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An investigation of interference coordination in heterogeneous network for LTE-Advanced systems

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Abstract. The novel “femtocell” in Heterogeneous Network (HetNet) for LTE-Advanced (LTE-A) set-up will allow Malaysian wireless telecommunication operators (Maxis, Celcom, Digi, U-Mobile, P1, YTL and etc.) to extend connectivity coverage where access would otherwise be limited or unavailable, particularly indoors of large building complexes. A femtocell is a small-sized cellular base station that encompasses all the functionality of a typical station. It therefore allows a simpler and self-contained deployment including private residences. For the Malaysian service providers, the main attractions of femtocell usage are the improvements to both coverage and capacity. The operators can provide a better service to end-users in turn reduce much of the agitations and complaints. There will be opportunity for new services at reduced cost. In addition, the operator not only benefits from the improved capacity and coverage but also can reduce both capital expenditure and operating expense i.e. alternative to brand new base station or macrocell installation. Interference is a key issue associated with femtocell development. There are a large number of issues associated with interference all of which need to be investigated, identified, quantified and solved. This is to ensure that the deployment of any femtocells will take place successfully. Among the most critical challenges in femtocell deployment is the interference between femtocell-to-macrocell and femtocell-to-femtocell in HetNets. In this paper, all proposed methods and algorithms will be investigated in the OFDMA femtocell system considering HetNet scenarios for LTE-A.

1. Introduction
Nowadays, the wireless subscriber increased exponentially day by day wireless industry challenged with an increasing demand for ubiquitous wireless coverage and larger data rates. To support this highly demand for data traffic, Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) Release 8 is tried experienced by the cellular operators. The release 8 standard offers significant advantages with respect to its prototype, High Speed Packet Access (HSPA), such as higher spectral efficiency, lower latency due to its flat all internet Protocol (IP) architecture, and larger throughputs [1]. However, the performance of Release 8 does not meet the International Mobile Telecommunications (IMT) Advanced requirements for the fourth generation of mobile networks defined by the International Telecommunication Union (ITU). Accordingly, to meet such necessities which is for downlink data rates of up to 100 Mb/s and 1 Gb/s for mobile and nomadic users,
respectively, LTE Release 10 is now under standardization. LTE-A femtocells (HeNodeBs) are viewed as a promising option for mobile operators to improve coverage and provide high-data-rate services in a cost-effective manner by reducing the macro-eNodeB traffic load and offloading it over public broadband connections to the core network. Though HeNodeB technology reduces the cost but at the same time introduced complexity of deploy higher-capacity links to the eNodeB. Furthermore, Deploying large number of HeNodeBs in the indoor/outdoor environment is also a critical problem for the synchronization. HeNodeBs synchronization and control is centralized using IEEE1588. Since HeNodeBs depends on third party broadband operators for the control purpose which creating many problems. Synchronization is one of the principle concerns because of high traffic and limited broadband services. HeNodeBs synchronization is very important in order to avoid the interferences. The co-channel deployment in macro-eNodeB and HeNodeBs could increase the capacity of the network manifold through high spatial frequency reuse. However co-channel deployment in macro-eNodeB and HeNodeBs results interference in the network the ultimate is total system performance degradation and this interference becomes a key challenge in HetNet. The key challenges for LTE HetNets include backhaul for the small cells and effective use of interference cancellation so that the various overlapping cells do not interfere with one another.

This paper is organized as follows: section 2 presents some heterogeneous network architecture for LTE-A system. Section 3 presents related works and section 4 presents the Performance Analysis of Self-organized Approaches. Conclusion is given in Section 5.

