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Research Article

Performance Analysis of Interference Coordination Techniques in Heterogeneous Network

Mohammad K. Hasan, A.F. Ismail, Aisha H. Abdalla, Khaizuran Abdullah and H.A.M. Ramli
Department of Electrical and Computer Engineering, Faculty of Engineering,
International Islamic Universiti, Kuala Lumpur, Malaysia

Abstract: Deploying femtocell in heterogeneous network (HetNets) are promising because of improved coverage as well as system capacity. The challenge for inter-cell and intra-cell interference has taken seriously by the industry. However, some distinctive characteristics presents key problem to mitigate the interference. The random deployment of femtocell (HeNodeB) and other small cell in HetNet becomes a key considerations issue because of interference which lead the performance degradation. The interference occurs between HeNodeB-to-macro cell and HeNodeB-to-HeNodeB in the case of uplink/downlink with the user equipments. Consequently, researchers have proposed some techniques to take over the interference in HetNet which need to be investigate, identify, quantify along with solution. Therefore, the aim of this study to evaluate the performance of potential interference alleviation schemes/techniques in Orthogonal Frequency Division Multiple Access (OFDMA) considering HetNets uplink/downlink scenario.

Keywords: Femtocell, HetNet, inter-cell interference, OFDMA, self-organizing

INTRODUCTION

As the wireless subscriber increased exponentially day by day, telecom-operators is challenged by an increasing demand for ever-present wireless coverage and larger data rates. To support this highly demand for data traffic, Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) Release 8/9 is tried experienced by the cellular operators. The release 8/9 standard provides major advantages with respect to its prototype, High Speed Packet Access (HSPA). Higher spectral efficiency, lower latency due to its flat all Internet Protocol (IP) architecture and larger through puts are few of the advantages (Lopez-Perez *et al*., 2011). Never the less, the performance of Release 8/9 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.

The motivation of this study is to analyze, evaluate the performance of the self organized interference coordination approaches and techniques as well as the architecture of LTE-A HetNet.

Corresponding Author: Mohammad Kamrul Hasan, Department of Electrical and Computer Engineering, Faculty of Engineering, International Islamic Universiti, Kuala Lumpur, Malaysia

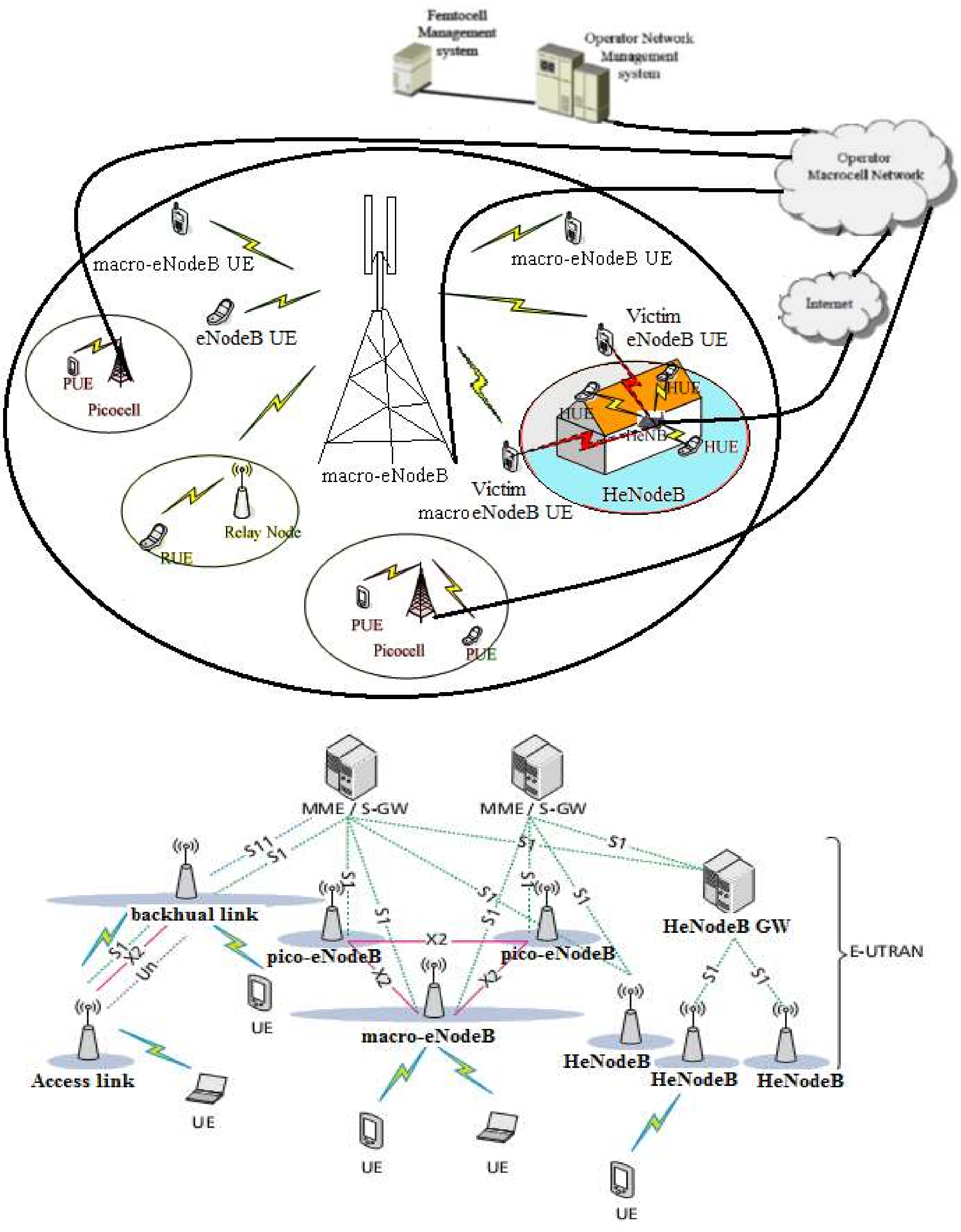

Fig. 1: LTE-A HetNet network architecture with the interfaces (Aleksandar *et al*., 2011)

HETEROGENEOUS NETWORK ARCHITECTURE

A Heterogeneous Network (HetNet) is the result of an operation approach consisting of two or more cellular layers (Khandekar *et al*., 2010). 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). Surrounded by the HetNets, HeNodeB and Pico-eNodeBs will perform as the 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 (Lopez-Perez *et al*., 2011). In Fig. 1 HetNet network scenario is decomposed. Pico-eNodeBs usually have the same back-haul and access features as macro-eNode Bs. Pico-eNodeB transmits power 23 to

