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Evaluation of the performance of the network while using ABS, and with an optimized ratio of ABS that is proposed

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Abstract

The enhanced Inter-Cell Interference Coordination (eICIC) in heterogeneous networks introduced in LTE-Advanced solve the problem of intercell interference, which become a challenge. Since the resources of wireless network are limited due to the limitation on the spectrum and limited frequencies that is distributed on the network which limit the resources. URBAN coverage have a standard scenarios parameter that offered from ITU, each scenario covers a grid with x and y distance area and a well-defined power, frequencies range, and distance between network elements (Femto, PICO and Micro cells), so intercell interference problem exist and requires an enhancement technique two method are proposed to solve the problem the eICIC in time domain almost blank sub frame (ABS) and the reduced power almost blank sub frame (RP-ABS). The aim of the project is to develop an adaptive time domain intercell interference (A-eICIC) reduction methods that enhance the represented in ABS and RP-ABS. therefore The time domain eICIC was selected then a simulation was done using MTALAB 2016 was done in order to evaluate the performance of the two methods. An evaluation between these techniques were done in term of QoS parameters such as (delay, SINR, Spectral Efficiency, Throughput and outage probability). And it was found that the reduction of the A-eICIC is efficient compared to the ABS by 23% for all of the results obtained.

Keywords: Almost Blank Subframes (ABSF), Reduced Power Almost Blank Subframes (RP-ABSF), LTE-A, eICIC, intercell interference coordination.

PREFACE

Long term evolution "LTE" is the standard that the "3GPP" invented to be an evolution of "UMTS". With the Long term evolution "LTE" a higher throughput and lower latency is offered compared to the "UMTS" due to the larger dedicated spectrum used in Long term evolution "LTE". LTE are upcoming the theoretical limitations in terms of spectral efficiency. Subsequently spectrums become a rare resource today, new developed ways must be found to improve the network performance.

The heterogeneous networks method consists of accompanying the Macro layer with low power nodes such as "Micro" or "Pico" base stations. This method has been reflected a path to improve the capacity and data rate in the coverage area by these low power nodes; they are spread based on the areas that generate higher traffic. As known that cell selecting of users mainly based on the "Downlink-Power- Level". Mainly the transmitting power differences between "Macro" and "Pico" nodes, "Pico" nodes might be underutilized, that's mean a low number of users are attached to the "Pico" nodes compared to "macro" node. To solve the problem an offset to the received power measurements used in selecting the cell increasing the number of users to join the "Pico" nodes, and it's called "Range Extension" which represents the "Extended-Coverage-Area" of the "Pico" nodes.

Mobile broadband traffic has been rising very fast through the earlier few years; it exceeded voice traffic and is predictable to produce much faster in the upcoming years. This development mainly provided by a new network services and the development of terminals capabilities. Yearly traffic is expected to double yearly during the next years so that by 2020 the average user traffic will exceeds "1GB" of data monthly compared to "100" or "200" MB in this days [5]. The mobile industry has been determined to improve data rates indoors and outdoors to be able to meet the development of mobile services.

The enhanced Inter-Cell Interference in heterogeneous networks is the main problem reducing the network performance, the "LTE-A" develop a new methods to enhance the intercell interference through a method called enhanced intercell interference coordination, which comes with time domain type and support two methods inside the "Almost-Blank-Subframes" "ABSFs" and can be described as a portion of Enhanced Inter-Cell Interference Coordination "eICIC" framework [1] that the 3GPP members have developed [2] as incomes to combat excessive co-channel cross-tier interference in heterogeneous network "HetNet" scenarios. "HetNet" scenarios are mainly "Cellular-Network-Scenarios" that cover diverse types of "low-power-nodes", such as "base-stations", "relays" or "remote-radio-heads", as driven to the regular "Macrocell-Tier". "HetNet" scenarios that are definitely targeted to advantage from "ABSFs" are mixtures of "Macrocells" with near access "Picocell" ("Macro/Pico") and "Macrocells" with open access "Picocells" ("Macro/Pico") [3].

Ever increasing multimedia services make telecom operator to use the spectrum more aggressively. By doing aggressive utilization of the spectrum turns out an enhancement of inter-cell interference (ICI) in the network which creates traffic jam in telecommunication network infrastructure. Allocation of the same frequency in neighboring cells deteriorates the performance of ICI. When this is the case, network designers are required to analyze the behavior of ICI so that they can better quantify the network performance for real-time applications such as video conferencing traffic and proper resource optimization.

