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Study Paper  
on  
HetNet: The LTE Perspective

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# **HetNet : The LTE perspective**

## **A Study Paper**

### **1.0 Introduction**

The consumption of data over the cellular networks is increasing at an exponential rate. This being so because the users are downloading and sharing data, at an ever increasing rate, in form of videos, photos, text etc. generally using smartphones and tablets. The ease of access and use of these devices is also contributing to this exponential growth in data consumption.

According to findings presented during the “Small cell Network summit” held in Mumbai in July, 2016, there will be 50 billion connected devices across the world by 2020. Mobile traffic will grow globally with a CAGR of 84% over next 7 years, and will overtake fixed data traffic in 2019.

The Service Providers need to meet this ever increasing demand for data while retaining profitability. This, amongst others, is one of the important factors that has forced the Service Providers to look for more innovative techniques of carrying data. Some of the approaches used by the operators to enhance system capacity and carry data at higher speeds are as under:

- ) Upgradation of radio access technology at the macro cell sites. LTE, for example, is considered a very efficient radio technology and provides users with data access generally in the range of 5 to 25 Mbps (depending on configuration) while reducing the cost per bit for the Service Provider.
- ) Deploying multiple antennae and allocating more spectrum
- ) Increasing the number of cell sites in a given area whereby low power pico cells, femtocells and Wi-Fi hotspots may be added to interwork together with the macro cell thereby forming a multilayer large capacity heterogeneous network. These small cells can also be deployed within the user premises, residential or official, thereby bringing the network closer to the customer.

The idea of merging small cells with the macro cell network has the advantage of offloading traffic from the macro cell sites to the smaller cells while the macro cell operates at its normal capacity. However, such consolidation has to be transparent to the customer. The handoffs between the multiple sized cells also has to be seamless and facilitate uninterrupted services for the user. A key component of such heterogeneous networks, which helps in meeting the above requirements is network intelligence via the SON (Self Organising Network). SON is automation technology that enables the network to set itself up and self-manage resources and configuration to achieve optimal performance in an integrated network approach. The

self-organizing, self-optimizing capability of the small cell smoothen the path for implementation of such heterogeneous networks.

### What is HetNet

“HetNet” basically refers to Heterogeneous Networks, which is nothing but a combination of networks of different access technologies and cell types (See Box 1 for Various types of cells and their characteristics) interworking with each other to give user a better, seamless and reliable, communication experience. The user gets the feel of being connected to a single never failing network. The prime motivation for deploying “HetNet” is to boost the network capacity/capability.

A typical deployment of HetNet can be depicted as in Figure 1 below.

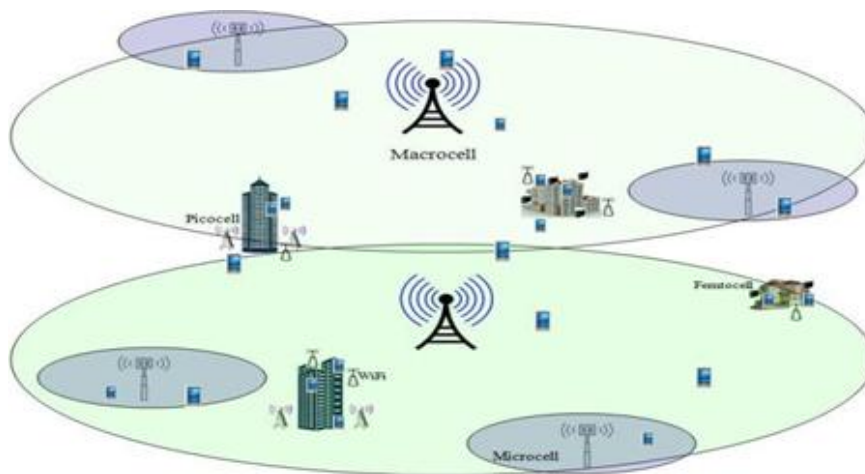


Figure 1 : Typical HetNet Deployment

(Source: <http://www.3gpp.org/hetnet>)

Two arguments in favour of using small cells are the reduced capital and operational expenditure (CAPEX and OPEX), as compared to techniques like cell splitting, and the ability of small cells to provide adequate coverage in extremely densely populated areas.

### Box 1: Various types of cells and their characteristics

There are different types of cell used for different applications. The traditional macro cells are still needed to provide general coverage, and connectivity particularly for those in outlying areas or in fast moving in vehicles where multiple handovers are not desirable. However, where high data rates are needed in buildings or urban areas, a variety of small cell technologies can be used. These may use one of a variety of backhaul technologies. However, the most important aspect is that, these need to appear as a single network to the user, providing the same enhanced performance level.

