

## Performance Evaluation of Reduced-Power ABS and Zero-Power ABS Time Domain Interference Mitigation Technique in Femto-Macro Heterogeneous Network

Tekanyi A.M.S, Kassim A. Y, Sani S. M, Usman A. D, Abdulkareem H. A & Muhammad Z.Z.

Department of Communications Engineering,

Ahmadu Bello University, Zaria- Nigeria.

aykassim2019@gmail.com

### Abstract

Femtocells deployment has become a new paradigm in improving the mobile network's services for indoor users, by providing better data rates and coverage. Femtocells deployment results to a heterogeneous network that requires two layers of utilization of the available radio resources and this leads to interference. Despite the improvements brought about by the zero-power ABS time domain technique, it suffers reduced throughput of femtocell users in a femto-macro heterogeneous network. A method used in this research to address this limitation was the reduced-power ABS time domain technique that mitigated interference. A comparison was made between the two schemes and it was found that the reduced-power ABS scheme provided higher throughput to femtocell users when muting ratios of 0, 0.3, 0.5 and 0.8 were used. The results obtained achieved optimal and fair overall performance. This research centered on communication in the downlink direction only.

### ARTICLE INFO

Article History

Received: March, 2019

Received in revised form: April, 2019

Accepted: May, 2019

Published online: July, 2019

### KEYWORDS

Interference, Zero-power, ABS, Reduced-power ABS, Femtocell, Throughput.

### INTRODUCTION

There are unprecedented trends in the growth of mobile data traffic in recent years and that will continue globally for years to come. The technical challenge of high demand for mobile data traffic on cellular networks, in terms of data throughput and network capacity, is promised to be addressed by Heterogeneous Networks (HetNets) (Ali, 2015). Mobile data traffic has surpassed voice traffic in 2009 and it is anticipated to continue consistently (Ericsson, 2013). It is anticipated that there will be annual growth in mobile video traffic by 45 percent through 2023 which will account for 73 percent of all mobile data traffic. Also, it is anticipated that over the next 6 years, data traffic from social networking applications will grow steadily by 31 percent annually (Ericsson, 2018).

The telecommunications industry is faced with the urgent need of expanding the mobile access network capacity by 1000 times in order to accommodate this exponential growth for the demand for high mobile data. Recently, customers communicate with one another anytime, anywhere, and through any available media, including voice calls, video calls, instant messages, video conferencing, and email (Afolalu *et al.*, 2016). The increasing number of smartphone subscriptions and increasing average data volume per subscription led to the growth in mobile data traffic, primarily propelled by more viewing of video content at higher resolutions (Ericsson, 2018).

The future demands for high data rates, reduced latency, and enhanced coverage in cellular networks can be met by the concept of heterogeneity and dense deployment of small cells (Hossain *et al.*, 2014; Kaddour *et al.*, 2015). HetNet is a collection of low power nodes distributed across a macrocellular network in order to improve the capacity and enhance the coverage of the network. These low power nodes include microcells, relays, picocells, remote radio heads, and femtocells, distinguished by transmit power, coverage area, capacity, and backhaul. The low power nodes are deployed at hotspots, enterprise environment, homes, and low geometry locations (Saad *et al.*, 2013).

Studies have shown that 50 percent of the total voice traffic and 70 percent of the total data traffic are generated indoors and for the mobile operators to provide better Quality of Service (QoS) to these indoor users, femtocells deployment is considered a promising solution (Cao & Fan, 2013). A femtocell is defined as a small size, low powered node with short service range. It is also known as Home enhanced NodeB (HeNB). Femtocells provide high spectral efficiency, low cost of deployment and maintenance which made it to gain enormous attention in the wireless industry (Bouras *et al.*, 2013). Deployed femtocell makes use of the same or different carrier frequencies with the existing macrocell network. Using different carrier frequencies prevents inter-cell interference

\*Corresponding author: Muhammad Z. Z. ✉ [zzmuhammad38@gmail.com](mailto:zzmuhammad38@gmail.com) ✉ Department of Communications Engineering, Ahmadu Bello University, Zaria. © 2019 Faculty of Technology Education, ATBU Bauchi. All rights reserved

between macrocell and femtocells, but require more radio resources. Following the fact that licensed spectrum is scarce and expensive, network operators make use of the same carrier frequency (co-channel) in order to reduce large spectrum requirements (Bartoli *et al.*, 2014). Although, the same carrier frequency deployment ensures efficient spectrum utilization and larger bandwidth for both macrocell and femtocells, this results in cross-tier interference that prevents the macro users within the vicinity of the femto eNodeBs from having good Signal-to-Interference-Plus-Noise Ratio (SINR) (Kurda *et al.*, 2015). Typically, femtocells are deployed in closed access mode, where the network is only accessed by users enlisted in the Closed Subscriber Group (CSG). In the downlink transmission, femtocells operating in CSG mode tends to subject macro users in its vicinity to severe cross-tier interference (Wang & Pedersen, 2011).

#### RELATED WORKS

Kshatriya *et al.*, (2013) employed an Orthogonal Almost Blank Subframe (OABS) scheme. The scheme determined the location and number of subframes that were to be muted at each interfering cell. The number of subframes to be muted depended on the number of users experiencing interference and users that were not interfered. In the work, a HetNet comprising of macrocell, picocells, and femtocells was considered. Simulation results showed that the throughput of the victim user equipment was significantly increased. The OABS scheme showed an improvement on the performance of the victim user equipment. The increase in the number of small cells deployed within an existing macrocell resulted in diminishing returns in the network capacity due to increased inter-cell interference.