2. Heterogeneous Network Architecture for LTE-A System

A Heterogeneous Network (HetNet) is the result of an operation approach consisting of two or more cellular layers [2]. Consequently the resulting network comprises a various mix of base-stations types such as macro-eNodeB, micro- eNodeB, Pico-eNodeB and more in recent time’s HeNodeBs (femtocells). In HetNet among the low-power nodes, HeNodeB and Pico-eNodeBs will play a key role. As HeNodeB, Pico-eNodeBs are low-power nodes that are typically deployed by operators within the coverage areas of eNodeB for capacity enhancement and coverage extension. In figure 1 HetNet network scenario is decomposed. Pico-eNodeBs usually have the same back-haul and access features as macro-eNodeBs. However, Pico-eNodeBs have lower transmit powers ranging from 23 to 30 dBm, and serve tens of User Equipment’s (UEs) within a coverage range of up to 300 m. The roll-outs of Pico-eNodeBs are expected to offload eNodeBs and increase network capacity. However, they also face technical challenges arising from the large difference in Down Link (DL) transmit powers among eNodeB (=46 dBm) and pico BSs (=30 dBm) [3]. However, HetNets are not a completely new concept; there is much unexploited potential branching from new network topologies. LTE-Advanced includes features that improve the support for heterogeneous deployments such as enhanced Inter-Cell Interference Coordination (eICIC).

To get rid of these issues and offer a noteworthy network performance leap, HetNets have been initiated in the LTE-standardization. LTE-A is a flat network based on packet only RAN architecture where macro-eNodeBs are interlinked through X2 interfaces. The basic principles for LTE-A are as bellows:

1. OFDMA (Orthogonal frequency division multiple access) in downlink.
2. SC-FDMA (Single carrier frequency division multiple access) in uplink
3. Scalable spectrum use from 1.4MHz to 20MHz.
4. Localized or distributed resource allocation for frequency selective or frequency diverse scheduling
5. Support for spatial multiplexing (MIMO/MU-MIMO)
6. Frequency and time division duplex for paired and unpaired spectrum
2.1. OFDMA for Downlink
The OFDM signal used in LTE includes a maximum of 2048 different sub-carriers with a spacing of 15 kHz. Although it is obligatory that the mobiles to be accomplished for receiving all 2048 sub-carriers. Here not all are required to be transmitted by the base station; rather it is only required to support the transmission of 72 sub-carriers. Like this way all mobiles will be able to communicate with any base station. Inside the OFDM signal it is likely to select between three types of modulation which are QPSK (= 4QAM) 2 bits per symbol, 16QAM 4 bits per symbol, and 64QAM 6 bits per symbol. The precise format is selected based on the predominant circumstances. QPSK, the lower forms of modulation, do not necessitate such a big signal to noise ratio but are not capable of sending the data in a faster rate. The larger order modulation format can be used only when a satisfactory signal to noise ratio exists.

In case of downlink, the subcarriers are divided into resource blocks which empower the system to be capable of arranging the data across standard numbers of subcarriers compartment wise. Resource blocks comprise of 12 subcarriers, one slot in the time frame irrespective of the general LTE-A femtocell signal bandwidth (see in figure 2). It can be understood that dissimilar LTE signal bandwidths will have diverse numbers of resource blocks.

2.2 SC-DMA for Uplink
For the LTE uplink, a different perception uses of the access technique while still using OFDMA technology, the implementation is called Single Carrier Frequency Division Multiple Access (SC-FDMA). A major parameter that has an effect on all mobiles is that of battery life. Despite the fact that the performance of battery is being upgraded continuously, it is still crucial to assure that the mobiles
use as little battery power as possible. With the RF power amplifier that transmits the radio frequency signal through the antenna to the base station being the maximum power item inside the mobile, it is essential that it functions as competent mode as possible. It can be meaningfully affected by the procedure of radio frequency modulation and signal format. Signals containing a large peak to average ratio and necessitate linear amplification do not lend themselves to the usage of efficient RF power amplifiers. Consequently the implication of a transmission mode has a continuous power level while in function. However, OFDM contains a high peak to average ratio. While this is not a difficulty for the base station where power is an imprecise problem, it is unsuitable for the mobile. Thus, LTE makes use of a modulation method addressed as SC-FDMA- Single Carrier Frequency Division Multiplex which is hybrid format and integrates the low peak to average ratio, where offered by single-carrier systems along with the multipath interference resilience as well as flexible subcarrier frequency allocation offered by OFDM.

