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Department of Electronics and Information Systems

Radio Resource Management Centralized for Relayed Enhanced LTE-Networks

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Title:

Radio Resource Management Centralized for Relayed Enhanced LTE Network

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Abstract:

Relaying is a potencial solution to improve the coverage and capacity in LTE-Networks. In this project is studied the radio resource management (RRM) in a case centralized for Relayed Enhacement LTE-Network for uplink considering the channel effects and the interferences provide by others UEs in the system. For its study is compared several aspects like SINR or the throughtput between a scenario with Relay and another without Relay having implemented a LTE-Uplink Fractional Power Control and a RRM based on a matrix algorithm which use a priority metric based on Time Domain Proportional-Fair (TD-PF).

Preface

The project report on Radio Resource Management Centralized for Relayed Enhacement LTE-Network has been written by Javier Aparicio Rodriguez at the department Electronics and Information System (ESN) at Aalbor University. The title of Master Thesis is "Radio Resource Management Centralized for Relayed Enhancement during October 2008 to June 2009. The project is divided in two parts, the first part based on modeling of a Relayed Enhacement Network considering the interferences and channel effects, and one second part based on to implement RRM centralized for Uplink considering LTE-Uplink Fractional Power Control. The final result is the comparasion between a scenario relayed and another not relayed.

This report is divided in two parts too. The first part which explains the implementation of the simulator that generates the results, and another parts which analyzes the results obtained and comments the conclusion and the future work.

To Express special thanks to its supervisors Troels B. Sorensen and Oumer Teyeb for their ideas and their support.

The report is developed by:

Javier Aparicio Rodríguez

List of Abbreviations

3GPP	3rd Generation Partnership Project
BS	Base Station
CQI	Channel Quality Indicator
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
HSPA	High Speed Packet Access
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
TD-PF	Time Domain Proportional Fair
RS	Relay Station
SINR	Sigtal-to-Interference and Noise Ratio
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WiMax	Worldwide Interoperability for Microwave Access

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Chapter 1

Introduction

1.1 Motivation

Nowadays, the mobile communications have become usual situation where the users demand on services and applications more and more complex which will use more resources of the system. Due to the increase of services which need more broadband, a standars-developing body which name is Third-Generation Partnership Project (3GPP) is working on an approach for 3G evolution, LTE. *LTE can operate in new and more complex sprectrum arrangements with the possibility for new desings that do not need to cater for terminals of early releases.* [1].

In order to obtain this higher data rates and other aspects like to extend the coverage cell, the system can introduce a kind of stations which name is Relay Stations. Various studies have showed that the use of relays in a cellullar network improve these aspects mencionated above.

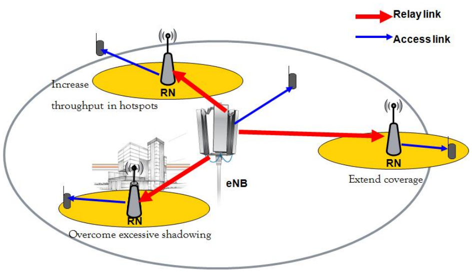

Figure 1.1: *Relayed network.*

The main target of the thesys is the study and to compare a scenario with Relay with another scenario without when is realized a radio resource management centralized for these relay stations. For obtain the results is necessary to implement in a simulator both scenario and the differents aspects which require like Power Control or RRM.

1.2 State of the art (Background)

Relaying networks rise up as an attractive technical solution which leads to higher data rates, but also increases the coverage of medium rates; both requirements of latest standards which aim to accomplish IMT-A goals.

The IEEE group 802.16j has the objective of set the standard for the relaying architecture of WiMAX, also known as 802.16. This standard considers two access technologies: OFDMA and SC-FDMA. The latter is targeted for the uplink due to its good PAPR (peak to average power ratio) behaviour, but while it operates on the 10-66 GHz band and considers point-to-point transmission, OFDMA works at the 2-6 GHz band. This access technique, also known as 802.16d, is the standard for the downlink for WiMAX, and, therefore, relaying architecture is standardized for it.

The distribution of BS and RS, their functional division and link level issues, like QoS or radio resource management, are among this group task. There are three different types of relay station consider: mobile RS, like those located on public transport looking to enhance the signal inside them; nomadic RS - generally placed as temporal enhancing devices for events where the number of users temporary increases - and fixed RS, which are situated in fix position.

There are great benefits expected from the implementation of relaying structures, turning it into a hot topic. Several works have focused on it, showing the overall gain of performance attained thanks to multi hoping.

1.3 Project objectives

- System level modeling of a relay enhanced LTE network.
- Implementing LTE uplink Fractional Power Control
- Implementing centalized RRM.
- Comparing the performance of the scenario with Relay and without Relay.

1.4 Guidelines

- The chapter Simulator explains a description about how have been implemented the scenarios in Matlab. Furthermore is explained the differents aspects like RSs, interferences, power distribution, channel allocation).
- Results. In this chapter is shown the results obtained of the simulations for the different scenarios.
- Conclusions. This chapter analyzes and comments the results obtain in the previous chapter

Chapter 2

Simulator

This chapter begins with a introduction part about the simulator that have been used in this project. The rest of the chapter is divided in different sections where is explained all elements implemented in this thesis.

The Section 3.2 Description explains the main features of the simulations. The process of simulations is explained in the section 3.3 and the verification in the section 3.4.

2.1 RUNE simulator

The tool used for the simulations is called RUNE which is based on MATLAB. This tool have been developed at Ericsson and consists in a serie of functions which allow simulate a cellular network. In the beginning, this tools was implemented in order to simulate GSM network but it can be configured for others mobile's generations implementing new functions.

Various cellular system aspects like creation of cells, base stations, channel assignment, propagation losses, interference and mobility can be easily handled by the functions used in RUNE [?]. However, RUNE not provides all functionalities necessary and therefore new scripts have been implemented in order modeling of a relay enhanced LTE network.

2.2 Description

2.2.1 Scenario

The first step in the simulations is to make the scenario where the simulations takes place. Following 3GPP-LTE specifications the radius of the cell will have a size R=577m where the ISD will be 1732m as can be seen in the table 2.1. For the simulations, the scenario maked have 4 sites where each site have three hexagonal cell as can be seen in the figure 2.1 (12 BS in whole scenario). The whole scenario as can be seen in the figure 2.2.