Problem Statement

Due to the limitation of the resources on mobile network and the problem of sharing the resources between network elements, the spectrum sharing, bandwidth and sub channel frequencies that is used around the network with a synchronization methods and rules, many methods was developed to enhance the network by reducing the intercell interference that may occur while the mobile is signaling between PICO and Micro cells, developers indent to resolve the problem by using eICIC time domain solution which is represented by almost blank subframes (ABS) and reduced power blank subframes (RP-ABS), researchers focus on evaluating the performance of these two methods. In this research an adaptive power optimization will be applied to solve the problem of expanding the tire among the PICO cell without interfering the Micro users.

- The high power of the macro cell affects the pico users and the user equipment becomes a victim
- ABS reduces throughput on the RP-ABS network
- The high power of the Pico cell can interfere with users of the macro cell Tire expansion requires high power on the part of the Pico

Aims and Objectives

- Analysis of the network while using several Bandwidth settings and number of users.
- Improve network performance "increasing throughput" and "load balancing" using optimized number of ABS "Dynamically depends on the network condition".

Contribution

Analysis will be done on cell range expansion to find the optimal number of ABS while expanding tire of Pico Cell.

Methodology

Urban is a geographical area that represent the coverage of the mobile network, the scenarios of picking the places of the Macrocells, PICO cells are related to ITU standard, including the antenna height, transmission power and the coverage area that are aimed so many interference scenarios can be analyzed based on the distance between nodes, estimated number of users, the core network features and configurations. All of the scenarios includes a problem of intercell interference which requires to be enhanced using enhanced intercell interference coordination eICIC in time domain as a reference taken for this study that includes two methods the almost blank subframe (ABS) and the reduced power almost blank subframe (RP-ABS). in this research one of the interference scenarios was chosen to examining the new adaptive enhanced intercell interference regarding the ITU standard “Standard parameters such as distance between PICO and MICRO cells, coverage area, bandwidth, antenna height and etc.”. Matlab 2019 a was used to simulate the scenario and emulate the processing of the network in order to evaluate the performance of the network while using ABS, and with an optimized ratio of ABS that is proposed

Simulation Scenario

The simulation will cover a scenario of standard 3GPP and ITU standards for configuring a Macro cell that have coverage of several Micro cells and Pico cells, the scenario covers the antenna used, antenna height, modulations techniques, transmission power, number of resource block that depends on the bandwidth of the system.
Assume there are total N microcells in the network and each microcell is served by an eNB. A number of Pico cells are randomly distributed in entire network. The UE which is located outdoor and served by macrocell eNB is referred as MUE while user equipment which is located outdoor and served by Pico cell. “HeNB” is referred as PUE (Pico cell user equipment).

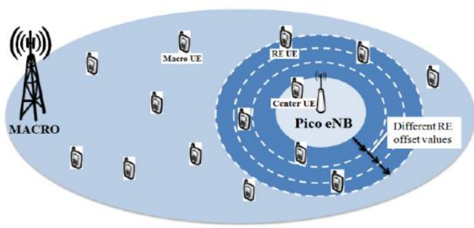

Figure 1: Macro - Pico Scenario with different RE values

The scenario has parameters settings including the minimum value of inferences to the maximum value of inferences, and the noise value which effect the signal, also the minimum signal gain with the maximum signal gain was set in the simulation.

For the modulation technique the QAM was chosen with a different code rate and modulation order, packet size and the number of users is included. And mainly the number of subframes and frames initially used the number of radio frames and the bandwidth for the simulation is a range from 1.3 MHz to 20MHz.

The system starts with setting the number of micro cells in the simulation then setting the number of Pico cells in the simulation based on the ITU standards, the standards of ITU give an exact interference distance that may occur in the scenario, then according to the standards of LTE-A the SINR has a unique value which is the optimal for the network, thus a comparison between the SINR in a specific simulation time is compared to the target to initialize a communication between the Micro cell and Pico Cell through x2 interface to start using the reduced power ABS.