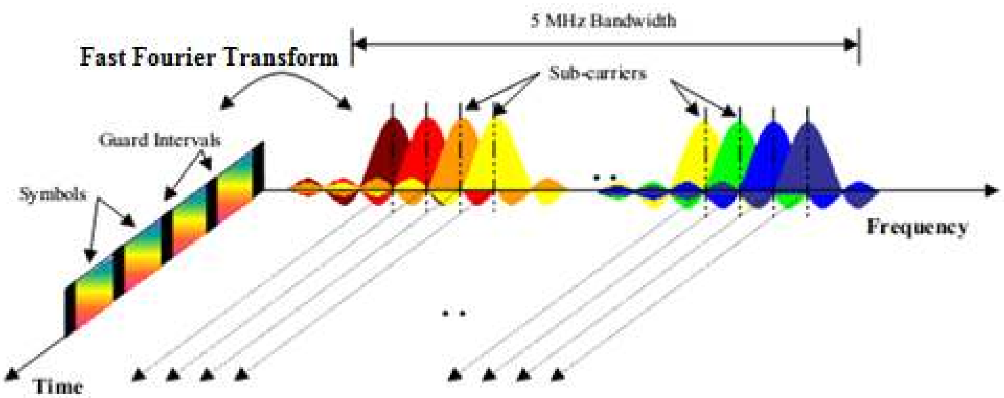

Fig. 2: Frequency-time illustration of an OFDM signal (Erik *et al*., 2011)

30 dBm and oblige ten User Equipment's (UEs) within a coverage range of up to 300 m. However, 20 dB power transmits to 30 m coverage area within four to five UEs The roll-outs of Pico-eNodeBs are expected to offload eNodeBs and increase network capacity. Meanwhile HeNodeBs usually deployed in indoor environment to extend the coverage. However, they also face technical challenges arising from the large difference in Down Link (DL) transmit powers among macro-eNodeB (≈46 dBm), pico BSs (≈30 dBm) and HeNodeB ((≈20 dB) (Claussen*et al*., 2008; Mohammad *et al*., 2012). Furthermore, HetNets are unexploited potential branching from new network topologies. LTE-Advanced includes features that improve the support for HetNets 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 (Aleksandar *et al*., 2011). The basic principles for LTE-A are as bellows:

- OFDMA in downlink
- SC-FDMA (Single Carrier Frequency Division Multiple Access) in uplink
- Scalable spectrum use from 1.4 to 20 MHz
- Localized or distributed resource allocation for frequency selective or frequency diverse scheduling
- Support for spatial multiplexing (MIMO/MU-MIMO)
- Frequency and time division duplex for paired and unpaired spectrum

OFDMA for downlink: The OFDM signal that is utilized in LTE includes a maximum of 2048 different sub-carriers with a spacing of 15 kHz. Even though it is obligatory that the mobiles to be accomplished for receiving all 2048 sub-carriers. Here not all are required to be disseminated by the base station; rather it is only required to support the transmission of 72 sub-carriers (Holma and Toskala, 2011). In this way, the communication with base station will become more feasible for all mobiles. Three types of modulation is likely to be inside for the LTE-A OFDM signal it is likely to be selected between three types of modulation, which are QPSK 2 bits/symbol, 16 QAM 4 bits/symbol and 64 QAM 6 bits/symbol. QPSK the lower forms of modulation, which hinders 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. Figure 2 displays an OFDM signal (Erik *et al*., 2011) with 5 MHz bandwidth. It is significant that the data symbols are individually modulated and transmitted over a densed spaced orthogonal sub-carriers.

Table 1: The channel bandwidth per number of resource block

Channel bandwidth $BW_{channel}$ [MHz}	1.4	3	5	10	15	20
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

In 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 (Fig. 3). It can be understood that dissimilar LTE/LTE-A signal bandwidths will have diverse numbers of resource blocks. The channel bandwidth per number of resource block is tabulated in Table 1.

Furthermore, the subframes are assembled in 10 ms radio frames, which holds two 5 ms halves containing the signals essential to acquire the physical identity of the cell. The signals are the primary and secondary synchronization signals for aquisition channels, also called the Physical Cell Identity (PCI) of the cell and the Physical Broadcast Channel (PBCH), be responsible for some critical system information such as the DL transmission bandwidth and the number of DL antenna ports. The acquisition channels share the property of