Bartoli *et al.*, (2014) studied a method that adaptively determine the most suitable muting ratio in an ABS scheme based on suitable threshold values. The number of subframes to be blanked was a function of the network traffic load. A HetNet consisting of a macrocell and a femtocell was considered. The femtocell was deployed in the Open Subscriber Grouped (OSG) mode. Interference experienced by user equipment in the CRE region was mitigated using ABS scheme. The use of opened access femtocell was a limitation to the work because most commercial femtocells available operate in the closed access mode.

Nasri *et al.*, (2015) proposed a new algorithm that integrated interference avoidance and interference cancellation to mitigate the effect of interference in the downlink channel of a macro-

femto HetNet. The scheme implemented interference avoidance at the transmitter and interference cancellation at the receiver. At the transmitter, Low Power Almost Blank Subframe (LP-ABS) was used to minimize the effect of interference by transmitting signals with low power during the ABS instead of muting the frames completely. The downlink interference cancellation scheme reduced the effect of interference on users by optimizing their received Signal-to-Interference plus Noise Ratio (SINR) at the receiver. System level simulation results showed an enhancement in network performance and user experience in terms of total throughput and received SINR. There is still room for improvement on the capacity of the network by using suitable adaptive LP-ABS such that the interfering cell can transmit on both normal and ABS.

Koutlia *et al.*, (2015) utilized a new enhanced Inter-Cell Interference Coordination (eICIC) technique for managing ABS subframes. The algorithm jointly exploited power, frequency and time dimensions in order to balance the tradeoff between capacity degradation of macro users and interference mitigation in small cells. This was aimed at providing efficient utilization of the available spectrum resources. Simulation results presented higher capacity gains without subjecting the victim users to severe interference. Limitation of the work was that interference experienced by small cell users that were not in the CRE region was not mitigated.

Magaji *et al.*, (2017) developed an adaptive hybrid technique to mitigate cross-tier interference in a femto-macro HetNet. Depending on the position of the victim macro user, the technique used power control or Zero-power ABS based time domain technique to mitigate the effect of interference. A target Signal-to-Interference-plus-Noise Ratio ( $SINR_{tar}$ ) and a threshold distance  $D_{min}$  was set for all users. For macro users at the cell edge, meaning users that were at distances greater than  $D_{min}$ , the scheme implemented power control technique by adaptively changing the transmit power of the femto base station. The scheme implemented Zero-power ABS time domain technique for macro users at distances less than  $D_{min}$ . Simulation results showed that the hybrid scheme performed better in terms of SINR and throughput when compared to implementing only power control or time domain technique. The limitations of this work was that time domain technique using zero power ABS limited the capacity of the femtocell which in turn degraded the throughput of the femtocell users and also led to spectrum underutilization. This left room for the

\*Corresponding author: Muhammad Z. Z. ✉ [zzmuhammad38@gmail.com](mailto:zzmuhammad38@gmail.com) ✉ Department of Communications Engineering, Ahmadu Bello University, Zaria. © 2019 Faculty of Technology Education, ATBU Bauchi. All rights reserved

modification or enhancement of the ABS scheme in order to provide better SINR, higher throughput, and enhanced spectral efficiency.

### SYSTEM MODEL

The femtocells deployed in a macrocell network can introduce cross-tier Interference to the network. Severe interference scenario could be caused in both downlink and uplink of nearby macro UE due to the operation of femtocell in closed access mode (Lopez-Perez *et al.*, 2011). The ad hoc deployment of femtocells makes it difficult for the operators to supervise the network effectively (Palanisamy & Nirmala, 2013). The femtocell's proper operation strongly depends on

their sensing, self-optimizing features, and continuous monitoring of the radio environment in order to adaptively mitigate interference (Claussen *et al.*, 2008).

For macro users at the edge of a femtocell operating in a CSG, the macro eNodeB tries to initiate a handover request which fails because it is not in the CSG list (Zhenwei *et al.*, 2011). This makes the macro UE to experience severe cross-tier interference in the downlink, which results to a decrease in the SINR of the user and this interference is a major technical challenge in HetNet. Figure 1 shows the cross-tier interference scenario in a femto-macro HetNet.

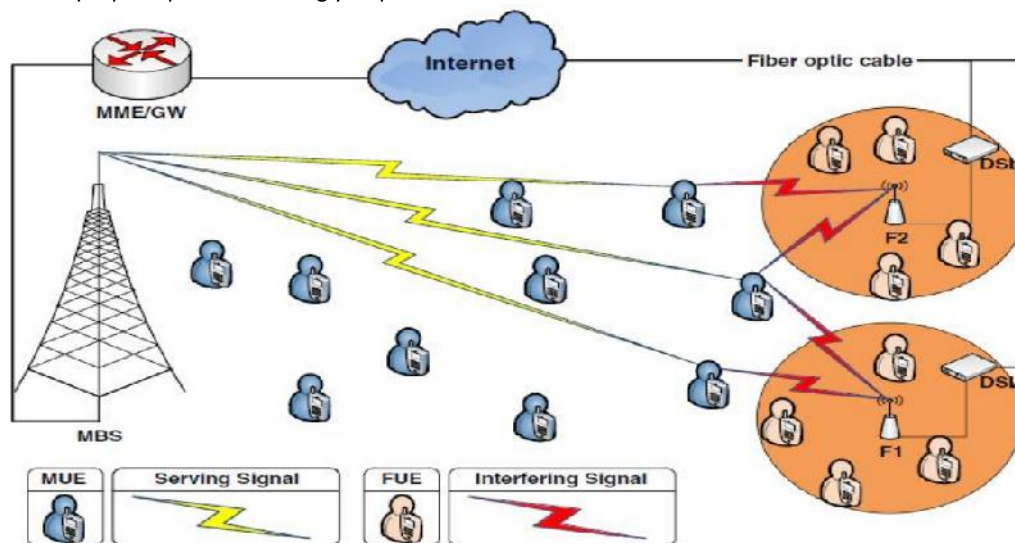


Figure 1: Cross-Tier Interference Scenario in a Femto-Macro HetNet (Kurda *et al.*, 2015)