A small cell is a miniature version of the traditional macro cell. It compresses the attributes of a cell tower like radio and antenna into a low power, portable and easy to deploy radio device. Small cells typically have a range varying from 10 meters to a few hundred meters and are used by operators to either offload traffic from the macro network in a high density short range environment or to strengthen the range and efficiency of a mobile network.

Different types of cells and their characteristics are as under:

- a. **Macro cells** are the common cells sites supporting technologies like HSPA+ and LTE. The normal range may vary from a few hundred meters to a few kilometres. Output power is of the order of tens of watts.
- b. **Microcells** typically cover smaller areas maybe up to a kilometre. They usually transmit within a range of milliwatts to a few watts. Microcells are deployed for providing temporary cellular coverage and capacity to places like sports stadiums, convention centres etc. Sometimes, microcells may use distributed antenna systems (DAS) to improve bandwidth and reliability.
- c. **Pico cells** offer capacities and coverage areas, supporting up to 100 users over a range of less than 250 yards. Pico cells are frequently deployed indoors to improve poor wireless and cellular coverage within a building, such as an office floor or retail space.
- d. **Femtocells** are typically user-installed to improve coverage area within a small vicinity, such as home office or a dead zone within a building. Femtocells can be obtained through the service provider or purchased from a reseller. Unlike pico cells and microcells, femtocells are designed to support only a handful of users and is only capable of handling a few simultaneous calls. They are sold by the operator but self-installed by the customer.

## 1.1 Important attributes including HetNet, of LTE-A network towards achieving enhanced data speeds

LTE, as a wireless access technology, is being deployed around the world at a rapid pace. The operators are already talking about its next version, LTE Advanced (LTE-A). LTE Advanced is a superior form of LTE and is basically a conglomeration of a number of technologies.

As per the 3GPP standards, LTE-A networks should theoretically support downlink data speeds up to 3 Gbps and uplink speeds up to 1.5 Gbps. The primary features of LTE-A that would propel LTE towards achieving those speeds were formalized as part of 3GPP Release 10. The following five functionalities are generally considered to be the vital differentiating factors which separate LTE-A from its predecessors as well as makes it easily adaptable to “HetNet” deployments.

**A.Carrier Aggregation:** One of the most popular aspects of LTE-A is that it allows a combination of up to five component carriers of varying bandwidth to aggregate and form a cumulative bandwidth of up to a maximum of 100 MHz. Carrier Aggregation can be achieved within the same band using contiguous or non-contiguous stream of channels or between channels from two different bands.

**B. Higher Order MIMO:** Multiple Input Multiple Output (MIMO) increases the bitrate by using multiple transmission and receiver antennas. While LTE can support 4x4 MIMO configuration, LTE-A will have the capability to run 8x8 configurations in downlink and 4x4 in the uplink. This Higher order MIMO directly improves spectral efficiency and throughput.

**C. Relay Nodes and Heterogenous Networks:** Relay nodes are deployed to provide better coverage and capacity at cell edges. Such nodes are low power base stations that act as repeaters to enhance the signal quality and rebroadcast the signal. They connect with eNodeB via wireless interface and offer substantial cost savings as compared to a new eNodeB installation.

**D.Enhanced Inter-Cell Interference Coordination:** It is the primary interference management and mitigation procedure adopted in the LTE-A network. It is typically used in a heterogeneous network where both macro and other small cells transmit and receive data at the same time. The weaker signal from the smaller cell can be easily overpowered by the stronger signal from the larger cell. Advanced interference mitigation schemes have been used in LTE networks, but with the increasingly high density of wireless network cells, more sophisticated schemes like eICIC are required.

**E. Coordinated Multipoint (CoMP) Transmission** :This was formalized in 3GPP Release 11. CoMP is another key characteristic of a LTE Advanced network. In a Coordinated multipoint transmission and reception scenario, multiple eNodeBs work with each other dynamically to avoid interference with other transmission signals. This leads to a better utilization of system resources and an enhancement of both network coverage and quality for cell edge users.

## **2.0 Implementation of HetNet from LTE/LTE A perspective : Various Aspects**

Heterogeneous network planning has already been 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. In LTE networks, the actual cell size depends not only on the eNodeB power but also on antenna position, as well as the location environment; e.g. rural or city, indoor or outdoor etc. Different nodes, for small cells, used in LTE/LTE-A HetNets are listed below:

(i) **Home eNodeB (HeNB)** , a 3GPP term for femto-cell in LTE, was introduced in LTE Release 9 (R9). It is a low power eNodeB which is mainly used to provide indoor coverage, for Closed Subscriber Groups (CSG), for example, in office premises. See Figure 2. HeNBs are privately owned and deployed without coordination with the macro-network. If the frequency used in HeNB is the same as the frequency used in the macro-cells, and the HeNB is only used for CSG, then there is a risk of interference between the HeNB and the surrounding network. The solution to address this issue has been discussed later in this paper.

