Adaptive Control of CRE with Proportional Fair Resource Scheduling in LTE HetNets

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List of Acronyms

LTE	Long term evolution
3GPP	3rd Generation Partnership Project
LPN	Low Power nodes
HETNETS	Heterogeneous Networks
CRE	Cell Range Extension
CSO	Cell selection offset
UE	User Equipment
SON	Self-Organizing Network
RB	Resource Block
PF	Proportional fair
RR	Round Robin
SSDL	Strongest signal in DL
RSRP	Reference signal received power
PLUL	Path loss for uplink
CSG	Closed Subscriber Group
DSL	Digital subscriber line
ICIC	Inter cell interference coordination
PFS	Proportional fair scheduling
SINR	Signal to interference plus noise ratio
GSM	Global system for mobile
GPRS	General packet radio Service
EDGE	Enhanced Data for GSM Evolution
UMTS	Universal Mobile Telecommunication system
HO	Handover
ENB	E node B
SCTP	stream control transmission protocol
EPS	Evolved packet system
NAS	Non access stratum
RLC	Radio link control
PDCP	Packet Data convergence protocol
MBSFN	Multicast-broadcast single-frequency network
FDMA	Frequency division multiple access
CDMA	Coded division multiple access
OFDM	Orthogonal Frequency Division Multiplexing
MBMS	Multimedia Broadcast and Multicast Services
FDD	Frequency division duplex
TDD	Time division duplex
MIMO	Multiple input and multiple output
WIMAX	Worldwide Interoperability for Microwave Access
HSPA	High Speed Packet Access

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Abstract

Cell range extension (CRE) has been used as a method to increase the area under the small cell and balance the loads between small and large cell by adding a cell selection offset (CSO) to small cells in heterogeneous network deployment.

Previously most of the other literatures considered CSO setting for round robin resource scheduling but in this study we have considered Proportional Fair Resource Scheduling to make the computations realistic.

This work paves a way to achieve better load balancing by selecting a CSO value to have equal average cell data rates by means of proportional fair resource scheduling in LTE HetNets. Simulation results indicate that this method can achieve a better average user throughput in networks with different densities of small cells.

CHAPTER 1

INTRODUCTION

Introduction

Cellular networks play a significant role in global networking and communication infrastructure. The topology and architecture of cellular networks are undergoing a major paradigm shift from voice centric, circuit-switched and centrally optimized to data-centric , packet switched and organically deployed for capacity . To ensure and even enhance availability of the connectivity, the improved and new processes of communication systems is developed keeping in mind the factors reliability, interoperability and security although the increase in data traffic demand at an exponential rate forces the consideration of novel research results during standardization [1] . Mobile data traffic is predicted to increase 13-fold between 2012 and 2017, culminating in a monthly global data traffic of more than 10 Exabyte's by 2017 [2].
To cope with the increasing demand providers introduced the new mobile communication standard Long Term Evolution (LTE) later which was developed and standardized as LTE-advanced, in the third generation partnership project (3GPP) [3,4]. Heterogeneous network has been included in this version of LTE .A heterogeneous network is typically composed of multiple radio access technologies, transmission solutions, and base stations of varying transmission power [5].

The heterogeneous networks (HetNets) are introduced in LTE-Advanced to enhance coverage and capacity greatly. A HetNet consists of regular macro cells transmitting typically at high power level, overlaid with low power small cells such as pico cell, femto cell, remote radio head (RRH), and relay node (RN) . In this paper, the HetNet is considered to have only pico cells and femto cells and they both are referred to as small cells. The small cells offload traffic from the macro cell and offer extension of the reach of coverage. They improve the conditions in coverage holes providing higher data rates at cell edge or in hot spots. The small cells have smaller base stations with lower antenna gain compared to macro cells. So, the site acquisition for the addition of small cells can be simpler and they require little additional backhaul expenses. However, there are some challenges that need to be addressed in HetNets.

Since the macro eNodeB transmits much higher power, the UE tends to be connected to the macro cell even when the path loss between the UE and the small cell is smaller. This makes the load among tiers unbalanced. Therefore, 3GPP has standardized the provision for cell range expansion (CRE), which virtually increases the coverage area of small cells. In the case of CRE, by biasing handover decision toward a small cell, the users are handed over to the small cell earlier than usual and thus, the load is shifted from the macro cell to the small cell. Similarly, cell reselection can also be biased for users in RRC_IDLE state. However with CRE, the users, switched to small cells earlier than usual, receive low power from the serving small cell and high interference from the macro cell and thus, suffer from low SINR at the cell edge.

Hetnet is a promising approach for capacity extension in certain areas ,e.g. the so-called traffic hotspots , where short range cells created by Low-Power Nodes , or LPNs may be efficiently used to provide additional resources for the enhancement of network performance .

From a network density perspective ,In order to enhance capacity , providers deploy more base stations (eNodeBs). Especially in areas of high user equipment (UE) density, e.g. the Hotspots , the density of high power macro eNodeBs starts to become saturated. Hence, in LTE a new type of low power eNodeBs, called pico eNodeBs, with reduced transmission power and lower antenna elevation operating on the same frequency band as the macro eNodeBs is introduced to enhance the capacities in these traffic hot spots [7].

The pico eNodeBs are deployed in the coverage area of the cellular network created by the macro eNodeBs [8]. In Hetnets . one typical scenario is that the coverage area of the LPNs and macro cells are overlapped with each other. As the carrier frequencies of macrocell's are reused throughout the network, the interference between macrocells and LPNs is a very alarming issue which needs to be evaluated in order to optimize the network performance and end-user experience . Poorly planned LPNs location or configuration not only results in unsatisfactory end-user experience but also may cause performance degradation and overload state in macrocell [9].

Previously researches were done considering the scenario in which the small cells has sparse distribution within the coverage of the macro cell .[8] .

In this case we often consider the scenario in which the macro cells and LPNs are sharing the same spectrum and the inter cell interference is evaluated by Cell Range Extension (CRE) . [10]To extend the coverage of low power pico BSs , Cell Range Expansion (CRE), which enables a UE to associate with a BS with lower downlink SINR, is a comparatively simple yet effective method . From the macro cell to the pico cell , more traffic offloading, hence increased system capacity is possible because of CRE. [11].
CRE is actually a technology by which a cell selection offset (CSO) is added to LPNs during cell selection/reselection procedure so that the end-user would select the higher priority LPN .

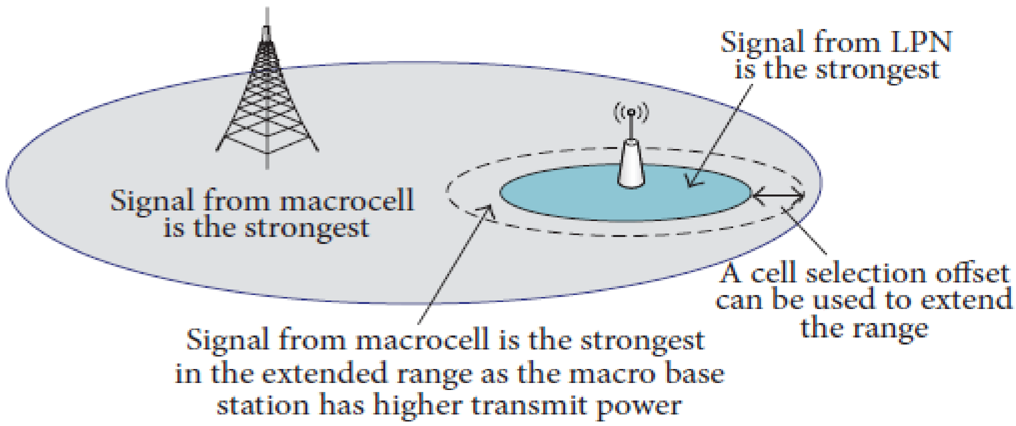

FIGURE 1: Illustration of cell range extension.

Fig 1.1 Illustration of Cell Range Extension

However, when extending the range of LPNs, users located in the extended range could suffer from severe interference from the nearby macro base station due to the difference between the transmit powers of the macro base stations and the LPNs which is illustrated by Figure 1. There is a trade-off between the LPN offloading ratio and the user experienced interference in LPNs especially in the extended LPN range. Therefore, it is essential to set the CSO properly [12] .

However, the optimal cell selection method is not yet perfect and in previous studies offset was fixed for all UEs. This paper proposes an adaptive control CRE which can increase the cell edge user throughput while maintaining average user throughput. [18]

In case of HetNets, Self-Organizing Network(SON) is still an effective way to achieve network self-configuration and self-optimizing [13-16].
There were some attempts to use SON to adaptively adjust the CSO setting, for example, in [17, 18, and 19].

In [17] an adaptive bias configuration strategy to decide the CSO value was proposed based on the end-user performance feedback. However, there are limitations with the algorithm in [17]. Firstly, to decide the associated load in each cell , the number of users was used which is not sufficiently accurate in reality. Secondly, it was proposed to use cell edge user throughput and average user throughput as inputs to the adaptation algorithm whereas both average user throughput and cell edge user throughput can't be obtained from the network side directly.

In [18], the authors proposed an adaptive CRE controlling technique that improves the cell edge user throughput in Hetnets, in which UE can automatically choose an optimal CSO from either CSOhigh or CSOlow. However, The effect of transmission power changes in macro cells along with some considerations for ICIC were to be further investigated .

In [19] an adaptive algorithm to decide the CSO value was proposed based on assumption using a round robin (RR) scheduling

strategy. here the deployment of the Small Cells are in a more dense manner than the previous literatures in which CSO setting were considered in sparse small cell network . The possibility for a user to obtain a resource block is inversely proportional to the number of users staying at a macro cell or a small cell .However, round robin wouldn't get that much accurate CSO as the whole system RB's are not same all over the network system.

Proportional fairness is more accurate in case of getting the proper CSO setting. In [20] and [21], user association methods are proposed that maximize the network resource utilization ratios among the BSs from the proportional fairness point of view . The focus on the optimal user association from the viewpoint of maximizing the downlink system throughput where the system throughput is based on proportional fairness. [22] .

In [23-25] a decentralized user association method that maximizes the system throughput was proposed which was based on proportional fair . Similar approaches are also found in [26-29].
This paper proposes a better adaptive CSO setting through a new user association method to maximize the downlink system throughput where the system throughput is based on proportional fairness.

Chapter 2

Overview of LTE

Long Term Evolution (LTE)

Long Term Evolution (LTE) telecommunication system constitutes the next step beyond third generation mobile networks and a step behind the fourth generation mobile standard. LTE supports scalable carrier bandwidths, from 20 MHz down to 1.4 MHz and provides downlink peak rates of at least 100 Mbps and round-trip times less than 10 ms. LTE introduces several techniques in order to achieve increased performance.

