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INTERFERENCE MITIGATION USING E-COMP IN MULTI-LAYERED NETWORKS OF LTE

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ABSTRACT

Various technical solutions and innovations are enabling the move from macro only scenarios towards heterogeneous networks with a mixture of different base station types. But the major drawback with these heterogeneous networks is the interference management between large and small cells. Advanced interference mitigation techniques relying on multipoint coordination have attracted significant attention from the wireless industry and academia in the past few years. In 3GPP LTE-Advanced, a work item on Coordinated Multiple Point transmission and reception (CoMP) was initiated, and it is one of the core features of Release 11. The main idea of this paper is to introduce an advanced CoMP technique in order to mitigate the interference and to optimize the power compared to the other existing techniques in Heterogeneous networks. In this paper, interference management in multi-layer LTE-Advanced networks and especially address aspects are proposed. The network controlled time domain enhanced inter-cell interference coordination (eICIC) concept is outlined by explaining the benefits and characteristics of this solution. Extensive system level performance results are presented with bursty traffic to demonstrate the eICIC concepts ability to dynamically adapt according to the traffic conditions.

Keywords: LTE, LTE-A, CoMP, HetNets, eICIC.

I. INTRODUCTION

Figure 1 shows a generic LTE architecture. The access network of LTE, called E-UTRAN, consists of a network of eNodeBs connected via different interfaces. In LTE, eNodeBs are normally inter-connected with each other by means of an interface called X2 and to the core network through an interface called S1. Although 3GPP-LTE employs a flat architecture, for purposes of exposition, cells can be classified in terms of their transmission powers, antenna heights, the type of access mechanism provided to users, and the backhaul connection to other cells.

Macrocells cover a large cell area (typical cell radius being of the order of 500 meters to a kilometer), with transmit antennas above the clutter and transmission power of the order of 46 dBm (20 watts). They provide service to all users.

Femtocells, also called **Home eNodeBs (HeNBs)** are lower power cells installed (typically indoors) by the end-consumer. HeNB access is classified either as a closed, hybrid or open access type. A closed access HeNB maintains a Closed Subscriber Group (CSG) white-list where access is limited only to subscribed users (i.e. to UEs that are members of the CSG). Hybrid access HeNBs allow limited access to non-subscribed UEs, but provide differentiated higher quality of service to CSG users. Open access HeNBs provide undifferentiated access to all UEs. In Rel-10, X2 interface is used between open access HeNBs and between closed/hybrid access HeNBs with identical CSG IDs and between closed/hybrid HeNBs and open access HeNBs.

Picocells are operator deployed cells, with lower transmission powers – typically an order of magnitude smaller – relative to macrocell eNodeBs. They are installed typically in wireless hotspot areas (for example, malls) and provide access to all users.

Relay Nodes are operator deployed and are primarily used to improve coverage in new areas (e.g. events, exhibitions etc.). Unlike HeNBs and picocells which connect to the macrocell over X2 backhaul, Relay nodes backhaul their traffic through a wireless link to a *Donor* eNodeB. Inband relays use the same frequency of operation over their backhaul link as the access (relay-
UE) links. Outband relays, on the other hand, use different spectrum over backhaul and access link.

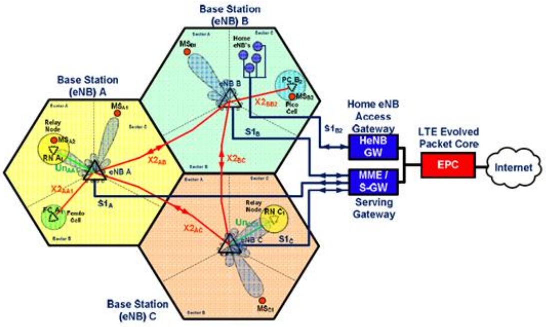

Fig 1: Generic LTE architecture

II. MULTI-LAYERED NETWORKS

Effective network planning is essential to cope with the increasing number of mobile broadband data subscribers and bandwidth-intensive services competing for limited radio resources. Operators have met this challenge by increasing capacity with new radio spectrum, adding multi-antenna techniques and implementing more efficient modulation and coding schemes.