(ii)**Relay Node (RN)** is another type of low-power base station added to the LTE R10 specifications. In LTE-Advanced, the possibility for efficient heterogeneous network planning is increased by the introduction of Relay Nodes (RNs). The Relay Nodes are low power base stations that will provide enhanced coverage and capacity at cell edges, and hot-spot areas and it can also be used to connect to remote areas without fibre connection. The Relay Node is connected to the **Donor eNodeB (DeNB)**<sup>1</sup> via a radio interface, Un, which is a modification of the E-UTRAN air interface Uu.

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<sup>1</sup> E-UTRAN supports relaying by having a Relay Node (RN) wirelessly connect to an e NodeB(eNB) serving the RN, called Donor eNB (DeNB), via a modified version of the E-UTRA radio interface called the Un interface. The RN supports the eNB functionality meaning it terminates the radio protocols of the E-UTRA radio interface, and the S1 and X2 interfaces. DeNB provides the necessary signalling protocol gateway functions for the operation of RNs connected to the DeNB. The relay node acts first as a classical UE for the Donor eNodeB; <http://blog.3g4g.co.uk/2011/10/donor-enb-denb-and-relay-node-rn.html>

Hence in the Donor cell the radio resources are shared between UEs served directly by the DeNB and the RN. When the Uu and Un use different frequencies, the RN is referred to as a Type 1a RN, whereas for Type 1 RN Uu and Un utilize the same frequencies, see figure 2. In the latter case there is a high risk for self-interference in the Relay Node, when receiving on Uu and transmitting on Un at the same time (or vice versa). The RN will to a large extent support the same functionalities as the eNB. 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 (See Figure 2).

**(iii) RRHs (Remote Radio Head) connected to an eNB via fibre can also be used to provide small cell coverage.** It is an alternative solution to a BTS housed in a shelter at the bottom of the tower. It is a distributed base station, in which the majority of the base station equipment is no longer located in the shelter, but in an enclosure at the top of the tower near the antennae. This separate but integrated radio frequency (RF) unit is called a remote radio unit or remote radio head. It is compact in size. RRH is generally used to extend the coverage of a base station sub-system in the remote rural areas.

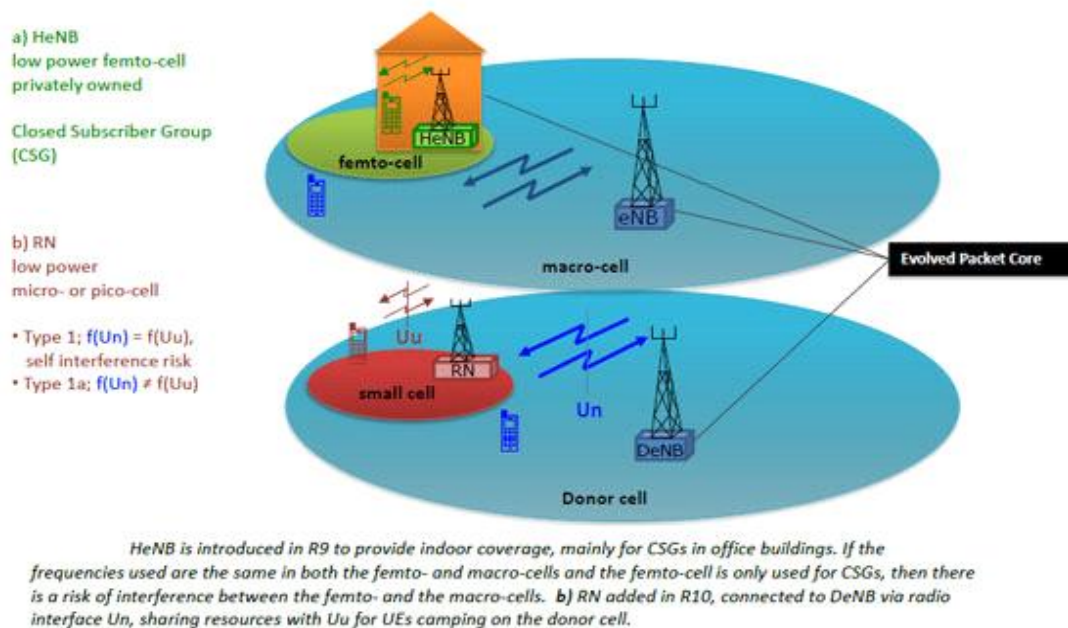


Figure 2 HeNB and Relay Node  
(Source: <http://www.3gpp.org/hetnet>)

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 3.