Mathematical Model

Taking into consideration easy setup having a 1 cell network with the subsequent features:

This cell contains 1 Macro-eNB and assured number N_{pico} of Pico- eNBs. The Pico-eNBs are randomly distributed in the cell.

a. The users are randomly distributed throughout the cell area.
b. All Pico-eNBs have the same number of users in the range extension area.
c. If consider a channel model that is only impaired by additive white Gaussian noise (AWGN) and interference, then the (c) capacity will be according to the following equation

$$u_c = \frac{Number\ of\ Subframes}{Number\ of\ Users} * BW \log_2(1 + \|h_c\| SINR_c) \qquad 1$$

Number of subframe is supposed to be 1.

Next notation will be used in the deduction.

- Cell selection is founded on a downlink reference signal power the users attached to Macro-eNB (N_m) have a higher downlink power coming from the Macro-eNB than Pico- eNBs.

- While center Pico-eNB users (N_{p-c}) receive a reference signals from Pico-eNB with a higher power than a signals coming from Macro-eNB.

- for range extension Pico-eNB , users (N_{p-re}), although they receive reference signals from Macro-eNB with a higher power but due to a range extension offset, these users are attached to Pico-eNB. So using the above notation the capacity for the users attached to a different nodes can be formulated as follows starting by u_m the Macro-eNB user capacity in equation (2).

$$(u_m)_c = \frac{1}{N_m} \log_2(1 + \|(h_{m-ue})_c\|^2 (SINR)_m)_c)(1-\alpha) \qquad 2$$

$$(u_{p,c})_{c,k} = \frac{p_m}{N0 + p_p \sum_{k=1}^{N_{pico}} \|(h_{p-ue})_{k,c}\|^2} \qquad 3$$

Users capacity in equations (2), (3) and (7) as a function of α, by selecting one user from every group (Macro, center Pico also range extension Pico) then specifying values for the different parameters (channel gains p_m, p_p, N_m, N_{p-c} *and* N_{p-re})

-To find maximize cell edge users capacity should to know the intersection oint between a lowest range extension capacity corresponding to a range extension user having lowest capacity -also a first line intersects with which lowest Macro-eNB or center Pico-eNB user capacity Can define the intersection point, which is basically found by a search over α , with the following criterion:

$$min\{(u_m)_c(\alpha),(u_{p-re})_{c,k}(\alpha)\} = (u_{p-re})_{c,k}(\alpha) \quad 4$$

this situation will not consider the center Pico-eNB capacity line therefore only focus on the range extension also Macro-eNB users as in actuality center Pico-eNB users are not affected by the ABS ratio, but here assume that center Pico-eNB users are only allowed to transmit during non-ABS to make the scheduler simpler and giving the Macro-eNB user and Pico-eNB range extension user the same chance to be scheduled.

Will indicate a Macro-eNB user having a lowest capacity by user "m" having the following capacity

$$(u_m)_m = \frac{1}{N_m} log_2(1 + \|(h_{m-ue})_m\|^2 (SINR)_m)_m)(1-\alpha) \quad 5$$

$$(SINR_m)_{m,m} = \frac{p_m}{N0 + p_p \sum_{k=1}^{N_{pico}} \|\llbracket(h\rrbracket_{p-ue})_{k,m}\|^2} \quad 6$$

Will indicate a range extension user having a lowest capacity by user "n" and supposing that this user belongs to the k^{th} Pico-eNB with the following capacity

$$(u_{p-re})_{n,k} = \frac{1}{N_{p-re}} log_2\big(1 + (h_{m-ue})_{n,k}\|^2 (SINR)_{p-re})_{n,k}\big)\alpha \quad 7$$

$$(SINR_{p-re})_{n,k} = \frac{p_m}{N0 + p_p \sum_{k=1_{j\neq k}}^{N_{pico}} \|(h_{p-ue})_{j,n}\|^2} \quad 8$$

Intersection point can be acquired analytically by equating equations (7) and (.8) to find the optimum alpha that maximizes the cell edge capacity.

$$= \frac{1}{N_m} \log_2(1 + \|(h_{m-ue})_m\|^2 (SINR)_m)_m)(1-\alpha) \quad 9$$

Reordering the previous equation, the following equation can be considered optimal value of α to optimize the 0% worst user throughput.

$$\alpha = \frac{1}{1 + \frac{N_m \log_2\left(1 + \|(h_{p-ue})_{n,k}\|^2 (SINR)_{p-re})_{n,k}\right)}{N_{re} \log_2(1 + \|(h_{m-ue})_m\|^2 (SINR)_m)_m)}} \quad 10$$