LTE networks offer high capacity and are specified and designed to accommodate small, high performance, power-efficient end-user devices. The investigation of inter-channel interference mitigation techniques has become a key focus area in achieving dense spectrum reuse in next generation cellular systems. Fractional Frequency Reuse (FFR) has been proposed as a technique to overcome this problem, since it can efficiently utilize the available frequency spectrum.

LTE standard achieves considerable advancements in system capacity and throughput, but the deployment of macro cells results in high operational and capital expenditures. A way to increase cost-capacity of the networks is to deploy a large number of smaller and cheaper cells, i.e. femtocells which improve coverage in indoors, contributing to offload the macro network, yet very important considering that a large amount of wireless traffic is originated in indoor

Furthermore, the evolved Multimedia Broadcast and Multicast Services (e-MBMS) feature constitutes the evolutionary successor of MBMS for LTE systems. The key motivation for integrating multicast and broadcast extensions into mobile communication systems is to enable efficient group related data distribution services, especially on the radio interface.

Table 2.1 Evolution of 3GPP technologies

Generation	**Technologies**	**Service**	**Theoretical Data Rate**	**Multiplexing Technique**
2G	GSM	Voice	9.6-19.2 kbps	FDMA/TDMA
2.5G	GPRS	Data	44-171.2 kbps	
2.75G	EDGE	Data	384 kbps	

Finally, to meet the error free transmission requirement of demanding multicast applications, 3GPP recommends the use of the systematic, fountain Raptor code as an Application Layer FEC (AL-FEC) protection mechanism exclusively for MBMS, In order to meet the error free transmission requirement of demanding applications, 3GPP recommends the use of the systematic, fountain Raptor code as an Application Layer FEC (AL-FEC) protection mechanism exclusively for MBMS providing enhanced reliability control over LTE multicast services.

LTE is a very good, easily deployable network technology, offering high speeds and low latencies over long distances. For example, two of the four operators' LTE networks in New York City were rated well for achieving this goal. Verizon's LTE service was rated with an average download speed of 31.1Mbps and an average upload speed of 17.1Mbps. T-Mobile's LTE service was rated with an average download speed of 20.5Mbps and an average upload speed of 13.5Mbps.

Of course, that doesn't mean all networks are created equal. Some aren't quite able to achieve these goals. For example, Sprint's LTE service was rated with an average download speed of 4.0Mbps and an average upload speed of 2.5Mbps. AT&T's LTE service was much better than Sprint's, but still bad with an average download speed of 7.6Mbps and an average upload speed of 2.4Mbps.

Main Features of LTE

Much of the LTE standard addresses the upgrading of 3G UMTS to what will eventually be 4G mobile communications technology. A large amount of the work is aimed at simplifying the architecture of the system, as it transitions from the existing UMTS circuit + packet switching combined network, to an all-IP flat architecture system. E-UTRA is the air interface of LTE. Its main features are:

Peak download rates up to 299.6 Mbit/s and upload rates up to 75.4 Mbit/s depending on the user equipment category (with 4×4 antennas using 20 MHz of spectrum). Five different terminal classes have been defined from a voice centric class up to a high end terminal that supports the peak data rates. All terminals will be able to process 20 MHz bandwidth.

Low data transfer latencies (sub-5 ms latency for small IP packets in optimal conditions), lower latencies for handover and connection setup time than with previous radio access technologies.

Improved support for mobility, exemplified by support for terminals moving at up to 350 km/h (220 mph) or 500 km/h (310 mph) depending on the frequency band.

Orthogonal frequency-division multiple access for the downlink, Single-carrier FDMA for the uplink to conserve power.

Support for both FDD and TDD communication systems as well as half-duplex FDD with the same radio access technology.

Support for all frequency bands currently used by IMT systems by ITU-R.

Increased spectrum flexibility: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells are standardized. (W-CDMA has no option for other than 5 MHz slices, leading to some problems rolling-out in countries where 5 MHz is a commonly allocated width of spectrum so would frequently already be in use with legacy standards such as 2G GSM and cdmaOne.)

Support for cell sizes from tens of meters radius (femto and picocells) up to 100 km (62 miles) radius macrocells. In the lower frequency bands to be used in rural areas, 5 km (3.1 miles) is the optimal cell size, 30 km (19 miles) having reasonable performance, and up to 100 km cell sizes supported with acceptable performance. In city and urban areas, higher frequency bands (such as 2.6 GHz in EU) are used to support high speed mobile broadband. In this case, cell sizes may be 1 km (0.62 miles) or even less. Supports at least 200 active data clients in every 5 MHz cell.

Simplified architecture: The network side of E-UTRAN is composed only of eNode Bs.

Support for inter-operation and co-existence with legacy standards (e.g., GSM/EDGE, UMTS and CDMA2000). Users can start a call or transfer of data in an area using an LTE standard, and, should coverage be unavailable, continue the operation without any action on their part using GSM/GPRS or W-CDMA-based UMTS or even 3GPP2 networks such as cdmaOne or CDMA2000.

Packet switched radio interface.

Support for MBSFN (Multicast-broadcast single-frequency network). This feature can deliver services such as Mobile TV using the LTE infrastructure, and is a competitor for DVB-H-based TV broadcast.

Network architecture

All the network interfaces are based on IPprotocols. The eNBs are interconnected by means of an X2 interface and to the MME/GWentity by means of an S1 interface as shown in Figure 2.1.

The S1 interface supports a many-to-many relationship between MME/GW and eNBs.

The functional split between eNB and MME/GW is shown in Figure 2.2. Two logical gateway entities namely the serving gateway (S-GW) and the packet data network gateway (P-GW) are defined. The S-GW acts as a local mobility anchor forwarding and receiving packets to and from the eNB serving the UE. The P-GW interfaces with external packet data networks (PDNs) such as the Internet and the IMS. The P-GW also

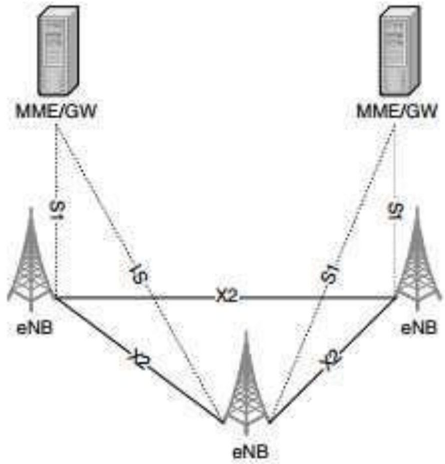

Figure 2.1. Network architecture.

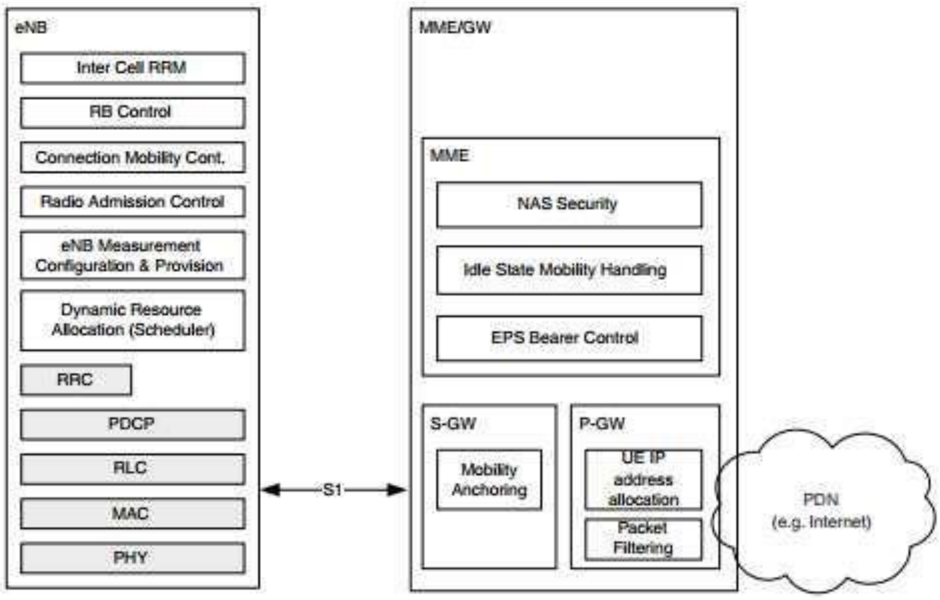

Figure 2.2. Functional split between eNB and MME/GW.

performs several IP functions such as address allocation, policy enforcement, packet filtering and routing. The MME is a signaling only entity and hence user IP packets do not go through MME. An advantage of a separate network entity for signaling is that the network capacity for signaling and traffic can grow independently.

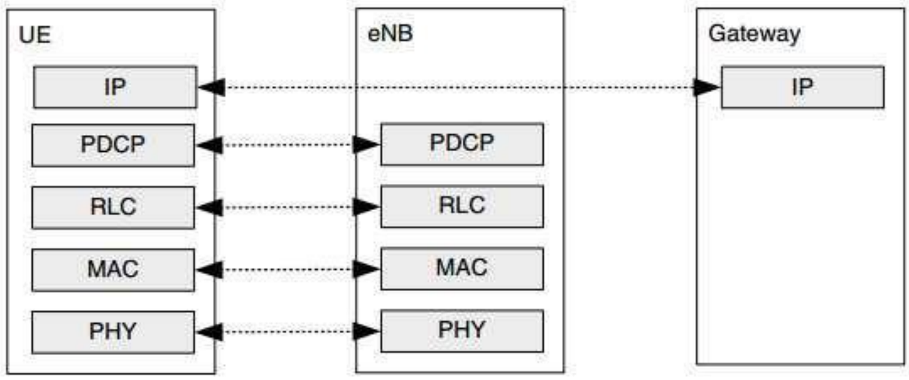

Figure 2.3. User plane protocol.

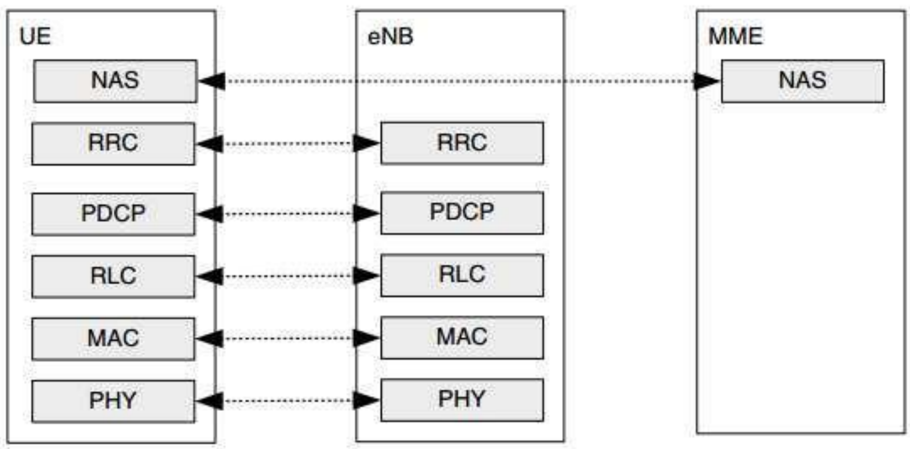

Figure 2.4. Control plane protocol stack.

