International Journal of Multimedia and Ubiquitous Engineering
Vol.11, No.10 (2016), pp.253-262
http://dx.doi.org/10.14257/ijmue.2016.11.10.24

Biogeography-based Interference Mitigation Scheme for OFDMA System in Heterogeneous Network

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Abstract

In Heterogeneous Network (HetNet), the small base station such as femtocells are deployed in indoor and multiple business complexes in order to extend the coverage and capacity. The deployment of co-channel (i.e. shared channel) for femtocells along with macrocell induces the severe interference issues. This is because of effects on SINR and thereby capacity become deteriorated. Therefore, this paper investigates the interference mitigation techniques and come out with a proposal to improve the Signal to Interference Noise Ratio (SINR) performance as well as total capacity in Heterogeneous Network (HetNet).The simulation results show that the achieved capacity is maximized than the existing technique.

***Keywords**: Heterogeneous network, LTE-A, OFDMA, Interference, Biogeography-based optimization*

1. Introduction

Nowadays, following the IMT-Advanced the Long Term Evolution–Advanced LTE-A is able to extend the bandwidth up to 1.5Gbps for downlink and 500Mbps for uplink communication. Therefore, the HetNet adopted the femtocells (HeNodeBs) to extend the capacity in indoor. However, due to the sharing the channel between HeNodeBs and the macro-eNodeB faces the interferences. There are two types of interference are mainly cross-tier and co-tier interference on the uplink and downlink communications respectively. The interference mainly happened in OFDMA resources. The OFDMA system model is shown in Figure1, where, the total process of resource allocation from OFDMA transmitter to receiver is highlighted [1].

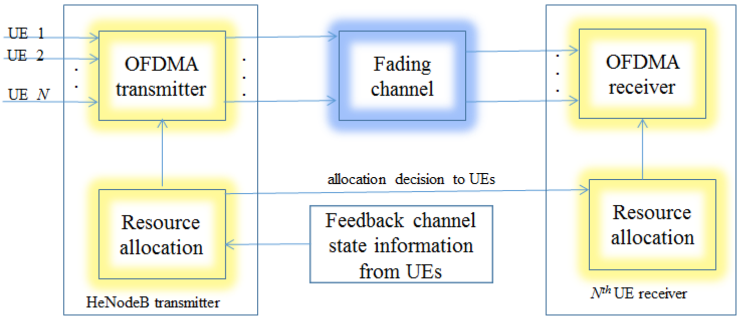

Figure 1. The System Model of OFDMA

ISSN: 1975-0080 IJMUE

In OFDMA system resource allocation, the subcarriers are divided into Resource Blocks (RBs) which empower the system to be capable of arranging the data across standard numbers of subcarriers compartment wise. RBs are comprised of 12 subcarriers, one slot in the time frame irrespective of the general LTE-A HeNodeB signal bandwidth [2-6] (see in Figure 2.). Furthermore, the sub-frames are assembled in 10 ms radio frames, which hold two 5ms halves containing the signals essential to acquire the physical identity of the cell.

