



Understanding LTE-A HetNet Interference Mitigation Techniques

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1. Overview

This white paper discusses the evolution from LTE to LTE-A, and the benefits and challenges this has brought about. It then talks about heterogeneous networks (HetNet), the interference challenges they create, and the interference mitigation techniques added in response.

2. Background

The demand for high-speed, ubiquitous data is always increasing. Until recently, Long Term Evolution (LTE) was able to meet the demand for higher speed data in two ways: (1) expanding Single-Input/Single-Output (SISO) links to Multiple-Input/Multiple-Output (MIMO) links; and (2) expanding Wideband Code Division Multiple Access (WCDMA) to Orthogonal Frequency-Division Multiplexing (OFDM). Both of these solutions were physical-layer changes that essentially “widened the pipe”. The transition from third-generation mobile telecommunications technology (3G) to LTE was essentially a revolution at the physical layer.

LTE-A is now being looked at as the solution to meet the demand beyond what LTE can deliver. The transition from LTE to LTE-A (LTE Advanced) is a different story. The “A” in LTE-A, as we will see, represents both a physical-layer evolution and a network paradigm revolution. LTE-A provides high-speed access through a variety of techniques:

- Multiple simultaneous connections (e.g., carrier aggregation, coordinated multipoint or CoMP)
- Network densification through heterogeneous networks (HetNet)— multiple cells of different sizes, but of the same technology

One of the consequences of network densification is the increased interference; a dense network results in an interference-dominated environment. LTE-A offers a variety of complex and advanced techniques at both the network and the device level to mitigate this interference: Inter Cell Interference Coordination (ICIC), Enhanced ICIC (eICIC), Further Enhanced ICIC (FeICIC), Self-Organizing Network (SON), Network Assisted Interference Cancellation and Suppression (NAICS), and advanced interference cancellation receivers.

While these techniques help mitigate the interference inherent to HetNet, they also increase the overall complexity of the system. This causes a fundamental change in how networks and devices are deployed, as well as how they are tested.

3. HetNet

LTE-A uses an optimized mix of high-powered macrocells and low-powered small cells of various types (see “Small Cells”) to improve both capacity and coverage. The chief advantage of HetNet is that it incorporates, by definition, multiple types and sizes of cells. This allows a greatly expanded mosaic of coverage, and inter-cell communication with smooth handoff among the network components delivers broader coverage in ways transparent to users.

Different types of cells

Macrocell—Operator deployed. Typical cell radius in the order of miles

Femtocell/Home eNodeBs—Consumer deployed. Lower power cells installed by the end-consumer. Access to a femto cell can be closed, open, or hybrid.

Closed access—Limits access to subscribed users

Hybrid access—Offers a higher service quality to subscribed users and limited access to others

Open access—Offers undifferentiated access to all users

Picocell—Operator deployed, lower transmission powers. Usually deployed in hot zones and accessible by all users.

Relay Node—Operator deployed. Primarily used to improve coverage in new areas (e.g., events, exhibitions, etc.). Unlike picocells and femtocells, uses a wireless link as backhaul to the eNodeB.