### Zero-power ABS

Almost Blank Subframes also known as ABS is defined as a minimum transmission subframe where no data signal is transmitted from the interfering cell but only transmit most critical information required for the system to provide support to legacy LTE (Release 8/9) user equipment. Subframe alignment is achieved using the so called Almost Blank Subframe (ABS) (Lopez-Perez *et al.*, 2011). For ABS application, both the HeNBs and the macrocells should be aware of the muting pattern. Strict time synchronization between the two networks layers that is the macrocell and the femtocell is required. The macrocell scheduler

primarily schedules the users close to non-allowed HeNBs when they are muted. The cost of ABS muting is the degraded HeNB performance, which decreases linearly with the muting ratio (Kshatriya *et al.*, 2013). During ABS, no control or data signal is transmitted (Koutlia *et al.*, 2015). The ABS is created by the interfering eNodeB. Victim user equipment are scheduled during the subframes overlapping with the ABS of the interfering eNodeB. In this way, inter-cell interference between femtocell and macrocell is significantly mitigated. Figure 2 shows a scenario where transmission takes place on all subframes for the macro base stations and HeNBs are muted twice every 8 subframes.

\*Corresponding author: Muhammad Z. Z. ✉ [zzmuhammad38@gmail.com](mailto:zzmuhammad38@gmail.com) ✉ Department of Communications Engineering, Ahmadu Bello University, Zaria. © 2019 Faculty of Technology Education, ATBU Bauchi. All rights reserved

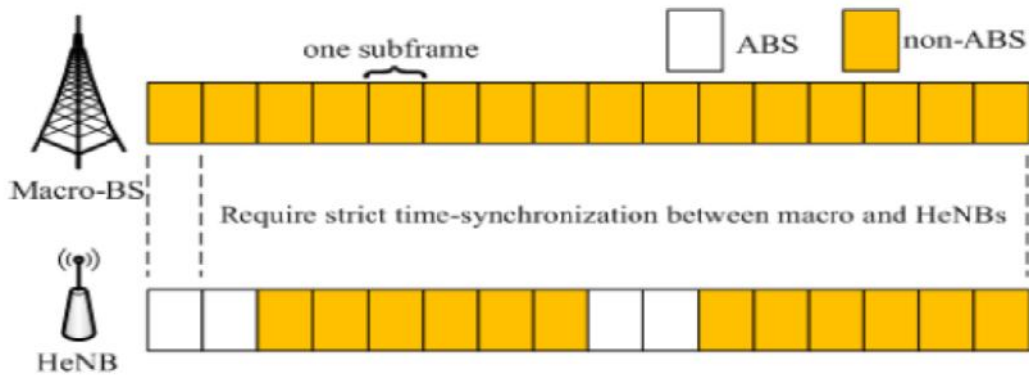


Figure 2: Almost Blank Subframe Synchronization (Wang & Pedersen, 2011)

**Reduced power ABS**

The creation of ABS by the interfering base station results in the loss of valuable spectrum resources due to the need that the interfering base station completely blanks the subframe without sending any data traffic in it (Ali, 2015). The reduced power ABS allows the interfering eNodeB to transmit data at a reduced power to the cell centre

users instead of completely blanking the subframe during ABS. In this way, the interfering cell effectively utilizes the entire subframe, thus efficiently utilizing the spectrum. In literature, reduced power ABS and low power ABS are interchangeably used (Ali, 2015). Figure 3 shows the ABS power patterns.

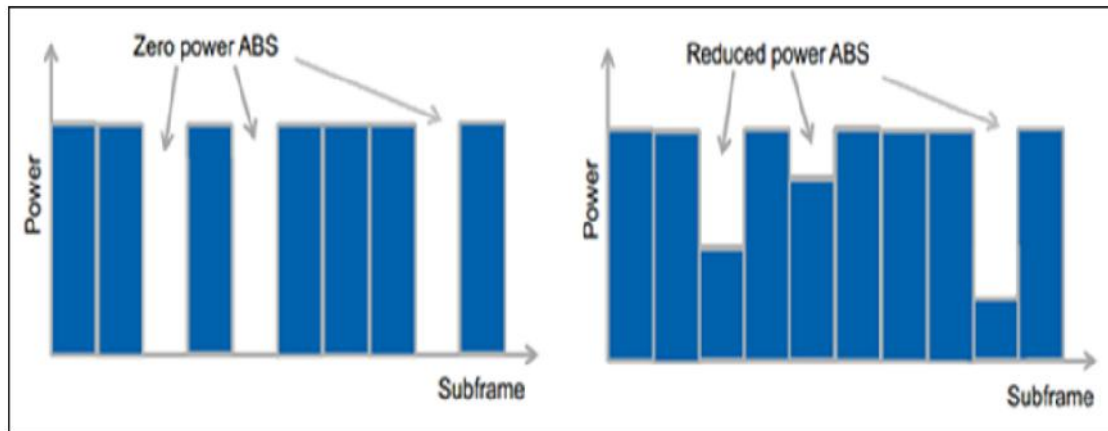


Figure 3: Almost Blank Subframe Power (Ali, 2015).