The main functions of MME are idle-mode UE reachability including the control and execution of paging retransmission, tracking area list management, roaming, authentication, authorization, P-GW/S-GW selection, bearer management including dedicated bearer establishment, security negotiations and NAS signaling, etc. Evolved Node-B implements Node-B functions as well as protocols traditionally implemented in RNC. The main functions of eNB are header compression, ciphering and reliable delivery of packets. On the control side, eNB incorporates functions such as admission control and radio resource management. Some of the benefits of a single node in the access network are reduced latency and the distribution of RNC processing load into multiple eNBs. The user plane protocol stack is given in Figure 2.3. We note that packet data convergence protocol (PDCP) and radio link control (RLC) layers traditionally terminated in RNC on the network side are now terminated in eNB. The functions performed by these layers are described in Section 2.2. Figure 2.4 shows the control plane protocol stack. We note that RRC functionality traditionally implemented in RNC is now incorporated into eNB. The RLC and MAC layers perform the same functions as they do for the user plane. The functions performed by the RRC include system information broadcast, paging, radio bearer control, RRC connection management, mobility functions and UE measurement reporting and control. The non-access stratum (NAS) protocol terminated in the MME on the network side and at the UE on the terminal side performs functions such as EPS (evolved packet system) bearer management, authentication and security control, etc.

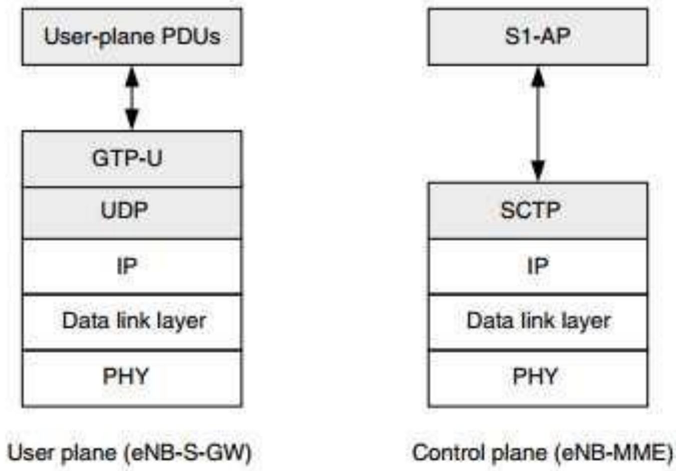

Figure 2.5. S1 interface user and control planes.

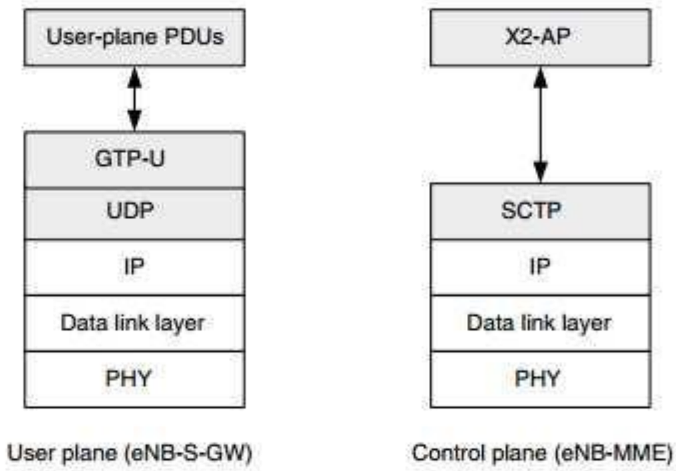

Figure 2.6. X2 interface user and control planes.

The S1 and X2 interface protocol stacks are shown in Figures 2.5 and 2.6 respectively. We note that similar protocols are used on these two interfaces. The S1 user plane interface (S1-U) is defined between the eNB and the S-GW. The S1-U interface uses GTP-U (GPRS tunneling protocol – user data tunnelin g) [2] on UDP/IPtransport and provides non-guaranteed delivery of user plane PDUs between the eNB and the S-GW. The GTP-U is a relatively simple IP based tunneling protocol that permits many tunnels between each set of end points. The S1 control plane interface (S1-MME) is defined as being between the eNB and the MME. Similar to the user plane, the transport network layer is built on IP transport and for the reliable

transport of signaling messages SCTP (stream control transmission protocol) is used on top of IP. The SCTP protocol operates analogously to TCP ensuring reliable, in-sequence transport of messages with congestion control [3]. The application layer signaling protocols are referred to as S1 application protocol (S1-AP) and X2 application protocol (X2-AP) for S1 and X2 interface control planes respectively.

Seamless mobility support

An important feature of a mobile wireless system such as LTE is support for seamless mobility across eNBs and across MME/GWs. Fast and seamless handovers (HO) are particularly important for delay-sensitive services such as VoIP. The handovers occur more frequently across eNBs than across core networks because the area covered by MME/GW serving a large number of eNBs is generally much larger than the area covered by a single eNB. The signaling on X2 interface between eNBs is used for handover preparation. The S-GW acts as anchor for inter-eNB handovers. In the LTE system, the network relies on the UE to detect the neighboring cells for handovers and therefore no neighbor cell information is signaled from the network. For the search and measurement of inter-frequency neighboring cells, only the carrier frequencies need to be indicated. An example of active handover in an RRC CONNECTED state is shown in Figure 2.7 where a UE moves from the coverage area of the source eNB (eNB1) to the coverage area of the target eNB (eNB2). The handovers in the RRC CONNECTED state are network controlled and assisted by the UE. The UE sends a radio measurement report to the source eNB1 indicating that the signal quality on eNB2 is better than the signal quality on eNB1. As preparation for handover, the source eNB1 sends the coupling information and the UE context to the target eNB2 (HO request) [6] on the X2 interface. The target eNB2 may perform admission control dependent on the received EPS bearer QoS information. The target eNB configures the required resources according to the received EPS bearer QoS information and reserves a C-RNTI (cell radio network temporary identifier) and optionally a RACH

preamble. The C-RNTI provides a unique UE identification at the cell level identifying the RRC connection. When eNB2 signals to eNB1 that it is ready to perform the handover via HO response message, eNB1 commands the UE (HO command) to change the radio bearer to eNB2. The UE receives the HO command with the necessary parameters (i.e. new C-RNTI, optionally dedicated RACH preamble, possible expiry time of the dedicated RACH preamble, etc.) and is commanded by the source eNB to perform the HO.

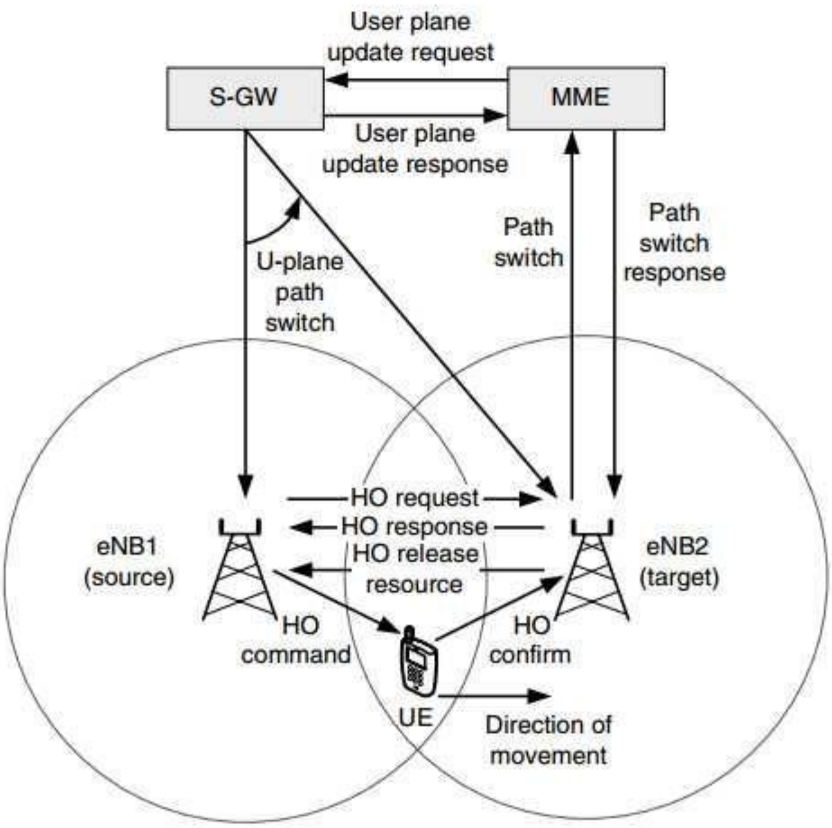

Fig 2.7: Active Handovers

The UE does not need to delay the handover execution for delivering the HARQ/ARQ responses to source eNB. After receiving the HO command, the UE performs synchronization to the target eNB and accesses the target cell via the random access channel (RACH) following a contention-free procedure if a dedicated RACH preamble was allocated in the HO command or following a contention-based procedure if no dedicated preamble was allocated. The network responds with uplink resource allocation and timing advance to be applied by the UE. When the UE has successfully accessed the target cell, the UE sends the HO confirm message (C-RNTI) along with an uplink buffer status report indicating that the handover procedure is completed for the UE. After receiving the HO confirm message, the target eNB sends a path switch message to the MME to inform that the UE has changed cell. The MME sends a user plane update message to the S-GW. The S-GW switches the downlink data path to the target eNB and sends one or more "end marker" packets on the old path to the source eNB and then releases any user-plane/TNL resources towards the source eNB. Then S-GW sends a user plane update response message to the MME. Then the MME confirms the path switch message from the target eNB with the path switch response message. After the path switch response message is received from the MME, the target eNB informs success of HO to the source eNB by sending release resource message to the source eNB and triggers the release of resources. On receiving the release resource message, the source eNB can release radio and C-plane related resources associated with the UE context. During handover preparation U-plane tunnels can be established between the source eNB and the target eNB. There is one tunnel established for uplink data forwarding and another one for downlink data forwarding for each EPS bearer for which data forwarding is applied. During handover execution, user data can be forwarded from the source eNB to the target eNB. Forwarding of downlink user data from the source to the target eNB should take place in order as long as packets are received at the source eNB or the source eNB buffer is exhausted. For mobility management in the RRC IDLE state, concept of tracking area (TA) is introduced. A tracking area generally covers multiple eNBs as depicted in Figure 2.14. The tracking area identity (TAI) information indicating which TA an eNB belongs to is broadcast as part of system information. A UE can detect change of tracking area when it receives a different TAI than in its current cell. The UE updates the MME with its new TA information as it moves across TAs. When P-GW receives data for a UE, it buffers the

Packets and queries the MME for the UE's location. Then the MME will page the UE in its most current TA. A UE can be registered in multiple TAs simultaneously. This enables power saving at the UE under conditions of high mobility because it does not need to constantly update its location with the MME. This feature also minimizes load on TA boundaries.