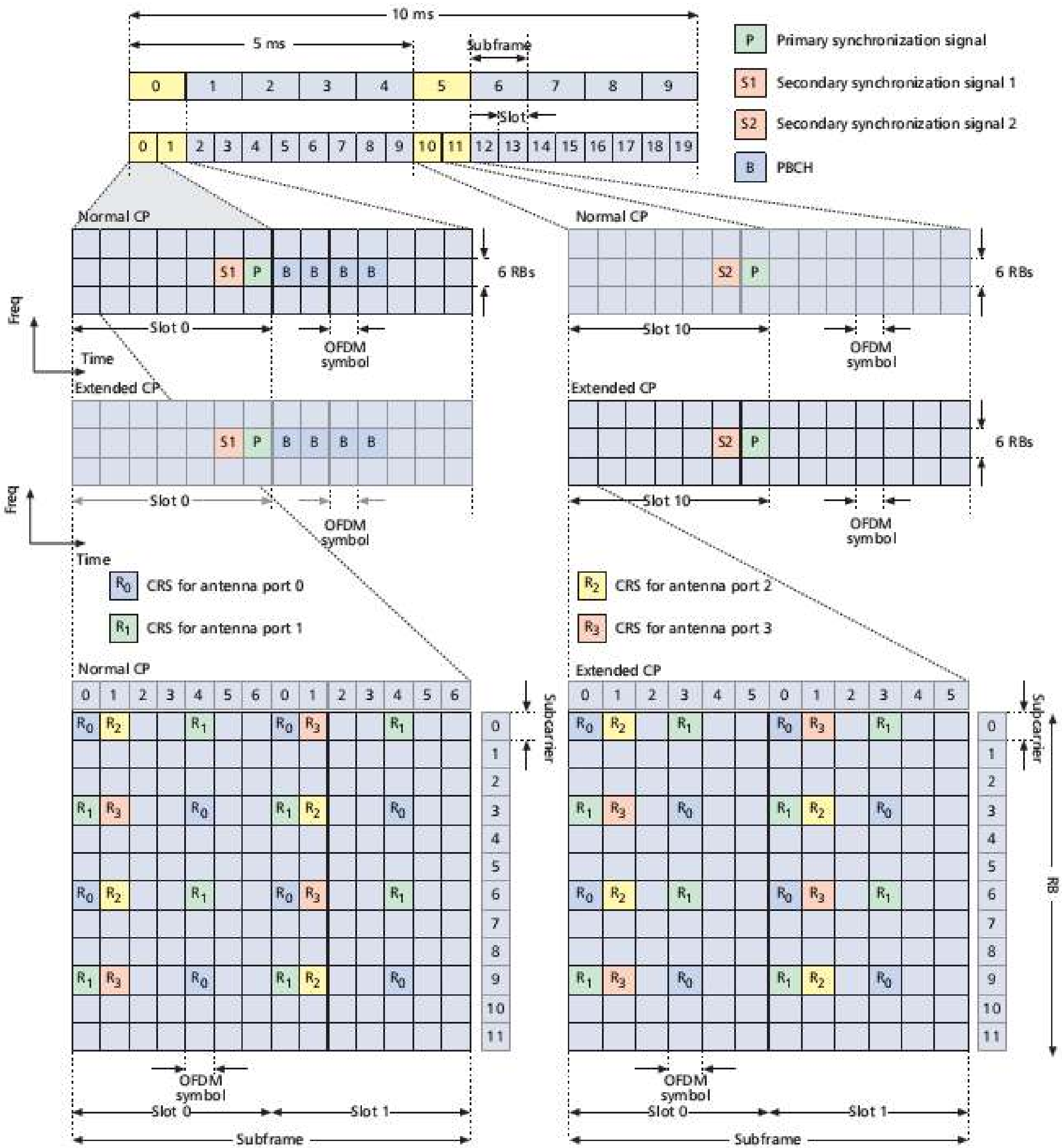

Fig. 3: Illustration of for OFDMA DL physical layer arrangement (Aleksandar *et al*., 2011)

spanning the middle six RBs of the system band-width (Aleksandar *et al*., 2011).

SC-DMA for uplink: For the LTE uplink, a different perception uses of the access technique while still using OFDMA technology, the implementation is known as 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 (Holma and Toskala, 2011). However, 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

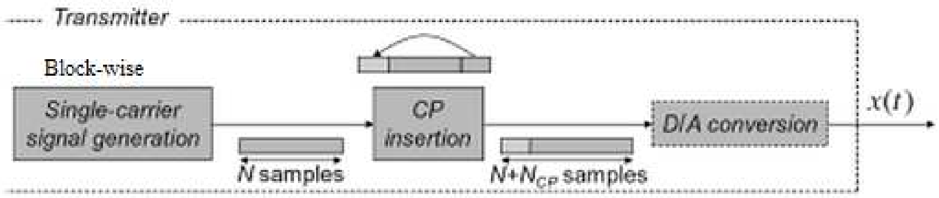

Fig. 4: CP adding in a single carrier transmission (Erik *et al*., 2011)

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/LTE-A makes use of a modulation method addressed as SC-FDMA-Single Carrier Frequency Division Multiplex. This is hybrid format and integrates the low peak to average ratio offered by single-carrier systems along with the multipath interference resilience as well as flexible subcarrier frequency allocation offered by OFDM. In LTE-A the guard interval is a Cyclic Prefix (CP) which is inserted prior to each OFDM symbol. In the time domain, adding a CP to each symbol can be useful to mitigate inter-OFDM-symbol-interference due to channel delay spread. The data throughput capacity will be reduced once the CP length is too long. For LTE-A, the standard length of the cyclic prefix has been chosen to be 4.69 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 (Erik *et al*., 2011). In Fig. 4 demostrated the CP adding in a single carrier transmission.

However, the block-wise single carrier generation equalization need to most accurate and the channel should be constant over time span corresponding to the size of the processing block. This constraint provides an upper limit on the block size N that fully depends on the rate of the channel variations. Additionally, the OFDM subcarrier spacing $\Delta f = 1/T_u$ depending on the rate of the channel variations (Erik *et al*., 2011).

LITERATURE REVIEW

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 (Mehmet *et al*., 2009). 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. The uplink interference in two-tier HeNodeB networks was evaluated (MacDonald, 1979), 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 (Begain *et al*., 2002; 3GPP RI-050507, 2005; 3GPP RI-060291, 2006). 3GPP were explored in 3GPP RI-050507 (2005) for downlink network capacities under open and closed access; possible combinations of HeNodeBs and macro-eNodeBs under the restriction of network interference were scrutinized (Begain *et al*., 2002). Different developments were detailed in (3GPP RI-060291, 2006) for comparing HeNodeB open and closed access. All these simulations illustrate that with adaptive open access, the interference in two-tier networks is

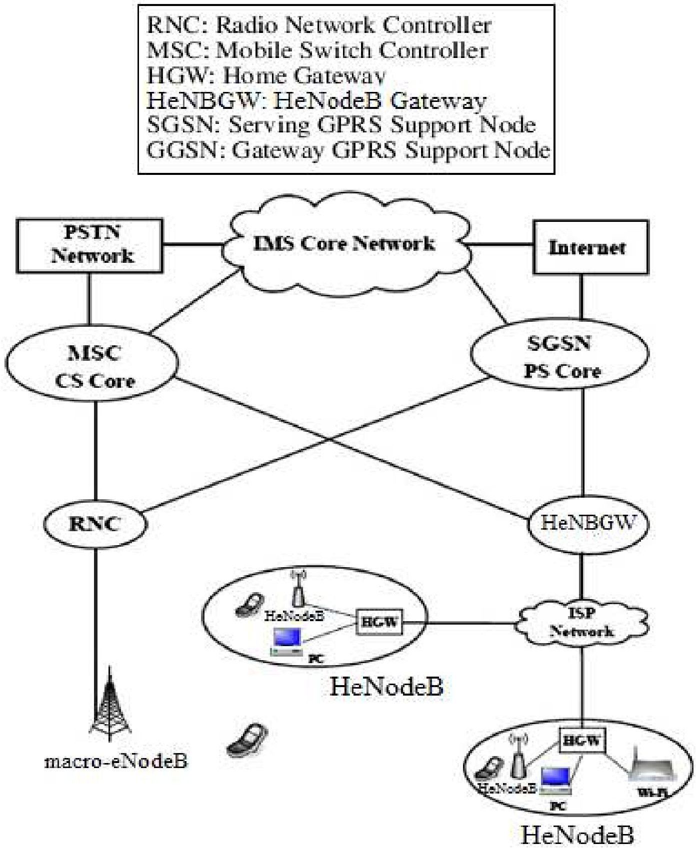

Fig. 5: The deployment of HeNodeB in SON (David, 2009)

diminished and the deployment of co-channel HeNodeBs becomes feasible (Ping *et al*., 2010). Nevertheless, as HeNodeBs are mounted and paid for by their owners, it is required to assess their damage of HeNodeB resources in open access. However, it is significant that the advantages of reduced interference are not undermined by the loss of HeNodeB resources, namely over-the-air and backhaul capacity.

The self-configuration function includes smart frequency allocation among HeNodeB neighbor networks, self-optimization feature includes optimization of transmission power HeNodeBs neighbor networks, maintenance of adjacent cell list, coverage control and robust mobility management; and self-healing feature includes automatic detection and resolution of most failures. Figure 5 shows the basic features and framework of SON-capable integrated HeNodeB/macro-eNodeB network architecture (David, 2009).