**PATH LOSS MODEL**

The path loss heavily depends on the technology used and environment in which the network is deployed. The path loss between the UE and their corresponding macrocell or femtocell is determined in the following ways (Bouras *et al.*, 2012):

**Path loss between femto user equipment and femtocell**

The path loss between a femto UE and a femtocell in the same apartment is given by Bouras *et al.*, (2012) as:

$$\begin{aligned}
 PL(\text{dB}) &= \max(15.3 + 37.6 \log_1 R, 38.46 + 20 \log_1 R) \\
 &+ 0.7d_{2 \text{ ii}} + 18.3n \left( \frac{(n+2)}{(n+1) - 0.46} \right) + q \\
 &* L_{i1} + L_o \quad (1)
 \end{aligned}$$

where:  
 $R$  and  $0.7d_{2 \text{ ii}}$  are transmit-receive distance and penetration loss due to walls inside the apartment respectively.  
 $n$  denote number of penetrated floors.  
 $q$  represents number of walls separating apartments between UE and femtocell.  
 $L_{i1}$  is penetration loss of the wall separating apartments.

\*Corresponding author: Muhammad Z. Z. [zzmuhammad38@gmail.com](mailto:zzmuhammad38@gmail.com) Department of Communications Engineering, Ahmadu Bello University, Zaria. © 2019 Faculty of Technology Education, ATBU Bauchi. All rights reserved

$L_{o1}$  and  $L_{o2}$  are the penetration loss of outdoor walls 1 and 2, respectively.

### Channel Gain

Channel Gain ( $G$ ) is a function of path loss and differs depending on the path loss model, whether it is indoor or outdoor. In order to determine the channel gain  $G$ , the calculation of path loss is required according to the following expression (Bouras *et al.*, 2013):

$$G = 10^{-\frac{P}{1}} \quad (2)$$

Where,  $P$  is path loss between the UE and the eNodeB.

### Signal-to-Interference-plus-Noise Ratio Model

The estimation of the received Signal-to-Interference-plus-Noise Ratio (SINR) of a macro user,  $m$  on a sub-carrier,  $k$  associated with a macrocell,  $M$  when it is interfered by neighboring macrocells,  $M'$  and femtocell,  $F$  is determined by Afaz *et al.*, (2014) as:

$$S_{i_{m,k}} = \frac{P_{M,k} G_{m,M,k}}{N_0 \Delta f + \sum_{M'} P_{M',k} G_{m,M',k} + \sum_{F'} P_{F',k} G_{m,F',k}} \quad (3)$$

where:

$P_{M,k}$  and  $P_{M',k}$  are the transmit power of serving macrocell and the neighboring macrocell on sub-carrier, respectively.

$G_{m,M,k}$  is the channel gain between macro user and serving macrocell on subcarrier.

$G_{m,M',k}$  represents the channel gain from neighboring macrocell.

$P_{F',k}$  denotes the transmit power of neighboring femtocell on sub-carrier.

$G_{m,F',k}$  is the channel gain between macro user and neighboring femtocell on sub carrier.

$N_0$  stands for the white noise power spectral density and  $\Delta f$  is sub-carrier spacing.

Similarly, for a femto user,  $f$  on sub-carrier,  $k$  associated with a femtocell,  $F$  when it is interfered by all neighboring femtocell,  $F'$  and macrocell,  $M$ , the SINR can be obtained as follows (Bouras *et al.*, 2012):

$$SINR_{f,k} = \frac{P_{F,k} G_{f,F,k}}{N_0 \Delta f + \sum_M P_{M,k} G_{f,M,k} + \sum_{F'} P_{F',k} G_{f,F',k}} \quad (4)$$

where:

$P_{F,k}$  and  $P_{F',k}$  are the transmit power of serving and neighboring femtocell on subcarrier respectively.

$G_{f,F,k}$  is the channel gain between femto user, and serving femtocell on subcarrier.

$G_{f,F',k}$  denotes the channel gain from neighboring femtocell.

$P_{M,k}$  represents the transmit power of neighboring macrocell on subcarrier.

$G_{f,M,k}$  means the channel gain between femto user, and neighboring macrocell on subcarrier.

$N_0$  is the white noise power spectral density and  $\Delta f$  is subcarrier spacing.

### THROUGHPUT MODEL

The throughput is determined after determining the path loss and the SINR of a user depending on its environment. The capacity of the macro user,  $m$ , and femto user,  $f$ , on a sub-carrier  $k$ , is given by Bouras *et al.*, (2012) as:

$$C_{m,k} = \Delta f \cdot \log_2(1 + \alpha S_{i_{m,k}}) \quad (5)$$

$$C_{f,k} = \Delta f \cdot \log_2(1 + \alpha S_{i_{f,k}}) \quad (6)$$

$$\alpha = \frac{-1.5}{\ln(5B)} \quad (7)$$

where:

$C_{m,k}$  is macro user capacity on a sub-carrier  $k$ .

$C_{f,k}$  represents femto user capacity on sub-carrier  $k$ .

$\Delta f$  denotes bandwidth of operation.

$S_{i_{m,k}}$  stands for macro SINR on subcarrier  $k$ .

$S_{i_{f,k}}$  marks femto SINR on subcarrier  $k$ .

$\alpha$  is a constant for target bit error rate.