3. Related works
Nowadays, different industrial challenges towards large deployment of HeNodeBs have been deliberated and researcher has considered it for achieving the solution. The interference is vastly occurred in macro-eNodeB-to-macro-eNodeB, HeNodeB-to-HeNodeB, and macro-eNodeB-to-HeNodeB which eventually worsen system performance. With the increasing number of cells the number of users at cell edges suffers from low throughput caused by interference [4]. However, interference for LTE-A systems is regarded as a key challenge in heterogeneous multi-cell networks where HeNodeBs makes use of identical licensed frequency spectrum with macro-eNodeB. Consequently, interference is a noteworthy issue connected with HeNodeB within HetNets. Several key issues regarding the interference should be studied for ensuring that the deployment of any HeNodeBs in HetNet will occur effectively. The query increases from the circumstance that HeNodeBs will apply the spectrum formerly allocated for cellular telecommunications. The HeNodeBs will be deployed where it can be termed an ad-hoc fashion; devoid of the network planning which is considered for the deployment of cellular telecommunications base stations in general. Therefore interference will be increasing to a greater extent. Certain difficulties will arise with the main network causing unexpected performance level degradation by both the HeNodeB-UEs and people who may be collaborating through the principal cellular network. Consequently, the level of performance trims down which is notified as a challenging concern for the telecom operators with the intention of managing the interference from the HetNets HeNodeBs-HeNodeBs and HeNodeBs-macro-eNodeB. Nevertheless, for enhancing the overall performance of the network an appropriate interference management is needed in OFDMA for the HetNet of LTE-A systems. Accordingly, an actual investigation is needed and the difficulties should be encountered for enhancing the performance of the HetNet. A number of requirements and parameters to be used for HeNodeB self-organization have been recognized in [5]. The uplink interference in two-tier HeNodeB networks was evaluated in [5], illustrating that tier-based open access can lessen the interference and offer an advancement in the network-wide area spectral efficiency – the feasible number of HeNodeBs and macro-eNodeB UEs per cell-site. Nevertheless, the evaluation of a self-organizing technique is still required and extra requirements and parameters are needed to investigate. Identical conclusions were established in different simulation-centric studies accomplished by the 3GPP RAN 4 group [6-8]. Downlink network capacities under open and closed access were explored in [7]; possible combinations of HeNodeBs and macro-eNodeBs under the restriction of network interference were scrutinized in [6]. Different developments were detailed in [8] for comparing HeNodeB open and closed access. All these simulations illustrate that with adaptive open access, the interference in two-tier networks is diminished and the deployment of co-channel HeNodeBs becomes feasible. Nevertheless, as HeNodeBs are mounted and paid for by their owners, it is required to assess their damage of HeNodeB resources in open access. It is significant that the advantages of reduced interference are not undermined by the loss of HeNodeB resources, namely over-the-air (OTA) and backhaul capacity.
4. Performance Analysis of Self-organized Approaches

Macro-eNodeB networks require complex and expensive manual planning and configuration. The main functionalities of SON for integrated HeNodeB and macro-eNodeB networks are self-configuration, self-optimization, and self-healing. The self-configuration function includes smart frequency allocation among HeNodeB neighbour networks, self-optimization feature includes optimization of transmission power HeNodeBs neighbour networks, maintenance of adjacent cell list, coverage control, and robust mobility management; and self-healing feature includes automatic detection and resolution of most failures. In hybrid solution SON logic is divided between network management system and network elements. However, decentralized approaches also need to be more concern for SON. In OFDMA based technology, an option for the femtocell is to select those subcarriers not being in use by the macro-eNodeB network [9]. In order to solve the problem for better system performance of the self-organization of Orthogonal Frequency Division Multiple Access (OFDMA) HeNodeBs needs more focus on dynamically air interface and tune its sub-channel allocation to reduce inter-cell interference and enhance system capacity [10]. SON permit HeNodeBs to associate themselves into the network of the operator and learn about their neighbouring cells, interference and tune their parameters (power, frequency) consequently [11]. If HeNodeBs and macro-eNodeBs share the similar spectrum, interference difficulty rises [12]. In [13], a power control method for pilot and data channels is introduced in UMTS networks that assure a continuous coverage HeNodeB radius. Every HeNodeB sets its power to a value that is almost equivalent to the power received from the nearest macro-eNodeB at a target HeNodeB radius. However, with the purpose of fully benefit from LTE-A HetNet deployments, the main challenges for comprises interference. A number of self-organized interference management techniques and methods are discussed in the following subsections.