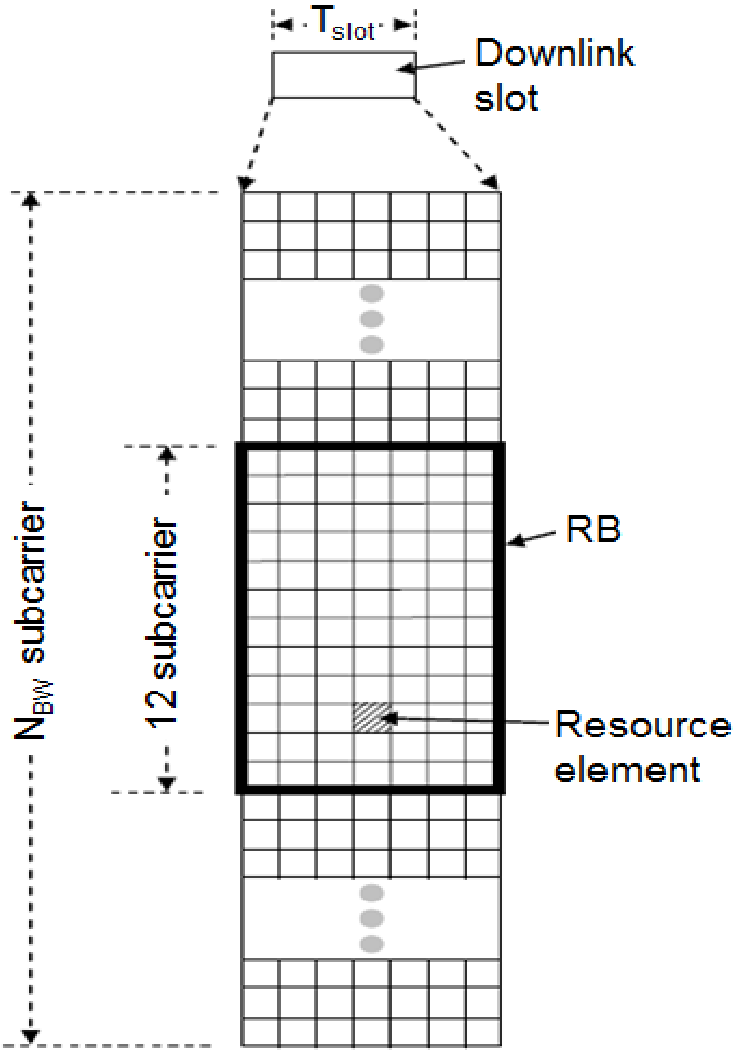

Figure 2. OFDMA Resource Frame in Downlink

Therefore, the OFDMA subcarrier are needed to allocate by reusing the resources to mitigate cross-tier interferences as well as co-tier interference [7-10].

The rest of the paper is structured as: Section 2 provides the architectural description of HetNets. After that, Section 3 investigates the interferences and its related works. The SINR is formulized in Section 4. This is followed by the discussion of the Biography algorithm to allocate the subcarriers in OFDMA in Section 5. Finally, the results are discussed in Section 6 which is followed by the conclusion in section 7.

2. Architecture of Heterogeneous Network

The HetNet mainly multimodal, multi-access network, which comprise with HeNodeB, pico-eNodeB, radio heads and macro-eNodeB. Recent attractions of LTE and LTE-A in HetNet due to higher capacity and interoperability with backward-compatibility. The HetNet architecture for LTE-A is depicted in Figure3, where the HeNodeBs are connected with macro-eNodeB network via S1/MME interface and residential gateway.

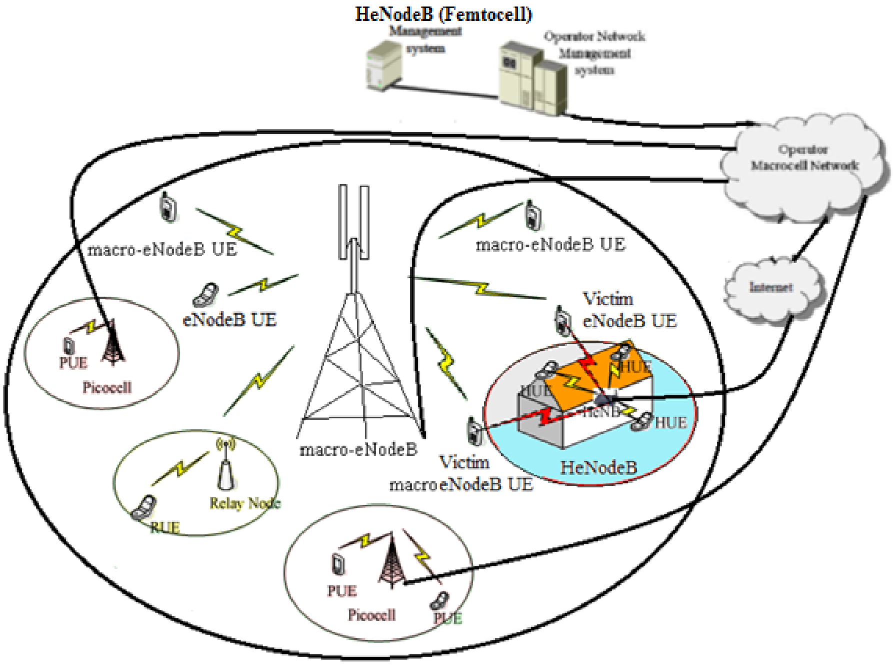

Figure 3. Heterogeneous Network Architecture

In HetNet, LTE-A is set with vigorous enactment desires that be certain of physical layer technologies such as OFDMA, Multiple-Input Multiple-Output (MIMO) systems, and Smart Antennas for accomplishing. The efficiency is enhanced with the implementation of Carrier Aggregation (CA), though CA execution may limit to downlink as well as uplink carriers. The deployment of TV-White Physical Resource Blocks (PRBs) may combine to FDD as well as TDD. This may performs better to achieve higher SINR and total capacity.