Characteristics of the scenario	
Cell radius: R [m]	577
ISD: ISD [m]	1732
Number of sites	4
Number of BSs	12

Table 2.1: *Scenario characteristics*

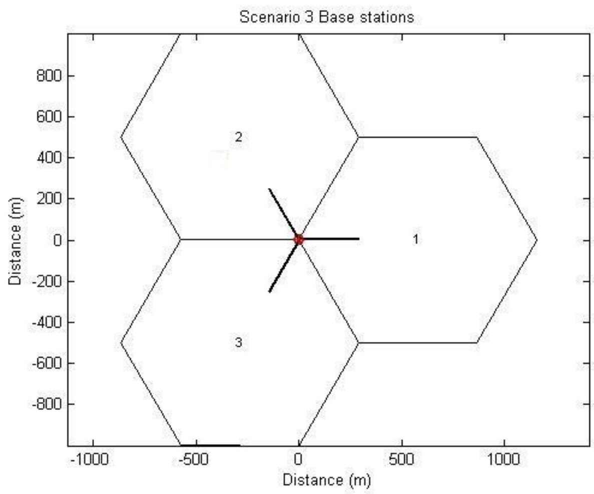

Figure 2.1: *Site with 3 cells.*

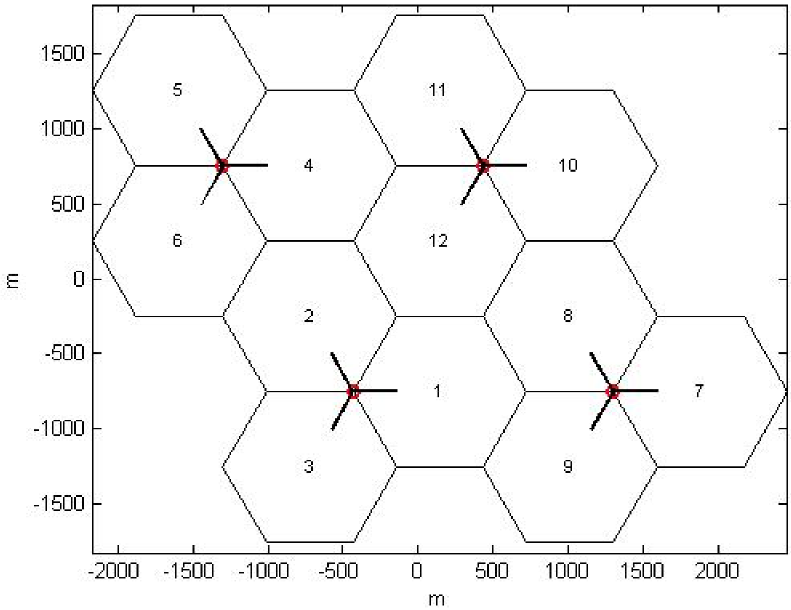

Figure 2.2: *Scenario with 4 sites.*

2.2.2 Relay

One aim of this thesys is to check the benefits for using Relay in a celullar network LTE. For this project is only necessary to drop one relay per cell in order to compare the scenario with Relay and without Relay. The position of the Relay is determinated for other projects which indicate that the best place to locate the relay is between 0.7R and 0.9R. It seems logic to locate the RSs close to the edge of the cell in otder to help the UEs which are not so good covered [**?**]. The final scenario with Relay as can seen in the figure 2.3 where the red cross indicate the RSs.

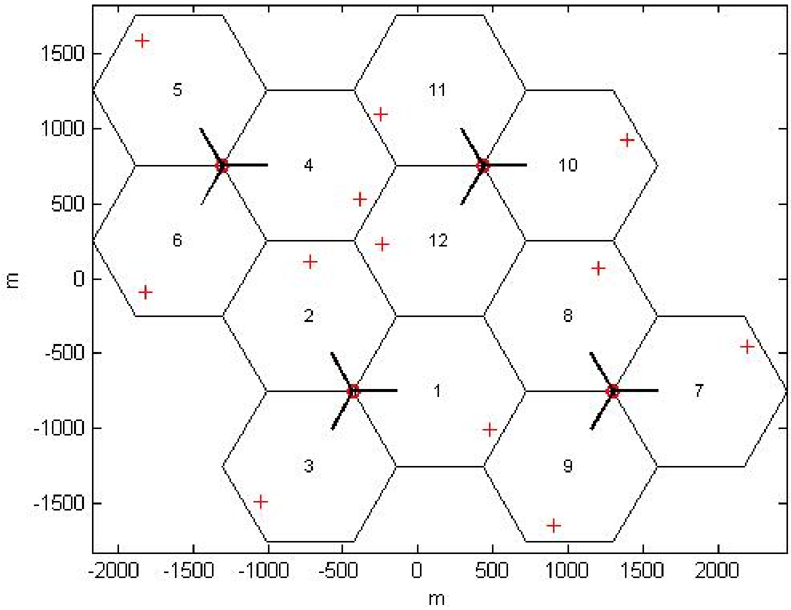

Figure 2.3: *Scenario with RSs.*

2.2.3 UEs Distribution

Another point very important is the UEs distribution. The distribution used for the simulations is 12 UE per cell, with a total of 144 UE in the system as can be shown in the figure 2.4 where the UEs are represented like blue asterisk. This distribution have been by this way in order to have the same conditions in each cell.

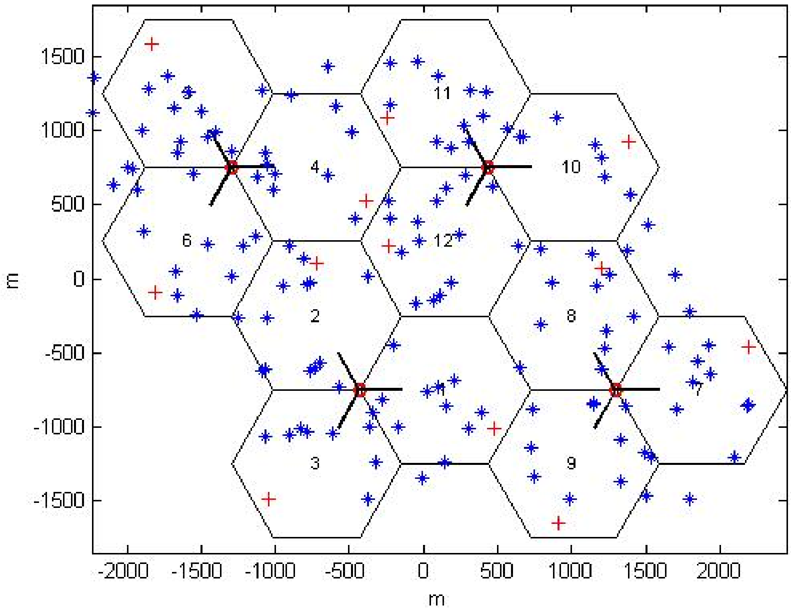

Figure 2.4: *Scenario with UEs dropped*

One problem with the distribution was that RUNE drops the UEs in random positions. Thus, it have been necessary to check the distribution of UEs was the correct and remove the UEs not necessary in order to drop more UEs until the distribution was correct.