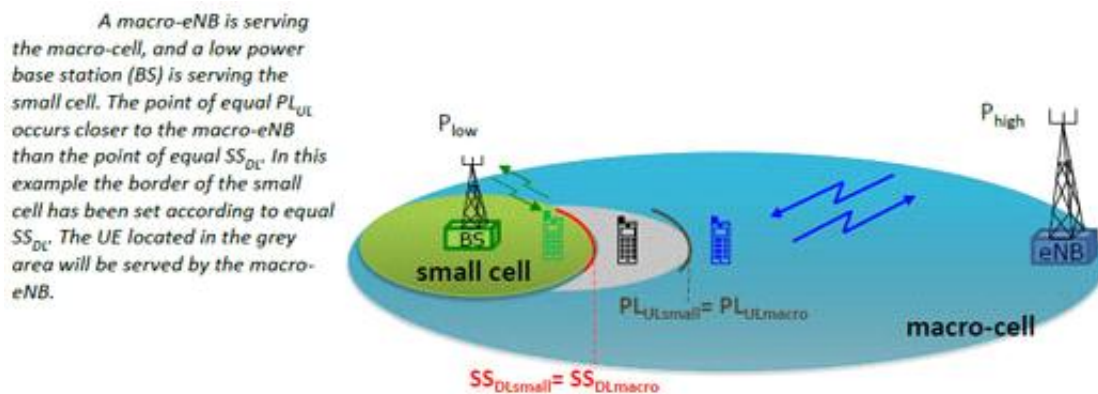


Figure 3 Complexity in a HetNet  
(Source: <http://www.3gpp.org/hetnet>)

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)<sup>2</sup>. See Figure 4.

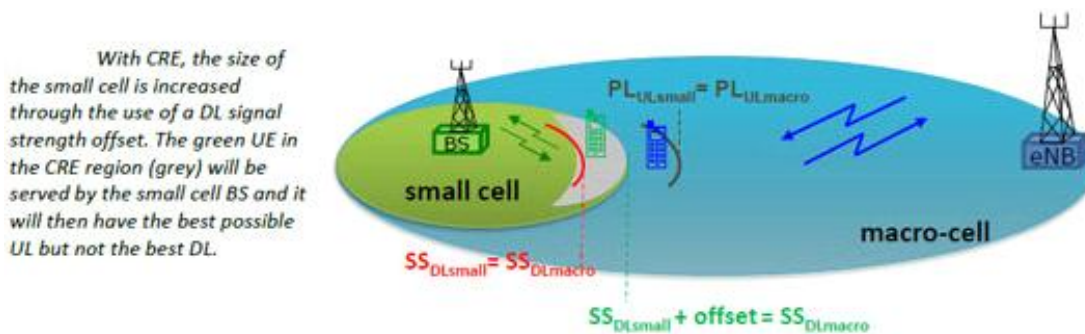


Figure 4 Cell Range Extension  
(Source: <http://www.3gpp.org/hetnet>)

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.

<sup>2</sup> Extending the coverage of a cell by means of connecting a UE to cell that is weaker than the strongest detected cell is referred to as cell range extension; <http://howtestuffworks.blogspot.in/2016/02/cell-range-extension-cre.html>

A number of features added to the 3GPP LTE specification can be used to mitigate the above-mentioned interference problem in heterogeneous networks with small cells. Some of the important techniques are described below:

### A. Inter-cell Interference Coordination: ICIC

ICIC was introduced in R8. The eNBs can communicate using ICIC via the X2 interface to mitigate inter-cell interference for UEs at the cell edge. The X2AP message used for this is called “Load Information”. See Figure 5. Through the “Load Information” message an eNB can inform neighbouring eNBs about: UL interference level per Physical Resource Block (PRB); UL PRBs that are allocated to cell edge UEs, and hence are sensitive to UL interference; and if DL Tx power is higher or lower than a set threshold value. The eNBs receiving these messages can use the received information to optimize scheduling for UEs at cell edges.

