

# Enhanced CoMP technique for interference cancellation in HETNets of LTE

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## ABSTRACT

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 objective of this work item is to provide the necessary specification support to efficiently realize the benefits of cooperative transmission in the downlink and cooperative reception in the uplink. In this paper, LTE CoMP techniques are explained and the interference problems are also been discussed. The main idea of this paper is to propose an advanced CoMP technique in order to mitigate the interference and to optimize the power compared to the other existing techniques in Heterogeneous networks.

**Key Words:** LTE, LTE-A, CoMP, HetNets.

## 1. Introduction

LTE CoMP or Coordinated Multipoint is a facility that is being developed for LTE Advanced. Many of the facilities are still under development and may change as the standards define the different elements of CoMP more specifically. LTE Coordinated Multipoint is essentially a range of different techniques that enable the dynamic coordination of transmission and reception over a variety of different base stations. The aim is to improve overall quality for the user as well as improving the utilization of the network. Essentially, LTE Advanced CoMP makes the inter-cell interference, ICI, into useful signal,

especially at the cell boundaries where performance may be degraded.

Over the years, the importance of inter-cell interference, ICI has been recognized, and various techniques used from the days of GSM to mitigate its effects. Here interference averaging techniques such as frequency hopping were utilized. However as technology has advanced, much tighter and more effective methods of combating and utilizing the interference have gained support.

### 1.1 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 providing 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.

### 1.2 Concept of LTE Advanced CoMP - Coordinated Multipoint:

In essence, 4G LTE CoMP, Coordinated Multipoint falls into two major categories:

- *Joint processing:* Joint processing occurs where there is coordination between multiple entities base stations that are simultaneously transmitting or receiving to or from UEs.
- *Coordinated scheduling or beam forming:* This often referred to as CS/CB (coordinated scheduling / coordinated beam forming) is a form of coordination where a UE is transmitting with a single transmission or reception point - base station. However the communication is made with an exchange of control among several coordinated entities.

To achieve either of these modes, highly detailed feedback is required on the channel properties in a fast manner so that the changes can be made. The other requirement is for very close coordination between the eNBs to facilitate the combination of data or fast switching of the cells. The techniques used for coordinated multipoint, CoMP are very different for the uplink and downlink. This results from the fact that the eNBs are in a network, connected to other eNBs, whereas the handsets or UEs are individual elements.

### 1.3 Downlink LTE CoMP:

The downlink LTE CoMP requires dynamic coordination amongst several geographically separated eNBs transmitting to the UE. The two formats of coordinated multipoint can be divided for the downlink:

- *Joint processing schemes for transmitting in the downlink:*

Using this element of LTE CoMP, data is transmitted to the UE simultaneously from a number of different eNBs. The aim is to improve the received signal quality and strength. It may also have the aim of actively cancelling interference from transmissions that are intended for other UEs.

This form of coordinated multipoint places a high demand onto the backhaul network because the data to be transmitted to the UE needs to be sent to each eNB that will be transmitting it to the UE. This may easily double or triple the amount of

data in the network dependent upon how many eNBs will be sending the data. In addition to this, joint processing data needs to be sent between all eNBs involved in the CoMP area.

- The scheduling decisions as well as any beams are coordinated to control the interference that may be generated. The advantage of this approach is that the requirements for coordination across the backhaul network are considerably reduced for two reasons:
  - UE data does not need to be transmitted from multiple eNBs, and therefore only needs to be directed to one eNB.
  - Only scheduling decisions and details of beams needs to be coordinated between multiple eNBs.

### 1.4 Uplink LTE CoMP:

- *Joint reception and processing:* The basic concept behind this format is to utilise antennas at different sites. By coordinating between the different eNBs it is possible to form a virtual antenna array. The signals received by the eNBs are then combined and processed to produce the final output signal. This technique allows for signals that are very low in strength, or masked by interference in some areas to be receiving with few errors. The main disadvantage with this technique is that large amounts of data need to be transferred between the eNBs for it to operate.
- *Coordinated scheduling:* This scheme operates by coordinating the scheduling decisions amongst the ENBs to minimize interference. As in the case of the downlink, this format provides a much reduced load in the backhaul network because only the scheduling data needs to be transferred between the different eNBs that are coordinating with each other.

### 1.5 Overall requirements for LTE CoMP:

One of the key requirements for LTE is that it should be able to provide a very low level of latency. The additional processing required for multiple site reception and transmission could add significantly to any delays. This could result from the need for the additional processing as well as the communication between the different sites.

To overcome this, it is anticipated that the different sites may be connected together in a form of centralised RAN, or C-RAN.

## 2. HETEROGENOUS 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 1.

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.

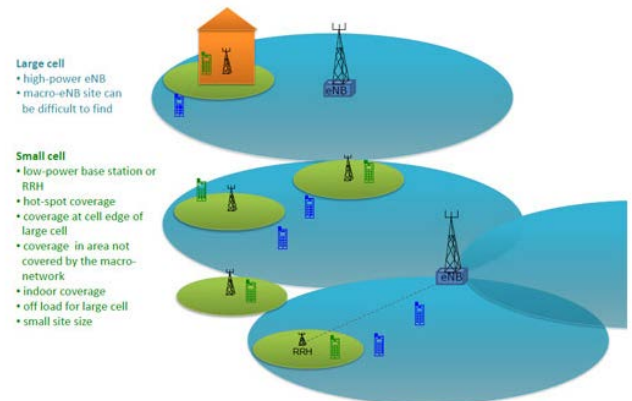


Fig1: Heterogenous network with large and small cells

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 2.