Due to Peer-to-peer handover between HeNodeBs on the grid no central controller needed. SON works as centralized and hybrid approach. 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 HeNodeB is to select those subcarriers not being in use by the macro-eNodeB network.

PERFORMANCE ANALYSIS OF NTERFERENCE MITIGATION APPROACHES

A number of problem already identified for the SON which are parameter selection such as sub-carrier selection, FFR, frequency resuse, power adjustment, allowing open access to the HeNodeB. Here, the evaluation of a self-organizing strategy is still needed and parameters are interesting to investigate. And additional requirements OFDMA based SON should be revised. 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 (Lopez-Perez, 2009). SON permit HeNodeBs to associate themselves into the network of the operator and learn about their neighboring cells, interference and tune their parameters (power, frequency)

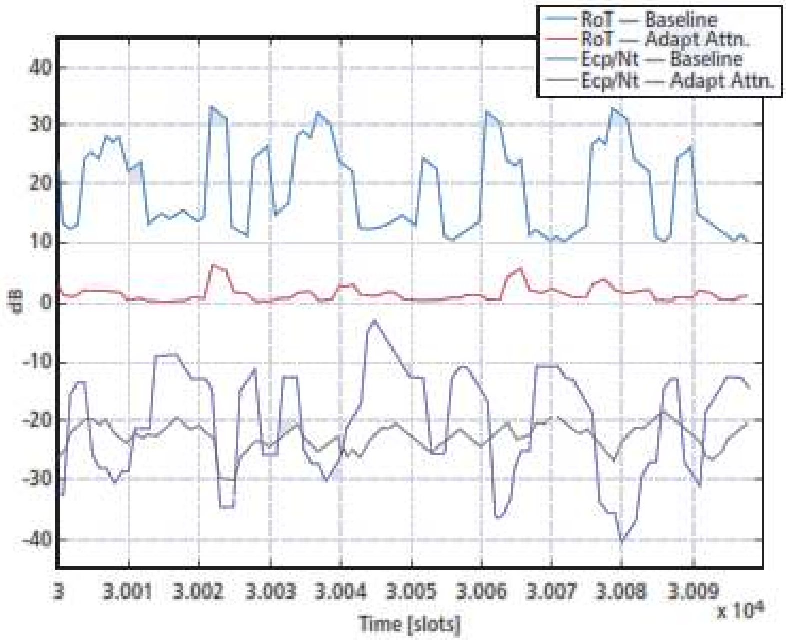

Fig. 6: Interference performance of HeNodeB UL (Mehmet *et al*., 2009)

consequently. If HeNodeBs and macro-eNodeBs share the similar spectrum, interference difficultyrises (Juan and Jan, 2009). However, with the purpose of fully benefit from LTE-A HetNet deployments, the main challenges for comprises interference. Power control, resource partitioning, hardware centric, frequency reuse,adaptive frequency reuse techniques were proposed to mitigate the interference (Himayat *et al*., 2010; Mehmet *et al*., 2009; Jun *et al*., 2012; Chandrasekhar *et al*., 2008; Lopez-Perez, 2009; Gen *et al*., 2010; Suzan *et al*., 2009; Jun *et al*., 2012; Zheng *et al*., 2010). The details of these techniques are analyzed in this section with the performance analysis.

Power control technique: Power control techniques dynamically tune LPNs and macro-eNodeBs transmit power according to the changing condition of passing users, as well as for the neighboring cells and channel quality. For instance, a proposal for a self-organizing power control mechanism has been made by the authors (Himayat *et al*., 2010) to ensure a constant femtocell coverage radius, where each femtocell sets its power to a value that on average is equal to the power received from the closest macro-eNodeB at a target HeNodeB radius. From this method, it can be summarized that each femtocells set its power to a value that on average minimizes the number of attempts of passing macro-eNodeB users for connecting to a HeNodeB. However, power control methods may lead eventually to insufficient coverage of LPNs. Interference avoidance schemes in frequency dimension usually assume the transmit powers of LPNs and macro-eNodeBs are fixed. This is a major concern as on how to allocate frequency resources for interference coordination which needs determine.

The authors (Mehmet *et al*., 2009) has shown the interference management techniques for both uplink and downlink of HeNodeBs operating based on HSPA+. HeNodeB carrier selection and HeNodeB DL transmit power self-calibration techniques, which are used for the interference management techniques of downlink, were suggested by the authors. A suggestion of usage of Uplink interference management was given by using the adaptive attenuation and controlling the transmitting power at the HeNodeB and HeNodeB UEs at a limited level. A demonstration of the existence of 10 units of macro-UE and 12 of HeNodeB UE per macro-eNodeB cell has been shown in Fig. 6. When there is an absence of HeNodeBs, 22 (10+12) UE units per cell, which is operated by the macro, will be present.

Furthermore, the adaptive UL attenuation algorithm has been shown in Fig. 7. It confirms the stable UL operation and with the existence of strong explodes interference; it ensures much improved user experience.

An illustration of HSPA + throughput Cumulative Distributed operations (CDFs) has been shown in Fig. 7 and 8 and it is based on the shared frequency with and without HeNodeB the deployment for the DL and UL. There is an existence of 10 units of macro-eNodeB UE and 12 of HeNodeB UE per macro-eNodeB, with the

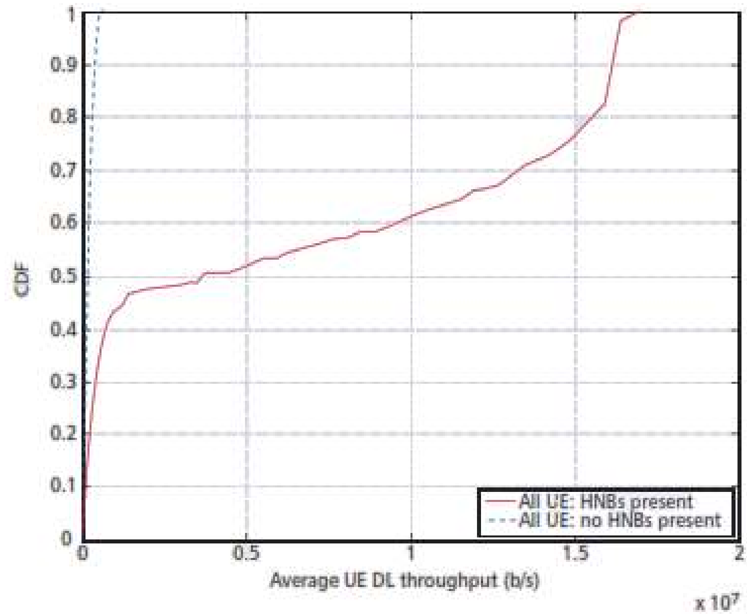

Fig. 7: DL user throughput distributions on shared frequency (Mehmet *et al*., 2009)