Since the m^{th} Macro-eNB user capacity is given by eq. (11) so considering that only this Macro-eNB user gets all the resources all the time then the capacity would be given by the following expression, i.e. putting the number of users to 1 in equation 2

$$(u_{macro-max})_m = \log_2(1 + \|(h_{m-ue})_m\|^2 (SINR)_m)_m) \quad 11$$

Which can call the maximum Macro-eNB user capacity, so $(u_{macro-max})_m$ is the same as $(u_m)_m$ but only assuming that the Macro-eNB is only serving this user m, this is why it is called $(u_{macro-max})_m$Because is the maximum capacity that this user can reach. And doing the same for the n^{th} range extension Pico-eNB user

$$(u_{re-max})_m = \log_2\left(1 + \|(h_{p-ue})_{p,n}\|^2 (SINR)_{p-re})_{n,k}\right) \quad 12$$

Then α can be expressed as

$$\alpha = \frac{1}{1 + \frac{N_m (C_{re-max})_n}{N_{re}(C_{macro-max})_m}} \quad 13$$

This equation can see that alpha depends on 2 factors:

1- The ratio between the numbers of Macro-eNB use to the number of range extension use per Pico-eNB.

2- The ratio between the maximum capacity of a range extension user $(u_{re-max})_m$ and maximum capacity of a Macro-eNB user $(u_{macro-max})_m$. Focusing on the second factor and trying to simplify starting with the maximum Macro-eNB user capacity

$$(u_{macro-max})_m = log_2\left(1 + \|(h_{m-ue})_m\|^2 \frac{p_m}{N0 + p_p \sum_{k=1}^{N_{pico}} \|(h_{p-ue})_{k,m}\|^2}\right) \quad 14$$

Since a noise value is very small can neglect it also assuming the value of p_m to be very large $\|(h_{m-ue})_m\|^2 p_m$ is much bigger than the term in the denominator then can approximate the previous equation to

$$(u_{macro-max})_m = \log_2\left(\|(h_{m-ue})_m\|^2 \frac{p_m}{p_p \sum_{k=1}^{N_{pico}} \|(h_{p-ue})_{k,m}\|^2}\right) \quad 15$$

most users attached to Macro-eNB are placed close, even some Macro-eNB users are placed very close to Pico-eNB due to the high transmission power of Macro-eNB but will consider only a user's closer to Macro-eNB, and assuming that the interference to these users is dominated by one or at most two Pico-eNBs while the rest cause negligible interference. Under this assumption can approximate the interference term $p_p \sum_{k=1}^{N_{pico}} \|(h_{p-ue})_{k,m}\|^2$ with a constant (I) since it is assumed to be independent on the number of Pico-eNBs and is dominated by the interference caused by the closest 1 or 2 interferer Pico-eNBs.

$$(u_{macro-max})_m = \log_2\left(\|(h_{m-ue})_m\|^2 \frac{p_m}{I}\right) \quad 16$$

Since$(u_{macro-max})_m$ is assumed to be independent on N_{pico} so it can be considered as a constant and can be denoted by l1. Now focusing on the second term which is $(u_{re-max})_n$.

$$(u_{re-max})_n = \log_2\left(1 + \|(h_{p-ue})_{k,n}\|^2 (SINR)_{k-n}\right. \quad 17$$

Inserting the SINR_3 expression

$$(u_{re-max})_n = log_2\left(1 + \|(h_{p-ue})_{k,n}\|^2 \frac{p_p}{N0 + p_p \sum_{k=1, j\neq k}^{N_{pico}} \|(h_{p-ue})_{j,n}\|^2}\right) \quad 18$$

Assuming that have a very large N_{pico} then N0 can be neglected, considering that $p_p \neq 0$, and the interference term in the denominator would be larger than the numerator so the previous equation can be approximated to

$$(u_{re-max})_n = \frac{\|(h_{p-ue})_{k,n}\|^2}{\sum_{k=1_{j\neq k}}^{N_{pico}} \|(h_{p-ue})_{j,n}\|^2} \quad (19)$$

Same mean value and u_{re-max} can be expressed as a final point

$$\frac{(u_{re-max})_n}{(u_{macro-max})_m} \approx \frac{l_2}{l_1 N_{pice}} \quad (20)$$

$$\alpha = \frac{1}{1 + \frac{N_m}{N_{re}} - \frac{l_2}{l_1 N_{pice}}} \quad (21)$$

$N_{re}{*}N_{pice}$ is equal to total number of range extension users that can be denoted by N_{re_total}.