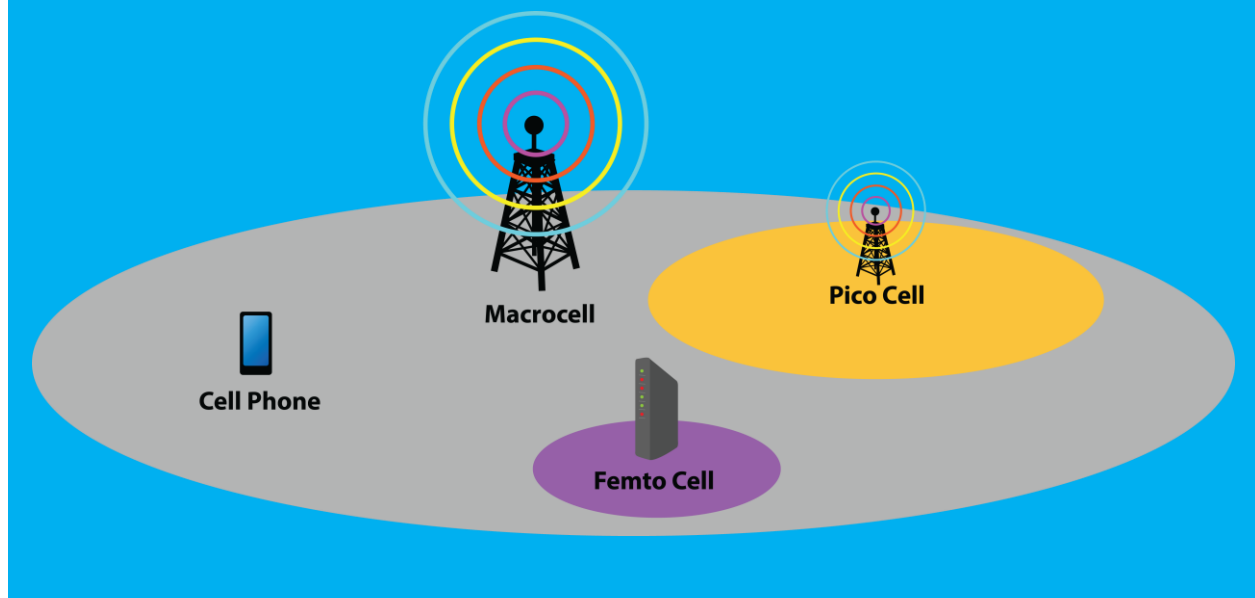


Figure 1: Different types of cells

There are new challenges, of course. Until now, small cells have been used to fill service holes by providing focused coverage that doesn't necessarily cause interference issues. However, with LTE-A, small cells are being deployed to provide additional capacity—for example, deploying small cells even in areas where there is already macrocell coverage. More signal sources means increased interference.

In a homogeneous network, devices are typically served by the cell with the strongest signal, even if the cell is not the closest or even if there is another cell with more available capacity. LTE-A HetNet changes this. In HetNet, the various cells serve devices in ways that maximize resource usage and overall system capacity using techniques such as **cell range expansion (CRE)**. (*See sidebar*)

Given this scenario, a given device may not always be served by the strongest cell in LTE-A HetNet, and it often has to operate in an interference-dominated environment—an issue that is inherent to all HetNet deployments. We discuss some of the interference mitigation techniques developed to address this issue on the following pages.

Overall, HetNet provides a range of benefits:

- gets devices closer to the cell, which drives up throughput and drives down interference
- helps manage load more effectively
- provides coverage in “dead spots” (e.g., in buildings) not covered well by the macrocell
- allows scalable and cost-effective ubiquitous high-speed service

Cell Range Expansion (CRE)

Small cells have lesser coverage, due to the lower transmit power. Biases/offsets are used to keep devices on a small cell—even if the signal-to-interference-plus-noise ratio (SINR) is better from another cell—to help with load balancing and to improve overall system capacity.

Since this expands the range of the small cell without actually increasing the transmit power, this technique is called **range expansion**. One of the challenges of range expansion is that devices might stay on a cell with a lower SINR, with increased interference coming from a stronger cell: the interferer will be the macro in a femto-macro scenario, and the pico in a pico-macro scenario.

4. HetNet Interference Mitigation Schemes

4.1. ICIC: Inter-Cell Interference Coordination

ICIC is a coordinated resource management technique designed to mediate among competing or interfering base stations. Introduced in 3GPP Release 8 to address interference issues at cell edges, ICIC uses the X2 interface for inter cell signaling, and employs power and frequency domain resource partitioning among neighboring cells to mitigate interference (for the traffic channels only).