However, these measures alone are insufficient in the most crowded environments and at cell edges where performance can significantly degrade. Operators are also adding small cells and tightly-integrating these with their macro networks to spread traffic loads, widely maintain performance and service quality while reusing spectrum most efficiently.

One way to expand an existing macro-network, while maintaining it as a homogeneous network, is to “densify” it by adding more sectors per eNB or deploying more macro-eNBs. However, reducing the site-to-site distance in the macro-network can only be pursued to a certain extent because finding new macro-sites becomes increasingly difficult and can be expensive, especially in city centres. An alternative is to introduce small cells through the addition of low-power base stations (eNBs, HeNBs or Relay Nodes (RNs)) or Remote Radio Heads (RRH) to existing macro-eNBs. Site acquisition is easier and cheaper with this equipment which is also correspondingly smaller.

Small cells are primarily added to increase capacity in hot spots with high user demand and to fill in areas not covered by the macro network – both outdoors and indoors. They also improve network performance and service quality by offloading from the large macro-cells. The result is a heterogeneous network with large macro-cells in combination with small cells providing increased bitrates per unit area. See Figure 2.

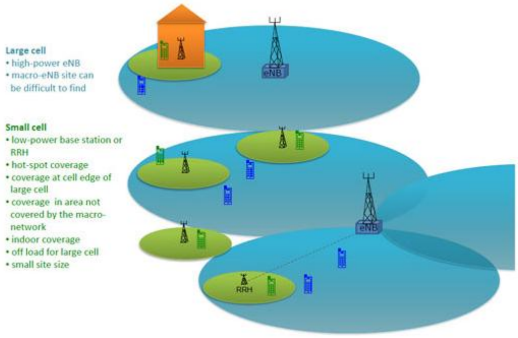

Fig 2: Heterogenous network with large and small cells

Heterogeneous network planning was already used in GSM. The large and small cells in GSM are separated through the use of different frequencies. This solution is still possible in LTE. However, LTE networks mainly use a frequency reuse of one to maximize utilization of the licensed bandwidth.

In heterogeneous networks the cells of different sizes are referred to as macro-, micro-, pico- and femto-cells; listed in order of decreasing base station power. The actual cell size depends not only on the eNB power but also on antenna position, as well as the location environment; e.g. rural or city, indoor or outdoor . The HeNB (Home eNB) was introduced in LTE Release 9 (R9). It is a low power eNB which is mainly used to provide indoor coverage, femto-cells, for Closed Subscriber Groups (CSG), for example, in office premises. See Figure 3.

Specific to HeNBs, is that they are privately owned and deployed without coordination with the macro-network. If the frequency used in the femto-cell is the same as the frequency used in the macro-cells, and the femto-cell is only used for CSG, then there is a risk of interference between the femto-cell and the surrounding network.

The Relay Node (RN) is another type of low-power base station added to the LTE R10 specifications. The RN is connected to a Donor eNB (DeNB) via the Un radio interface, which is based on the LTE Uu interface. See Figure 2. When the frequencies used on Uu and Un for the RN are the same, there is a risk of self interference in the RN. From the UE perspective the RN will act as an eNB, and from the DeNB's view the RN will be seen as a UE. As also mentioned, RRHs connected to an eNB via fibre can be used to provide small cell coverage.

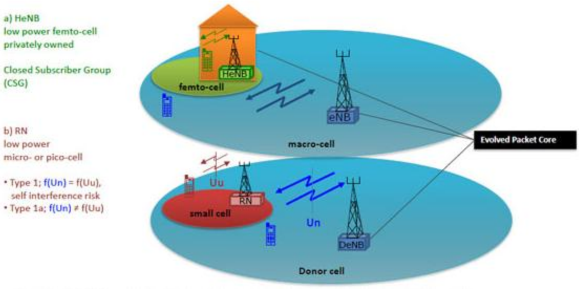

Fig 3a &b: Interference between femto and macro cells,

Introducing a mix of cell sizes and generating a heterogeneous network adds to the complexity of network planning. In a network with a frequency reuse of one, the UE normally camps on the cell with the strongest received DL signal (SSDL), hence the border between two cells is located at the point where SSDL is the same in both cells. In homogeneous networks, this also typically coincides with the point of equal path loss for the UL

(PLUL) in both cells. In a heterogeneous network, with high-power nodes in the large cells and low-power nodes in the small cells, the point of equal SSDL will not necessarily be the same as that of equal PLUL. See Figure 4.