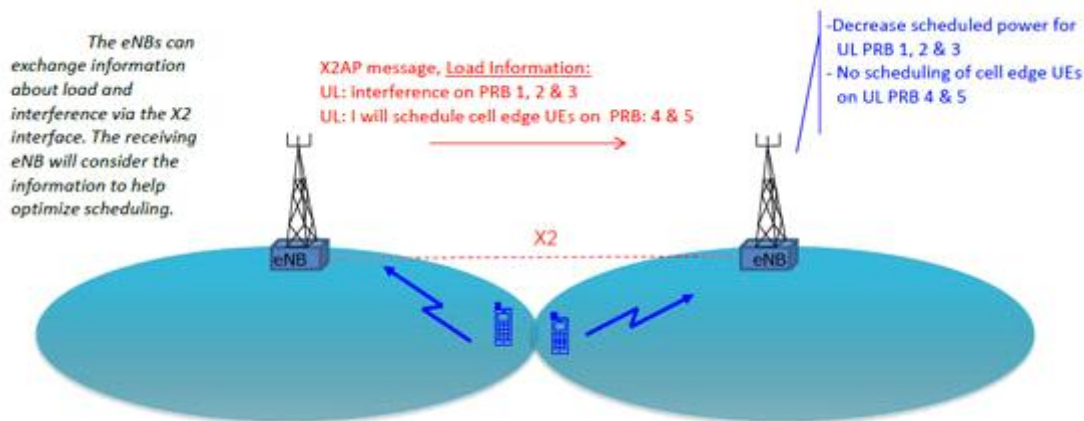


Figure 5 ICIC  
(Source: <http://www.3gpp.org/hetnet>)

ICIC has evolved to better support heterogeneous network deployments -- especially interference control for DL control channels. Subsequently enhanced ICIC (eICIC) was introduced in LTE R10. The major change is the addition of time domain ICIC, realized through use of Almost Blank Subframes (ABS). ABS includes only control channels and cell-specific reference signals, no user data, and is transmitted with reduced power. When eICIC is used, the macro-eNB will transmit ABS according to a semi-static pattern. During these subframes, UEs at the edge, typically in the CRE region of small cells, can receive DL information, both control and user data. The macro-eNB will inform the eNB in the small cell about the ABS pattern. See Figure 6.

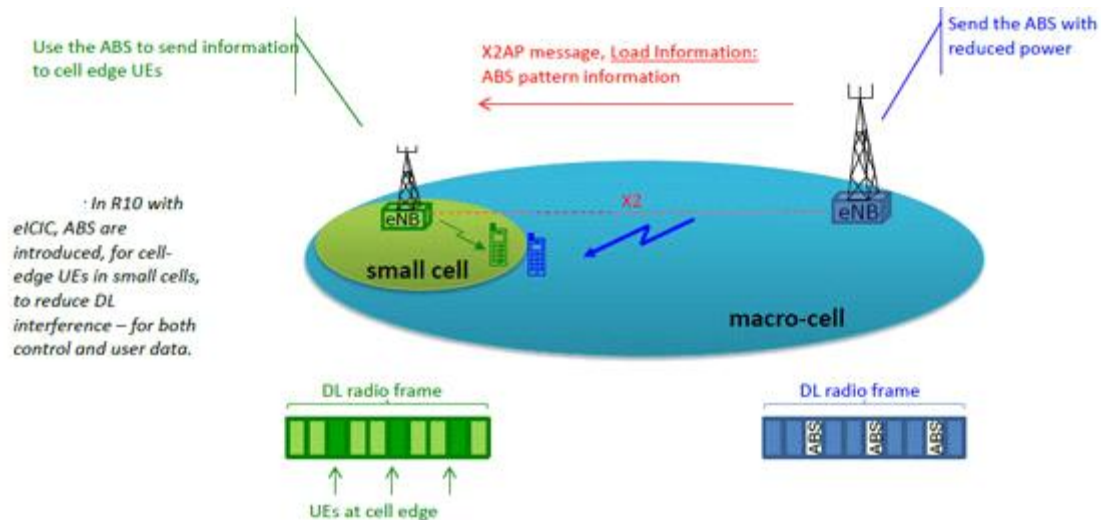


Figure 6 eICIC  
(Source: <http://www.3gpp.org/hetnet>)

ICIC is evolved in LTE R11 to further enhanced ICIC (feICIC). The focus here is interference handling by the UE through inter-cell interference cancellation for control signals, enabling even further CRE (Cell range extension). eICIC and feICIC are especially important when Carrier Aggregation (CA) is not used.

## B. Carrier Aggregation with cross-carrier scheduling

Carrier Aggregation (CA) is introduced in R10, with backward compatibility to R8, to increase the total bandwidth available to UEs and hence their maximum bitrates. When CA is used a number of R8 carriers, referred to as Component Carriers (CC), are aggregated and any CA-capable UE can be allocated resources on all CCs, while R8/R9 UEs can only be allocated resources on one CC. Cross-carrier scheduling is an important feature in heterogeneous networks. Using cross-carrier scheduling it is possible to map the Physical DL control channels (PDCCH) on different CCs in the large and small cells (See Figure 7). The PDCCH, carrying DL Control Information (DCI) with scheduling information, must be received by the UEs at the cell edge; PDCCH may be transmitted with higher power than the traffic channels. Hence, using different carriers for the PDCCH in the large and small cells reduces the risk of PDCCH interference.