How LTE is configured for deployment

LTE supports deployment on different frequency bandwidths. The current specification outlines the following bandwidth blocks: 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, and 20MHz. Frequency bandwidth blocks are essentially the amount of space a network operator dedicates to a network. Depending on the type of LTE being deployed, these bandwidths have slightly different meaning in terms of capacity. That will be covered later, though. An operator may choose to deploy LTE in a smaller bandwidth and grow it to a larger one as it transitions subscribers off of its legacy networks (GSM, CDMA, etc.).

MetroPCS was an example of a network operator that has done this. Before it was acquired by T-Mobile, a majority of its spectrum is still dedicated to CDMA, with 1.4MHz or 3MHz dedicated for LTE depending on the market. There were a few markets with 5MHz deployed, but these were the exception, not the rule. Leap Wireless (who did business as Cricket Communications) had also done the same thing prior to being acquired by AT&T, except it used 3MHz or 5MHz instead of 1.4MHz or 3MHz. Neither of these operators could afford to cut CDMA capacity by a significant degree just yet, so LTE operated on tiny bandwidths. Additionally, neither operator had enough backhaul (the core network infrastructure and connections to the internet) dedicated to

LTE to make larger bandwidths worth it either. Of course, these issues went away when they were acquired. MetroPCS and Cricket transitioned service to the T-Mobile and AT&T networks, respectively. Their networks are being wound down and their spectrum is redeployed to support their new parent companies' GSM/UMTS/LTE networks.

On the other hand, Verizon Wireless has been using 10MHz wide channels for LTE all across the board for 750MHz, since it has the national allocation of spectrum available for it. In addition to that, the AWS spectrum it acquired from the cable companies and other transactions have allowed it to roll out a second LTE pipeline with 15MHz or 20MHz channels in most places. Like Verizon, T-Mobile is also rolling out wide channels for LTE on it's AWS spectrum. Combined with excellent backhaul, LTE service from those two companies promise to be best in class. On AT&T's side, LTE channel sizes vary depending on the market. In most markets, AT&T has 10MHz channels on 700MHz, but there are many where it only has 5MHz. It has resorted to cutting down GSM capacity to reuse the spectrum to support its customers, as singular 5MHz or even 10MHz channels aren't enough. Sprint has a similar problem, as its main network is a singular 5MHz channel nationally. It is using the spectrum it has from acquiring Clearwire to supplement it with 20MHz channels for additional capacity.

Less spectrum means that fewer customers can obtain the same high speeds that Verizon's LTE customers get when connected to any particular cell. LTE can support up to 200 active data clients (smartphones, tablets, USB modems, mobile hotspots, etc.) at full speed for every 5MHz of spectrum allocated per cell. That means that if a particular tower has 20MHz of spectrum allocated to it, it can support up to 800 data clients at full speed. There are ways of supporting more data clients per 5MHz, but doing so requires sacrificing speed and capacity, as the 200-per-5MHz ratio is the optimal configuration. However, spectrum isn't ever ything to LTE quality, as we will discuss later.

How LTE actually works

LTE uses two different types of air interfaces (radio links), one for downlink (from tower to device), and one for uplink (from device to tower). By using different types of interfaces for the downlink and uplink, LTE utilizes the optimal way to do wireless connections both ways, which makes a better-optimized network and better battery life on LTE devices.

For the downlink, LTE uses an OFDMA (orthogonal frequency division multiple access) air interface as opposed to the CDMA (code division multiple access) and TDMA (time division multiple access) air interfaces we've been using since 1990. What does this mean? OFDMA (unlike CDMA and TDMA) mandates that MIMO (multiple in, multiple out) is used. Having MIMO means that devices have multiple connections to a single cell, which increases the stability of the connection and reduces latency tremendously. It also increases the total throughput of a connection. We're already seeing the real-world benefits of MIMO on WiFi N routers and network adapters. MIMO is what lets 802.11n WiFi reach speeds of up to 600Mbps, though most advertise up to 300-400Mbps. There is a significant disadvantage though. MIMO works better the further apart the individual carrier antennae are. On smaller phones, the noise caused by the antennae being so close to each other will cause LTE performance to drop. WiMAX also mandates the usage of MIMO since it uses OFDMA as well. HSPA+, which uses W-CDMA (a reworked, improved wideband version of CDMA) for its air interface, can optionally use MIMO, too.

For the uplink (from device to tower), LTE uses the DFTS-OFDMA (discrete Fourier transform spread orthogonal frequency division multiple access) scheme of generating a SC-FDMA (single carrier frequency division multiple access) signal. As opposed to regular OFDMA, SC-FDMA is better for uplink because it has a better peak-to-average power ratio over OFDMA for uplink. LTE-enabled devices, in order to conserve battery life, typically don't have a strong and powerful signal going back to the tower, so a lot of the benefits of normal OFDMA would be lost with a weak signal. Despite the name, SC-FDMA is still a MIMO system. LTE uses a SC-FDMA 1×2 configuration, which means that for every one antenna on the transmitting device, there's two antennae on the base station for receiving

MULTIPLE ACCESS TECHNIQUES

The OFDM technology is based on using multiple narrow band sub-carriers spread over a wide channel bandwidth. The sub-carriers are mutually orthogonal in the frequency domain which mitigates intersymbol interference (ISI) as shown in Figure 1. Each of these sub-carriers experiences 'flat fading' as the y have a bandwidth smaller than the mobile channel coherence bandwidth. This obviates the need for complex frequency equalizers which are featured in 3G technologies.

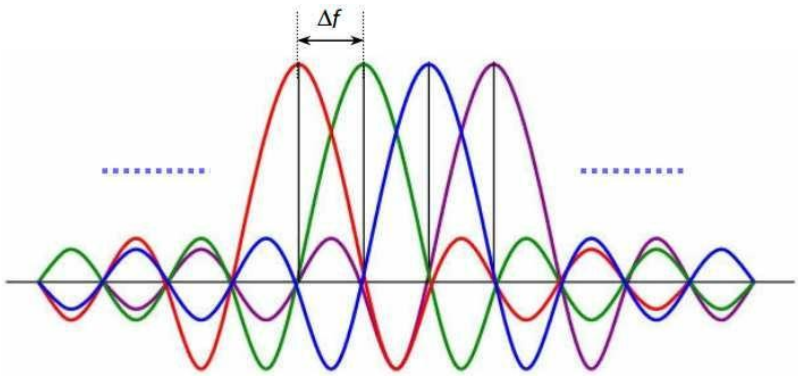

FIGURE 1 OFDM SUBCARRIER SPACING.

The information data stream is parallelized and spread across the sub-carriers for transmission. The process of modulating data symbols and combining them is equivalent to an Inverse Fourier Transform operation (IFFT). This results in an OFDM symbol of duration Tu which is termed 'useful symbol length'. In the receiver, the reverse operation is applied to the OFDM symbol to retrieve the data stream – which is equivalent to a Fast Fourier Transform operation (FFT). The mobile propagation channel is typically time dispersive: multiple replicas of a transmitted signal are received with various time delays due to multipath resulting from reflections the signal incurs along the path between the transmitter and receiver. Time dispersion is equivalent to a frequency selective channel frequency response. This leads to at least a partial loss of orthogonality between sub-carriers. The result is intersymbol interference not only within a sub-carrier, but also between sub-carriers. To prevent an overlapping of symbols and reduce intersymbol interference, a guard interval Tg is added at the beginning of the OFDM symbol. The guard time interval, or cyclic prefix (CP) is a duplication of a fraction of the symbol end. The total symbol length becomes Ts = Tu + Tg. This makes the OFDM symbol insensitive to time dispersion.

There are many advantages to using OFDM in a mobile access system, namely:

1- Long symbol time and guard interval increases robustness to multipath and limits intersymbol interference.

2- Eliminates the need for intra-cell interference cancellation.

3- Allows flexible utilization of frequency spectrum.

4- Increases spectral efficiency due to orthogonality between sub-carriers.

5- Allows optimization of data rates for all users in a cell by transmitting on the best (i.e. non-faded) subcarriers for each user.

This last feature is the fundamental aspect of OFDMA: the use of OFDM technology to multiplex traffic by allocating specific patterns of sub-carriers in the time-frequency space to different users. In addition to data traffic, control channels and reference symbols can be interspersed. Control channels carry information on the network and cell while reference symbols assist in determining the propagation channel response. The downlink physical layer of LTE is based on OFDMA. However, despite its many advantages, OFDMA has certain drawbacks such as high sensitivity to frequency offset (resulting from instability of electronics and Doppler spread due to mobility) and high peak-to-average power ratio (PAPR). PAPR occurs due to random constructive addition of sub-carriers and results in spectral spreading of the signal leading to adjacent channel interference. It is a problem that can be overcome with high compression point power amplifiers and amplifier linearization techniques. While these methods can be used on the base station, they become expensive on the User Equipment (UE). Hence, LTE uses Single Carrier FDMA (SC-FDMA) with cyclic prefix on the uplink which reduces PAPR as there is only a single carrier as opposed to N carriers. Figure 2 illustrates the concepts of OFDMA and SC-FDMA.

For practicality, SC-OFDMA is implemented in LTE using a Discrete Fourier Transform Spread OFDM transmission (DFTS-OFDM) which is commonly referred to as a frequency-domain generalization of SC-FDMA. The DFT is used to multiplex uplink transmissions in specific frequency allocation blocks within the overall system bandwidth according to eNodeB scheduler instructions. The bandwidth of the single carrier is determined based on the required data rate by the user. Data remains serial and not parallelized as done on the downlink with OFDMA (i.e. one information bit is being transmitted at a time). This leads to similar link performance parameters for the uplink and downlink. However, there would be relatively high intersymbol interference for the uplink due to the single carrier modulation. This requires a low-complexity block equalizer at the eNodeB receiver to correct for the distorting effects of the radio channel. SC-FDMA is not as sensitive to frequency instability and Doppler Effect as OFDM because of its single carrier nature.