2.2.4 Antennas

The simulator has two different kind of anntenas as have been mentioned before. Each kind of anntena corresponds if the station is BS or RS. Following the 3GPP-LTE specifications [4], each site are composed by three cells where the antenna used is a sectorial antenna (120). The antenna pattern of BS is defined by the equation 2.1 considered in 3GPP-LTE.

$$A(\Theta) = -min[12(\frac{\theta}{\theta_{3db}})^2, A_m] \tag{2.1}$$

where:

A_m	- 20dB
θ_{3dB}	- 70^o

The radiation pattern of RS is omnidirectional with a gain of 6dB according to 3GPP-LTE specifications.

2.2.5 Thermal noise

One aspect considering in the simulations is the Thermal noise. This noise is defined by the equation 2.2

$$N_{thermal} = 4kTB \tag{2.2}$$

where:

$N_{thermal}$	- Thermal noise
k	- Boltzman constant
T	- Temperature
B	- Bandwitch

2.2.6 Fading

The effects of channel considering in the thesys are three: Path-loss, shadow fading and fast fading. The path-loss and the shadow fading are used to assign the BS which the UEs will be connected. However, the path-loss and the shadow fading are process very different.

In first place, the path-loss is a deterministic process which depends on some variables. However, the shadow fading is a process which follows random variables. The another effect is the fast fading which consider in order to obtain the SINR or CQI.

About the path-loss, there are two different propagation models depending if the UE is connected to BS or RS. The equation 2.3, define the path-loss and the values for the propagation models can be seen in the table tb-ph. Furthermore, it is including a factor of penetration loss.

$$P_{loss} = A + 10K \log_{10}(d) \tag{2.3}$$

Propagation model	A	K	Penetration Loss
UE-BS	-15.3 dB	3.76	-20 dB
UE-RS	-30 dB	3.67	-20 dB

Table 2.2: *Propagation models.*

In RUNE, the shadow fading is determinated by parameters which simulate a scenario with differents objects that cause the shadow and the fading of the signal. In the table 2.3, can be seen the values for these parameters and in the figure 2.5 how this shadow fading influence in the scenario.

Parameters	
Lognormal fading on the links between the stations and one UE	0.5
Distance until the correlation in the map decreased to 1/e[m]	100
$\sigma \quad UE - BS[dB]$	8
$\sigma \quad UE - RS[dB]$	10

Table 2.3: *Shadow fading parameters*

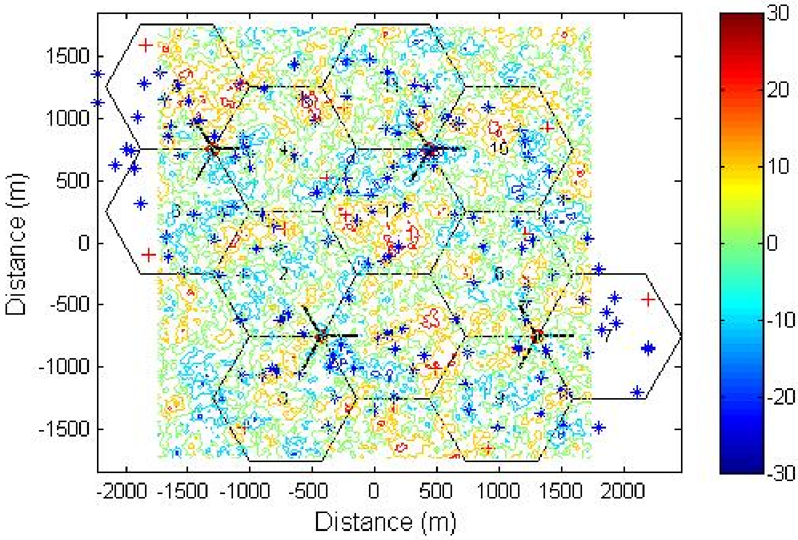

Figure 2.5: *Scenario with Shadow fading - 8dB*

Finally, the fast fading have been implemented using a variable H which represent the frequency domain channel in a frequency resolution of 180kHz and time resolution of 0.5ms; hence the file represents the frequency domain channel over 9MHz and 2.5s. The UEs is indexing in different positions of time and when the UEs came to the end of the variable, the next position in time is the beginning of the variable.

The values of the variable H containts complex numbers that represent the gain at that particular frequency. The power gain for a frequency in a determinate instant of time is the value in position multiply by its conjugate. For including this fast fading only is necessary to multiply the value of path-loss and shadow fading with this power gain.

Finally, to comment that this variable H was provide by my supervisors.

2.2.7 Transmission Power

This section explain how assign the transmission power of UE through a mechanish of power control. The role of the power control becomes decisive to provide the required SINR, while controlling at the same time the interference caused to neighboring cells. This is the target of the Fractional Power Control (FPC) algorithm lately approved in 3GPP. [5].

In our case, the study is realized for Uplink and the LTE Uplink Fractional Power Control is determinated by the equation eq-pc The name and value of parameters can be seen in the table 2.4.

$$A(\Theta) = min[P_{max}, P_0 + 10\log_{10} M + \alpha L] \tag{2.4}$$

where:

P_{max}	Maximun transmission power of the mobile
P_0	Initial power parameter
M	The number of resource blocks (channels) used by the mobile
α	Path loss correction factor
L	Path-loss measured in the UE

Parameters	
$P_{max}[dbm](UE)$	24
$P_0[dBm]$	-58
α	0.6

Table 2.4: *LTE Uplink Fractional Power Control Parameters*

2.2.8 Channel allocation

This is one of more important point of this thesys and this section explain how the spectrum of frequency is divide and how assign each resource block to each UE.

Firstly, the bandwitch of the system is 10 MHz divided in 50 channels (each channel have a bandwitch 180 kHz). As the study is realized for Uplink, following the 3GPP-LTE specifications the channels which use the UEs must be together. By this way and as in the simulations there are 12 UEs per cell, the spectrum will be divided in blocks of 4 channels in order to have 12 resource block (48 channels) and 2 channels will be used for other functions. Therefore, the channels 1 to 4 correspond to resource block 1, the channels 5 to 8 correspond to resource block 2 (this way until 12 resource block)...