Finally $\propto$ is expressed by

$$\alpha \approx \frac{1}{1 + \frac{N_m}{N_{re\_total}} - \frac{l_2}{l_1}} \quad (22)$$

That condition l_2 and l_1 assumed to be almost equal, now can $\propto_{opt}$ considered to simulations, to optimized value that gives optimal or suboptimal of $\propto$

$$\alpha_{opt} \approx \frac{1}{1 + \frac{N_m}{N_{re\_total}}} \quad (23)$$

$$\text{Finally } \alpha_{opt} \approx 1 + \frac{N_{re\_total}}{N_m} \quad (24)$$

That means ABS ratio $\propto$ is proportionate to the ratio between the numbers of users attached to Macro-eNB also total number of range extension users attached to Pico-eNBs.

Table 1. Descriptions and Symbols

Descriptions	Symbols
channel gain	h_c
signal to interference also noise ratio	SINR c
bandwidth is measured to be 1 Hertz	BW
user capacity	c
Macro-eNB transmission power	p_m
Pico-eNB transmission power	p_p
Channel gain from Macro-eNB to the user	$(h_{m-ue})_c$
Channel gain from the Pico-eNB to the user	$(h_{p-ue})_{c,k}$
number of user per Macro-eNB	N_{macro}
number of users per Pico-eNBs	N_{pico}
number of center Pico-eNB use per Pico-eNB	N_{p-c}
number of range extension use per Pico-eNB	N_{p_re}
Almost blank subframes ratio	α (Alpha)
noise in the system	N0
Capacity at Center Macro	Cm
Capacity at Center Pico	Cp-c

Number of Pico user Cells	K
Number of Pico Cells	n

Simulation Results

After finishing the mathematical model, and using Matlab to simulate the development on the performance metrics, the chosen metrics are: Signal to Interference plus noise ratio, Throughput, Spectral efficiency, Transmission delay, and Outage probability.

The results was obtained from a different configuration to the inputs, such as varying the power of the transmitted subframe and showing the results, variation on the number of Subframes and the effect on throughput results, testing the outage probability for both systems RP-ABS and ABS. moreover the Subframes delay time comparison which is a relation between the number of Subframes and the delay time in seconds or ms. The simulation covers some of the quality of service parameters.

The aim of the results is to obtain an analysis and discussion related to the results in order to evaluate the performance of the enhanced intercell interference method in time domain, nevertheless two method was compared the almost blank subframe and the reduced power blank subframe.

Signal to Interference plus Noise Ratio

The following figure represent the Signal to noise interference and noise ratio in db vs. Transmission Power in db, the x axes represent the transmission power and the y axes represent the Signal to noise interference the configuration of bandwidth was 1.3 MHz for figure 4.1a and 20MHz for figure 1

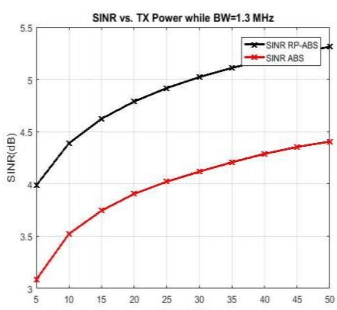

Figure 1: Compare SINR between RP-ABS and ABS while Bandwidth 1.3MHz

In Figure 1, RP-ABS method results in SINR improvement of an average around 7 dB over ABS method, where black line determines using RP-ABS and the red line ABS.

For the 20MHz bandwidth configuration the average difference is about 14 db the enhancement on the SINR was obtained from increasing the power and bandwidth for the two methods which reduce the noise effect, and the increasing of RP-ABS is due to the low power on transmission which is synchronized between the Macrocell and Pico Cell.

Throughput

The following figure represent the throughput of the system vs. number of Subframes, the x axes represent the number of received and the y axes represent the throughput while configuring the packet size is set to 512 in figure 2.

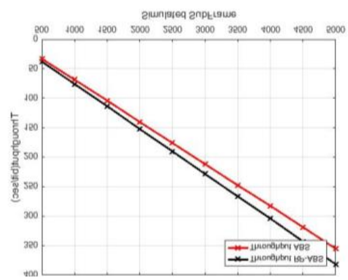

Figure 2 Comparison of Throughput RP-ABS scheme and ABS

The throughput shown in Figure 2 and figure 4.2b, in which black line determine the RP-ABS and the red line determine ABS scheme, increased by 7.5% than ABS due to the variation on number of bits that transmitted from RP-ABS and ABS while 1024 packet size. And it was increased while the packet size decreased due to the increased number of Subframes in reduced method that can handle the packet in less delay time.

