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Inter-cell Interference Mitigation through Flexible Resource Reuse, LP-OFDM and Coordination techniques for LTE Advanced in Dense Urban Area

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Abstract

The inter-cell interference problem is a key issue in LTE Advanced system especially in dense urban environments. This paper present a new inter-cell interference reduction technique for LTE Advanced downlink system in dense urban area based on a new coordination algorithm with the use of linear precoding OFDM, coordination between cells and power management techniques. The objective of our new technique is to improve cell edge and centre capacity in LTE Advanced downlink system. For this purpose, we prove with real time simulations using Matlab that the S.F.R and P.F.R scheme with our algorithm is a good candidate to enhance the average cell capacity and edge user experience, without sacrificing the average cell throughput.

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1. Introduction

The growing demands on mobile networks to support higher throughputs and spectral efficiencies have driven the need to develop the 5th generation networks.

In September 2015, 3GPP launched the workshop "Start of Something", [1] to establish the vision of the 3GPP 5G network in 2020. The discussion around the 5G is divided between two main roads, a thought that sees 5G as a consolidation of 2G, 3G, 4G, Wi-Fi and other innovations providing much greater coverage with more reliability, the second thinking way is led driven by the need for a big change in the speed of data and reducing latency.

The first phase of the 5G study is planned between 2015 and 2017 and its deployement is expected in 2020. This phase has already begun with the specification 13, and continuing with the birth of the specification 14 of the 3GPP, one of the major objectives of this phase is improving performances of Dense Network in LTE Advanced. Currently, the call for 3GPP project specification 14 [2]; always open; aims to find solutions to reduce interference in dense urban and urban environments, such as the coordination between cells and the feedback to control interference.

This paper focuses on a new inter-cell interference reduction technique for LTE Advanced downlink system in dense urban area based on coordination algorithm with the use of linear precoding OFDM (LP-OFDM), coordination between cells and power management techniques. The objective of our new technique is to improve cell edge and centre capacity in LTE Advanced downlink system. For this purpose, we conducted real time simulations with the program developed using Matlab for LTE advanced system, then we compared the obtained results to those with reuse factor1. The targeted goal is to highlight the advantage of this new technique compared to the standard solution.

This paper is organized as follows. In section 2 we provide, a summary of the conducted research on the impact of inter-cell interference in dense urban environment, and some simulation results demonstrating the negative impact of the inter-cell interference on the LTE Advanced downlink cell capacity. The new technical algorithm and the power allocation schemes are discussed in section 3. The Downlink system-level used simulation methodology is introduced in section 4. In section 5, the results of the dynamic simulations are shown and discussed. Finally, conclusions are drawn in section 6.

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2. LTE Multi-Cellular System in Urban Environment: Inter-Cell Interference Impact on the Downlink Radio Transmission

The LTE network performance is estimated by the simulation testing results [3]. According to the 3GPP model, the SINR values are rarely below – 8 dB. The 3GPP urban test network model contains only 19 hexagonal base stations with OMNI single antennas with an uniform population density and a mobility less than 30 km/h, the neighbouring cells don't contribute enough to the cell interference even if they are fully charged. To give quantitative results of the impact of intercellular interference in a dense urban environment we realized realistic simulation according to the model A below.

2.1. Simulation Model A and Assumptions

Simulation Model A and assumptions are aligned with the 3GPP recommendations for urban area. Table 1 contains the main parameters of the simulation model A. The evaluation method is based on multi-cellular time dynamic simulations [4].

Table 1. Main Parameters of the Simulation Model A

Simulation Model	Model A
Geometry and number of cells	Regular hexagonal grid, 19 Site with 3 Sector (Cell) by Site and 1 indoor Femto-cell by Sector [4]
Settings	Value
Traffic model	Full buffer
Inter cell distance	500 m
Radius of the indoor Femto-cell	20 m
Central frequency	2.14 Ghz
Used band	20Mhzby Sector and 20Mhz by indoor Femto-cell
Path loss Model (Urban area)	TS36942, Recommended by TS 36.942, sub clause 4.5 [5]
Downlink transmission Feedback Channel	Each 3 T.T.I (Transmission Time Interval)
Micro scale fading (between E-node B and attached users)	Winner II Channel model [Reference channel model vr1.1] [6]
Number of users	10 User by Sector (Cell) and 10 user by indoor Femto-Cell
Users distribution	Normal distribution
Users speed	(5 km/h -30 km/h – 60 km/h) and (5 km/h in indoor Femto-Cell)
Base station power	(0.1 Watt Femto-cell power)
The transmitting antenna configuration	Kathrein 742212 [7] 8 degree of Electrical tilt
Transmission mode	C.L.S.M (Closed Loop Spatial Multiplexing) n.TX =2 and n.RX =1
Scheduler	Round Robin
Receiver type	Zero Forcing

2.2. Simulation Results and analysis

This part gives simulation results that demonstrate the impact of inter-cell interference in dense urban environments.