In the beginning, there is a static channel allocation which will be modificated only one part of it. As the study is realized only for one cell, the channel allocation only for the UEs of the cell which is studied and the channel allocation will remain constant for the rest of UEs in each TTL.

During the simulations, the scheduling of resource blocks will be realized each TTL and the way to make the schedule is with a algorithm called *matrix algorithm*.

The first step is to build a matrix which saves certain values (metric) for each UEs and each resource block (12 UEs by 12 RBs). The next steps are,

1. Find the the highest metric and select the UE and RB where is.
2. Schedule the RB to the UE
3. Delete the row (UE) and column (RB) where is the highest metric
4. Came back to point 1 with the resulting sub-matrix

This approach provides a significant gain over a static scheduling (like a random allocation) **??**

The metric used in this thesis for the algorithm matrix have been Time-Domain Proportional Fair (TD-PF) which is obtained from this equation 2.5

$$P_{i,j}[n] = \frac{r_{i,j}[n]}{T_i[n]} [\textbf{?}] \tag{2.5}$$

where:

$P_{i,j}[n]$	- Metric of UE 'i' in the channel 'j' in the instant 'n'
$r_{i,j}[n]$	- Shannon CQI of UE 'i' in the channel 'j' in the instant 'n'
$T_i[n]$	- Average delivered user throughput in the past

The CQI is calculated from the equation 2.6, and the Shannon CQI from the equation 2.7.

$$CQI = \frac{G}{Noise + Interferences} \tag{2.6}$$

where:

CQI	- Channel Quality Indicator
G	- Gain of the signal between UE and the BS o RS
$Noise$	- Thermal noise
$Interferences$	- Interferences with others UE that transmitted in the same resource block

$$CQI_{shannon} = B \log_2 1 + CQI \tag{2.7}$$

where:

$CQI_{shannon}$	- Shannon Channel Quality Indicator
CQI	- Channel Quality Indicator
B	- Resource block Bandwitch (4x180kHz)

The Shannon CQI is used instead that CQI in order not to give more preference to resource block with a high CQI.

The average throughtput is based on transmitted and the equation 2.8 define how calculate it.

$$T_i[n] = Th_i[n]\frac{1}{\tau} + T_i[n-1](1 - \frac{1}{\tau})[6] \tag{2.8}$$

where:

$Th_i[n]$	- Throughput of the UE 'i' in the instant 'n'
τ	- Time constant of the smoothing filter (100ms)

The throughput is calculated from this equation eq-th using the SINR which is derived from the equation 2.10

$$Th = B \log_2 1 + SINR \tag{2.9}$$

where:

Th	- Throughput
$SINR$	- Signal Interferences Noise Ratio
B	- Resource block Bandwitch (4x180kHz)

$$SINR = \frac{PG}{Noise + Interferences} \tag{2.10}$$

where:

$SINR$	- Signal Interferences Noise Ratio
P	- Transmission Power of the UE
G	- Gain of the signal between UE and the BS o RS
$Noise$	- Thermal noise
$Interferences$	- Interferences with others UE that transmitted in the same resource block

2.3 Simulator's Algorithm

In this section, the simulator's algorithm used to generate the results will be described. This algorithm is divided in 2 parts.
The first part consists in to distribute the UEs throughout the scenario. As was discussed before, the number of UEs per cell will be 12 in both scenarios where in the scenario with Relay, 8 UEs will be connected to the BS and 4 UEs to the RS. The assignment the BS to UEs is realized according to the path-loss (including the shadow fading) between the UEs and the different BSs.
The second part consists in simulate during a period of time (6000 TTL) and to derive

different parameters like SINR or the throughput according a radio resource management based on PF-TD for each TTL.

The steps for this algorithm are,

1. Generate the scenario and the different variables used in the simulations
2. Drop the UEs in the scenario
3. Choose the best source (BS or RS) for each UE
4. Check if the distribution UEs is correct
5. If the distribution UEs is not correct, remove the UEs that are not necessaries (excess the number of UEs connected to BS or RS).
6. Return to the point 2 until the distribution UEs will be correct.
7. Select the UEs of the cell which will analyze.
8. Obtain the transmission power of the UEs
9. Establish a default channel assignment; later this assignment will change only for the UEs belong to the cell studied.
10. Generate the indexes for each UEs in order to use the variable H for fast fading.

    The next steps correspond to the second part which is a loop of 6000 interactions (time of simulation).

11. Derive the CQI for each UE in each channel.
12. Calculate the average CQI in blocks of 4 channels for each UE.
13. Derive the SINR, the throughput and the Shannon CQI for each UE.
14. Obtain the average delivered user throughput which is necessary to apply TD-PF
15. Derive the metric TD-PF

16. Apply the matrix algorithm with the metric TP-PF in order to schedule the radio resource.

17. Refresh the indexes.

18. Came back to step 11.

2.4 Verification

In this section is checked the good behaviour of the simulator. To do show, various simulations for different cases.

For the case download link, there will not be RSs and the sum of gains will be the sum of all gain between the UE and the rest of BS (sum of the all row values least the higher value of the row). There are 144 mobiles stations which are connected to base stations in group of 12 UEs per each BS (4 channels per UEs).

The value of Pmax used is 20 Watios. Furthermore, I have realized 2 different simulations with values of P_{max} 1W and 50W to compare the results. This results can be checked in the figures 2.6, 2.7.

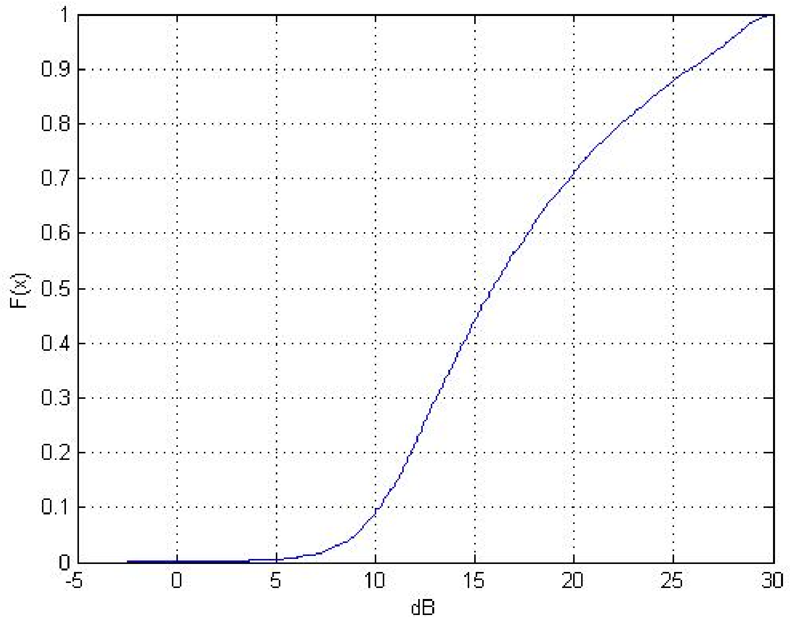

Figure 2.6: *Downlink SINR* ($P_0 = 20\ W$).