In PHY layer of LTE-A, a Cyclic Prefix (CP) is introduced which is put in preceding to each of the OFDMA symbols. In TDD, the CP addition to the symbols may useful to mitigate inter-OFDMA-symbol-interference. On the other hand, the data rate as well as capacity can be deteriorated if the CP length is too long. Therefore, the CP length also recommended to 4.7 µs. This enables the system to accommodate path variations of up to 1.4 km with the symbol length in LTE set to 66.7 µs [4]. The operation features of LTE-A OFDMA for HeNodeBs are listed in Table 1.

Table 1. LTE-A Henodeb Operation Specification

Description	Specification
Spectrum	Licensed (Operator assigned)
Frequency band	1800MHz, 2.6 GHz
System Bandwidths	20 MHz per Component Carrier(CC)
	100MHz (Carrier Aggregation)
Data rate	73Mbps
	1.5 Gbps (DL)

Power	10mW to 100mW
Ranges	20m to 30m
PHY layer	OFDMA for Downlink
	SC-FDMA for Uplink
	Multiple subcarriers
Connectivity	IP connectivity
Mac Layer	Dedicated control channel
	Spectrum scheduling
Application	Voice, video and Data
Phase offset tolerance	1 μs
Phase skew tolerance	16 ppb (parts per billion)
CP length	4.7 μs

In OFDMA the subcarriers are separated with Resource Blocks (RBs) which enable the system to be accomplished of spacing out the data across standard subcarriers slot-wise. As the RBs are comprised of 12 subcarriers, LTE/LTE-A signal bandwidths will have various numbers of RBs. Once the signal is interrupted in subcarriers of OFDMA, the interference occurred. This is because, the inference of a transmission mode has a continuous power level and a very high peak to average ratio, whereas the HeNodeB has the lower power transmission which is an absolute differences in transmit power. Due to this imprecise power, the interferences occurred in OFDMA.

3. Related Works

To mitigate interference, researcher had put effort by proposing several techniques such as power allocation, cognitive based spectrum allocation, and frequency reuse. The power allocation technique has been proposed by applying the interference feedback based power allocation in uplink [14]. It can be seen that, the scheme has limited throughput due to the power allocation and also if the number of Users (UEs) increases nearby/ in HeNodeB coverage then the severe interference in OFDMA. Among other technique, a distributed interference mitigation technique has proposed by applying the frequency reuse in order to ensure the Quality of Service (QoS) [11]. The investigation suggests that, scheme that were applied multipath channel fading and Nakagami fading to achieve the improved outage rate and higher spectral efficacy. Moreover, fixed threshold as well as signal transmission/reception were used to detect the unoccupied spectrums and also to detect interferer. Hence, the victim MUE applies the threshold and also allowing to other HeNodeBs (interferer) to reuse spectrum. A game theory based interference mitigation technique has proposed which is mainly energy based and uses the handover supported protocol [12](see in Figure4). The interference has reduced by the mutual aid to lessen energy consumption which targets to improve channel state as well as increase system capacity. However, by using the power allocation can be reduced up to certain level where as in practical this would be impossible to manage the power allocation dynamically on demand.

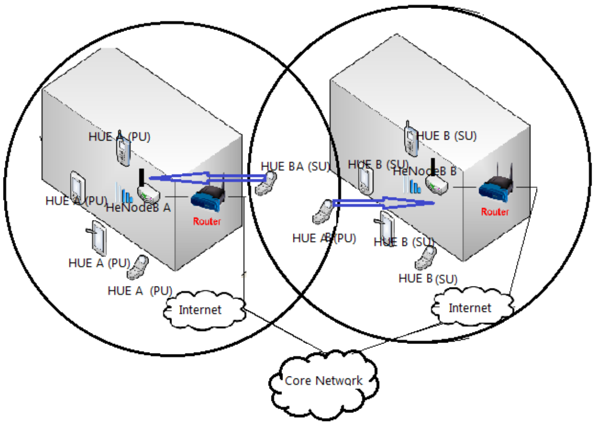

Figure 4. Mutual Handover Based Power Allocation [12]

However, this paper presents the dynamic subcarrier allocation to mitigate the interference. To allocate subcarriers dynamically, SINR model is formulized. Moreover, the subcarrier allocation problem is derived in order to maximize the throughput.