From Figure 1, 2 and 3 we can conclude that low SINR (SINR <= 0 dB) deteriorate considerably the downlink throughput of users having mobility speed higher or equal to 30 km/h. Also we deduce the critical impact of interference on Cell edge users. The interferences can be very high in a way that the throughput of edge user, in the best case not exceeds 0.26 Mb/s, which greatly degrade the user experience in cell border.

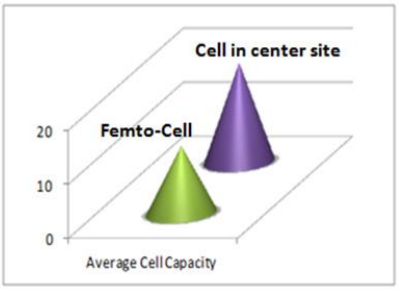

Figure 1. Downlink Average Cell Capacity (Mb/s) According to the Simulation Models A

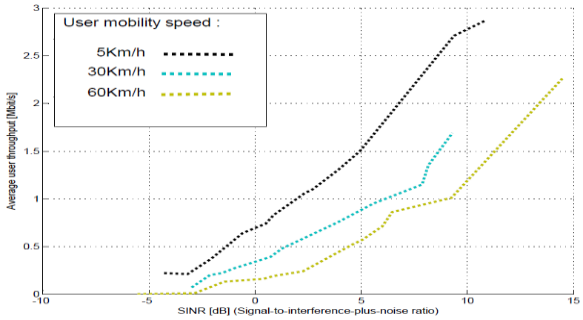

Figure 2. Average user downlink throughput according to the variation of SINR at Different user mobility speed (5 km/h, 30km/h and 60km/h).

Table 2. Downlink LTE User Experience According to Model A

User mobility speed (Km/h)	Average spectral efficiency [Bit/cu]
5 Km/h	0.77 Bit/cu
30 Km/h	0.45 Bit/cu
60 Km/h	0.37 Bit/cu

User mobility speed (Km/h)	(peak/average/edge) user throughput [Mbit/s]
5 Km/h	2.87/1.25/0.21
30 Km/h	2.45/0.7/0.1
60 Km/h	1.74/0.56/0.01

MIN SINR	MAX SINR
-5.54dB	14.89dB

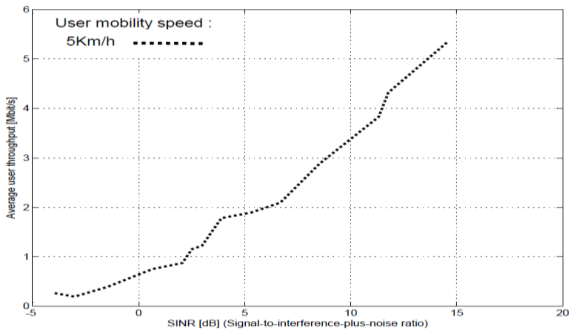

Figure 3. Average user Downlink Throughput Femto-Cell according to the Variation of SINR at 5 km/h user Mobility Speed.

Table 3. Downlink LTE user Experience Femto-Cell According to model A

User mobility speed (Km/h)	Average spectral efficiency [Bit/cu]
5 Km/h	1.11 Bit/cu

User mobility speed (Km/h)	(peak/average/edge) user throughput [Mbit/s]
5 Km/h	5.35/1.84/0.26

MIN SINR	MAX SINR
-3.96dB	14.56dB

From Figure 1 we can notice that the addition of indoor Femto-cell improves the experience of users inside the Femto-cells but adds additional interference to the system which reduces the ability of the cell to 81.63% of loss compared to the Total. The interferences also affect the Femto-cells and reduce their capacity to 87.51%.