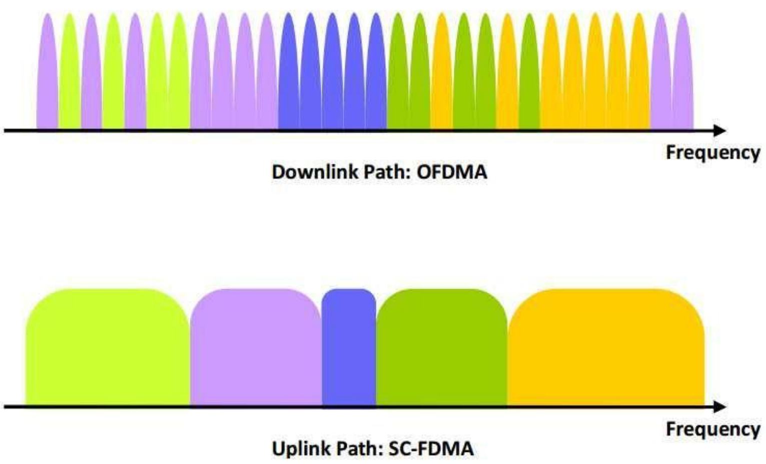

FIGURE 2 FREQUENCY DOMAIN REPRESENTATION OF DOWNLINK AND UPLINK LTE ACCESS TECHNOLOGIES.

Chapter 3

Introduction to HetNets

Introduction To HetNets

Traffic demand in Cellular networks today is increasing at an exponential rate . As the link efficiency is approaching its fundamental limits , further improvements in system spectral efficiency are only possible by increasing the node deployment density . In a relatively sparse deployment of macro base stations , adding another base station does not severely increase intercell interference , and solid cell splitting gains are easy to achieve . However , in already dense deployment today , cell splitting gains are significantly reduced due to already severe intercell interference . Moreover, site acquisition costs in a capacity limited dense urban area can get prohibitively expensive .

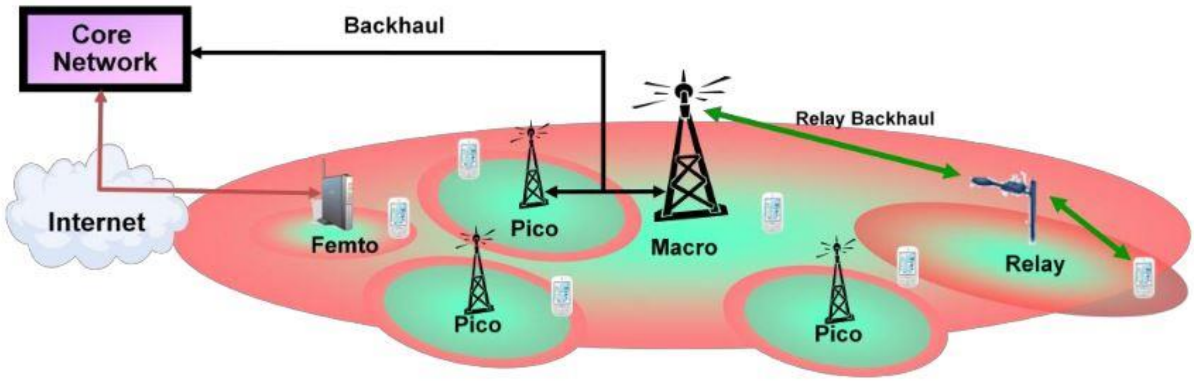

Fig 3.1 Typical Heterogeneous network

Challenges associated with the deployment of traditional macro base stations can be overcome by the utilization of base stations with lower transmit power . We classify Power nodes as Pico, femto and relay nodes . If the low Power nodes are intender for outdoor deployments , their transmit power ranges from 250 mW to approximately 2 W . They do not require an air-conditioning unit for the power amplifier , and are much lower in cost than traditional macro base stations , which transmit power typically varies between 5 and 40 W . Femto base stations are meant for indoor use , and their transmit power is typically 100 mW or less . Unlike Pico, femto base stations maybe configured with a restricted association , allowing access only to its closed subscriber group members . Such femto base stations are commonly referred to as closed femtos . A network that consists of a mix of macrocells and low-power nodes , where some maybe configured with restricted access and some may lack wired backhaul , is referred to as a heterogeneous network .

Homogeneous and Heterogeneous network

Initial deployments of LTE networks are based on so-called homogeneous networks consisting of base stations providing basic coverage (called macro base stations). The concept of heterogeneous networks has recently attracted considerable attention to optimize performance particularly for unequal user or traffic distribution. Here,the layer of planned high-power macro eNBs is overlaid with layers of lower-power eNBs that are deployed in a less well planned or even entirely uncoordinated manner. Such deployments can achieve significantly improved overall capacity and cell-edge performance and are often seen as the second phase in LTE network deployment .

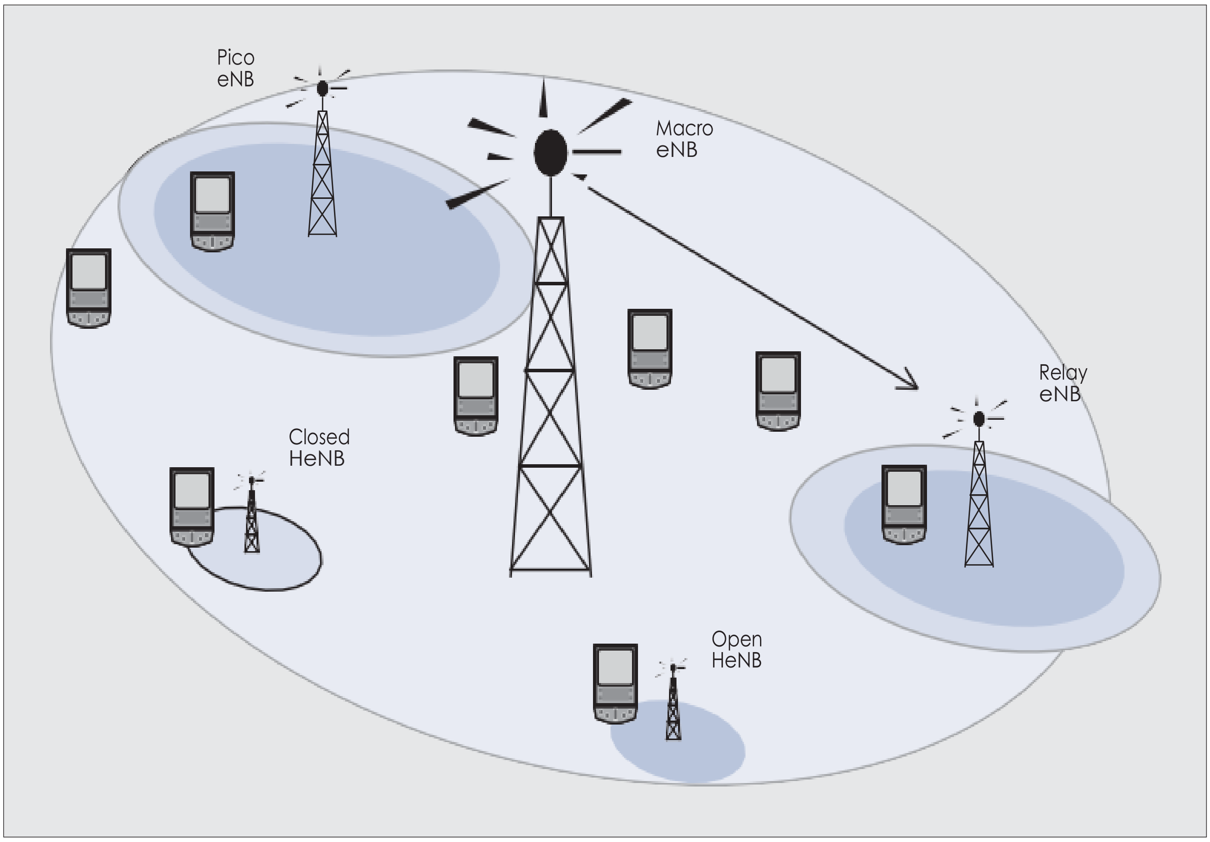

Fig 3.2 Different cells in HetNets

In homogeneous networks the User Equipment (UE) normally access to the cell with the strongest received Down Link signal (SSDL), hence the border between two cells is located at the point where (SSDL) is the same in both cells, this also typically coincides with the point of equal Path Loss for the Up Link (PLUL) in both cells. But in a heterogeneous network with high-power nodes in the large cells and low-power nodes in the small cells, the point of equal strongest received Down Link signal (SSDL) will not necessarily be the same as that of equal Path Loss for the Up Link (PLUL); which called the imbalance area.

Different cells in HetNets :

Pico Cell : Picocells are regular eNBs with the only difference of having lower transmit power than traditional macro cells. They are, typically, equipped with omni-directional antennas, i.e., not sectorized, and are deployed indoors or outdoors often in a planned (hot-spot) manner. Their transmit power ranges from 250 mW to approximately 2 W for outdoor deployments, while it is typically 100 mW or less for indoor deployments. Since picocells are regular eNBs from the architecture perspective , they can benefit from X2-based intercell interference coordination (ICIC).

Table 3.1 Types of cell used in HetNets

Types of Nodes	Transmit Power	Coverage
Macro	46 dBm	Few km
Pico	23-30 dBm	<300 m
Femto	<23 dBm	<50 m
Relay	30 dBm	300 m
RRH	46 dBm	Few km

Femto Cells : Femtocells or HeNBs are typically consumer deployed (unplanned) network nodes for indoor application with a network backhaul facilitated by the consumer's home digital subscriber line (DSL) or cable modem. Femtocells are typically equipped with omnidirectional antennas, and their transmit power is 100 mW or less. Depending on whether the femto cells allow access and hence usage of the consumer's home DSL or cable modem to all terminals, or to a restricted set of terminals only, femto cells are classified as open or closed. Closed femtos restrict the access to a closed subscriber group (CSG), while open femtos are similar to picocells but with the network backhaul provided by the home DSL or cable modem. A femtocell can also be hybrid, whereby all terminals can access but with lower priority for the terminals that do not belong to the femto's subscriber group. Since closed femtos do not allow access to all terminals, they become a source of interference to those terminals. Co-channel deployments of closed femtos therefore cause coverage holes and hence outage of a size proportional to the transmit power of the femtocell

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 L TE Release 9 (R9).