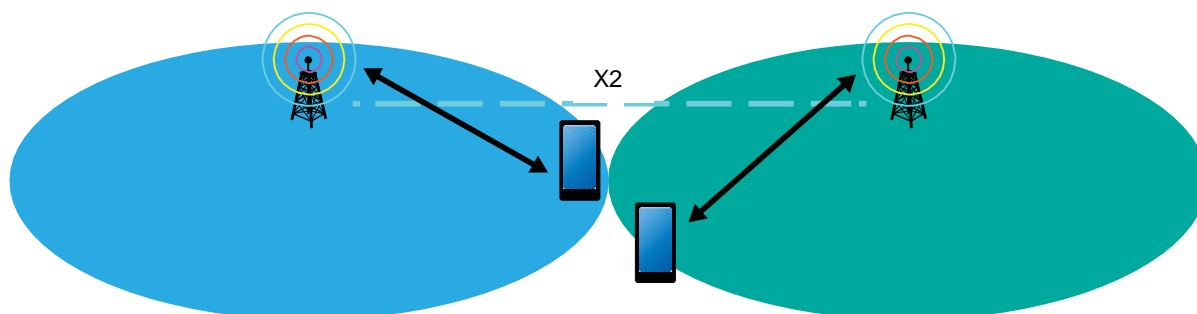


Figure 2: Interference Mitigation in ICIC

It does this through the following steps: (1) measure and generate interference information about neighboring cells, including data on relative narrowband-transmit power (RNTP), high-interference indicator (HII), and overload indicator (OI)*1; (2) share the interference information among the cells; (3) determine the resource coordination based on the shared interference information; and (4) share the resource allocation information with the local schedulers.

There are different ICIC implementations:

- **Type 1**—Neighbor eNBs use different sets of resource blocks throughout the cell at any given time to improve the cell-edge SINR. The downside of this implementation is that the resource blocks are not used to full capacity.
- **Type 2**—All eNBs use the complete range of resource blocks for centrally located users, but for cell-edge users, no two neighboring eNBs use the same set of resource blocks at any given time.
- **Type 3**—All the neighboring eNBs use different power schemes across the spectrum, although resource block assignment is similar to Type 2, with higher signal power for cell-edge users with a set of resources not used by neighbors, and low signal power for center users with all resource blocks.

*1: [Interference Coordination in LTE/LTE-A \(1\): Inter-Cell Interference Coordination \(ICIC\)](#) includes more detailed information on this.

4.2. eICIC: Enhanced ICIC

Whereas ICIC helps in reducing interference, there are some scenarios where it isn't completely adequate. Enhanced ICIC (eICIC), introduced in 3GPP Release 10 provides improved mitigation by addressing both the traffic and control channels. eICIC addresses interference issues by partitioning and apportioning power, frequency, and also time domain resources.

There are two different eICIC implementations:

- **Time domain mitigation using Almost Blank Subframes (ABS)**—As mentioned earlier, cell range expansion is used to expand the range of a cell and keep the device on a cell for longer. This is done through an artificial offset; however, this means that the device in the cell range expansion region is attached to a cell though there is another cell (which now becomes the interferer) that affords a better SINR.