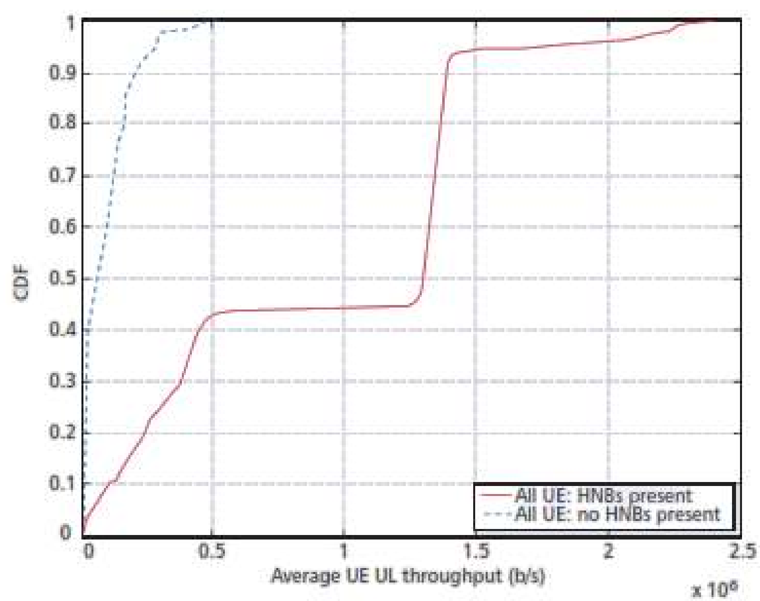

Fig. 8: UL user throughput distributions on shared frequency (Mehmet *et al*., 2009)

presence of HeNodeB UEs. There is also a presence of 22 (10+12) UE units per cell, which served by the macro-eNodeB, with the absence of HeNodeB (Fig. 8). Therefore, it can be apprehended from Fig. 7 and 8 that when HeNodeB is deployed, a significant capacity gains are achieved, thus providing an advantage for both macro-eNodeB8and HeNodeB.

Resource partitioning technique: Co-tier interference is consigned based on the undesirable signals received by UEs from the co-channel LPNs. Co-tier refers to interfering signal that is received from the similar network tier. Operator based planning with an open access LPNs, are Pico-eNodeBs and relay nodes, the co-tier interference is subsides between them. The interference can be handled effectively with the ICIC techniques standardized by 3GPP in LTE/LTE-A (Jun *et al*., 2012). The co-tier interference occurs in HeNodeBs in a very severe manner, thus deployment functions in a close access mode. HeNodeBs are usually deployed by end users and has a lack of influential backhauls, henceforth fast reacting ICIC

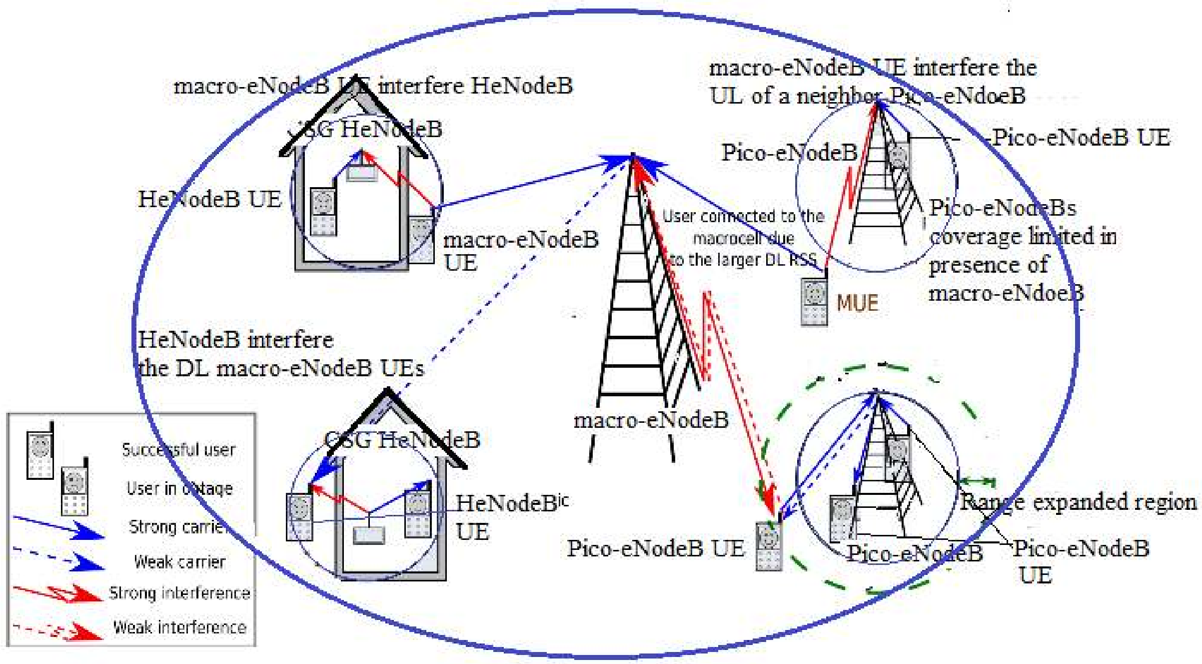

Fig. 9: Representation of UL/DL cross-tier interference scenarios in HetNet

techniques are impervious (Jun *et al*., 2012; Mohammad *et al*., 2012). In any case, co-tier interference is formed by HeNodeBs owing to the low isolation of walls or windows. The avoidance of co-tier interference is achievable by OFDMA HeNodeBs by properly assigning frequency resources among users in a bigger time scale or by self-organizing methods. Cross-tier interference represents the signal radiated on LPNs' UEs because of the concurrent transmissions of neighbouring macro-eNodeBs and vice versa. Conceptually, cross-tier interference is significant for macro-eNodeB users near Closed Subscriber Group (CSG) HeNodeBs, as they are not permitted to connect for closing HeNodeBs with reduced path losses than their operating macro-eNodeBs, which occurs due to the connectivity rights. Thus, the macro-eNodeB users may experience outage due to this reason and the general communication, which usually takes place, may not be continued since there will bo no competent backhaul connection between macro-eNodeBs and HeNodeBs. The DL/UL cross-tier interference scenario has been shown in Fig. 9.

Nonetheless, a breakout of cross-tier interference can be done by initiating a new interference coordination model in macro-eNodeB-Pico-eNodeB and HeNodeB heterogeneous networks.