Spectral Efficiency

The following figure represent the spectral efficiency of the system vs. number of users share the resources, the x axes represent the number of users and the y axes represent the spectral efficiency.

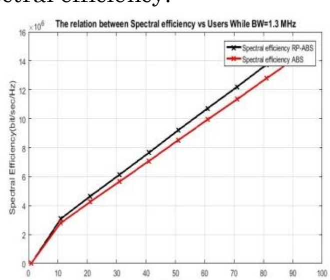

Figure 3: Compare Spectral efficiency between RP-ABS and ABS

The Corresponding to the increasing in the throughput by RP-ABS scheme lead to increase the Spectral efficiency as compared ABS 7.5%. Shown in Figure 3 while using 1.3 MHz bandwidth. The black line indicates to spectral efficiency RP-ABS and the red line for ABS. moreover while increasing the bandwidth to 20 MHz an enhancement of overall throughput of the two methods was increased due to the increasing of the spectral efficiency of the system.

Transmission Delay

The following figure represents the transmission of the system vs. number of Subframes, the x axes represent the number of Subframes and the y axes represent the delay time.

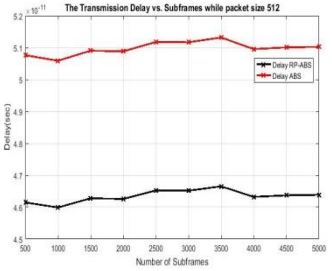

Figure 4: compare delay using RP-ABS and ABS

The delay time when using RP-ABS scheme is less than ABS scheme by 8.2% seen in a Figure 4.4a while setting the packet size to 512, where the black line represents RP-ABS and the red line represents ABS. This reduction in transmission delay is caused by the increasing of the data rate. While setting the packet size to 1024 the delay time of the reduced power method has a lower value and it can be explained as the reduced power frame has the ability to carry data compared to the ABS so the throughput is higher and the delay is low.

Outage probability

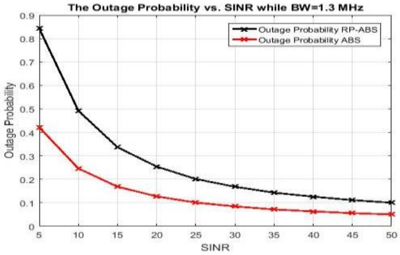

Figure 5 compare outage probability RP-ABS and ABS

The decrease in outage probability is achieved by increasing of the SINR as shown in Figure 5This decrement in Outage probability is a result of increasing the overall SINR. While using bandwidth variation between 1.3 MHz and 20 MHz the system enhanced its outage probability due to the availability of resources due to the increasing in bandwidth.

CONCLUSION

In this project the almost blank subframe (ABS) which are a part of Enhanced Inter-Cell Interference Coordination (eICIC) framework that was developed by the 3GPP. The 3GPP develop two major methods in the time domain ABS and RP-ABS, after study and investigation of these methods it was found that in the normal ABS a blank frames is send so a reduce in the throughput of the system can be the result, and at the RP-ABS a fixed power is used in the Subframes so it can effected by the signal to noise ratio SNR at a specific moment.

In addition the limitation of the resources on mobile network and the problem of sharing the resources between network elements, the spectrum sharing, bandwidth and sub channel frequencies that is used around the network with a synchronization methods and rules.The goal was reducing interference there are so many mechanisms including ABS and RP-ABS. So there is a need to compare the selected interference mitigation mechanisms to explore their strength and weaknesses under various conditions and adapt the ICIC in Macro-Cell and Micro-Cell Using RP-ABS.

After simulating the system on Matlab 2016a, it was concluded that the system become more reliable, and has a goodput.

Recommendations

To get the most benefits from the interference management in the LTE-A there are some recommendations should be taken under consideration in future research activities. To the best network performance Its better to choose the optimal bias value that minimizes the number of victim user equipment's for each base station individual and comparison of data rate and capacity for ABS & AABS.

As known the interference management in the LTE-A has more than one scenario, in this thesis the comparison eICIC time domain (ABS & AABS) was conducted, and it’s recommended to use different scenarios such as frequency domain in eICIC and all scenario for F-eICIC.

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