BER refers to the bit error rate which is set to  $10^{-6}$

### METHODOLOGY

The implementation of the Zero-power ABS scheme in a femto-macro scenario makes the throughput of the macro users in the vicinity of the femtocell to significantly improve due to the reduction in interference seen by these users. Conversely, this leads to decrease in throughput of the femtocells because femtocells are only allowed to transmit in normal subframes.

With respect to this, a mechanism was developed for the efficient utilization of the spectrum resources. The developed mechanism allow data transmission of the femtocell users in the ABS subframes under special conditions which also reduce interference generation to the macro users. The conditions are stated in terms of the maximum allowed transmit power and the allowed RBs in the frequency domain.

The equation for separating the resource blocks into reserved and non-reserved in this strategy is given as follows:

$$\varepsilon = \min([\alpha \cdot n_{mM}], n_{\mu}) \quad (8)$$

where:

$\varepsilon$  represents the number of reserved resource blocks

numMU denotes the number of macro users in the vicinity of the femtocell

$\alpha$  is the average number of reserved resource block per subframe

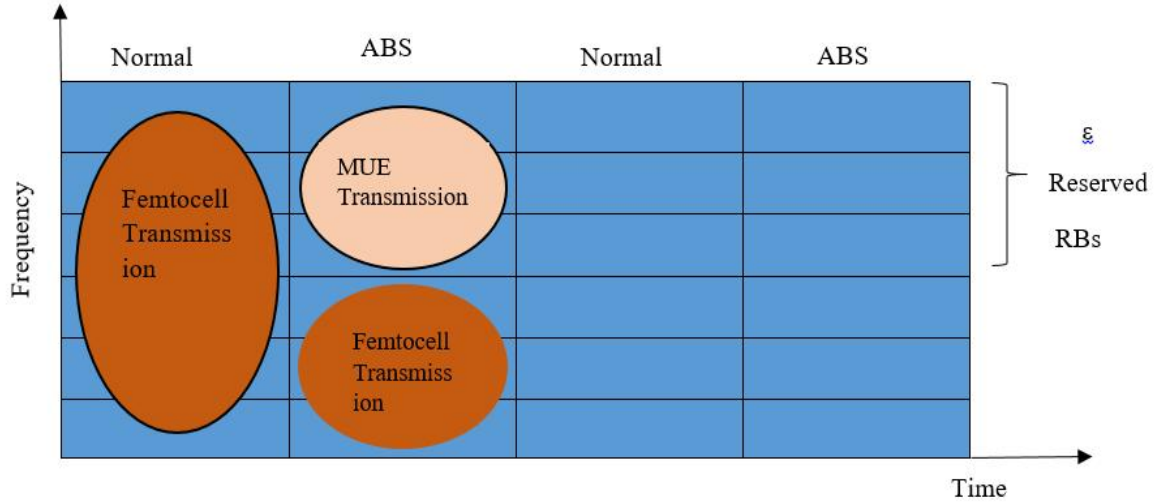
$n_{\mu}$  refers to the number of resource blocks

Instead of devoting all the RBs to the macro users in the vicinity of the femtocell in the ABS subframes as in the Zero power ABS scheme, the data



transmission was separated into two areas by splitting the frequency domain. This was achieved

by allocating RBs to both femtocell and macro users as shown in Figure 4.



**Figure 4:** Developed User Allocation Principles.

The macro users, being the victim users in the vicinity of the femtocell are allocated the reserved RBs, meaning only macro user data transmissions are permitted during these  $\epsilon$  RBs. Femtocell data transmissions take place in both the non-reserved RBs ( $numRB - \epsilon$ ) with the restriction

of low transmit power and normal subframes with high transmit power in the ABS subframes. By this, the interference experienced by macro users is reduced to a low level. Also, the non-silencing of the ABS subframe results to an increase in the femto user capacity.

PARAMETERS	VALUE/DESCRIPTION
Cellular layout	Single macrocell
Number of Macro eNodeB	1
Macrocell radius	250m
Macro eNodeB TX power	46dBm
Carrier frequency	2GHz
Femto eNodeB max TX power	20dBm
Femto eNodeB default TX power	11dBm
$D_{min}$	75% Femto range
Exterior wall loss	15dBm
Interior wall loss (low)	7dBm
Bandwidth	20MHz
Modulation Type	64QAM
Subcarrier spacing	15KHz
Number of Femtocell Users	5
Number of Femtocells	2
Number of macro users	5

## RESULTS AND DISCUSSION

The respective throughput of the femtocell users using 0, 0.3, 0.5 and 0.8 muting ratios are shown in Figures 5 through 8. The plots were obtained first by determining the path loss of the user from equation (1). The path loss depends on the distance of the user from the serving eNodeB. The gain between the femto user and femto eNodeB was obtained by inputting the path

loss value into equation (2). SINR was obtained by inputting the gain in the equation (4) and finally the throughput was obtained from equation (6) and plotted against distance from femtocell. Figure 5 shows the graph of throughput against distance. It is observed that the maximum throughput achieved was 24Mbps for both the Zero-power and Reduced-power schemes at 0m distance up to about 35m away from femtocell. At 40m away from the

\*Corresponding author: Muhammad Z. Z. ✉ [zzmuhammad38@gmail.com](mailto:zzmuhammad38@gmail.com) ✉ Department of Communications Engineering, Ahmadu Bello University, Zaria. © 2019 Faculty of Technology Education, ATBU Bauchi. All rights reserved

femtocell, the Reduced-power scheme has a throughput of 19.2Mbps as against the Zero-power scheme that has throughput of 13.5Mbps at 0 muting ratio which depicts a better quality of signal reception and thus a better quality of service. Similarly, different throughput values were

obtained for 0.3, 0.5 and 0.8 muting ratios using the same principle for analyses of different results. These were tabulated in table 1 for the respective throughput of the femtocell user for the different muting ratios at 40m away from the femtocell eNodeB.