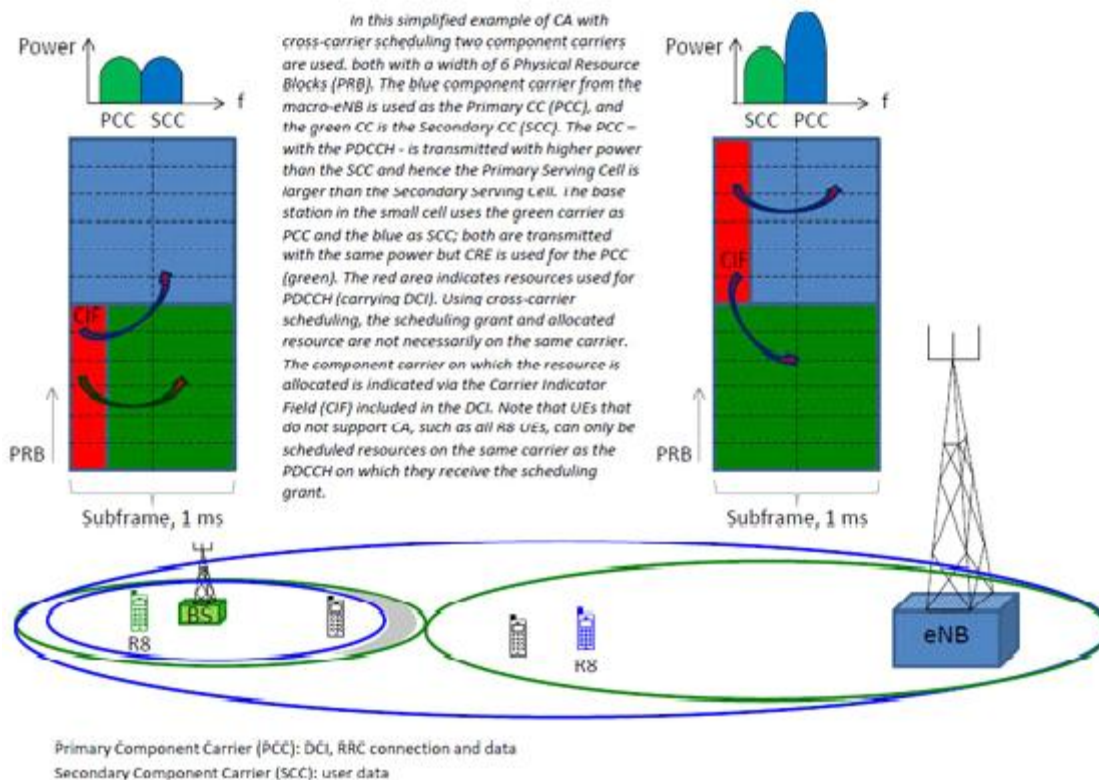


Figure 7 Cross-carrier Scheduling  
(Source: <http://www.3gpp.org/hetnet>)

### C.CoMP – Coordinated Multi Point

One way to ensure that a UE is using both the best DL and the best UL carrier in a heterogeneous network is to use CoMP, introduced in LTE R11. With CoMP a number of transmission/reception points (i.e. eNBs, RNs or RRHs) can be coordinated to provide service to a UE – for example, data can be transmitted at the same time in the same Physical Resource Blocks (PRBs) from more than one transmission point to one UE, or data can be received from one transmission point in one subframe and from another transmission point in the next subframe. CoMP can be used both in DL and UL. When CoMP is used in a heterogeneous network a number of macro-cells and small cells can be involved in data transmission to and from one UE. Especially useful in heterogeneous networks is the possibility for a UE in the cell range extension region to utilize the best UL in the small cell and the best DL in the macro-cell. See Figure 8. This, however, requires that the macro-eNB and the base station in the small cell are synchronized, and most likely it will require a combination of macro-eNB with RRHs in the small cell.

Using CoMP it is possible for the UE in the grey area to have both the best DL from the macro-eNB and the best UL to the base station, or RRH, serving the small cell.

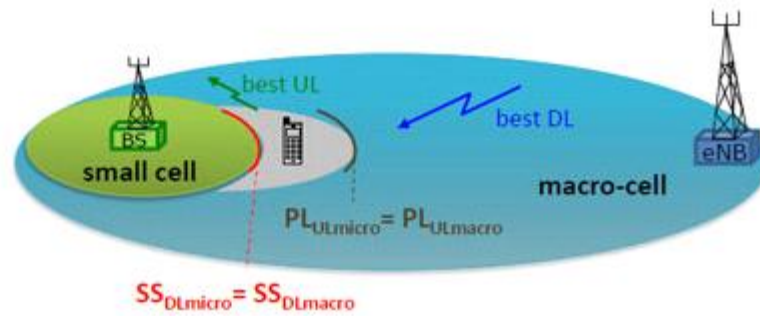


Figure 8 Coordinated Multi Point

(Source: <http://www.3gpp.org/hetnet>)

Further enhancements regarding heterogeneous network and small cells are coming in future 3GPP Releases on interference management for neighbour TDD cells, dual connectivity between the macro cell and small cells, mobility planning within hyper-dense environments and advances in carrier aggregation combinations.