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. 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

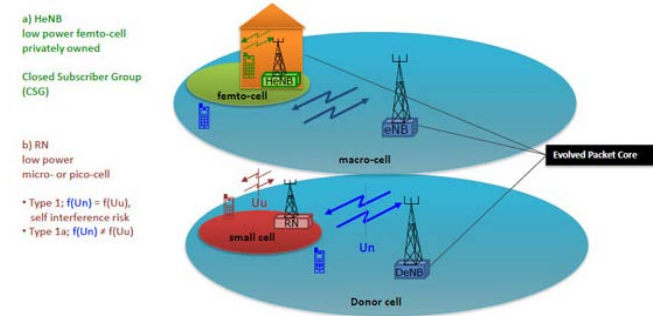


Fig 2: a) Interference between femto and macro cells, b) RN connected to DeNB via radio interface Un, sharing resources with Uu for UEs camping on the donor cell.

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 3.

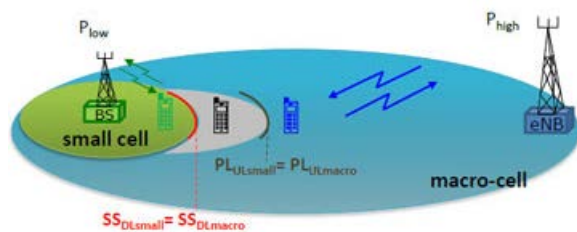


Fig 3: A Macro eNB serving the macro cell and a low power Base station serving the small cell. A major issue in heterogeneous network planning is to ensure that the small cells actually serve enough users. One way to do that is to increase the area served by the small cell, which can be done through the use of a positive cell selection offset to the SSDL of the small cell. This is called Cell Range Extension (CRE). See Figure 4. 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

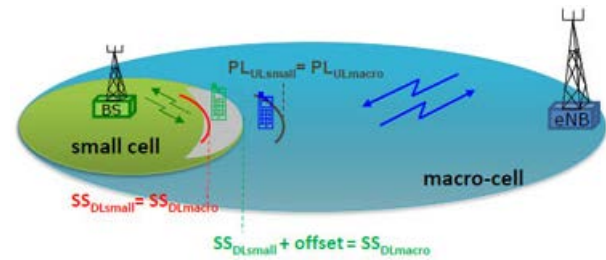


Fig 4: With CRE, the size of the small cell is increased through the use of a DL signal strength offset.

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.

### 3. INTERFERENCE CHALLENGES IN MULTI-LAYER NETWORKS

Assuming an operating bandwidth of 10 MHz, a typical configuration 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.

#### 4. Proposed interference mitigation in HetNets

Generally 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 pdch 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.

#### 5. RESULTS

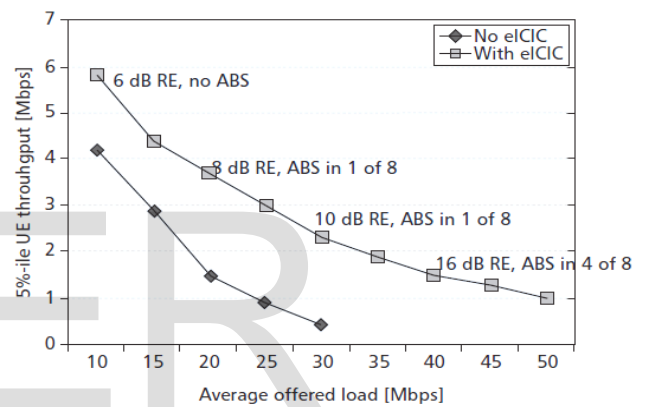


Fig 5: User throughput performance with / without eICIC for dynamic traffic vs the average offered load per macro cell area. The scenario includes 4 pico cells per macro cell (5%-ile UE throughput)

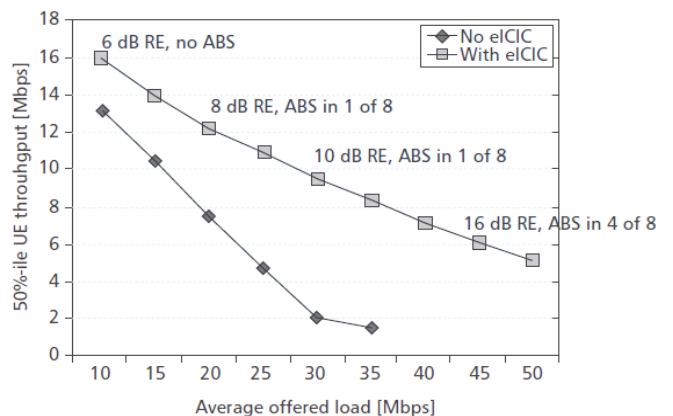


Fig 6: User throughput performance with / without eICIC for dynamic traffic vs the average offered load per macro cell area. The scenario includes 4 pico cells per macro cell (50%-ile UE throughput)

## 6. 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. 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 interference levels in heterogeneous 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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