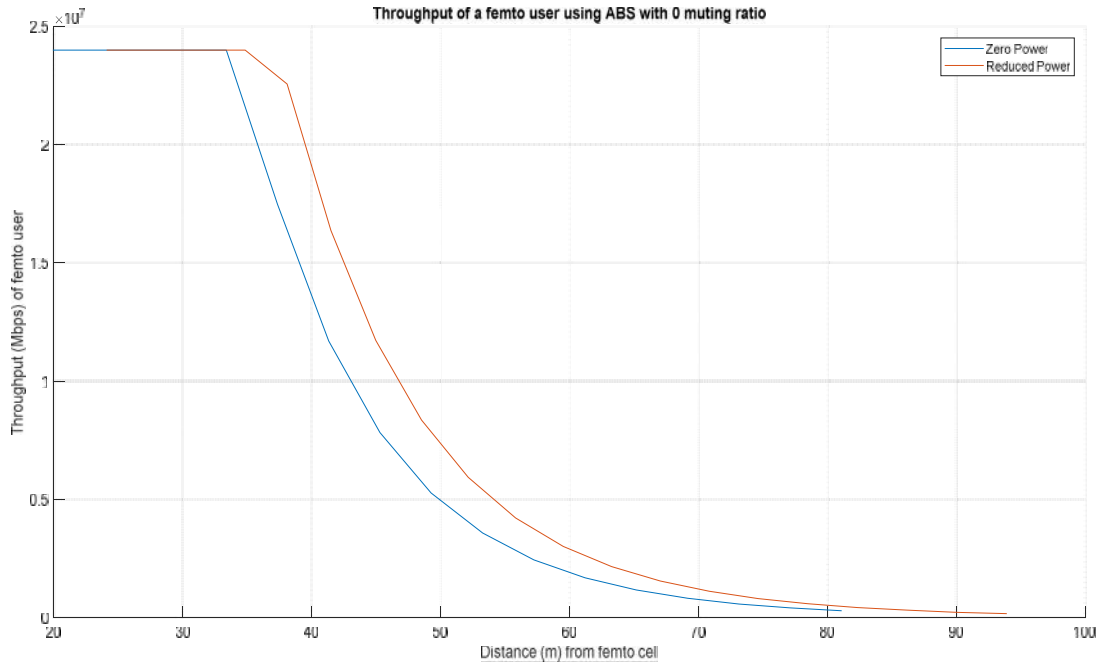


Figure 5: Throughput of a Femto User using ABS with 0 Muting Ratio.

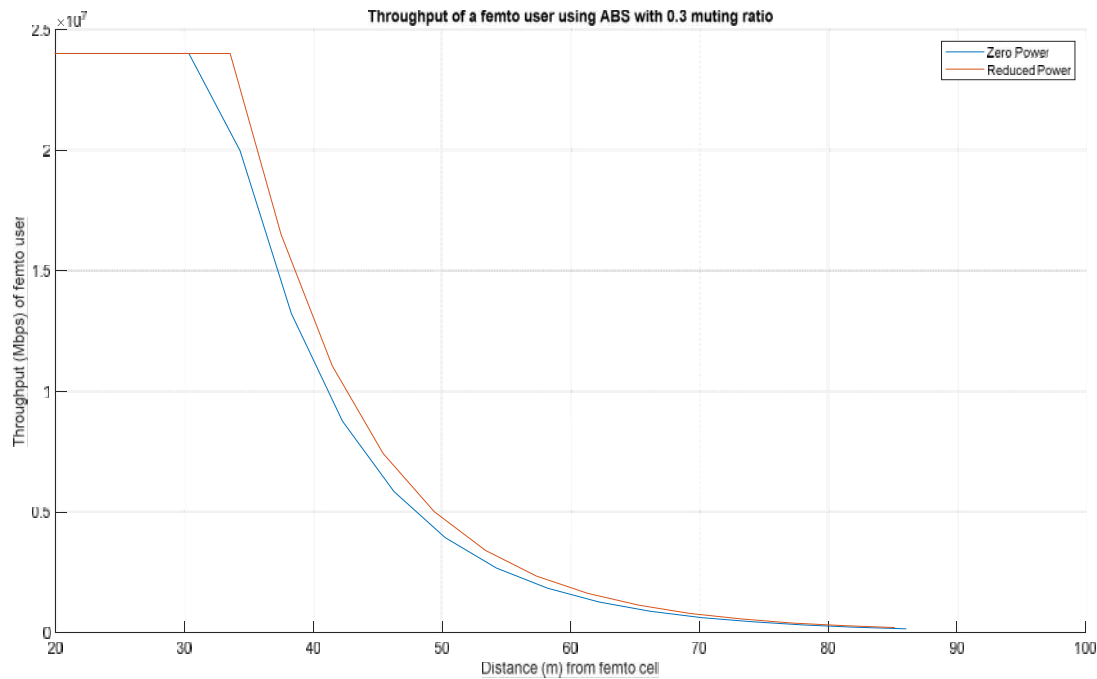


Figure 6: Throughput of a Femto User using ABS with 0.3 Muting Ratio.