### 3.0 Benefits of HetNet

The main benefits of HetNet solution are enriched capacity and guaranteed spot-free coverage. The overlay of small cells onto existing networks ensures high-speed, high-capacity communications for specific hot-spot area. This is especially desirable in densely-populated areas and business districts that need to provide reliable communication services to support an increasingly diverse and data-heavy range of applications. HetNet can boost capacity and system throughput many times more than that of a conventional network.

Small Cells can also be placed over gaps between cells to fill dead-spots, or added along the network rim to expand the network. A uniform coverage is increasingly important in today's world with so many content-based applications and services.

HetNets can also help maximize the cost efficiency of introducing a new network by providing cells of appropriate sizes. This flexible choice of cell size allows LTE services operators to enhance or expand their networks with minimum investment.

### 4.0 Challenges of HetNet

In HetNet introducing new forms of base station in the form of Pico cell or femtocell will help alleviate radio access network congestion, but then the backhaul network can become congested. Also congestion can start to move further into the core network. In addition to this,

there is some communication required to organise and configure the network and as a result there needs to be communication between the core and the periphery for some aspects of operation. Therefore, HetNets and HetNet structure is much more than simply adding femtocells or standard pico cells to the network as it requires the whole network to operate in a more efficient and seamless manner. Hence one of the key challenges of deploying HetNet is integration and proper dimensioning of different elements into the network.

With a variety of forms of base station deployed in HetNet another major task for its successful deployment is proper selection and implementation of the backhaul technology. Careful planning is required to achieve high performance. Every operator would like to have a fibre connection to the small cells. Macrocells have typically been linked back to the core network using fibre wherever possible, but with potentially hundreds or even thousands of small cells and Wi-Fi access points to connect on lampposts or sides of buildings across a busy city, it is unlikely to be practical or affordable to take the same approach.

If fibre is not a viable option for every new cell on the network, then a suitable wireless alternative needs to be found. However, it needs to be a carrier-class solution that delivers high capacity and low latency in a cost-efficient manner.

Moreover, It also needs to cope with new challenges in synchronisation, timing, and dimensioning because there are lot of small cells packed into highly dense areas and the number of handovers is extraordinarily high. Further, When UEs are constantly flip-flopping back and forth between cells, they end up with a massive amount of control traffic, which poses a burden on cell and the signalling gateway.

## **5.0 Deployment scenario of HetNets**

Most wireless operators believe that small cell deployment would be an essential part of their future strategy. This has given a big industry push towards HetNets. LTE - A and 5G will further drive the deployment and adoption of heterogeneous networks. As of now HetNets are in different stages of deployments in the wireless world.

Reliance Jio announced deployment of over 1,00,000 small cells in its LTE network during 2016. These are said to be carrying more than 350 TB of data and terminating more than five million VoLTE calls daily. Regarding the experience, the company maintains that these deployments have completely changed the traditional macro-centric deployment models by leveraging a Smart HetNet model supported and orchestrated by a cloud centric SON framework and that these deployments will allow Jio's self-healing HetNet to be able to



seamlessly transition to 5G. The company has immediate plans to increase the small cell deployments to 1,50,0000. In fact the company has made a statement that these deployments have enabled Jio to proactively and rapidly address data demand through targeted deployments.(Source: <http://telecom.economictimes.indiatimes.com/news/reliance-jios-massive-small-cell-deployment-to-enable-smooth-transition-to-5g-president-mathew-oommen/57378903>).

Jio's deployment of small cells is basically aimed at resolving the issue of in-building access, given its operations will be largely based on the 2300 Mhz band, which has indoor penetration challenges.

Airtel has also launched a Wi-Fi application called Airtel Hangout-Seamless Wi-Fi aimed at shifting data traffic away from the cellular network to help decongest it and improve services. The Wi-Fi offloading strategy of Bharti Airtel includes the deployment of small cells as well.

Similarly, in international market, Telstra, in June 2016, named 135 rural communities in Australia for rolling out small cell deployment in order to tackle mobile black spots as part of a government initiative to improve coverage. (Source: <http://www.totaltele.com/view.aspx?ID=494110>). Similar deployments have also been announced in Lowell, Massachusetts and New York in U.S.A.