4. System Model

The association of the j^{th} HeNodeB and i^{th} HUEs in a HetNet, considering the interference in downlink the victim HUE's SINR which are interfered by another HeNodeBs is presented in Eq.1.

$$\Upsilon_{i_n,Z}^{SINR} = \frac{\Gamma_z^{i_n}\,\vartheta_{i_n}\,\left|h_{q,z}^{j_n}\right|^2 d_{j_n}^{-\vartheta_{i_n}}}{\sum_{i_n\in J_{int,z}}^{Z}\left|h_{j_n,z}^{j_n}\right|^2\Gamma_z^{j_n} + \sum_{i_n\in i_{int,z}}^{Z}\left|h_{i_n,z}^{i_n}\right|^2 p_s^{i_n} + \Delta f\,\sigma^2} \tag{1}$$

Applying the Shannon's capacity law in Eq.2, we get the capacity in Eq.2.

$$\Phi_{z,i} = \sum_{s=1}^{z}\frac{\Theta_{i,z}}{Z}\log_2\left(1 + \frac{\Gamma_z^{i_n}\,\vartheta_{i_n}\,\left|h_{q,z}^{j_n}\right|^2 d_{j_n}^{-\vartheta_{i_n}}}{\sum_{i_n\in J_{int,z}}^{Z}\left|h_{j_n,z}^{j_n}\right|^2\Gamma_z^{j_n} + \sum_{i_n\in i_{int,z}}^{Z}\left|h_{i_n,z}^{i_n}\right|^2 p_s^{i_n} + \Delta f\,\sigma^2}\right) \tag{2}$$

So, the fitness problem of the subcarriers can be signified in Eq.3.

$$Maximize\left(Q_{i,z},\Gamma_Z^{i_n}\right) = \sum_{i}^{J}\sum_{s=1}^{Z}\theta_{i,z}\left[\frac{\Theta_{i,z}}{Z}\log_2\left(1+\Upsilon_{i_n,z}^{SINR}\right)\right] \tag{3}$$

The channel model is represented in Eq.4

$$C_{j_n,S}^{i,S} = \left|h_{q,s}^{j_n}\right|^2\ 10^{(-L(d)+Le)/10} \tag{4}$$

The path-loss model is considered as the type of links in between HUE and HeNodeB [2], [13-14]. Taking in consideration of co-tier interference in downlink between HUE and HeNodeB

5. Proposed Biogeography-based Dynamic Subcarrier Allocation

Due to the co-tier interference in OFDMA, the subcarrier allocation is needful to avoid the interference in downlink. Therefore, biogeography-based optimization algorithm is enhanced to search the idle subcarrier and thereby share the subcarriers to the adjacent HeNodeBs. This is to improve the SINR performance which ultimately effects the total capacity maximization in HetNet. Hence, the biogeography-based optimization algorithm procedures and the functionalities are listed below to allocate the subcarriers:

1) Firstly it generates a group of Z^{th} subcarrier allocation program as population.
2) Evaluates the fitness of the subcarrier by applying the biogeography immigration with the relation of emigrants and the immigration rates.
3) Detect the idle subcarriers among the adjacent HeNodeBs (*i.e.* pool),
4) Create the offspring subcarriers, encode and mutate the crossover subcarriers.
5) Estimates the condition of subcarrier fitness by apply the Eq.5.

$$fitness\ (Z) = \left\{ Maximize\left(Q_{i,z}, \Gamma_z^{i_n}\right) \right\} \tag{5}$$

6) Share the subcarriers among the HeNodeBs to allocate subcarriers to the HUEs in HetNet in order to improve the SINR and the total capacity.
7) Start the process of re-generation and follow the step 1 to 6.

6. Result and Discussion

In order to analyze the performance of the proposed biogeography based subcarrier allocation, the SINR and the total capacity is considered as the performance matric. The performance is evaluated using the developed LTE-A simulator. The simulation parameters are described in Table 2.

Table 2. LTE-A Henodeb Operation Specification

Description	Specification
Frequency band	2.6 GHz
No. of HeNodeBs	50
System Bandwidth	20MHz
No. of subcarriers	720
Distance between HeNodeBs	20m
macro-eNodeB transmission power	46 dBm
Transmission power for HeNodeB	23dBm
external wall loss *Le*	10dB
internal wall loss *Li*	0dB
Thermal noise factor σ^2	-174 Bm/Hz
shadowing correlation	0.7dB
Number of $_{\text{MUE}}$	50
penetration loss	5dB
Exponent factor α	3

For the simulation, heavy traffic loaded network is considered in to estimate the performance. The simulation results at first the network scenario is generated as it is shown in Figure5.