Chandrasekhar *et al*. (2008), analyzed interference avoidance with the usage of a time-hopped Code Division Multiple Access (CDMA) physical layer as well as sectorial antennas. As HeNodeBs are apprehended to be user-deployed, it is also able to arrange themselves for dimishing interference towards the macro-eNodeB and selecting optimal resource allocation for transmissions. Usually, when there is any consideration of OFDMA based technology, an option for the HeNodeB is to be selected by those subcarriers that are not being used by the macro-eNodeB network. In order to avoid continues collision within nearby OFDMA HeNodeBs, Long Term Evolution Advanced (LTE-A) system has been implemented with Orthogonal Frequency Division Multiplexing (OFDM) technique in the form of air-interface technology (Gen *et al*., 2010). The main goal to achieve these objectives is to accommodate large wireless data rates for increasing user demands. Yuanye and Klaus (2012) has stated the necessities of LTE-A system where enhancement of system capacity for supporting HeNodeB networks is discussed. Fundamentally, HeNodeB networks accommodate voice, data and videos along the unlimited wireless services within a small range of indoor coverage or inadequate geographical zone. Various companies raised these issue as a vital research field in the IMT-Advanced standardization exertions. Henceforth, it is imperative to analyze the interference coordination schemes to enhance the capacity of the HeNodeB networks. The inter-cell interference should be acknowledged and the intra-cell interference can be disregarded as the orthogonal frequency resource assigned in OFDM based cellular network. The reuse of frequency has been abundantly regarded as the wireless systems for reducing inter-cell interference (Gen *et al*., 2010).

Roshni and Shkumbin (2010) has a studied on interference management compared with IEEE 802.16

m (WiMAX) and 3GPP-LTE. In addition, Radio Resource Management (RRM) scheme, that contains a power control and adaptive fractional frequency reuse for the interference management, was addressed by the authors., For the enhancement of the total system performance in 802.16 m and 3GPP-LTE, attention is paid on numerous interference management schemes for enhancing the total system performance, as well as with the semi static RRM through adaptive Fractional Frequency Reuse (FFR) mechanisms, power control and smart antennas techniques were used to null the interference from other cells. The aim of these processes is to realize the forceful requirements of greater than 2X improvements in cell edge user throughput and complete spectral efficiency over prior releases (Roshni and Shkumbin, 2010; Himayat *et al*., 2010). A special consideration is given by the authors for RRM, based on the standard cellular network deployments, which abundantly partitions resources across cells to carry out per resource interference experienced in each cell for heterogeneous network deployments, namely HeNodeB, Pico-eNodeB low-power nodes from the macro-eNodeB (Himayat *et al*., 2010). Semi-static RRM methods were focused in 802.16 m and 3GPP-LTE, which assists in adaptation of a frequency reuse across cells based on user distribution and traffic load. Specifically, permission is given to each cell with a mixture of high and low frequency resources that are reusable. Resources administrated through reuse which can be assigned to users that are nearer to the centre of the cell. Accordingly experiencing less interference from other cells, while the lower reuse resources are assigned to the interference-limited users at the edge of the cell. With a low frequency reuse, arrangement of frequency reuse patterns is allowed to overcome the capacity inadequacy inherent, while conserving a small interference situation to uphold throughput and coverage for cell edge users. SINR metrics is essential in designing FFR rather than the original user location within the cell (Himayat *et al*., 2010).

Hardware centric approaches: Andrews (2005) a has presented a hardware centric approach for interference cancellation where the techniques employed MAC or physical layer to control interference (Mhiri *et al*., 2013). Practically, in the cellular system the downlink and uplink characteristics are very different for increasing the capacity of cellular systems. And from the downlink, each receiver requires the decode of a single desired signal from the *K* of intra-cell signals, while suppressing other cell interference from a few dominant neighbor cells, according to Fig. 10. Due to the origin of *K* user signal is from the base station, the link is synchronous and the *K-1* intra-cell interference is able to be orthogonalized at the base station transmitter (Andrews, 2005; Mhiri *et al*., 2013). However, some quadration is lost in the channel.

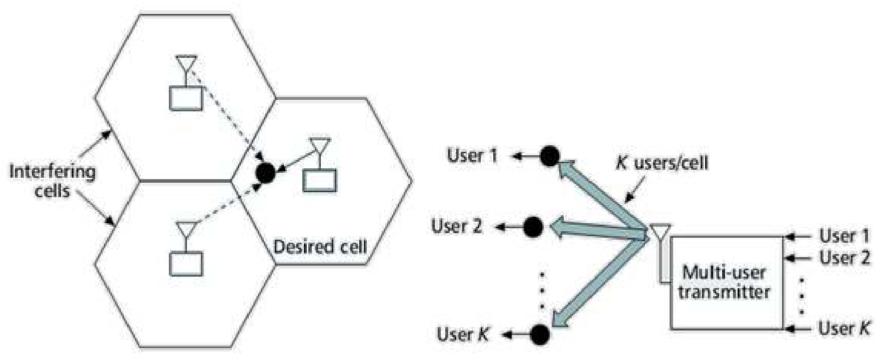

Fig. 10: Downlink interference scenario (Andrews, 2005)

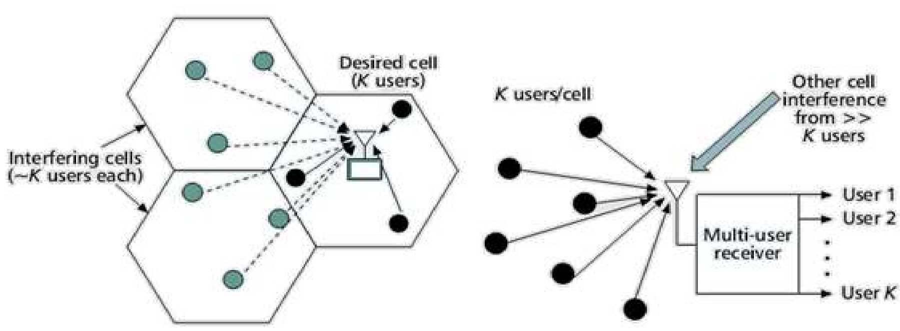

Fig. 11: Uplink interference scenarios (Andrews, 2005)

Besides that, the base station receiver must decode all K desired users in the uplink, while suppressing other cell interference from independent sources, as shown in Fig. 11.

Frequency reuse technique: Gen *et al*. (2010) has proposed an Adaptive Fractional Frequency Reuse (AFFR) scheme 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 Eq. (1) (Nishimori *et al*., 2012):

$$\begin{bmatrix} S = \left\{ BW_{eff} * \log_2 \left(1 + \dfrac{\overset{0\,SINR < SINR_{\min}}{SINR}}{\underset{5.SINR > SINR_{\max}\,4}{SINR_{eff}}} \right) \right. \\ SINR_{\min} \leq SINR_{\max} \end{bmatrix} \tag{1}$$

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

An interference avoidance using a time hopped Code Division Multiple Access (CDMA) physical layer and sectorial antennas is investigated (Rahman *et al*., 2009). Nevertheless, these methodologies are typically founded upon Wideband Code Division Multiple Access (WCDMA) networks and it is difficult to minimize the interference through sub-channel allocation, since these are sophisticated features of current Orthogonal Frequency Division Multiple Access (OFDMA) systems. Furthermore, Rahman *et al*. (2009) has explained 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.