The “HetNet Ecosystem (Small Cells, Carrier Wi-Fi, C-RAN & DAS): 2016 – 2030 – Opportunities, Challenges, Strategies & Forecasts” report published in Feb, 2016 presents an in-depth assessment of the HetNet ecosystem including enabling technologies, key trends, market drivers, challenges, standardization, regulatory landscape, deployment models, use cases, vertical markets, operator case studies, opportunities, future roadmap, value chain, ecosystem player profiles and strategies. The report also presents forecasts for HetNet infrastructure investments from 2016 till 2030. The report has the following key findings:

- Global investments on small cells, carrier Wi-Fi, C-RAN and DAS are expected to be nearly \$13 Billion by the end of 2016.
- Small cell and C-RAN solutions are beginning to converge as small cell OEMs seek to capitalize on the benefits of centralized coordination for in-building and enterprise coverage
- The market is further expected to grow at a CAGR of 15% between 2016 and 2020, as mobile operators remain committed to tackle the continued growth of mobile data traffic and evolving coverage requirements.
- Despite opposition from the Wi-Fi community, unlicensed LTE small cell shipments are beginning to gain traction, with shipment revenues potentially expected to reach \$220 Million by the end of 2020.

## **6.0 Conclusion**

Optimizing current macro cell and future heterogeneous networks requires a multi-dimensional approach. It begins with an operator cost efficiently optimizing an existing macro cell network. The next step is densification of the network with the addition of small cells to the existing infrastructure. Capacity and coverage are driving this approach. The combination of using small cells has a force multiplier effect both on backhaul saving and quality of experience. Future enhancements to the resulting HetNets should be made with the goals of further cutting backhaul costs and improving the customer's quality of experience.

HetNet architecture allows capacity expansion to be based on actual demand in data traffic. By deploying small cells and HetNet networks, operators can address both short term and long-term challenges to enhance the network capacity and quality. The business case for a high Quality of Experience (QoE) network that is "always-on, and available anywhere, any time" is also driving the network evolution towards HetNet. However, Harmonization and optimisation between asymmetrically sized cells would be an additional area of focus in a heterogeneous network. To sum up, HetNet is a complex architectural change which will affect technology, deployment and monetization, and will be an important stepping stones to 5G.



## ACRONYMS

|         |   |
|---------|---|
| 2G      | Second-generation wireless, such as GSM         |
| 3G      | Third-generation wireless, such as UMTS /WC DMA |
| 3GPP    | Third Generation Partnership Project            |
| 4G      | Fourth-generation wireless, such as LTE         |
| ABS     | Almost Blank Subframe                           |
| BS      | Base Station                                    |
| CA      | Carrier Aggregation                             |
| CAGR    | Compound Annual Growth Rate                     |
| CC      | Component Carriers                              |
| CIF     | Carrier Indicator Field                         |
| CoMP    | Coordinated Multipoint                          |
| C-RAN   | Centralized Radio Access Network                |
| CRE     | Cell Range Extension                            |
| CSG     | Closed Subscriber Group                         |
| DAS     | Distributed Antenna System                      |
| DeNB    | Donor eNode B                                   |
| DL      | Downlink  |
| eICIC   | enhanced ICIC                                   |
| eNode B | Evolved NodeB                                   |
| E-UTRA  | Evolved UMTS Terrestrial Radio Access           |
| E-UTRAN | Evolved Universal Terrestrial Access Network    |
| FCC     | Federal Communications Commission               |
| feICIC  | Further Enhanced ICIC                           |
| GSM     | Global System for Mobile                        |
| HeNB    | Home eNode B                                    |
| HetNet  | Heterogenous Network                            |
| HSPA    | High Speed Packet Access                        |
| HSPA+   | Evolved HSPA                                    |
| ICIC    | Inter Cell Interference Coordination            |
| LTE – A | LTE Advanced                                    |
| LTE     | Long term evolution                             |
| MIMO    | Multiple Input Multiple Output                  |
| OEM     | Original Equipment Manufacturer                 |
| PCC     | Primary Component Carrier                       |
| PDCCCH  | Physical DL Control Channels                    |
| PLUL    | Path Loss for the UL                            |
| PRB     | Physical Resource Block                         |
| QoE     | Quality of Experience                           |
| RF      | Radio Frequency                                 |
| RN      | Relay Node                                      |
| RRH     | Remote Radio Head                               |
| SON     | Self Organizing Network                         |
| SSDL    | Strongest Received DL Signal                    |
| UE      | User Equipment                                  |
| UL      | Uplink  |
| Wi-Fi   | Wireless Fidelity                               |
| X2AP    | X2 Application Protocol                         |

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