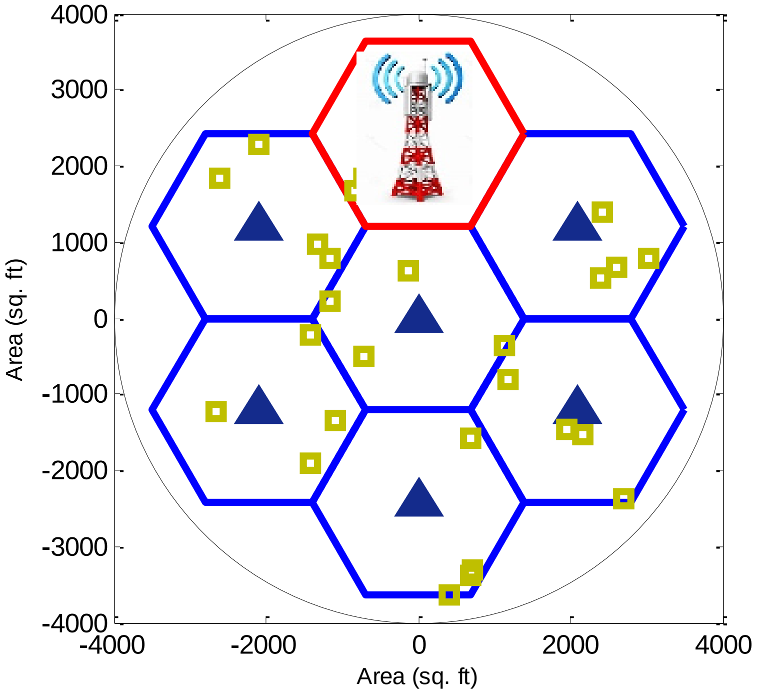

Figure 5. Network Scenario

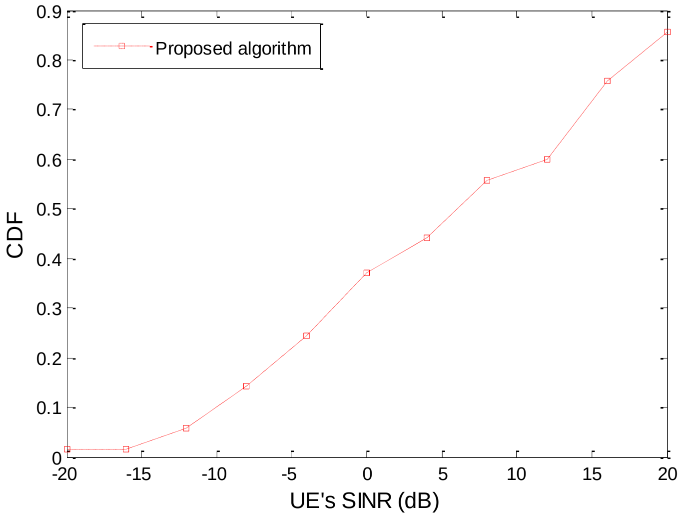

Figure 6. Users SIINR Performance

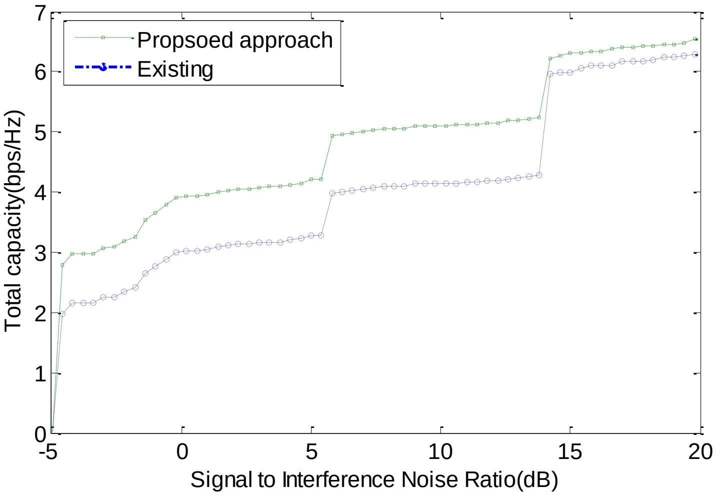

Figure 7. Total Capacity vs. SINR

The cumulative distribution for the SINR is presented in Figure 6 and the total capacity is evaluated in result Figure7. The SINR evaluation also suggests that, if the number of HUEs is increases then also the achieved SINR is perform better. This indicates that, the subcarrier sharing with other HeNodeBs and the allocation to HUEs are efficient. Thereby, the performance effect can be noticed from the enhanced total capacity. In our case, we were able to achieve the total capacity up to 6.9 bps/Hz if the SINR is 20dB. In contrast, in low SINR (*i.e.* 0 dB, 5 dB and even in 10 dB) the capacity gained to 3 bps/Hz to 5.4 bps/Hz. So, the proposed algorithm is better in terms of SINR and total capacity than the existing methods.