We show through simulation results that the impact of inter cell interference should not be under estimated, especially with high population density areas. The SINR optimization in LTE, and LTE advanced networks must take into account the cells distribution and capacity. Indeed, the only way to optimise LTE Advanced for dense urban area is with the existence of communication interfaces between neighbouring cells (X2 interfaces) and collaboration in power management and resource sharing. With this vision we give a proposal for a new optimization technique based on a distributed architecture in our article named "LTE–Inter-Cell Interference management to improve the quality reception in downlink radio resources links" [8], this technique may improve the downlink user experience in inner cell and also in cell edge.

In section 3 we provide a new solution based on the use of power allocation technique to reduce the impact of inter-cell interference for LTE Advanced in Dense Urbain Area [8].

3. Interference Mitigation Algorithm and Schemes

To improve the user throughput in downlink the proposed solution is based on two schemes; SFR (Soft Frequency Reuse) and PFR (partial frequency reuse) with a scheduling according to round robin algorithm, coupled with two radio transmission techniques. Namely: LP-OFDM in inner-cell and the simultaneous transmission of several physical resources block (PRB) from different adjacent base stations in cell-edge.

We assume that each cell always uses its maximum total transmission power, which is kept constant and the same for all the schemes that we are going to analyze. In this paper, we use a static power allocation over the physical resource block PRB on the available frequency band. So the power per PRB is fixed and no adaptive power loading is employed. But, transmission rate adaptation is still performed by altering the modulation and coding scheme on the PRB.

3.1. Scheme 1 – Soft Frequency Reuse:

The soft frequency reuse scheme according to our algorithm works as follows: for each cell in the network; a part of the frequency band is reserved for the cell edge users, on which the transmission power is amplified. In a tri-sector network, the reserved part is normally 1/3 of the total frequency band and is orthogonal among the neighbouring cells. It is called soft frequency reuse as the frequency partition only applies to the cell edge users, whilst the effective frequency reuse factor is still close to one.

Figure 4 gives a presentation of SFR used with our algorithm for intercellular interference mitigation.

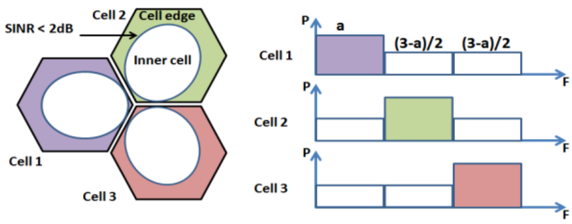

Figure 4. Scheme 1 SFR for Algorithm of Intercellular Interference Mitigation

For scheme 1 we will refer to the 1/3 frequency sub-band that has amplified power as the cell edge band, since the cell edge users are restricted to use this frequency sub-band only.

On the other hand, the remaining 2/3 frequency sub-band for each cell is called the cell center band, since it's used by the cell center users only. However, if the cell edge band is not occupied by data of the cell edge users, it can still be used by the cell center users. Users at the cell center could use the whole frequency band (painted white), but with lower priority than the cell edge users on the cell edge band. The separation between the central cell and the cell edge is given by the threshold value of 2 dB SINR. We denote "a" ($1<a<3$) the power per PRB on the edge band which is the power amplification factor.

3.2. Scheme 2 – Partial Frequency Reuse:

The idea about PFR is to partition the whole frequency band into two parts, with reuse factor 1 on one part and reuse factor 3 on the other one. We refer to the partial frequency reuse scheme as Scheme 2. Just like in Scheme 1, the reuse factor 3 part of the frequency band is called the cell edge band, the other part is called the cell center band. The restrictions of frequency access for the cell center/edge users are the same as in Scheme 1, that the cell edge users are only allowed to use the cell edge band, while the cell center users are allowed to access both the cell center and edge band, but with lower priority than the edge users. The separation between the central cell and the cell edge is like scheme 1 given by the threshold value of 2 dB SINR and we use constant power allocation in inner cell and cell edge.

The Figure 5 gives the presentation of scheme 2.