4.1 Power Control Technique

In [4], the authors projected interference management techniques for both downlink and uplink of HeNodeBs operating based on HSPA. Authors suggested HeNodeB carrier selection and HeNodeB DL transmit power self-calibration techniques for interference management techniques for downlink. Uplink interference management was proposed using adaptive attenuation and limiting the transmitting power at the HeNodeB and as well as HeNodeB UEs. Figure 3 demonstrated that 10 units of macro-UE and 12 of HeNodeB UE per macro-eNodeB cell exist with the presence of HeNodeBs. There are 22 (10 + 12) UE units per cell operated by the macro when HeNodeBs are not present.

Figure 3: HSPA+ HeNodeB UL performance with strong interference [4].

Additionally, in figure 3 illustrates that the adaptive UL attenuation algorithm assures stable UL operation and better user experience with the existence of strong explode interference. Figure 4
illustrates the HSPA+ throughput cumulative distributed operations (CDFs) on the shared frequency with and without HeNodeB deployment for the DL and UL, correspondingly. 10 units of macro-eNodeB UE and 12 of HeNodeB UE per macro-eNodeB exist with the presence of HeNodeB UEs. Besides, 22 (10+12) UE units per cell served by the macro-eNodeB. Besides, it can be perceived from Figure 4 that when HeNodeB deployed significant capacity gains achieved which is advantageous for both macro-eNodeB and HeNodeB.

4.2 Resource Partitioning Technique

Co-tier interference is addressed by the undesirable signals received by UEs from co-channel LPNs. Co-tier refers to interfering signal coming from the similar network tier. As open access LPNs, namely Pico-eNodeBs, relay nodes, are planned by operators; the co-tier interference is less strong between them. ICIC techniques standardized by 3GPP in LTE/LTE-A can handle this interference effectively. The most severe co-tier interference occurs in HeNodeBs, deployment which typically functions in close access mode. HeNodeBs are usually deployed by end users and has lacking of powerful backhauls, henceforth fast reacting ICIC techniques are inaccessible [4]. On the contrary, co-tier interference is produced by HeNodeBs owing to the low isolation of walls or windows. Nevertheless, OFDMA HeNodeBs are capable of avoiding co-tier interference by assigning frequency resources appropriately among user in a greater time scale or by self-organizing methods. Nevertheless, cross-tier interference can be escaped by initiating a new interference coordination model in macro-eNodeB–Pico-eNodeB and HeNodeB heterogeneous networks.

In [15], interference avoidance is thoroughly analysed while using a time-hopped Code Division Multiple Access (CDMA) physical layer as well as sectorial antennas. As HeNodeBs are conceived to be user-deployed, it is of great interest that HeNodeBs is able to arrange themselves for diminishing interference towards the macro-eNodeB and selecting optimal resource allocation for transmissions. For instance, when OFDMA based technology is considered, an option for the HeNodeB is to choose those subcarriers not being in use by the macro-eNodeB network. For avoiding incessant collision within nearby OFDMA HeNodeBs, Long Term Evolution Advanced (LTE-A) system has implemented orthogonal frequency division multiplexing (OFDM) technique as the air-interface technology, the key target is to provide large wireless data rates for growing user demands. In [16], the necessities of LTE-A system are mentioned for supporting HeNodeB networks through enhancing the system capacity. Generally HeNodeB networks provide voice, data, video along with abundant wireless services within a small range of indoor coverage or inadequate geographical zone. These are raised by different companies as an important research field in the IMT-Advanced standardization exertions. Henceforth, it is indispensable to analyse the interference coordination schemes to improve the capacity of the HeNodeB networks. The inter-cell interference should be considered and the intra-cell interference can be avoided as the orthogonal frequency resource assigned in OFDM based cellular network. For reducing inter-cell interference, frequency reuse has been expansively regarded for wireless systems.