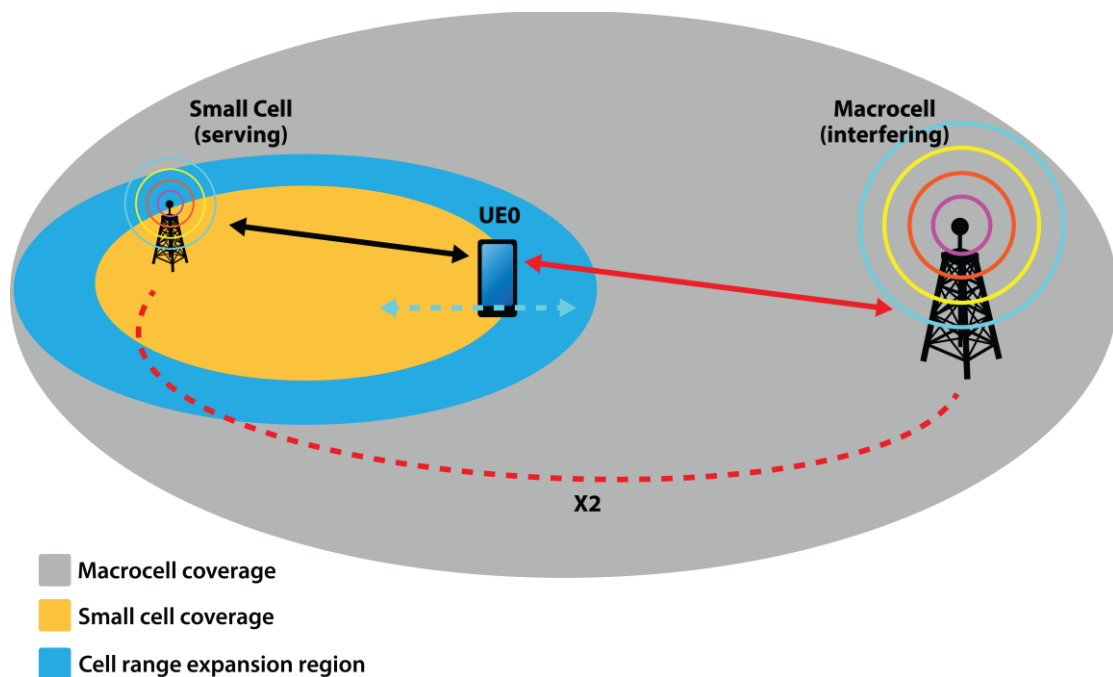


Figure 3: Cell Range Expansion

eICIC addresses this using the concept of almost blank subframes (ABS). As the name suggests, with ABS, there are some subframes where the macrocell goes almost blank, thereby providing a window of opportunity (with reduced interference) for the small cell to service the device (UE0) in the cell range expansion region, as shown below. ABS is done only on the data channels and not the control channels. When the macrocell goes blank is determined by the ABS pattern; 3GPP (TS36.101) lists the standard ABS patterns. The ABS pattern is shared via the X2 interface.

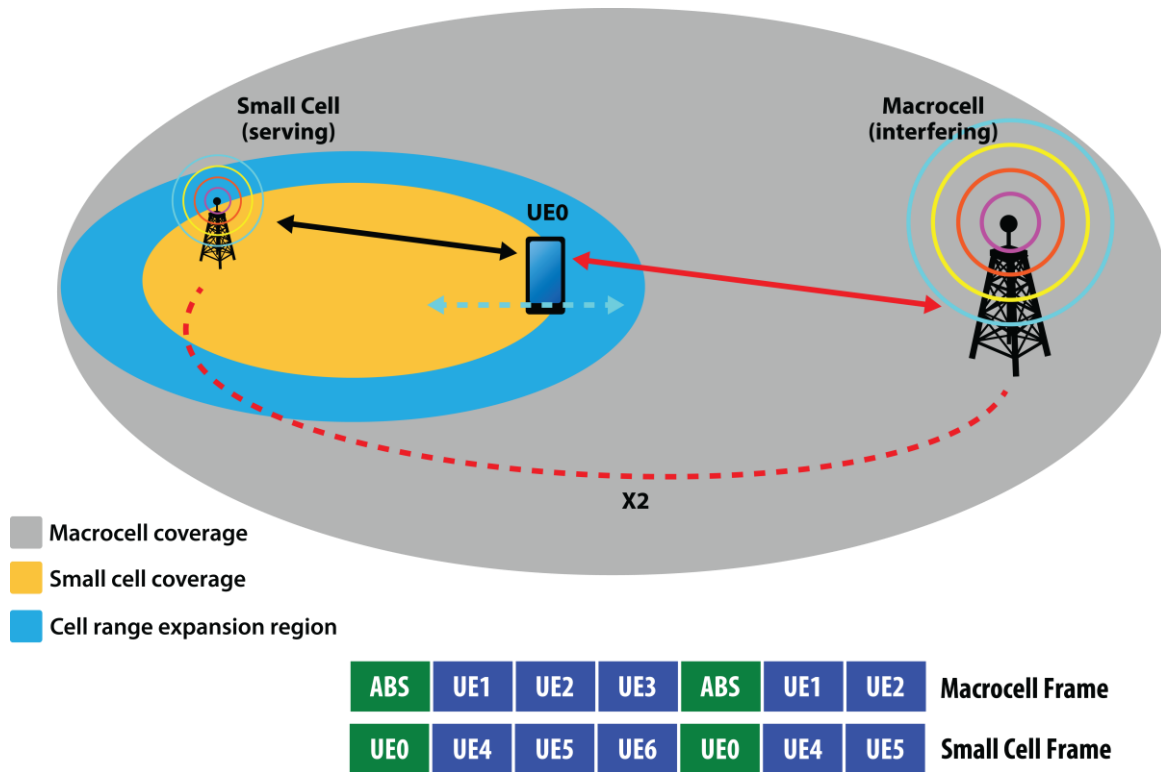


Figure 4: Interference mitigation in eICIC: time domain mitigation using ABS.