Suzan *et al*. (2009) has represented novel Adaptive Fractional Frequency Reuse scheme (AFFR) for multi-cell OFDMA based IEEE 802.16e network, where it is managed and operated by the Access Service Network Gateway (ASN-GW), which coordinates cluster. The cell area is virtually sorted to make the radio resources into the Fractional Frequency Reuse (FFR) zone where the users are suffering from high Inter-Cell Interference, ICI, from the neighboring cells and the Full Usage (FU) area where Inter-Cell Interference ICI is avoided. The base station BS allocates users to every zone dynamically depending on their channel state information. ASN-GW selects the set of subcarriers allocated to the FFR zone within each BS. In the FU zone all subcarriers accessible in the system may be used. Figure 12 illustrates the model.

However, from the figure, it is obvious that all of the studies formulated the orthogonal resource allocation among adjacent cells as a vertex coloring issue, which has been verified to be an NP hard problem.

Jun *et al*. (2012) projected a vibrant scheme of Frequency Reservation for Interference Coordination (DFR-IC) in order to deal with the cross-tier interference. Two factors to model the co-tier and cross-tier interference ratio of User Equipment's (UEs), namely $R_I^{macro-eNnodeB}$ and $R_I^{Pico-eNnodeB}$, are offered. Then, regarding the UEs' SINR and the two

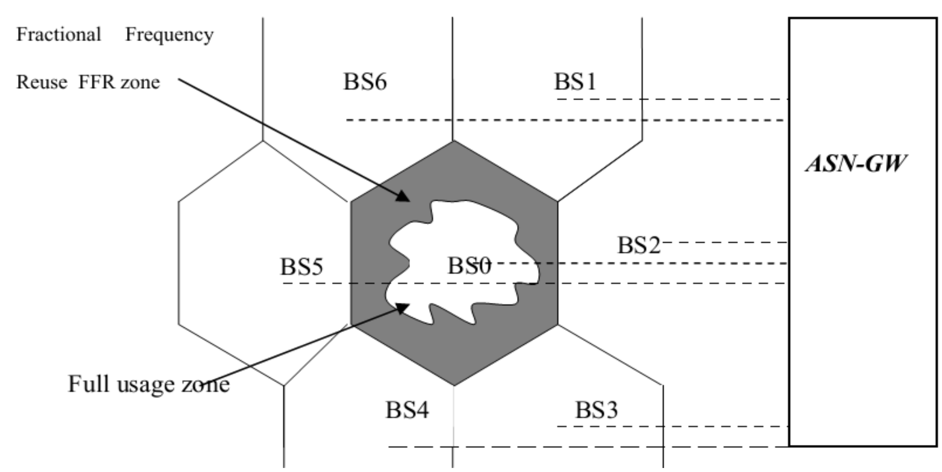

Fig. 12: AFFR system model (Suzan *et al*., 2009)

issues, each tier groups it's UEs into the protected UEs and the unprotected UEs. A portion of RBs are kept for the protected UEs who face low SINR or else dominant cross-tier interference. The number of the reserved RBs is vigorously modified to the SINR and interference circumstance of the protected UEs. Lastly, the protected UEs in one tier are scheduled on the reserved RBs of the other tier and the other UEs are scheduled on the residual RBs. With no cross-tier interference, the SINRs and throughput of the UEs scheduled on the reserved RBs are increased (Jun *et al*., 2012).

Subsequently HeNodeBs overlay the coverage of macro-eNodeBs in HetNets, more cell boundaries are created and UEs located in the boundary regions suffer both co-tier and cross-tier interference and experience low SINR resulting in low throughput. In heterogeneous networks, frequency reuse patterns have to be designed for enhancing the Area Spectral Efficiency (ASE). Three options for spectrum allocation are given below (Jun *et al*., 2012):

- Full reuse approach may reach a larger network spectral efficiency as both tiers is able to access all resources. However, cross-tier interference can happen which result in degradation of overall network performance.
- Non-reuse pattern allocates a number of frequency resources to macro-eNodeBs and to LPNs. Cross-tier interference is fully avoided since both tiers function at various frequency resources and the network spectral efficiency is low.
- Partial-reuse scheme is an intermediate approach where macro-eNodeB tier and LPNs can get access to two partial overlapping frequency resource sets. Larger spectral efficiency and lower cross-tier interference are the advantages of this scheme.

Hence, it is obvious that spectral efficiency per link as well as frequency reuse scheme have effect on ASE in the system. Full reuse scheme and Partial-reuse scheme are favored by operators because of cost full frequency bands.

Zheng *et al*. (2010) has projected the interference coordination between HeNodeBs through Carrier Aggregation (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 is prolonged for the cases with more than one UE per cell. 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 $a_{k,n} = 1$ is denoted as that carrier k is assigned to user n, or else $a_{k,n} = 0$. $A = \left\{a_{k,n} | a_{k,n} \in \{0,1\}\right\} K \times N$. Henceforth, the achievable rate on carrier k in HeNodeB n is expressed by the following Eq. (2) (Zheng *et al*., 2010):

$$\eta_{k,n} = Wlog_2\left(1 + \frac{L_{n,n}P_T}{\sum_{j=1,j\neq n}^{N} L_{n,j}a_{k,j}P_T + \sigma^2 N}\right) \qquad (2)$$

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 σ^2N is the noise power of the Additive White Gaussian Noise (AWGN). The main goal is to explore A to interference coordination difficulty, namely an optimization of objective function is made. Typically, the subsequent optimization difficulties with different objectives are required to be solved for interference coordination. Furthermore, Zheng *et al*. (2010) has shown to coordinate the interference problem, the maximization of throughput and maximization of the proportional fair with different objectives are an open challenge. To attain the maximum possible system spectrum efficiency, throughput maximization is essential which can be formulated to bring about the Eq. (3) shown below:

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

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 Eq. (4):

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

Furthermore, a disciplined organization of two steps based CA is made by the authors. The first step is found 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 equality between HeNodeBs, a single carrier is allocated to each HeNodeBs. In view of the second step, the carrier that has been already used by each HeNodeB is shared to other HeNodeBs for enhancing the spectrum efficiency of the network. It is based on the utility function calculated at HeNodeB UE in Eq. (5):

$$\xi_n^{(k)} = \frac{r_{n,n}}{\sum_{m \epsilon I_n^{(k)}} r_{n,m}} \qquad (5)$$

where, $r_{n,n}$ 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 different objectives. Regarding the maximum throughput or maximum proportional fair objective, the utility can be calculated by either of the formulas given as:

$$U_{k,n}^{A} = \frac{g_n^{(k)}}{\left\| I_n^{(k)} \right\|} \tag{6}$$

$$U_{k,n}^{B} = \frac{g_n^{(k)}}{\tilde{\eta}_n \cdot \left\| I_n^{(k)} \right\|} \tag{7}$$

$$\tilde{U}_{k,m}^{A} = g_m^{(k)} \tag{8}$$

$$\tilde{U}_{k,m}^{B} = \frac{g_m^{(k)}}{\tilde{\eta}_m} \tag{9}$$

where,

$g_m^{(k)}$: 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 $\xi_n^{(k)}$

$\tilde{\eta}_n$: Current throughput of HeNodeB, n without using carrier k

$\left\| I_n^{(k)} \right\|$: The size of set $I_n^{(k)}$

The Eq. (6) considers maximizing the sum through put of all the HeNodeBs and Eq. (7) for fairness issues.