4.3 Hardware Centric Approaches

Authors in [17] presented hardware centric approaches for interference cancellation. The techniques employed either at MAC or physical layer to control or mitigate interference. Practically, in the cellular system the downlink and uplink characteristics are very different to increase the capacity of cellular systems. In the downlink each receiver only needs to decode a single desired signal from the K of intra-cell signals, while suppressing other cell interference from a few dominant neighbour cells as shown in figure 5. As all K users’ signals originate at the base station, the link is synchronous and the K-1 intra-cell interferers can be orthogonalized at the base station transmitter [17]. However, some orthogonality is lost in the channel.
Conversely, in the uplink the base station receiver must decode all $K$ desired users while suppressing other cell interference from many independent sources, as shown in figure 6.

4.4 Frequency Scheduling Techniques

Authors in [18], a different type of interference challenges also observed where inter-carrier-interference (ICI) analysed. It is essential to manage the received interference by avoiding the use of those frequency resources at the HeNodeB network and exploited the spectrum resources competently. To mitigate the CSG HeNodeB deployment CCI problem between the HeNodeBs and macro-eNodeB UEs for both in UL and DL authors proposed an interference handling framework for near-by macro-eNodeB UEs and HeNodeBs. HeNodeB senses the spectrum during UL, identifies the close-by users through UL scheduling information, and avoids using their spectrum specified in DL scheduling information. However, this scheme utilizes the result of spectrum sensing in terms of energy detection with respect to the distance as availability of scheduling information. Authors in [18] proposed an interference-aware radio resource management scheme where receivers inform about their throughput, interference, and signal levels by means of broadcast messages tied to data reception. They propose a signaling structure for TDD systems that enables distributed interference-aware scheduling. In which, the receivers transmit a small broadcast interference report after reception of data, which allows other transmitters to become active on the corresponding resources only in the case when it is beneficial for the overall system performance. Furthermore, authors outlined the signaling implementation and distinguished the overhead caused. The performance of interference-aware scheduler are estimated in numerical instances, it’s also compared to both PF scheduler and the global optimum transmission schedule obtained by a centralized scheduler having full system wide information. However, in this proposed algorithm still there have research issues. For instance, the challenge stands that of the scalability with the amount of users per cell. In case the amount of UEs per cell grows, it becomes necessary to either time-domain multiplex the UEs over frames or subdivides the resource units to finer granularity. This would mean that the persistence would be partially lost or increased overhead.

4.5 Frequency Reuse Technique

In [19], an adaptive fractional frequency reuse (AFFR) scheme was proposed typically and implemented in planning cell coverage where SINR is calculated in accordance with the received signal power and interference power level. Furthermore, throughput attained through mapping the calculated SINR in accordance with the ideal link-adaptation based LTE link-level capacity. Single Input Single Output (SISO) system capacity is estimated through the following equation 1.

$$ S = \begin{Bmatrix} BW_{eff} \cdot \log_2 \left( 1 + \frac{\min \{ SINR_{SIR}, SINR_{SINR} \}}{\max \{ SINR_{SIR}, SINR_{SINR} \}} \right) & \text{for } 0.5 \cdot \frac{\min \{ SINR_{SIR}, SINR_{SINR} \}}{\max \{ SINR_{SIR}, SINR_{SINR} \}} \leq 1 \\ 0 & \text{otherwise} \end{Bmatrix} $$

(1)

where $S$ is signified as estimated spectral efficiency in bps/Hz, which is upper limited according to the hard spectral efficiency given by 64QAM with coding rate 4/5; $BW_{eff}$ adjusts for the system bandwidth.
efficiency of LTE and $\text{SINR}_{\text{eff}}$ adjusts for the SINR implementation efficiency of LTE. However, this scheme was not appropriate for the flexible deployment scenario as the HeNodeB networks.