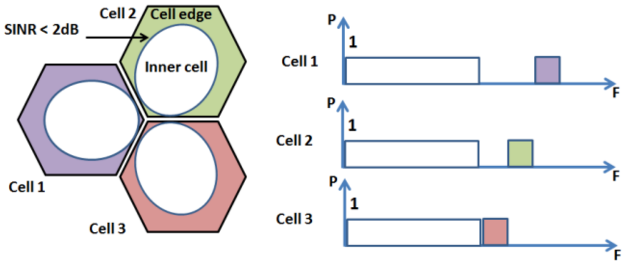

Figure 5. Scheme 2 PFR for Algorithm of Intercellular Interference Mitigation

3.3. Algorithm concept

In the proposed algorithm, the treatment of inter-cell interference for a cell is separate in two areas according to the value of SINR caught by user receivers.

1) In the inner-cell area: with SINR greater than or equal to 2 dB, the LP-OFDM (Linear Precoding - OFDM) is used,

2) In the cell-edge area: with SINR strictly lower than 2 dB, two or three PRB with OFDM modulation from different adjacent cells are allocated to the user. Figure II.2 gives an overview of this new technique.

The researches behind this algorithm are presented in our publication: “LTE – Inter-cell interference management to improve the quality reception in downlink radio resources links” [8]. Figure 6 give the operation’s principle of this algorithm.

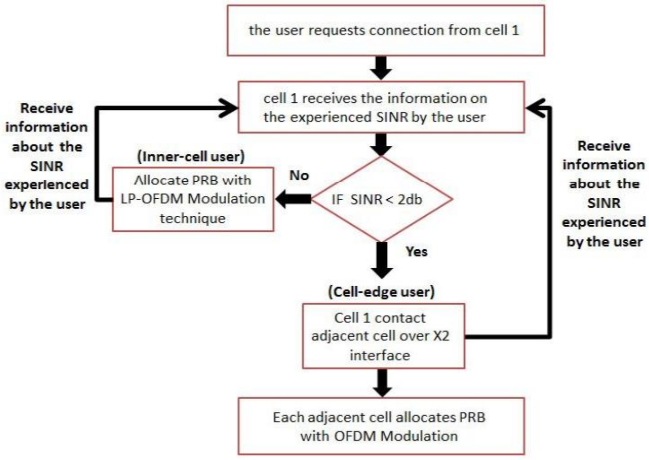

Figure 6. Algorithm for Managing Resource Allocation and Intercellular Interference Mitigation

Our researches results reveal that the use of LP-OFDM in inner-cell provide a gain greater than 2 dB for SINR higher than 2 dB and inter-cell coordination at cell-edge, can significantly, improve the transmission conditions with a gain of 3 dB with 2 PRB (physical resource block) and a gain greater than 6 dB with 3 PRB allocations [8].

In the next section we introduce our simulation methodology to give results about the advantages of using SFR and PFR schemes combined with our new algorithm of intercellular interference mitigation in dense urban area.

4. Simulation Methodology for the Downlink

We consider a tri-sector cell layout, with three 120 degree sectoral antennas per site. One BS (base station) is at the center of the site, controlling the three cells (sectors). On the downlink the modulated OFDM symbols are transmitted in the unit of Physical Resource Block (PRB). One PRB is defined as a block of physical layer resources that spans over one TTI (Transmission Time Interval) in time and a fixed number of adjacent OFDM subcarriers in the frequency domain. We assume that each cell always uses its maximum total transmission power, which is kept constant and is the same for all the schemes that we are going to simulate and analyse. Throughout this paper, we use a static power allocation over the PRBs on the available frequency band. So the power per PRB is fixed and no adaptive power loading is employed. However, transmission rate adaptation is still performed by using the modulation and coding scheme on the PRBs.

Simulation Models and assumptions are aligned with the 3GPP recommendations for dense urban area. Table 4 contains the main parameters of the simulation models. The evaluation method is based on multi-cellular time dynamic simulations.

Table 4. Main Parameters of the Simulation model using scheme1 and 2

	Scheme 1	Scheme 2	Reuse 1
Carrier frequency		2.1 GHz	
Bandwidth	15 MHz	10 Mhz inner cell / 5 Mhz Cell edge	15 MHz
Number of antennas		C.L.S.M (Closed Loop Spatial Multiplexing) 2 Tx – 1 Rx	
TTI		1ms	
Sub-frame duration		0.5 ms	
Inter Site Distance(ISD)		500 m	
Path loss model (in dB)		TS36942 [5]	
Downlink transmission Feedback Channel		Each 3 T.T.I (Transmission Time Interval)	
Micro scale fading (between E-node B and attached users)		Winner II Channel model [6]	
Number of users		10 User by Cell / 30 user by Site	
Users distribution		Normal distribution	
Users speed		5 Km/h	
Base station power		46 dBm (B.S does not emit when there's no attached user)	
The transmitting antenna configuration		Kathrein 742212 [7] 8 degree of Electrical tilt	
Transmission mode		C.L.S.M (Closed Loop Spatial Multiplexing) n.TX =2 and n.RX =1	
Scheduler		Round Robin	
Receiver type		Zero Forcing	