Deployment Scenarios and technical challenges:

A Pico base station has a comparably low transmit power, e.g. 1 W compared to 40 W of a macro base station. Additionally, Pico antennas have a lower gain compared to macro antennas and they are mounted lower than macro antennas which results in a higher path loss. Due to these reasons the footprint of a Pico cell is much smaller compared to the footprint of a macro cell. However, in most cases the same amount of bandwidth is used for Pico and Macro cells yielding an inhomogeneous distribution of network capacity: A low number of Pico users share the same amount of resources as the high number of macro users leading to unfairness with respect to the resources available for Macro and Pico users. Also, Macro UEs at the edge of Pico cell will cause serious uplink interference to Pico due to its high transmit power according to long distance from Macro cell.

Heterogeneous networks are networks deployed with a mix of traditional (high-power) macro and (low-power) pico, femto, and/or relay nodes. In addition to possibly having a mix of open and closed subscriber access, this type of networks is characterized by large disparities in the transmit power used by different types of network nodes. Such power disparities, in general, put the low power nodes (pico, femto, and relay) at a disadvantage relative to the high-power nodes (macrocells). In addition, the deployment of CSG cells poses the challenge of how to share physical resources (time/frequency) with the macrocell to avoid creating coverage holes in the macro network.

- **Intercell interference :** The backhaul network supporting different types of cells may have different bandwidth and delay constraints. E.g., femtocells are unlikely to be connected directly to the core network and thus only limited backhaul signalling for interference coordination is possible. The ICIC methods specified in Rel. 8 and Rel. 9 do not specifically consider HetNet settings and may not be effective for dominant HetNet interference scenarios (Fig. 1). In order to address such dominant interference scenarios, ***enhanced Inter-Cell Interference Coordination (eICIC)*** techniques were developed for Rel. 10, which can be grouped under three major categories according to:

–Time-domain techniques.

–Frequency-domain techniques.

–Power control techniques

Load balancing : To meet surging traffic demands, cellular networks are trending strongly towards increasing heterogeneity, especially through proliferation of small BSs, e.g., picocells and femtocells, which differ primarily in terms of maximum transmit power, physical size, ease-of-deployment and cost . Heterogeneous networks (HetNets) enable a more flexible, targeted and economical deployment of new infrastructure versus tower-mounted macro-only systems, which are very expensive to deploy and maintain . Even with a targeted deployment where these small BSs are placed in high-traffic zones, most users will still receive the strongest downlink signal from the tower-mounted macrocell BS. In order to make the most of the new low-power infrastructure, mobile users should be actively "pushed" onto the small BSs, which will often be lightly loaded and so can provide a higher rate over time by offering the mobile many more resource blocks than the macrocell. Similarly, a more balanced user association reduces the load on the macrocell, allowing it to better serve its remaining users , which ultimately leads to a process named CRE (cell range extension) in which the area served by the small cell is increased , which can be done through the use of a positive cell selection offset to the SSDL of the small cell

Chapter 4

Cell Range Extension (CRE)

CELL RANGE EXTENSION (CRE)

CRE and CSO

Cell range extension (CRE) has been used as a method to extend the coverage of small cells and help offload macro cell users to small cells by adding a cell specific offset (CSO) to small cells in heterogeneous network deployment. To increase the utilization of small cells generated by LPNs, cell range extension (CRE) is used to extend the coverage of the small cells by adding cell specific offset (CSO) to small cells during cell selection procedure To meet the exponentially increasing demand of mobile network traffic, heterogeneous network has been studied and proposed .
A heterogeneous network contains multiple of scenarios, one typical scenario is that the coverage area of macro cells and SCN , which usually consist of general class of Low Power Nodes (LPN), are overlapped. Previous researches have been focusing on this scenario where small cells have been deployed sparsely within the coverage of the macro cell . In this scenario, we often consider a case where the macro cells and SCNs are sharing the same spectrum and the interference between them is a very essential issue with cell range extension (CRE) . CRE is a technology which expands the coverage area of SCNs by adding a CSO to SCNs. This bias value should be properly set considering the trade-off problem between the SCN offloading ratio and the user experienced interference in SCNs. In previous literatures, some fixed CSO values were proposed in 3GPP based on system-level simulations. To further optimize the overall performance, several other papers have proposed some adaptive methods to alter the CSO value dynamically.

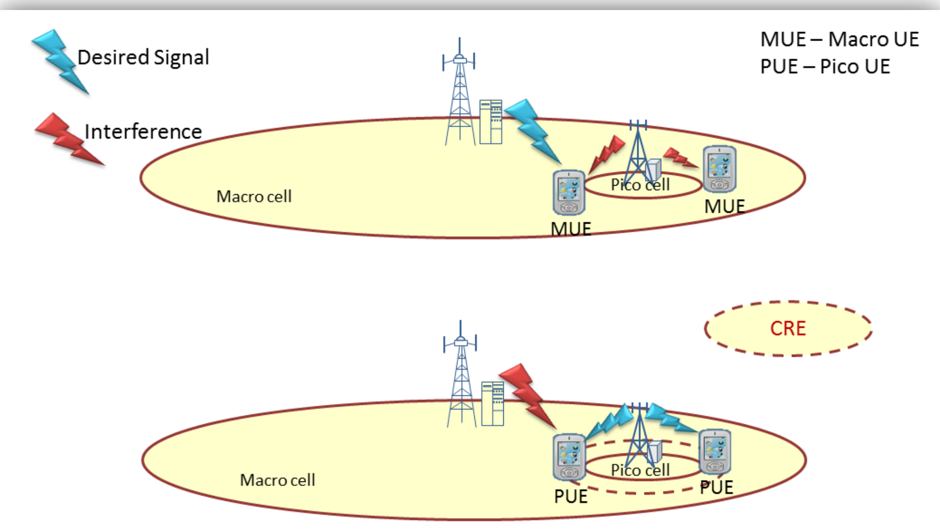

Fig 4.1 Cell Range Extension

CRE enables UEs to increase the probability of connecting to a pico-eNB. Accordingly, if the traffic demands are increased within a macro cell served by eNB, CRE makes it possible to offload the overload traffic to the pico-eNB. The method used to set the CSO depends on the difference in the transmitting power of the donor eNB and the pico-eNB .

The larger the CSO value, the more UEs will get access to small cells . Relatively large CSO value may help elevate average user throughput. A positive CSO used by a pico eNodeB signifies that a UE will select it even though the macro eNodeB RSRP is higher.

Cell Selection and Biasing :

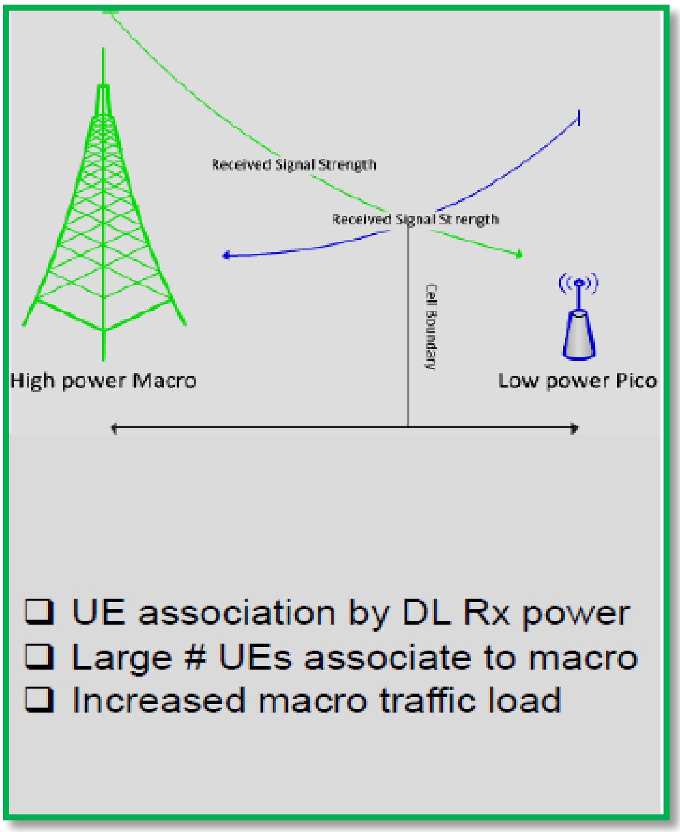

Fig 4.2 Cell boundary

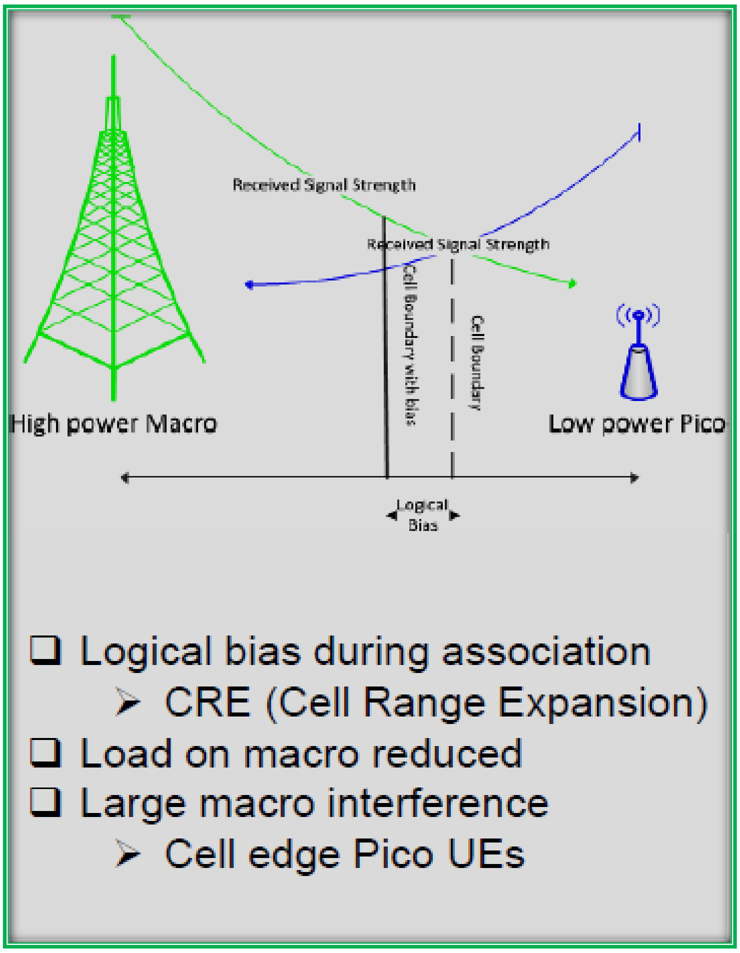

Fig 4.3 Cell biasing

The UE will be connected to the greater RSRP signal The intersection point at which both the power signals will be equal is called the cell boundary , After applying CRE the intersection point moves towards the macro cell ; hence the range of pico cell is increased .