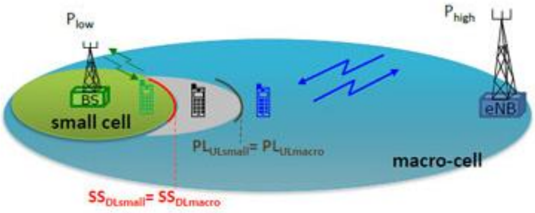

Fig 4: A Macro eNB serving the macro cell and a low power Base station (BS) serving the small cell.

A major issue in multi-layered network planning is to ensure that the small cells actually serve enough users. One way to do that is to increase the area served by the small cell, which can be done through the use of a positive cell selection offset to the SSDL of the small cell. This is called Cell Range Extension (CRE). See Figure 5.

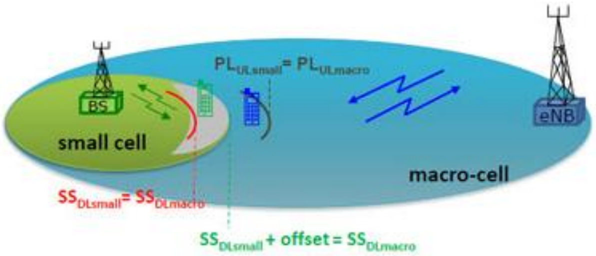

Fig 5: With CRE, the size of the small cell is increased through the use of a DL signal strength offset.

A negative effect of this is the increased interference on the DL experienced by the UE located in the CRE region and served by the base station in the small cell. This may impact the reception of the DL control channels in particular.

A number of features added to the 3GPP LTE specification can be used to mitigate the above interference with more advanced CoMP techniques.

III. DEPLOYMENT SCENARIOS

Two different het-net scenarios were investigated during the 3GPP-LTE Rel-10 work item phase:

(1) co-channel macro-femto deployment and (2) co-channel macro-pico deployment. In macro-femto deployments, macrocell UEs may experience large interference when they move close to CSG-HeNBs. In macro-pico deployments, interference may be larger at picocell UEs as a result of increasing the picocell radio range in order to offload greater numbers of users from the macrocell eNodeB on to picocells.

CSG Femtocell Deployment Aspects: In the co-channel macro-femto scenario, a macrocell UE must remain attached to its serving macrocell when it is in close proximity of a CSG femtocell if it does not belong to the femtocell's CSG group, resulting in unreliable PDCCH reception. During 3GPP studies it was found that a macro UE will, on an average, experience a PDCCH coverage hole, 20% of the time . Because the macro UE cannot decode its PDCCH reliably, it cannot be reliably scheduled over the downlink. Making matters worse, the UE will statistically experience a coverage hole for the physical broadcast channel (PBCH) – containing important system information for initial acquisition – roughly 15% of the time.

Picocells Deployment Aspects: In the macro-pico scenario, two problems that are caused by the difference in the transmission power between the macrocell eNodeB and picocell eNodeB and are shown in figure 6 (a&b).

Downlink/Uplink Imbalance. The downlink coverage of the macrocell eNodeB is much larger than that of the picocell eNodeBs. On the other hand, the difference in transmission power does not affect the coverage in the uplink, since the transmitter is the UE. Therefore, the eNodeB that provides the best downlink coverage may be different from the eNodeB providing best uplink coverage.