5. Simulation Results

With simulation we aim at a more realistic comparison of the different resource reuse schemes 1, 2 and Reuse 1, a verification of our initial goals, i.e. to improve cell edge user throughput as well as the average cell throughput, and also an examination of the results of the capacity estimation. In our simulations, each cell is running the same protocol stack and serving the same number of users. The users have random movement inside the cells and handover is avoided by re-positioning the users if necessary. For the case of simulation, we use two rings of sites and the center site is used for evaluation. This is reasonable since the majority of interference always comes from the first and second sites. Figure 7, 8 and Table 5 give simulation results for our proposed schemes.

From Figure 7 and 8 we can deduct the user downlink experience and cell capacity improvement in scheme 1 and 2 in comparison with Reuse 1. In scheme 1 (S.F.R) the impact of interference reaches 42.2% loss of the cell capacity, in scheme 2 the use of P.F.R reduce de cell capacity loss to 36.22%. In Comparison with Reuse 1 Model the cell capacity loss is 90.05%. Also we can deduce from Table 5 that the use of P.F.R and S.F.R with our algorithm can significantly improve the average cell throughput and downlink user experience about 6 times in comparison with the reuse 1 model.

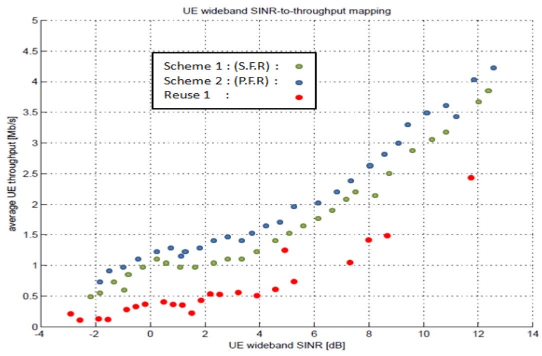

Figure 7. User Wideband SINR-to-throughput Mapping

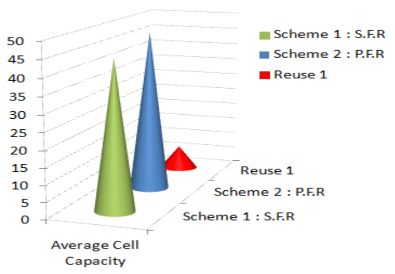

Figure 8. Cell Capacities for Simulated Schemes

Table 5. Main Results for the Simulation Model using scheme1, 2 and Reuse 1

	Scheme 1 (S.F.R)	Scheme 2 (P.F.R)	Reuse 1
Peak/Avg/Edge UE throughput	5.6/4.14/0.76 Mb/s	6.43/4.67/0.8 Mb/s	2.88/0.75/0.11 Mb/s
Average cell throughput	43.34 Mb/s	47.83 Mb/s	7.46 Mb/s
mean RB occupancy	93.36%	96.63%	80.76%

6. Conclusion

Our simulation results successfully estimates the average cell capacity under different reuse schemes.

The conclusions are the following:

1) Reuse factor 1 deployment in dense area reduce the average cell capacity about 90%.

2) By allocating more power to the cell edge users, and less to the cell center users, the soft frequency reuse (Scheme 1) with our algorithm has smaller capacity than reuse factor 1. But it greatly reduces the SINR and enhances the average cell and user throughput (Table 5).

3) Although the partial frequency reuse (Scheme 2) with our algorithm have better transmission quality (lower experimented SINR), and can reduce the average cell loss about 40%.

In sum, our simulation with homogeneous traffic load among cells both show that the S.F.R and P.F.R scheme with our algorithm is a good candidate to enhance the average cell capacity and edge user experience, without sacrificing the average cell throughput.

To give even more Results comparing between S.F.R and P.F.R with our algorithm we have to do other simulation that adds the factor of enhancing the number of users in the cell.

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