Each ABS pattern differs from another in terms of the actual pattern (i.e., subframes where we blank), the type of frames they blank on (i.e., multicast-broadcast single-frequency network or MBSFN vs. non-MBSFN), and the ABS ratio. The ABS ratio is a measure of the percentage of time the macrocell goes almost blank; the higher the ABS ratio, the more the subframes during which the macrocell goes almost blank.

An important thing to keep in mind with ABS is that while the almost-blank subframes enable the operation of devices in the CRE region, it does take away resources from the macrocell and hence has an impact on the macrocell's capacity. **This trade-off between the small cell and macrocell capacity is the reason why system capacity and other system level metrics become important metrics to examine.**

- **Frequency domain mitigation through cross-carrier scheduling—Carrier aggregation provides a** wider pipe for the device by aggregation a couple of carriers (also known as component carriers or CCs). While one carrier (associated with the primary cell, PCell) provides control/connectivity and a data pipe, other carriers (associated with the secondary cell, SCell) primarily provide just a data pipe. The carriers can be intra-band (within the same band) or inter-band (different bands), although, given the spectrum, with most operators, it ends up being inter-band. The carrier used for the PCell and the SCell is determined by a variety of factors such as the actual frequency (and hence associated range), load, etc.

With cross-carrier scheduling, different carriers are used on the small cell and the macrocell for carrying the control channels: Physical DL (downlink) Control Channel or PDCCH; PHICH Physical HARQ (Hybrid Automatic Repeat Request) Indicator Channel or PHICH; and Physical Control Format Indicator Channel or PCFICH. This minimizes the interference on these channels. Note that this can be leveraged only if the device supports carrier aggregation.

4.3. FeICIC: Further Enhanced ICIC

eICIC was further enhanced in 3GPP Release 11 to address some of the (capacity) trade-offs and some of the unmitigated interference in eICIC. One of those trade-offs with eICIC was essentially the difference between macrocell and small cell capacity when ABS is active, since the macrocell gives up resources when it goes blank. This trade-off is addressed in FeICIC by offering the possibility of having data transmitted on the PDSCH during the ABS subframe, but at a reduced power. This is called as reduced power ABS (RP-ABS).

FeICIC also addresses the fact that eICIC mitigates only the interference on the data channel (and the control channels with cross-carrier scheduling), but not the interference from the Cell Reference Signal (CRS). The CRS cannot be blanked out since doing so would affect legacy R8 and R9 devices. Instead, this is done in FeICIC through enhancements on both the transmitter and receiver sides. On the transmit side, advanced coding and rate matching is used to reduce the interference from a macrocell's CRS. On the terminal (device) side, this involves estimating the interferer and cancelling/removing it. As one can imagine, the above process can be repeated at the receiver side for all the estimated interferers.

4.4. NAICS: Network Assisted Interference Cancellation and Suppression

Unlike traditional receivers, interference rejection combining (IRC) receivers added in 3GPP Release 11 treat interference differently than AWGN, thereby improving the overall performance in an interference-dominated environment. These receivers primarily focus on cancelling the interference from the CRS.

This was further advanced in 3GPP Release 12 with NAICS that mitigate the effects of inter cell and intra cell interference. As the name suggests, with NAICS, the network aids with the interference cancellation and suppression by providing devices with additional information on scheduled transmissions, enhancing the performance of the interference cancellation receiver.

5. Summary

In this white paper, we learned about benefits of and challenges posed by the evolution of LTE to LTE-A and heterogeneous networks (HetNet). The paper focused on mitigation requirements for LTE-A HetNet deployment HetNet interference mitigation schemes, with an explanation of various inter cell interference coordination mitigation schemes (ICIC, eICIC, and FeICIC) as well as network assisted interference coordination and suppression (NAICS).

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