Problems of Static CSO:

The larger the CSO value, the more UEs will get access to small cells relatively large CSO value may help elevate average user throughput. But if the CSO value would exceed certain level, it might not be an optimal choice, on the contrary, it might lower the average user throughput. However, from a total system perspective, it is not clear whether or not a fixed CSO should be provided for all UEs   within the donor eNB. In dense small cell network, since the traffic load of small cells may be much lighter than macro cells, it is advisable for UEs to camp in small cells rather than macro cells. Under most circumstances, small cells should choose a relatively high CSO value, thus more UEs would transfer from macro cells to small cells. However, simply elevating CSO is not reasonable. If CSO had already been increased to a certain level, the traffic load of macro cells might not be that heavy and there was no need of further increasing CSO; on the contrary, the traffic load of some small cells within their coverage might already become a bit heavier. Besides that, CRE users will receive more interference, resulting in a smaller signal to interference plus noise ratio (SINR) which may also decrease users' throughput.

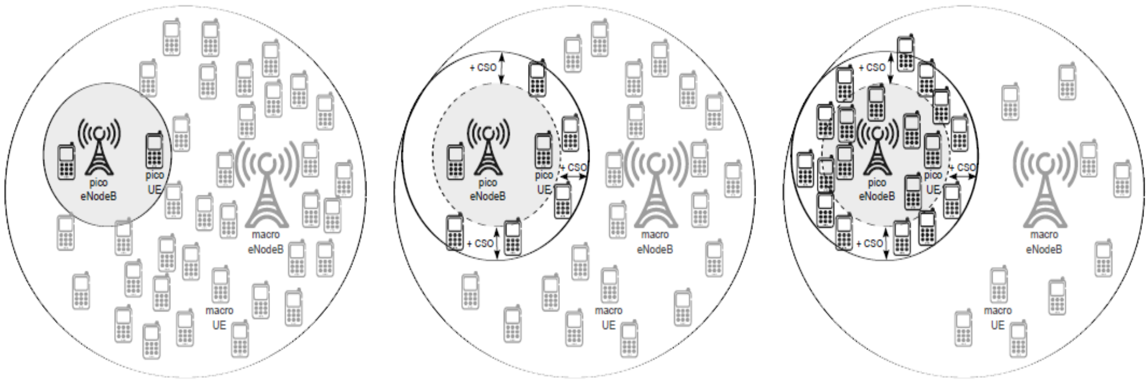

Fig 4.4 – Effect of Different CSO values on network

So if the CSO value would exceed certain level, it might not be an optimal choice, on the contrary, it might lower the average user throughput. Therefore, we propose an adaptive control CRE with a non-fixed CSO for all UEs within the donor eNB that can increase cell edge user throughput while maintaining the average user throughput . The CSO value is based on proportional fair resource scheduling .

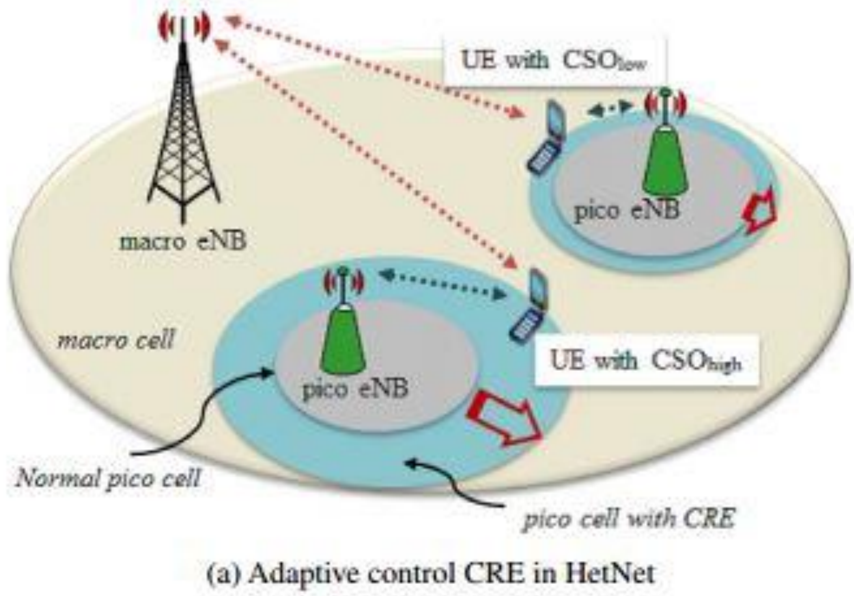

Fig 4.5 Adaptive CRE

This adaptive(dynamic) CSO value is selected based on the user distribution at a particular time between the cells .

Chapter 5

Proportional Fair

Different Schedulers:

- Proportional Fair (PF)
- Maximum Rate (Maximum Throughput)
- Round Robin (RR)
- Joint Time and Frequency domain schedulers
- Throughput to Average (TTA)
- Buffer-aware schedulers
- Modified Largest Weighted Delay First (MLWDF)
- Exponential Proportional Fair (EXP-PF)
- EXP-LOG Rule
- Frame Level Scheduler (FLS)

Proportional Fair:

Proportional fair is a compromise-based scheduling algorithm. It is a resource scheduling technique where the probability of a user to attain a resource block is inversely proportional to its distance from the base station. This method is superior to others in the consideration of portraying real life or practical scenario with precision. Here also the data rates of a UE has dependence on its past average data rate. So if a user enjoys higher data rate in one slot, it's probability to have higher allocation in the next slot decreases.

It is based upon maintaining a balance between two competing interests: Trying to maximize total [wired/wireless network] throughput while at the same time allowing all users at least a minimal level of service. This is done by assigning each data flow a data rate or a scheduling priority (depending on the implementation) that is inversely proportional to its anticipated resource consumption.

proportional fair scheduling (PFS) algorithm is considered an attractive bandwidth allocation criterion in wireless networks for supporting high resource utilization while maintaining good fairness among network flows. The most challenge of a PFS problem is the lack of analytic expression.
PF algorithm as a basic scheduling principle and apply the PF algorithm directly over each RB one-by-one independently

Comparison Between Proportional Fair And Round Robin:

Round robin resource scheduling allocates RBs to users regardless of their distance from the base station where as proportional fair employs a system where allocation decreases with distance.

Chapter 6

System Model and Problem Formulation

System Model and Problem Formulation

We consider LTE HetNets scenario a small cell is overlaid with a macro cell. For the purpose of formulation, we first derive resource allocation quantities, which can equally apply to any type of cell. LTE uses resource block (RB) as the basic unit for allocation of resources to the UE. Each RB consists of 12 adjacent subcarriers and six or seven symbols. A pair of RBs taking up one TTI is referred to as a scheduling block (SB) in this paper. We assume that both RBs in a SB are mapped onto the same frequencies.

The active users in the cell are identified as **K** ={1,2,…, *k*,.., K} where K is the total number of active users with data ready for transfer. For simplicity, it is assumed that a user can establish only one logical channel mapped to an EPS bearer. The possible MCS levels are **J** = {1,2, …, *j*,.. , J} where J is the total number of MCS supported and J is 29 for both downlink and uplink in LTE specifications. The SBs available in a TTI are identified as **N** ={1,2,…,*i*,…….., N} where N is the total number of SBs and it depends on the available bandwidth in the cell. For simplicity, the reduction in data rate due to packet losses and retransmissions is ignored, which in practice, depends on the SINR of the individual SBs. Thus, the estimated data rate corresponding to a SB for user *k* who can potentially use MCS *j* is given by

$$r_{j,k} = C_{j,k} log_2\left(M_{j,k}\right) \frac{S_{sb}-ND_{sb}}{T_s N_{sb}} \quad (1)$$

Here, $C_{j,k}$ is the code rate and $M_{j,k}$ is the modulation for MCS *j* used by the user *k* in a TTI. S_{sb} is the total number of resource elements in a SB. ND_{sb} is the number of resource elements used in a SB for purposes other than data. T_s is the symbol period and N_{sb} is the number of symbols in a subframe. $T_s N_{sb}$ is always 1 ms, which is the length of a subframe.

$b_{j,k}$ is set to 1 to indicate that MCS *j* is used for user *k* where $b_{j,k} \epsilon \{0,1\}$. Since all SBs allocated to a user must use the same MCS,

$$\sum_{j=1}^{J} b_{j,k} = 1 \quad \forall\, k \quad (2)$$

$\rho_{i,k}$ is set to 1 to indicate that i^{th} SB is allocated to user k where $\rho_{i,k} \epsilon \{0,1\}$. Since a SB can be allocated to only one user,

$$\sum_{k=1}^{K} \rho_{i,k} = 1 \quad \forall\, i \quad (3)$$

The overall data rate for user *k* is given by

$$R_k = \sum_{i=1}^{N} \rho_{i,k} \sum_{j=1}^{J} b_{j,k}\, r_{j,k} \quad (4)$$

Assuming that the user *k* is allocated ψ_k number of SBs

$$\sum_{i=1}^{N} \rho_{i,k} = \psi_k \quad (5)$$

The estimated data rate for user *k* is given by

$$R_k = \psi_k \sum_{j=1}^{J} b_{j,k}\, r_{j,k} \quad (6)$$

ψ_k is determined using a resource allocation algorithm. One of the very popular resource allocation methods is the proportional fair (PF) scheduling, which provides pretty high cell throughput while maintaining fairness among users to some good extent. The PF scheduler uses a PF metric for each user in the apportionment of the SBs among users. The PF metric for user *k* at *t* numbered TTI is computed by

$$PF_k(t) = \frac{R_k(t)}{\overline{R_k}(t)} \tag{7}$$

where $R_k(t)$ is calculated for *t* numbered TTI from previous estimated data rate using (6) and $\overline{R_k}(t)$ is calculated from previous actual data rates given by

$$\overline{R_k}(t) = \left(1 - \frac{1}{T_{PF}}\right)\overline{R_k}(t-1) + \frac{1}{T_{PF}} R_k(t-1) \tag{8}$$

where T_{PF} is the window size of the average throughput.
There are a few different ways to determine ψ_k using the PF metric. We suggest that the number of SBs to be allocated to different users increases proportionately with his PF metric, as indicated by

$$PF_1 : PF_2 : \ldots : PF_k : \ldots : PF_K = \psi_1 : \psi_2 \ldots : \psi_k \ldots : \psi_K \tag{9}$$

$\psi_k(t)$ can be computed as

$$\psi_k(t) = \left\lfloor \frac{PF_k(t)}{\sum_{k=1}^{K} PF_k(t)} \right\rfloor \tag{10}$$