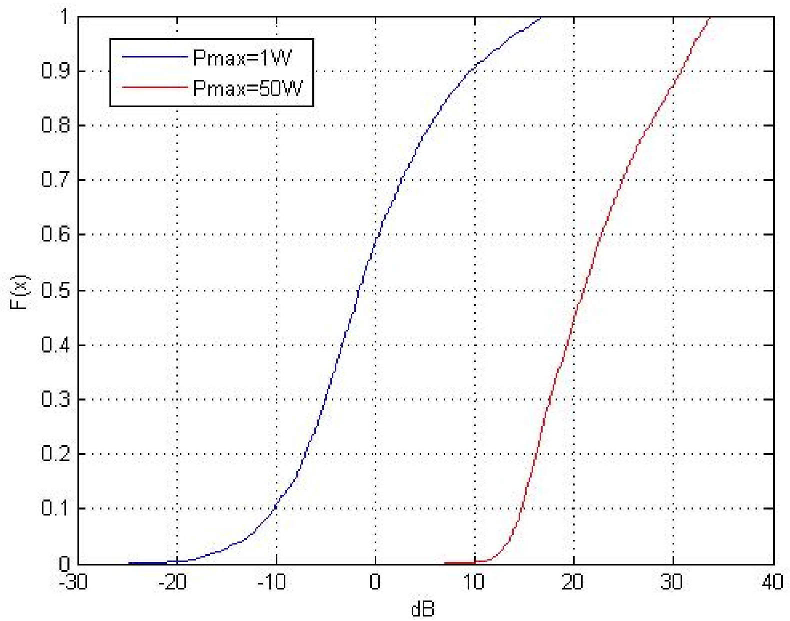

Figure 2.7: *Downlink SINR with different values of* P_{max}.

For the case upload link, there will be 2 cases: one without RSs and one with RSs. The value of the variable Po used is determinate by LTE uplink Fractional Power Control Formula. Without RSs (same number of UEs than the before case), the cdf will have the next shape as can be seen in the figure 2.8.

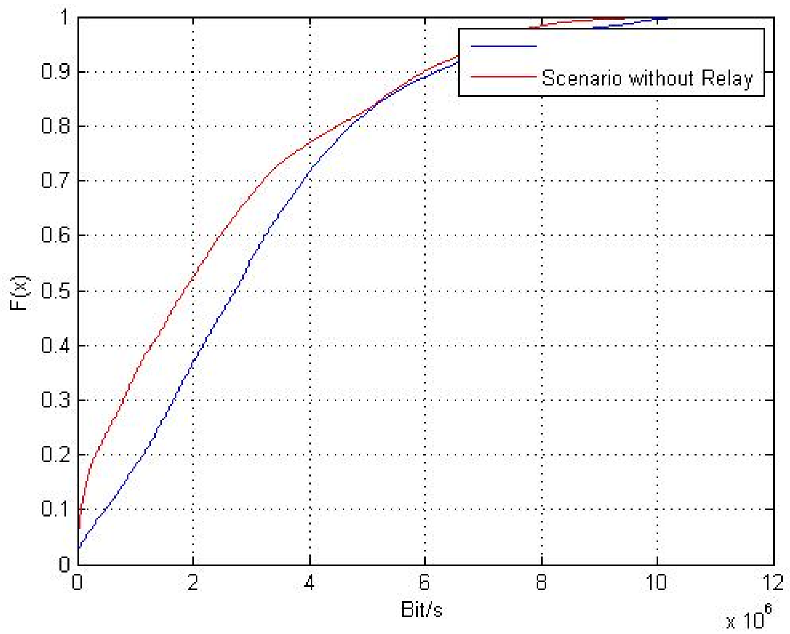

Figure 2.8: *Uplink SINR without RSs.*

The sum of gains in the equation in order to calculate the SINR is the gains of all UEs except the UEs of the same cell which the mobile station which is calculated the SINR (reuse factor 1).

Furthermore, another interesting is the figure 2.9 is the cdf of SINR of mobile stations connected to BS and the cdf of SINR of mobile stations connected to RS and compare both curves. The number of UEs connected to relay station is 4 per RS (one resource block per UE), so the number of UEs connected to BSs will be 8 (4 resource block per UE).