An instance of the AFR process is illustrated in Fig. 13, where three carriers are assumed to be present in the network. In Fig. 13 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 neighbors. 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 $I_n^{(2)}$ 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 $I_n^{(2)}$ HeNodeBa, c, d and f, calculate the $\tilde{U}_{2,m}^{A}$ or $\tilde{U}_{2,m}^{B}$, $(m = a, c, d, f)$ values. When $\tilde{U}_{2,m}^{A} < U_{2,g}^{A}$, $\tilde{U}_{2,m}^{B} < U_{2,g}^{B}$, 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 (Zheng *et al*., 2010).

In Fig. 14, the average Through Put (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

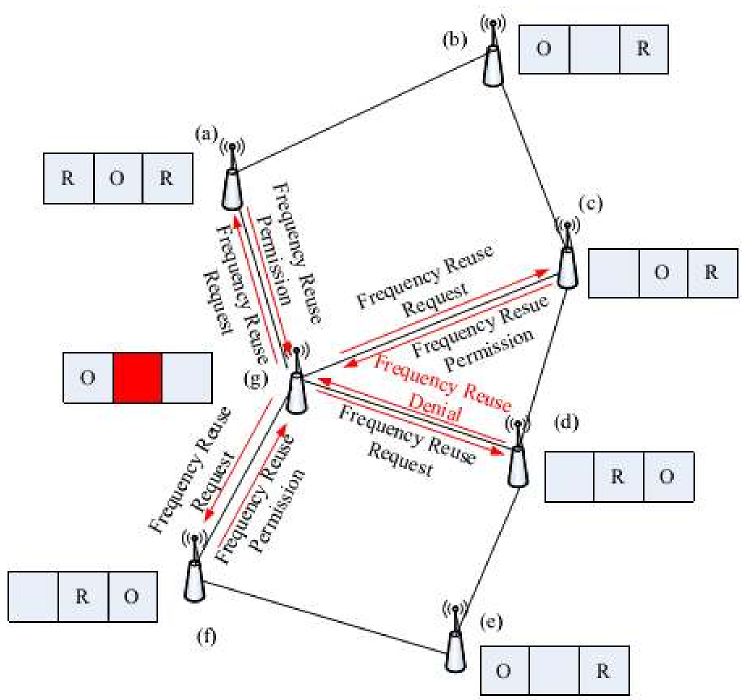

Fig. 13: Illustration of adaptive frequency reuse process (Zheng *et al*., 2010)

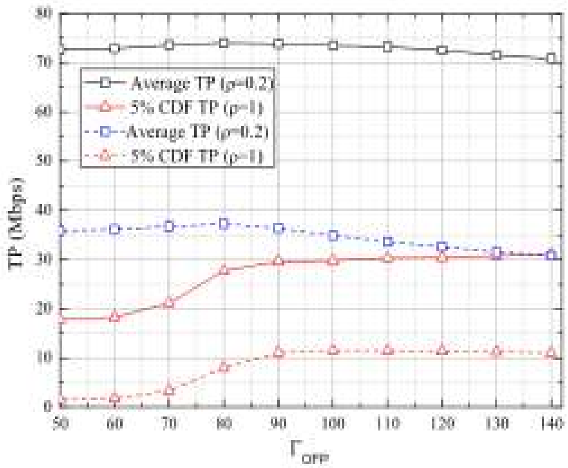

Fig. 14: Throughput performances with different threshold (Zheng *et al*., 2010)

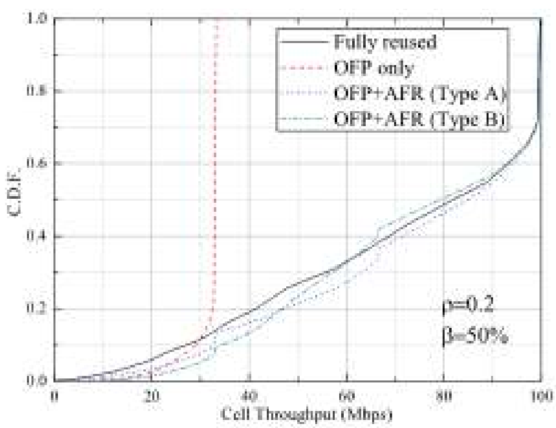

Fig. 15: Representation of CDF vs cell throughput (Zheng *et al*., 2010)

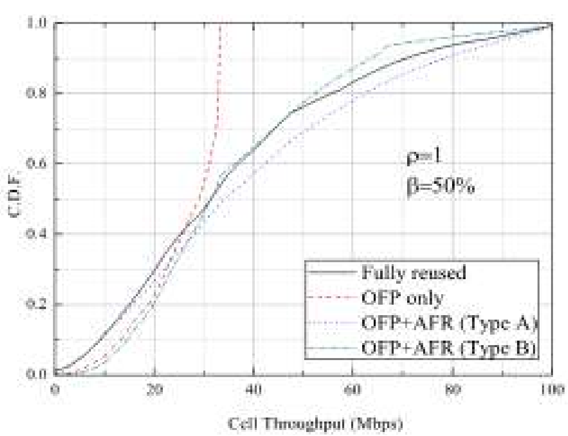

Fig. 16: Illustration of CDF vs. cell throughput with $\rho = 1$ and $\beta = 50\%$ (Zheng *et al*., 2010)

interference coordination arrangement are compared in Fig. 15 and 16, where the deployment ratio $\rho$is 0.2 and 1, respectively.

CONCLUSION

Aiming to improve the coverage and capacity of telecommunication service HeNodeB deployment is the critical challenge since co-channel and adjacent channel interference occurs in the macro-eNodeB with HeNodeB and HeNodeB with HeNodeB. Consequently, marco-eNodeB UE and HeNodeB UEs sufferer, the ultimate is the total system performance degradation. However, in this study, the architecture and the performance current self organizing approaches are investigated in HetNet. Mainly the co-channel interference among the macro-eNodeBs and HeNodeBsare highlighted. From performance analysis it can be conclude that to increase the system throughput inter-cell interference reduction is highly recommended.

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