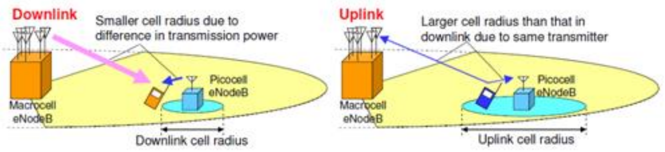

Fig 6a: Downlink/Uplink imbalance

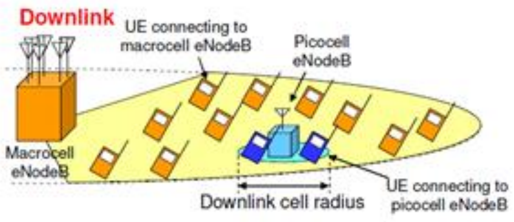

Fig 6b: Smaller number of UEs connected to Picocell eNodeB

Cell Range Expansion. The second problem is that the number of UEs connected to the picocell eNodeBs is much smaller than that of macrocell eNodeBs resulting in inefficient resource utilization. It is beneficial for the network to bias handover preferentially towards the picocell eNodeBs, e.g., add a handover offset to the picocell eNodeB reference signal received signal power (RSRP) so that the UE preferentially selects a picocell eNodeB even when it is not the strongest cell. This method is called Cell Range Expansion (CRE).

IV. COMP IN LTE

The concepts for Coordinated Multipoint, CoMP, have been the focus of many studies by 3GPP for LTE-Advanced as well as the IEEE for their WiMAX, 802.16 standards. For 3GPP there are studies that have focused on the techniques involved, but no conclusion has been reached regarding the full implementation of the scheme. However basic concepts have been established and these are described below.

CoMP has not been included in Rel.10 of the 3GPP standards, but as work is on-going, CoMP is likely to reach a greater level of consensus. When this occurs it will be included in future releases of the standards. Despite the fact that Rel.10 does not provide any specific support for CoMP, some schemes can be implemented in LTE Rel.10 networks in a proprietary manner. This may enable a simpler upgrade when standardization is finally agreed. 4G LTE CoMP, Coordinated Multipoint requires close coordination between a number of geographically separated eNBs. They dynamically coordinate to provide joint scheduling and transmissions as well as proving joint processing of the received signals. In this way a UE at the edge of a cell is able to be served by two or more eNBs to improve signals reception / transmission and increase throughput particularly under cell edge conditions.

V. INTERFERENCE CHALLENGES IN MULTI-LAYER NETWORKS

Assuming an operating bandwidth of 10 MHz, a typical con-figuration of the macro base station (eNB) is 46 dBm transmit (Tx) power per sector, and 14 dBi antenna gain (including feeder loss), which results in an equivalent isotropic radiated power (EIRP) of 60 dBm. The pico eNB only has an EIRP of 35 dBm which naturally results in significantly smaller coverage than the macro eNB. The HeNB has the smallest EIRP of only 20 dBm in the considered example. However, despite the relative low EIRP of the HeNB, each HeNB still creates a so-called dominance area where terminal devices, or user equipments (UEs) as they are called in LTE, served by the macro eNB will experience problems as they will be subject to too high interference from the HeNB.

The coverage area of the pico eNB is not only limited by its transmit power, but also to a large extent by the interference experienced from the macro eNB. Thus, if the serving cell selection is based on downlink UE measurements such as reference symbol received power (RSRP), only UEs in the close vicinity will end up being served by the pico. The service area of the pico can be increased by applying a so-called range extension (RE), where a cell specific bias to the UE measurement of X dB is applied for a pico to favour connecting to it. However, in a traditional co-channel scenario without any explicit interference management, it is typically only possible to use small values of the RE, say few dBs, as pico UEs will otherwise experience too high interference from the macro layer. The second problem addressed by eICIC is therefore the interference from macro to pico. Reducing the macro interference by means of resource partitioning will allow using much higher pico RE offsets to significantly increase the offload from the macro layer.

VI. PROPOSED INTERFERENCE MITIGATION IN HETNETS:

Generally Multi layered networks like Heterogenous networks are characterized by harsh inter cell interference between the Macro and the low power nodes, due to their closer proximity and different power classes.

The increasing traffic demand will lead to more interference in the existing HetNets. To compensate that, multi-antenna improvements with 3-D beam forming, potentially a new carrier type specifically aggregated for being backward compatible should be used.