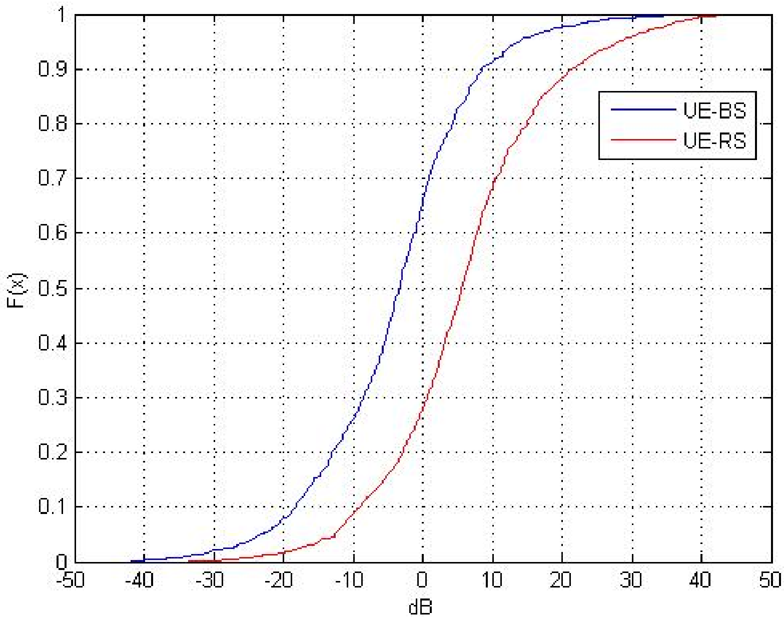

Figure 2.9: *Uplink SINR.*

Finally, the figure 2.10 is the cdf of SINR of whole UEs of the system,

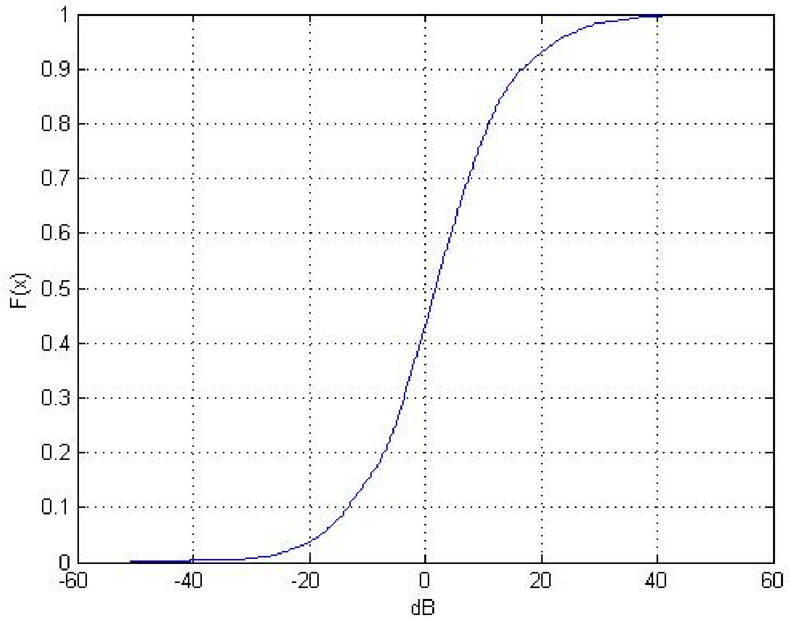

Figure 2.10: *Uplink SINR.*

In this figure, it is painted the cdf for a configuration upload link with relay. The values represented are the SINR of UEs connected with BS and RS. In the moment to calculate the SINR, the interferences considered in the sum of gains are the gain of all UEs (including UEs connected with RSs) to the BS which the UE is connected except the UEs of the same cell (including RS of the same cell).

Chapter 3

Results

In this chapter the results are descripted and in the next chapter they will be disscused and analyzed. The results shown compare the system without RS with the system with RS using a centralyzed radio resource management. The aspects disscussed are the transmission power to be used by the UEs, the SINR of the UEs, the CQI of the UEs in the channel that are used to transmit, the throughput (in the cell as for each user) and how and how often the mobile users change to channel.

To obtain these results, ten simulations were done and each simulation had a duration of 6000 TTL (6000 ms). Furthermore, in each simulation was considered the aspects mentioned in the preceding chapters like the scenario, UEs distribution...

On the other hand, the results obtained belong to only one cell but considering that the channel effects and interferences of the rest UEs belong to others cell and considering the channel allocation constant in the rest of cells.

3.1 Transmission Power

One aspect analyzed in this project is the Power's Distribution of UEs when they are transmitting. The power control mechanisc used is the Open-Loop Power Control which can be implemented through one formula which was explained in previous chapter.

The results obtained in the simulations are shown in the next figure 3.1, where the transmission power of UEs in the scenario with Relay is lower that one in the scenario without Relay since the transmission power depends on the path-loss. The path-loss in the scenario with Relay is lower because the UEs close to the edge of the cell are connected to the Relay which have a lower path-loss like was shown above.

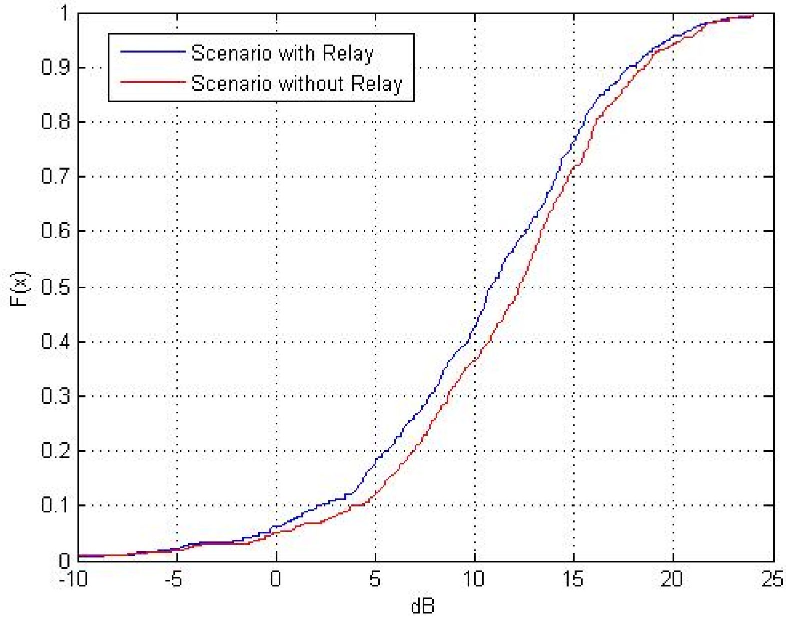

Figure 3.1: *Transmission power*

Throughput and SINR

And as well know, the throughput is based on statics interference+noise ratio (SINR). The results of SINR for each UEs in each TTL for both scenarios can be seen in the figure

3.2. Furthermore, throughput for each UEs in each TTL is compared for both scenario as shown in the figure 3.3 and, the average and total throughput in one cell for each TTL in the figures 3.4 and 3.5