7. Conclusion

This study is carried out with the depth investigation of LTE-A HetNets architecture, related researches in particular interference challenges in HetNets. After analysis, it has proposed a biogeography based dynamic subcarrier allocation algorithm. It is suggested that, the subcarrier allocation is one of the efficient technique in order to enhance the efficiency in HetNet by mitigating interference. It is determined that, the proposed algorithm improved the total capacity as well as the SINR performance. Due to the fading condition, the SINR faces the severe outage rate which effects the total performance in a network. However, it can be seen that, the proposed mechanism is improved and more proficient in terms of total capacity and SINR in LTE-A HetNets. The uplink interference can be carried out for the future recommendation.

Acknowledgements

This work is supported by the Ministry of Education for the education sponsorship, and the FRGS grant from the Research Management Centre (RMC), International Islamic University Malaysia (IIUM).

References

[1] M. S. Obaidat, F. Zarai, and P. Nicopolitidis, “Modeling and Simulation of Computer Networks and Systems: Methodologies and Applications”, Morgan Kaufmann, **(2015)**.

[2] M. 3GPP R4-100207, “Release 10 UE PUCCH/PUSCH configuration”, ed, **(2010)**.

[3] C. Cox, “An introduction to LTE: LTE, LTE-advanced”, SAE and 4G mobile communications: John Wiley & Sons, **(2012)**.

[4] E. Dahlman, S. Parkvall, and J. Skold, “4G: LTE/LTE-advanced for mobile broadband”, Academic press, **(2013)**.

[5] A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo and M. Vajapeyam, "A survey on 3GPP heterogeneous networks", Wireless Communications, IEEE, vol. 18, **(2011)**, pp. 10-21.

[6] M. Rumney, "LTE and the evolution to 4G wireless: Design and measurement challenges", John Wiley & Sons, **(2013)**.

[7] M. Hasan, A. F. Ismail, A. H. Abdalla, K. Abdullah, H. Ramli and S. Islam, "Inter-cell interference coordination in LTE-A HetNets: A survey on self-organizing approaches", in Computing, Electrical and Electronics Engineering (ICCEEE), 2013 International Conference on, **(2013)**, pp. 196-201.

[8] M. K. Hasan, A. F. Ismail, A.-H. Abdalla, H. Ramli, S. Islam and W. Hashim, "Cluster-Based Spectrum Sensing Scheme in Heterogeneous Network", in Theory and Applications of Applied Electromagnetics, ed: Springer, **(2015)**, pp. 1-11.

[9] M. K. Hasan, A. F. Ismail, A.-H. Abdalla Hashim, K. Abdullah, and H. Ramli, "Performance analysis of interference coordination techniques in heterogeneous network", Research Journal of Applied Sciences, Engineering and Technology, vol. 7, **(2014)**, pp. 1536-1550.

[10] D.-C. Oh and Y.-H. Lee, "Cognitive radio based resource allocation in Femtocells", Communications and Networks, Journal of, vol. 14, **(2012)**, pp. 252-256.

[11] C. H. De Lima, M. Bennis, and M. Latva-aho, "Coordination mechanisms for self-organizing femtocells in two-tier coexistence scenario", Wireless Communications, IEEE Transactions on, vol. 11, **(2012)**, pp. 2212-2223.

[12] A. Hayar, B. Zayen, and S. Bouferda, "Interference management strategy for deploying energy efficient femtocells network", in Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM), 2012 7th International ICST Conference on, **(2012)**, pp. 208-211.

[13] 3GPPTS32.500V10.1.0, "Universal Mobile Telecommunications System (UMTS) LTE; Telecommunication management; Self-Organizing Networks (SON); Concepts and requirements, Release 10", ed: 3GPP-ETSI, **(2011)**.

[14] M K. Hasan, A. F. Ismail, A. H. Abdalla, W. Hashim and S. Islam, "Throughput Evaluation for the Downlink Scenario of Co-Tier Interference in Heterogeneous Network", ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 21, **(2015)**, pp. 9664-9668.