In [24], the traditional frequency reuse strategy was proposed in on cellular clustering, which decreases inter-cell interference at the cost of both average cell throughput and spectrum efficiency. Originated from the idea of classical reuse clustering, fractional frequency reuse [25], soft frequency reuse [19] and partial frequency reuse [20] assigned the cell-edge users with advanced reuse factor than centre users in order to acquire an efficient factor larger than 1. A distributed utility based signal to interference plus noise ratio (SINR) adaptation in HeNodeBs was developed in [20] for reducing cross-tier interference at the macro-eNodeBs from co-channel HeNodeBs. An interference avoidance using a time hopped Code Division Multiple Access (CDMA) physical layer and sectorial antennas is investigated in [21]. Nevertheless these methodologies are typically founded upon wideband code division multiple Access (WCDMA) networks, and it is difficult to minimize interference through sub-channel allocation, since these are sophisticated features of current Orthogonal Frequency Division Multiple Access (OFDMA) systems. Furthermore in [21], the authors investigated a fixed frequency reuse scheme (FFR), which is competent for local area scenarios in the LTE-A system; though the restrictions on the frequency bandwidth reduce the spectrum efficiency.

In [22], authors projected the interference coordination between HeNodeBs in LTE-proposing CA-based interference coordination. In the Downlink LTE-A network with HeNodeB authors presumed few HUEs with very little or even no mobility linked to the HeNodeB in the small coverage area per cell for simplicity. Additionally, an analytical technique prolonged for the cases with more than one UE per cell [22]. For finding out the optimization issue author extended three equations. In the downlink transmission with N users and K carriers in the network are considered. The transmitting power $P_T$ is remained identical in each carrier per cell and for the resource allocation among the users a binary matrix is also assumed as below, where $\alpha_{k,n} = 1$ is denoted as that carrier $k$ is assigned to user $n$, or else $\alpha_{k,n} = 0$. $A = \{a_{k,n} | a_{k,n} \in \{0,1\}\} K \times N$. Henceforth, the achievable rate on carrier $k$ in HeNodeB $n$ is expressed by the following equation 2 [53].

$$\eta_{k,n} = W \log_2 \left( 1 + \frac{L_{n,j} P_T}{\sum_{j=1,j \neq n}^{N} L_{n,j} + \sigma^2} \right), \quad (2)$$

for $1 \leq k \leq K, 1 \leq n \leq N$

where $W$ is the carrier bandwidth $L_{n,j}$ is the path loss (PL) from the $j^{th}$ user’s serving HeNodeB to UE $n$, and $\sigma^2 N$ is the noise power of the additive white Gaussian noise (AWGN). The key objective is to find $A$ to interference coordination difficulty namely an objective function is optimized. Typically, the subsequent optimization difficulties with different objectives are required to be solved for interference coordination. Furthermore, authors in [23] further added that in order to coordinate the interference problem the maximization of throughput and maximization of the proportional fair with different objectives are required. To attain the maximum possible system spectrum efficiency throughput maximization is essential which can be formulated as equation 3.

$$\max_{A} \sum_{n=1}^{N} \sum_{k=1}^{K} a_{k,n} \eta_{k,n} \quad (3)$$

For attaining the maximum system throughput while assuring proportional fairness among HeNodeBs, the total of the logarithmic average cell throughput should be maximized as in equation 4.

$$\max_{A} \sum_{n=1}^{N} \log \left( \sum_{k=1}^{K} a_{k,n} \eta_{k,n} \right) \quad (4)$$

Furthermore, author’s also organized two steps based carrier aggregation (CA). The first step is founded on the measurement at HeNodeB of the inter-cell interference. Every HeNodeB is allocated to a carrier that is on-overlapping with its interfering HeNodeBs or involves the least interference. To assure the fairness between HeNodeBs, a single carrier is allocated to each HeNodeB.
In view of the second step, the carriers already used by a HeNodeB are shared to other HeNodeBs for enhancing the spectrum efficiency of the network. It is based on the utility function calculated at HeNodeB UE in equation 5.

\[ \phi(k) = \frac{r_{n,k}}{\sum_{m} I_{n}^{(k)} r_{n,m}} \]  

(5)