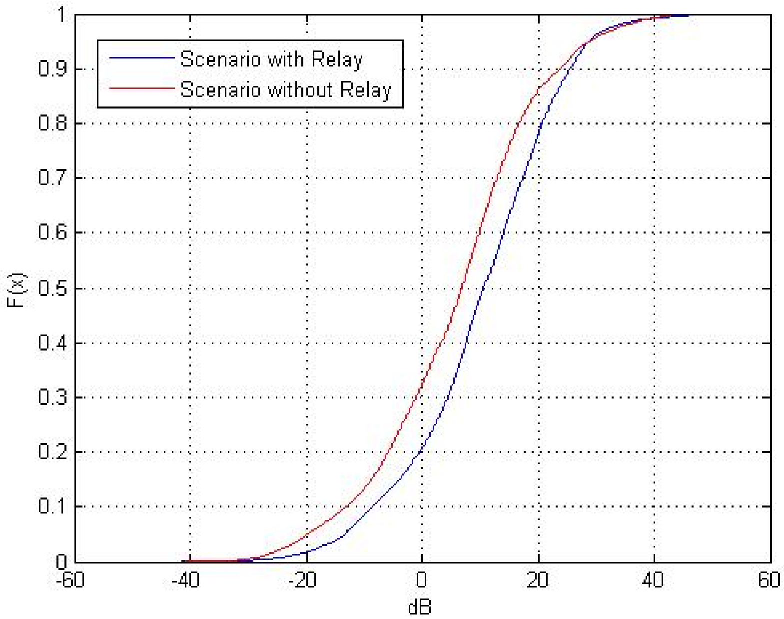

Figure 3.2: *UEs SINR*

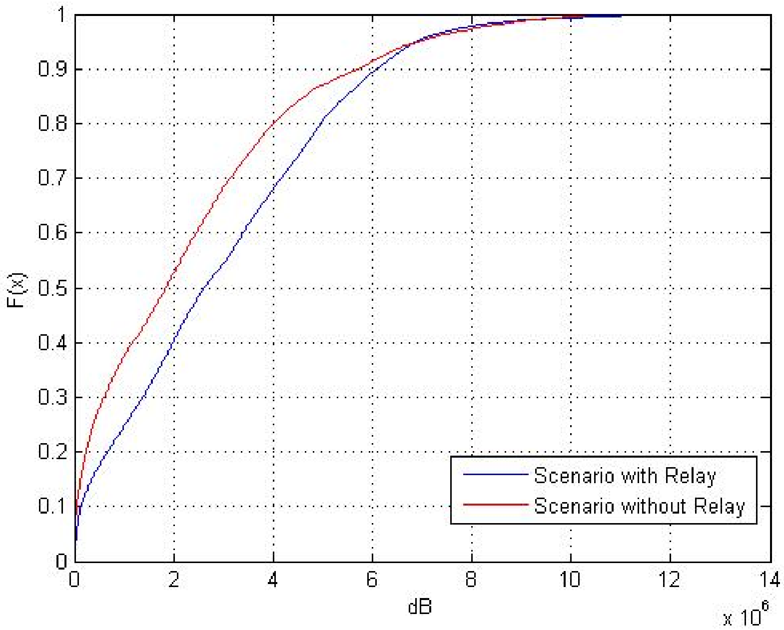

Figure 3.3: *UEs Throughput*

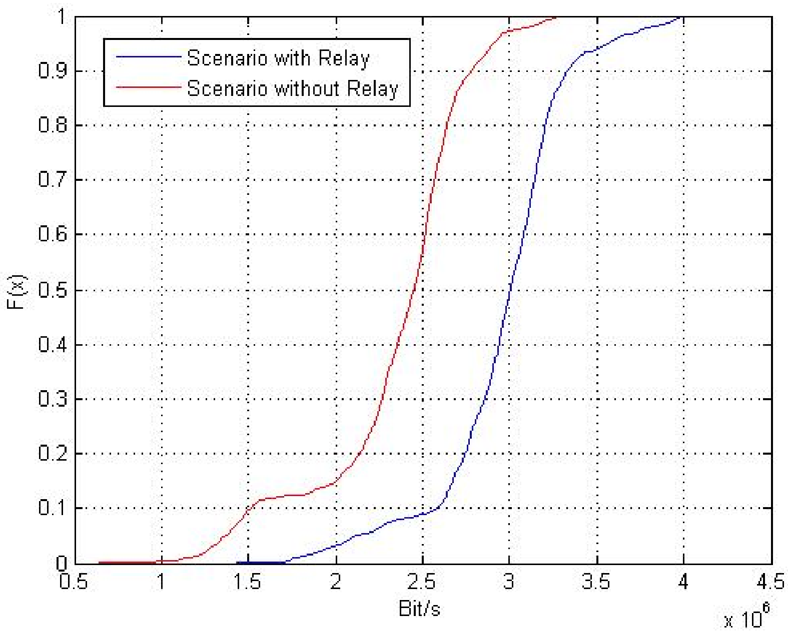

Figure 3.4: *Average Throughput UEs in the cell*

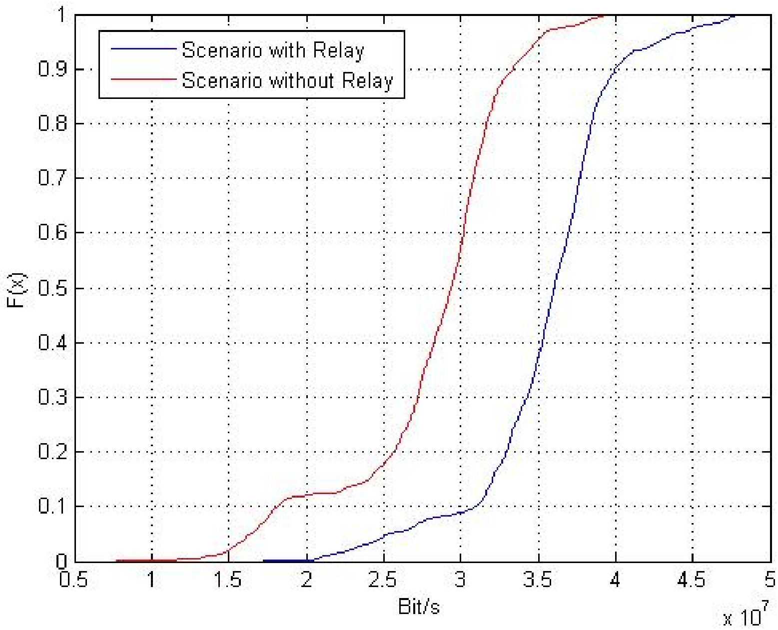

Figure 3.5: *Total Cell Throughput*

The SINR is determinated by the equation explained in the chapter 3. In the figure 3.2 can be seen that the scenario with Relay there is a higher SINR caused by the UEs connected to Relay since they have a lower path-loss. The througput depends on the SINR and as can be seen in the figures 3.3, 3.4, 3.5 the throughput in the scenario with Relay is higher than the scenario without Relay for the reason that the UEs in the scenario with Relay have a higher SINR.

3.1.1 CQIs

The Channel Quality Indicator is a parameter very useful since is used to schedule the radio resources of the system. Its way to calculate is very similar to SINR, however in this case the transmission power is not included. The figure 3.6 presents the CQIs for each UE studied in each TTL in the channel assigned to transmit.