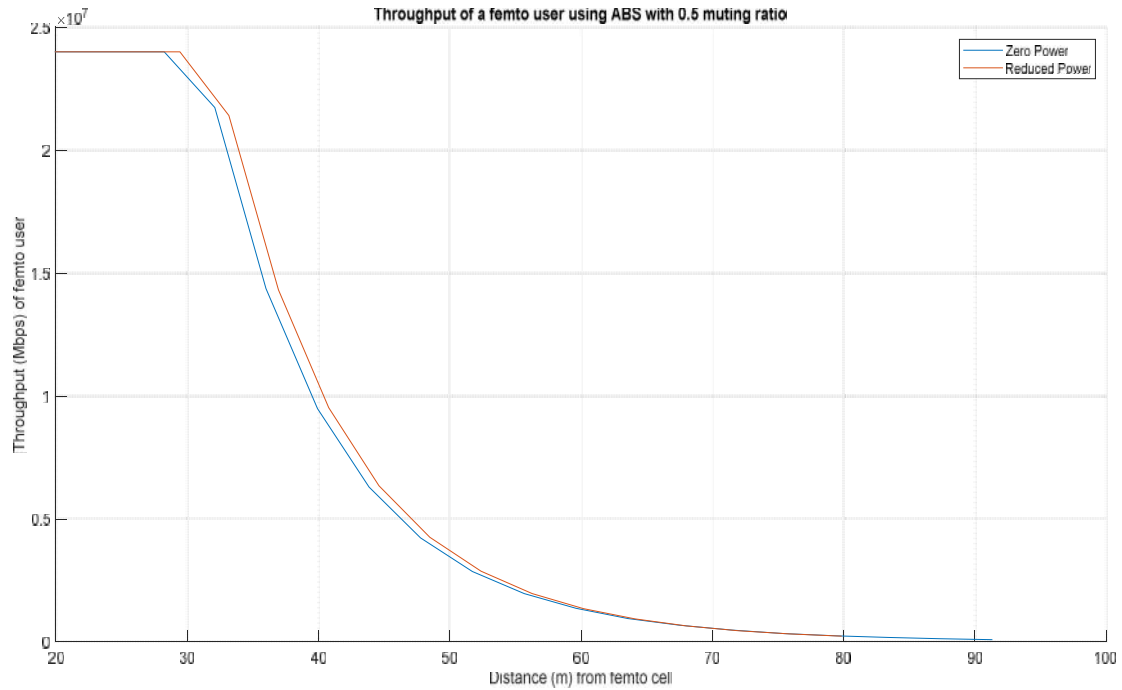


Figure 7: Throughput of a Femto User using ABS with 0.5 Muting Ratio.

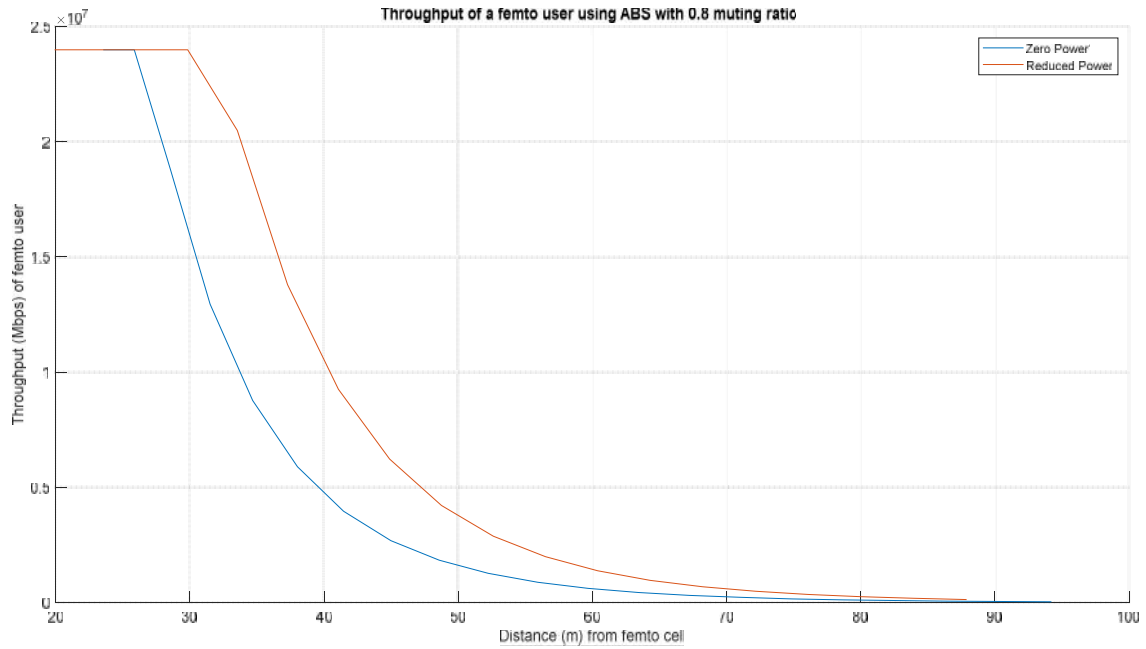


Figure 8: Throughput of a Femto User using ABS with 0.8 Muting Ratio.