Where \( r_{n,k} \) and \( r_{n,m} \) represent the RSRP measured at HeNodeB UE \( n \) and \( m \) from HeNodeB \( n \) and \( m \), correspondingly, and \( I_{n}^{(k)} \) embodies the set of interfering HeNodeBs of HeNodeB \( n \) which uses carrier \( k \). If SIR is more than a specific threshold HeNodeB \( n \) decides to use the carrier \( k \). It then sends a frequency reuse request to those HeNodeBs in \( I_{n}^{(k)} \) which are currently using carrier \( k \). The frequency reuse request message carries a utility value, which is determined by the different objectives. Regarding the maximum throughput or maximum proportional fair objective, the utility can be calculated by either of the formulas given as

\[ U_{k,n}^{A} = \frac{g_{n}^{(k)}}{\eta_{n}} \]  

(6)

\[ U_{k,n}^{B} = \frac{g_{n}^{(k)}}{\eta_{n}} \]  

(7)

\[ \tilde{U}_{k,n}^{A} = g_{m}^{(k)} \]  

(8)

\[ \tilde{U}_{k,n}^{B} = \tilde{g}_{m} \]  

(9)

\( g_{m}^{(k)} \) symbolizes the throughput gain of HUE \( n \) if carrier \( k \) is granted to it (i.e. the throughput of HeNodeB UE \( n \) on carrier \( k \) which is the function of \( \phi(k) \), \( \tilde{g}_{m} \) is current throughput of HeNodeB \( n \) without using carrier \( k \), and \( |I_{n}^{(k)}| \) signifies the size of set \( I_{n}^{(k)} \). The equation 6 considers maximizing the sum throughput of all the HeNodeBs and equation 7 for fairness issues.

Figure 7: Adaptive Frequency Reuse process

Figure 8: Throughput performances with different threshold in OFP

An instance of the AFR process is illustrated in figure 7, where three carriers are assumed to be present in the network. In figure 7, “O” symbolizes for orthogonal carriers while “R” signifies for the reuse carrier. Once HeNodeB g is powered on and has selected its orthogonal carrier, it scrutinized whether it is able to reuse the other carriers with its neighbours. Here, in this case, second carrier is the
candidate reuse carrier of HeNodeB $g$ is assumed. Afterwards, a “Frequency Reuse Request” signalling is sent to other HeNodeBs by HeNodeB $g$ belonging to the set $J_{m}^{(2)}$ which are using the second carrier. In the request signalling message, HeNodeB $g$ sends the value of its $U_{2,g}^{A}$ or $U_{2,g}^{B}$. After receiving the request signalling, the HeNodeBs in the set $J_{m}^{(2)}$ HeNodeB $a$, $c$, $d$ and $f$, calculate the $iU_{2,m}^{A}$ or $iU_{2,m}^{B}$, $(m = a, c, d, f)$ values. When $iU_{2,m}^{A} < U_{2,g}^{A}$, $iU_{2,m}^{B} < U_{2,g}^{B}$, HeNodeB $m$ will send a “Frequency Reuse Permission” signalling to HeNodeB $g$; otherwise, it will send a “Frequency Reuse Denial” signalling. HeNodeB $g$ cannot use the second carrier until all the HeNodeBs feedback “Frequency Reuse Permission” signalling messages.

![Figure 8: CDF of cell throughput in the network](image1)

![Figure 9: CDF of cell throughput](image2)

In figure 7, the average throughput (TP) performances of the network along with developed channel allocation method are detailed while using numerous values of threshold in the first step, i.e. OFP. More average throughput can be achieved because carriers are reused by femtocells more often with the lesser value of the threshold. The CDF performances of the networks with or without the suggested interference coordination arrangement are compared in figure 8 and figure 9, where the deployment ratio $\rho$ is 0.2 and 1, respectively.

5. Conclusion

With the intention of improving the coverage and capacity for the Malaysian Telecommunication service HeNodeB deployment is the critical challenge since all operators established their network with macrocell, microcell, radio heads, and relay station. In this paper, we investigated the HeNodeB deployment issues in heterogeneous network in LTE-A systems. Additionally in terms of HeNodeB adoption, the architecture for HetNets in LTE-A is also highlighted. Deploying HeNodeB in HetNets inter-cell interference was found one of the key issues. For interference mitigation a number of self-organizing approaches are evaluated with the performance analysis. From performance analysis it can be conclude that to increase the system throughput inter-cell coordination is highly recommended.

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