralize to reduce bandwidth allocation to this area, is seen same capacity to the sectoring.

Also is determined of Figure 5, that combine the rank 1 CLSM technique with cell division scheme, lead to sensible increase in capacity to the single cell division of and sectoring, and this the capacity gain, especially in cell boundary is more tangible. This is due to combined the SIR control property by pre-coding due to rotation of the antenna radiation pattern depending on the position of mobile user, with feature to reduce interfering users in the cell division.

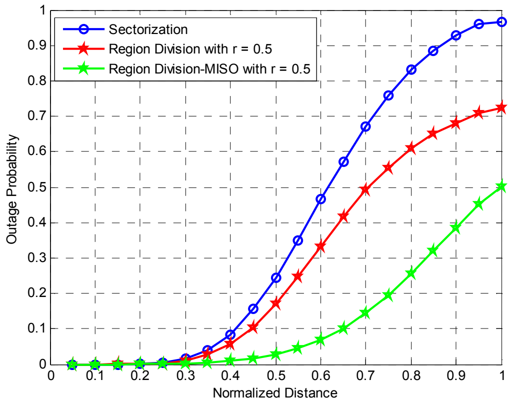

Fig. 4: Outage probability according to the distance of the user from the base station.

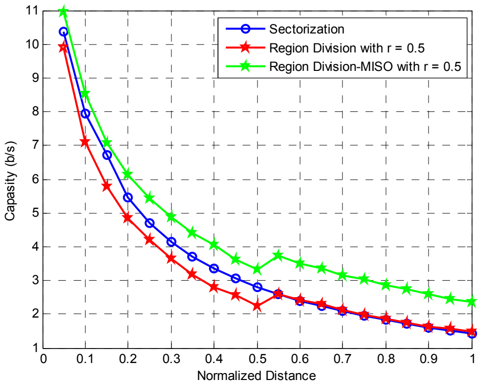

Fig. 5: Capacity according to the distance of the user from the base station.

In Figures 6 and 7 are shown, the outage probability and average capacity (average over all regions and users) in terms of percentage of network traffic load, respectively. As will be seen, in all schemes increase outage probability with increasing network traffic, but is obvious slow growth the outage probability in composition cell division scheme into the appropriate pre-coding technique. Here, separately for each user is selected the best code according to mobile user location and data in Table 2.

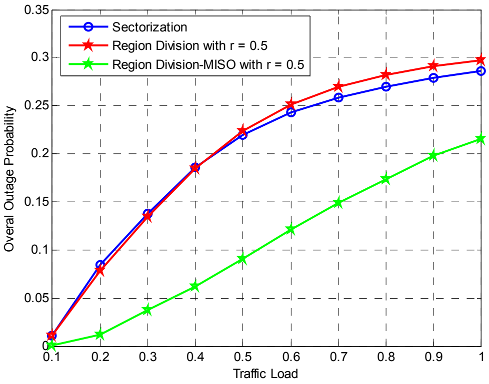

Fig. 6: Overall outage probability in each cell based on its traffic load cell.

Of course, seen that the precoder offers the most gain in the intermediate traffics, Because in the very busy network, the centralized base antenna beam can cause to increase interference for users that are in line with the desired user.

In Figure 7 is given, the average capacity gain network based on percentage of traffic load. Clearly seen that if we consider the capacity of the whole system, cell division scheme lead to a significant gain than sectoring scheme, and also using rank 1 CLSM will create a similar gain in all the traffic loads to cell division scheme . In Figure 7, we observed that the capacity of the whole system into the division region scheme, according to the better efficiency of frequency (bandwidth shared in the inner area), an average of about 22.5% compared to sectoring increases. In addition, the combined this scheme with transfer pre-coding technique, can be increase the average capacity of the total network about 20% compared to conventional cell division region scheme (single antenna).

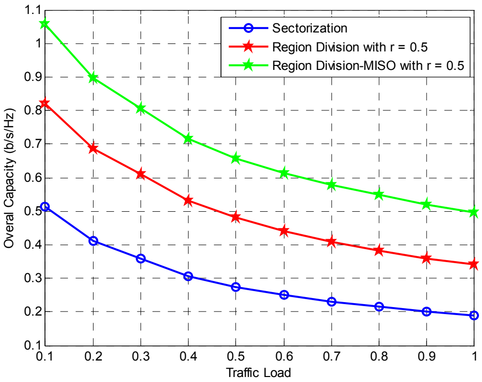

Fig. 7: Overall capacity in each cell based on the traffic load.

## 5. Conclusion

In this paper, we review the performance of the sectoring and cell division region schemes in a OFDM-based network such as LTE in terms of capacity and interference. Observed that the use of multiple antenna transmissions with appropriate pre-coding, creates allowing more efficiency from spectrum and quality of service better than previous cellular systems, and combining this structure with the frequency allocation schemes can lead to a significant increase in capacity and quality of service, especially in the middle traffic.

## 6. References

[1] Farroukh Khan. LTE for 4G Mobile Broadband. Cambridge Univercity Press , New York, 2009.

[2] D. Astély, E. Dahlman , A. Furuskär, Y. Jading, M. Lindström, and S. Parkvall. LTE : The Evolution of Mobile Broadband. IEEE Communications Magazine, April, 2009.

[3] E. Dahlman, S. Parkvall, J. Sköld and P. Beming . 3G EVOLUTION : HSPA and LTE for Mobile Broadband. Published by Elsevier Ltd, First edition 2007.

[4] S. E. Elayoubi , O. B. Haddada. Uplink Intercell Interference and Capacity in 3G LTE Systems. 15th IEEE International Conference (ICON), 2007.

[5] Theodor Rappaport. Wireless Communications Principles and Practice.

[6] H.K Son and S.H Lee. Bandwidth and Region Division for Broadband Multi-Cell Networks. IEEE Communications Letters, VOL. 10, NO. 5, MAY 2006.

[7] H.K Son and S.H Lee. The Cell Planning Scheme for ICI Mitigation. the 18th Annual IEEE International Symposium on Personal. Indoor and Mobile Radio Communications (PIMRC’07),2007.

[8] D. Tse, P. Viswanath. Fundamentals of Wireless Communication. Cambridge Univercity Press,New York, 2005.

[9] Volker K¨uhn . Wireless Communications over MIMO Channels . John Wiley & Sons, Ltd, 2007.

[10] S. Adhikari. Critical Analysis of Multi-Antenna Systems in the LTE Downlink. IEEE International Conference (IMSAA), Dec, 2009.