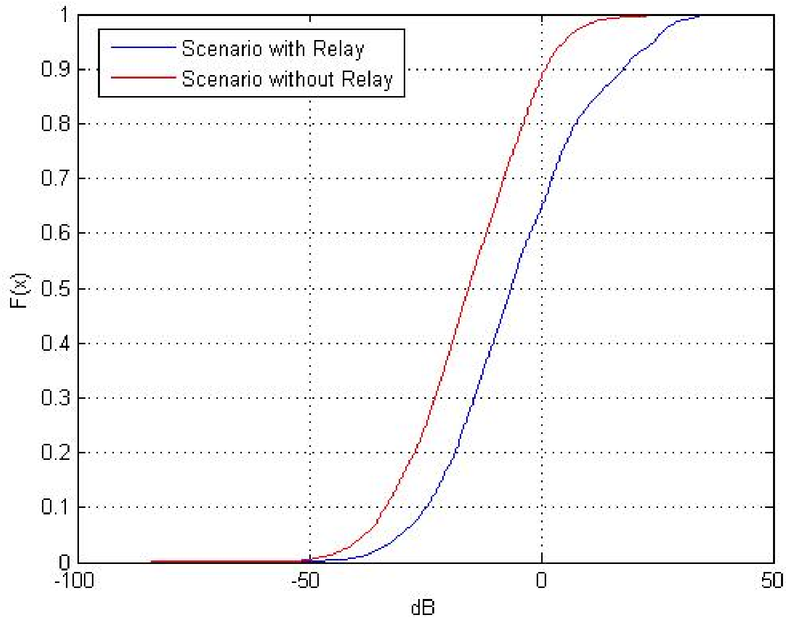

Figure 3.6: *CQI UEs*

As it can be observed, the shape of the figure 3.6 looks similar to the figure 3.2 because, as it was mentioned above, the way to obtain both parameters is very similar.

3.1.2 Scheduling

In this section, it is analyzed how often the UEs change to channel during the simulations. This result is shown in the figure 3.7. The way to assign the channel blocks is based on the matrix algorithm explained in the previous chapter which use a metric based on TD-PF as is also explained in the same chapter.

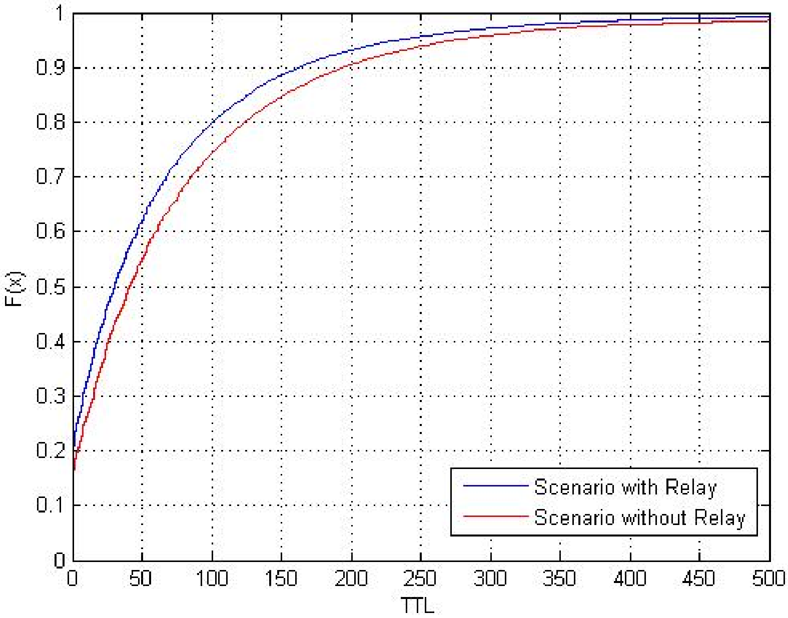

Figure 3.7: *Scheduling changes*

Chapter 4

Conclusions

This chapter summarizes the results generated in the simulations. In this thesis, several aspects of systems implementing a Relay enhanced LTE network with a centralized radio resource management are are studied and various of the advantages are described.

4.1 Conclusions

The use of Relay can improve many aspects in a LTE network. On the one hand, the first aspect considered is the transmission power of UEs. As can be seen in the previous chapter, the scenario where Relay is deployed, leads to a lower transmission power by the UEs. Nowadays, the UEs have a high consume of battery due to the applications and services more complex that modern communication network provide. Therefore, relaying is very attractive solution because it can prolong the battery lifetime for UEs by means of reducing the transmission power.

Another aspect studied is the throughput. In chapter Results is shown as the scenario with Relay provides a higher throughput per UE and consequently an overall throughput gain in the cell as can be seen in the figures. This higher throughput is generated by better values of SINR since the throughput depends on the SINR. Furthermore, the values of CQI is better too in the scenario with Relay which indicates that the quality in the channels of the scenario with Relay is better. However, these values already are only used for radio resource management and the real indicator of the quality is the SINR. As is written above, the UEs use services more complex that need higher throughput than before and this higher throughput is necessary in all areas of the cell. In areas close to the edge of cell or area where there are building that generate shadowed areas, the use the relay is very beneficial because it improves the throughput for theses UEs as can be seen in the results where the low margin of the figure (20% to 0%) is very different between the scenario with Relay and the scenario without Relay.

In all figures, the low margin in the figures is very different between the both scenarios. However, the higher values in the figures are very similar between both scenarios because these correspond to UE which are close to the BS. The reason because the low values are better in the scenario with Relay is due to the UE in the scenario without Relay are in positions where there are strongly shadowed or are far away to the BS and, thus, experiment a high path-loss. Therefore the UEs connected to the Relay have better conditions than the these UEs without Relay thanks to the propagation model of the UE-RS. In summary, the use the Relay can provide a high-bit-raye coverage in high shadowing environments. In consequence, another important aspect is that enhancing the cell capacity and effective throughput as can be seen in the figures too.

Finally, to comment that the system with Relay have least change of channel between UEs. It provokes that the waste to change of channel will be lower and can use the resources of change of channel in other aspects.

4.2 Future works

Between the future works that is possible to carry out and to study, it can be mentioned various of them. One aspect important to analyse would be the study of radio resource management in a decentralized case and to compare it with the case centralized. By this way, compare both radio resource management would be able to know which is the best configuration of the Relay in the moment to assign and allocate the channel to the UEs.

Another interesting work would be the study of a scenario more realistic with mobility and Relays because the mobility would influence in certain aspects negatives. With mobility would be important to study new methods to realize handover and to study the effects of channel that provoke this mobility.

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