This enhanced CoMP technique employes network assisted interference cancellation. Thus minimizing the interference in HetNets. The small cells and Hetnets can be self optimizing networks, in which the cell can switch off when not in use so as to minimize its power consumption. If a cell could switch on and off more frequent then it could reduce its power consumption further and could reduce interference that it generated elsewhere. The ultimate goal would be a cell that could switch on and off every subframe, although the impact on the specifications would be more severe. *Dual connectivity* is the ability of a mobile to communicate simultaneously with two base stations, namely a *master eNB* (MeNB) and a *slave eNB* (SeNB), which are typically a macrocell and a picocell using different carrier frequencies. Dual connectivity has three main motivations. The most important is to reduce the number of handover failures in a heterogeneous network. Handovers are difficult for a mobile that is moving out of a picocell because it may not have time to discover a surrounding macrocell before losing its original signal. By maintaining the RRC signalling within the macrocell, the robustness of the handover can be improved. In addition, the network's signalling load can be reduced by minimizing the total number of handovers, while the network's capacity and the user's throughput can both be increased. 3GPP also studied the introduction of a new carrier type, also known as a lean carrier. The new carrier does not transmit information such as the cell-specific reference signals or the legacy PDCCH so it cannot be used by legacy mobiles or as a stand-alone cell; instead, it is intended for use as a secondary cell during carrier aggregation or as a slave during dual connectivity.

VII. RESULTS

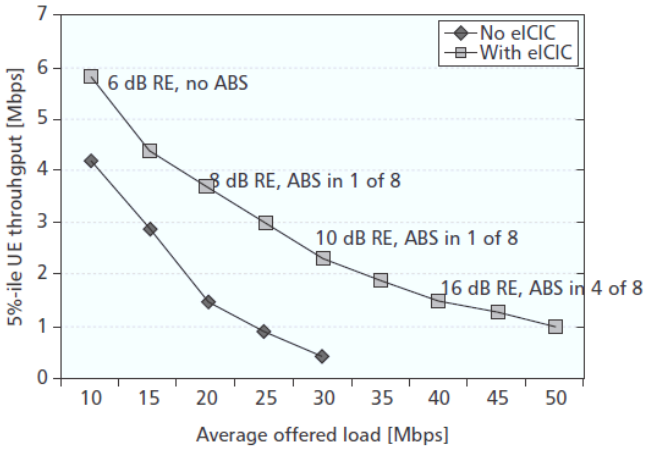

Fig 7: User throughput performance with / without eICIC for dynamic traffic vs the average offered load per macro cell area. The scenario includes 4 pico cells per macro cell (5%-ile UE throughput)

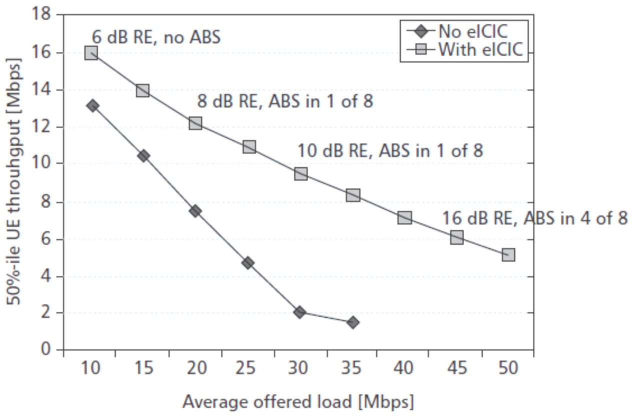

Fig 8: User throughput performance with / without eICIC for dynamic traffic vs the average offered load per macro cell area. The scenario includes 4 pico cells per macro cell (50%-ile UE throughput)

VIII. CONCLUSION

In this paper, we have discussed CoMP techniques and the target deployment scenarios being considered as part of the LTE-Advanced radio technology standard development in Multi-Layered networks. Evaluation studies have shown that CoMP can greatly improve the cell-edge user experience. Similar conclusions were made in the LTE Advanced CoMP study item report, where CoMP performance benefits were observed in both homogeneous and heterogeneous networks. The interest for the CoMP technology is expected to grow as new network topologies (e.g., heterogeneous networks) and geographically distributed antennas for single logical cell further demand solutions for interference mitigation. Lower cost radio nodes, improved backhaul connection links, faster processors at the base stations as well as user terminals, now allow CoMP to be considered as a viable technology for practical implementation and deployment. Finally, the intereference levels in Multi-Layered networks can be further reduced by using new carrier type and advanced beam forming. The throughput improvement is clearly shown in the results.

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