Table 1: Throughput of the Femtocell Users at 40m away from Femto eNodeB

Muting Ratio	0	0.3	0.5	0.8
Reduced-Power	19.2Mbps	13.2Mbps	10.6Mbps	10.4Mbps
Zero-Power	13.5Mbps	11.2Mbps	9.2Mbps	4.8Mbps



## CONCLUSION

One of the major technical challenges of HetNet deployment is cross-tier interference, which limits the potentials of HetNet in improving total network capacity. Most researches conducted focused on using the Zero-power ABS to mitigate interference in a femto-macro HetNet scenario which presents some drawbacks when it comes to the femtocell user capacity. This research used the reduced-power ABS time domain technique for interference mitigation. A comparison was made between the Zero-power and Reduced-power ABS schemes and it was found that the reduced-power ABS scheme provides higher throughput to femtocell users when 0, 0.3, 0.5 and 0.8 muting ratios were used.

## REFERENCES

- Afaz, U. A., Mohammad, T. I., & Mahamod, I. (2014). Dynamic resource allocation in hybrid access femtocell network. Paper presented at the *Scientific World Journal*, 539-720.
- Ali, M. S. (2015). An Overview on Interference Management in 3GPP LTE-Advanced Heterogeneous Networks. *International Journal of Future Generation Communication and Networking*, 8(1), 55-68.
- Afolalu O.F, Petinrin J.O and Ayoade M.A (2016). A Survey of Interference Challenges and Mitigation Techniques in 5G Heterogeneous Cellular Networks. *International Conference of Sciences, Engineering & Environmental Technology (ICONSEET)*, 1(2): 8-14.
- Bartoli, G., Fantacci, R., Marabissi, D., & Pucci, M. (2014). Adaptive muting ratio in enhanced Inter-Cell Interference Coordination for LTE-A systems. Paper presented at the *International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 990-995.
- Bouras, C., Kokkinos, V., Kontodimas, K., & Papazois, A. (2012). A simulation framework for LTE-A systems with femtocell overlays. *Proceedings of the 7th ACM workshop on Performance monitoring and measurement of heterogeneous wireless and wired Networks*,
- Bouras, C., Kokkinos, G, Diles, V., Kontodimas, K., & Papazois, A. (2013). A simulation Framework for evaluating interference mitigation techniques in heterogeneous cellular Environment. Springer, New York. DOI 10.1007/s11277-013-1562-5
- Cao, F., & Fan, Z. (2013). Downlink power control for femtocell networks. Paper presented at the *IEEE 77th Vehicular Technology Conference (VTC Spring)*, pp. 1-5.
- Claussen, H., Ho, L. T., & Samuel, L. G. (2008). An overview of the femtocell concept. *Bell Labs Technical Journal*, 13(1), 221-245.
- Ericsson mobility Report. (2013)
- Ericsson mobility Report (2018)
- Hossain, E., Rasti, M., Tabassum, H., & Abdelnasser, A. (2014). Evolution toward 5G multi-tier cellular wireless networks: An interference management perspective. *IEEE Wireless communications*, 21(3), pp. 118–127. <http://www.itresearchreport.blogspot.com>, accessed on June 20, 2018.
- Kaddour, F. Z., Denis, B., & Ktenas, D. (2015). Downlink interference analytical predictions under shadowing within irregular multi-cell deployments. In *Communications (ICC), 2015 IEEE International Conference*. pp. 1649–1654.
- Koutlia, K., Perez-Romero, J., & Agusti, R. (2015). On Enhancing Almost Blank Subframes Management for Efficient eICIC in HetNets. Paper presented at the *IEEE 81st Vehicular Technology Conference (VTC Spring)*, pp. 1-5.
- Kshatriya, S. N. S., Kaimalettu, S., Yerrapareddy, S. R., Milleth, K., & Akhtar, N. (2013). On interference management based on sub frame blanking in heterogeneous LTE networks. Paper presented at the *Fifth International Conference on Communication Systems and Networks (COMSNETS)*, pp. 1-7.
- Kurda, R., Boukhatem, L., & Kaneko, M. (2015). Femto-cell power control methods based on Users' context information in two-tier heterogeneous networks. *EURASIP Journal on Wireless Communications and Networking*, pp. 1-17.
- Lopez-Perez, D., Güvenç, S., De la Roche, G., Kountouris, M., Quek, T. Q., & Zhang, J. (2011). Enhanced intercell interference coordination challenges in heterogeneous networks. *IEEE Wireless Communications*, 18(3), pp. 22-30.
- Magaji S., Sani S. M. and Tekanyi A. M. S. (2017). Development of an Adaptive Hybrid Technique to Mitigate Cross-Tier Interference in a Femto-Macro Heterogeneous Network. *International*



- Journal of Computer Applications*. 168(12), pp. 21-29.
- Nasri, R., Affes, S., & Stephene, A. (2015). Combined Interference Cancellation and Avoidance over the Downlink of Spectrum-Sharing LTE HetNet. Paper presented at the *IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB), 2015*, pp. 1-6.
- Palanisamy, P., & Nirmala, S. (2013). Downlink interference management in femtocell networks-a comprehensive study and survey. Paper presented at the *2013 International Conference on Information Communication and Embedded Systems (ICICES)*, pp. 747-754.
- Saad, S. A., Ismail, M., & Nordin, R. (2013). A Survey on Power Control Techniques in Femtocell Networks. *Journal of Communications*, 8(12), 845-854.
- Wang, Y., & Pedersen, K. I. (2011). Time and power domain interference management for LTE networks with macro-cells and HeNBs. Paper presented at the *IEEE Vehicular Technology Conference (VTC Fall), 2011*, pp. 1-6.
- Zhenwei, W., Xiong, W., Dong, C., Wang, J., & Li, S. (2011). A novel downlink power control scheme in LTE heterogeneous network. Paper presented at the *2011 International Conference on Computational Problem-Solving (ICCP)*, pp. 241-245.