Once the computed $\psi_k(t)$ is used as the number of SBs allocated to user *k*, his estimated data rate given by (7) can be close to his actual data rate and so, we ignore their differences. Thus, the average user throughput is given by

$$R_{Ave} = \frac{1}{K}\sum_{k=1}^{K} R_k = \frac{1}{K}\sum_{k=1}^{K} \psi_k \sum_{j=1}^{J} b_{j,k}\ r_{j,k} \tag{11}$$

The average user throughput can be determined for both macro cells and small cells according to (11) and they are denoted as R_{Ave}^m and R_{Ave}^s, respectively. We define even load distribution as

$$R_{Ave}^m = R_{Ave}^s \tag{12}$$

We assume that the total number of current active users in the macro cell and the small cell, K_T has a fixed value. Representing the number of active users in the macro cell and in the small cell as K_m and K_s, respectively,

$$K_T = K_m + K_s \tag{13}$$

The active users in the small cell are identified as $\mathbf{K_s}$ ={1,2,...., K_s}. So, the number of the active users in the macro cell is $K_T - K_s$. For even load distribution between the macro cell and the small cell, a proper value needs to be set for K_s and it can be determined as

$$K_s^* = \underset{K_s \in \mathbb{Z}}{arg\,min}\, R_{Ave}^m - R_{Ave}^s \tag{14}$$

The UE is served by the cell from which the downlink received power, represented as reference signal received power (RSRP), becomes the maximum. So, The UE is served by *j* cell, which meets the condition shown as

$$. \quad \underset{j}{arg\,max}\, P_j G_j^k + CSO_j$$

where P_j and CSO_j are the transmit power and the CSO of *j* cell, and G_j^k represents the channel gain of user k from *j* cell. The channel gain is dominantly affected by Rayleigh fading H, log-normal shadowing X_α, and path losses PL_k. So, the channel gain of a user *k* can be shown as follows [16]:

$$G_j^k = 10^{(-PL_k + X_\alpha)/10} . |H_k|^2. \tag{15}$$

Path loss is calculated according to two formulas, shown in Table 2 [xx].

$$P_s G_s^k + CSO_s \; > P_m G_m^k + CSO_m \tag{16}$$

We assume that

$$CSO_m = 0 \tag{17}$$

$$CSO_s > P_m^k \, G_m^k - P_s G_s^k \Leftrightarrow k \in \boldsymbol{K_s} \tag{18}$$

A proper value of CSO_s needs to be set using (18), such that $K_s = K_s^*$ where K_s^* is given by (14). The joint optimization problem based on (14) and (18) is NP-hard. It cannot be solved by first determining K_s^* using (14) and determining CSO_s using (18). This is because G_j^k is different for different users and there is no priori information on which users may switch from the macro cell to the small cell with certain increase in CSO_s. Therefore, we propose an iterative procedure to reach a sub-optimal solution for CSO_s.

In practice, multiple small cells can be overlaid with the macro cell. In this case, the above analysis can be considered separately between each of the small cells and the macro cell. Similarly, each of the small cells can also employ the proposed method on a stand-alone basis.

Chapter 7

Proposed Scheme

Proposed Scheme

In this chapter a lucrative technique to overcome the problem in adding static cell selection offset (CSO) to the RSRP of small cell in LTE HetNets is presented via implementation of Adaptive CSO by means of proportional fair resource allocation.

We propose a self-updating CSO settings which adapts to the user distribution and radio-link quality in quick intervals. The CSO is changed in such a manner that the loads among the small and large cell are balanced. For to achieve that the system will opt for a CSO for which the average data rates of the two cells will be equal.

The users are allocated resources based on proportional fair resource allocation in which the probability of a user to obtain a resource block is inversely proportional to its distance from the eNodeB. That means the more closer the user is from the eNodeB, the more resources it gets, so higher data rates. The implementation of proportional fare in the computation of the CSO makes our proposal more practical and realistic.

According to the proposed scheme, the system will repetitively check for the present user distribution and update the CSO. After quick intervals, it will assess the conditions and then it will start iteration from CSO value 1 to 40 and for each CSO it will calculate macro and small cell user numbers (K_m & $K_{s)}$ and come up with a average data rate for both macro and small cell. The CSO which will lead the average data rates to be equal for both the cells will be selected for that time

$$R_{Ave}^{m} = R_{Ave}^{s}$$

. This process will occur in short intervals to keep the CSO updated to ensure that the loads among the cells are balanced and the

Algorithm 1: CSO Selection Algorithm

1. Start
2. Let **R_M** be the average data rate of macro cell, **R_S** be the average data rate of small cell and ***R*** be the difference of average data rates of macro and small cell.

3. **for** CSO = 1 to 50 do
4. R(CSO) = R_S - R_M
5. **if**
6. R(CSO)=min(R)
7. Selected CSO=CSO
8. **end if**
9. **end for**
10. Stop

This algorithm will constantly run at short intervals to check the average data rates of the two cells and compare them for each CSO and find out the CSO for maximum average data rate and update it instantly after those 10 steps.

Chapter 8
Simulations

SIMULATIONS:

In this chapter the system level simulation of the proposed scheme is shown in a precise way. The proposed scheme was simulated using the parameters shown at table 2.1. The Simulations were performed considering the effects of environment on the propagation of wave with implementation of Rayleigh Fading in the computation of data rates. Rayleigh Fading enables to simulate with highly built urban conditions. The users are also distributed in random distances from the base stations in order to add perfect real life feel to the simulations.

Table 8.1: Simulation Assumptions

Parameter	Macrocell	Smallcell
Transmit Power	43 dBm	30 dBm
No. Of Cell	1	1
Channel Bandwidth	10 MHz	
No. of RBs	100	
Macro Cell Radius	10km	
Distance From Macro To small Cell	8km	
Fading Profile	Rayleigh Fading	
path loss (d in km)	macro cell: PL = 128.1 + 37.6 log10(d) small cell: PL = 140.7 + 36.7 log10(d)	

In figure 8.1 the variation of mean proportional fair of a user with distance is shown. It shows that when a user goes away from the eNodeB the proportional fair value decreases. Again in figure 8.2 it is eminent that data rates decrease as the user goes away from the eNodeB.

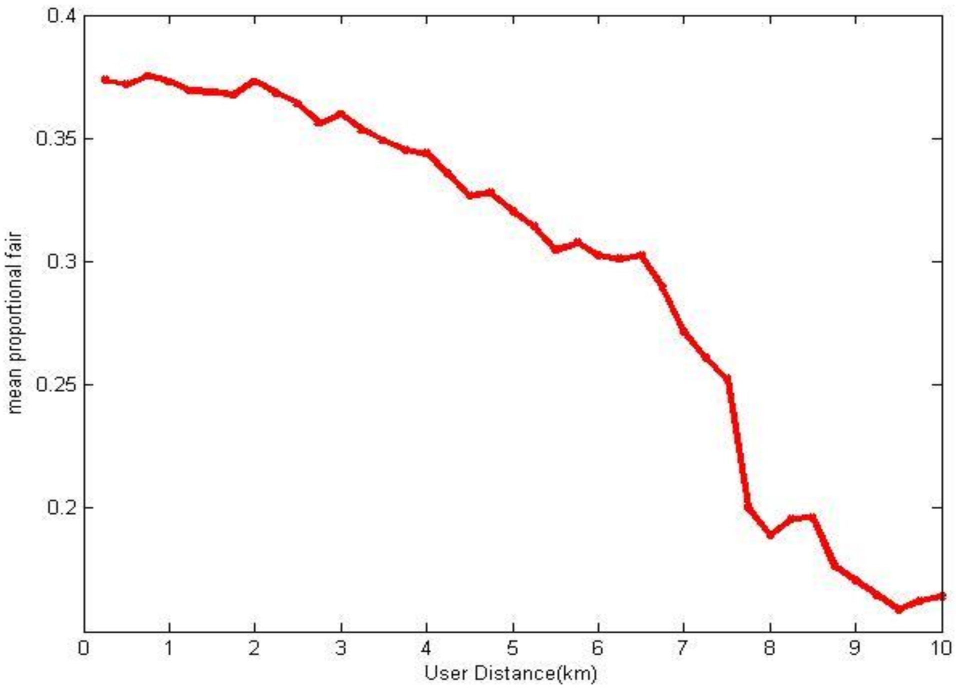

Figure 8.1: Mean Proportional Fair vs. User Distance

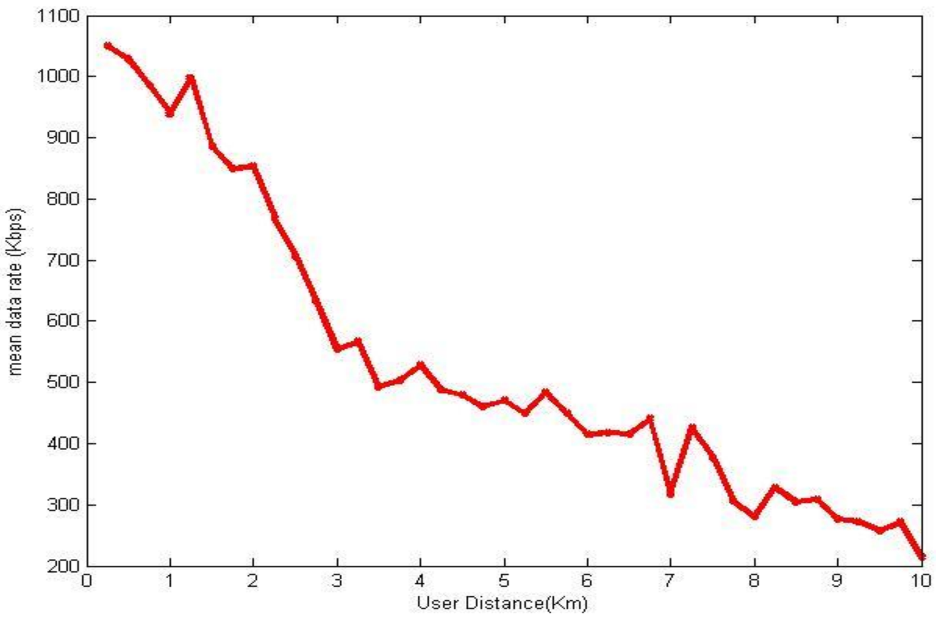

Figure 8.2: Mean Data Rate vs. User Distance

The main purpose of the scheme is to find a CSO for which the loads are balanced which is found from Figure 8.3. where the change in difference between avg. data rates of the two cells with increasing CSO is shown. The CSO for which the difference is lowest is selected for that time interval. In Figure 8.3, this has been shown for consecutively 3 time intervals **T1,T2,T3** and from the figure the system can find their corresponding CSO.

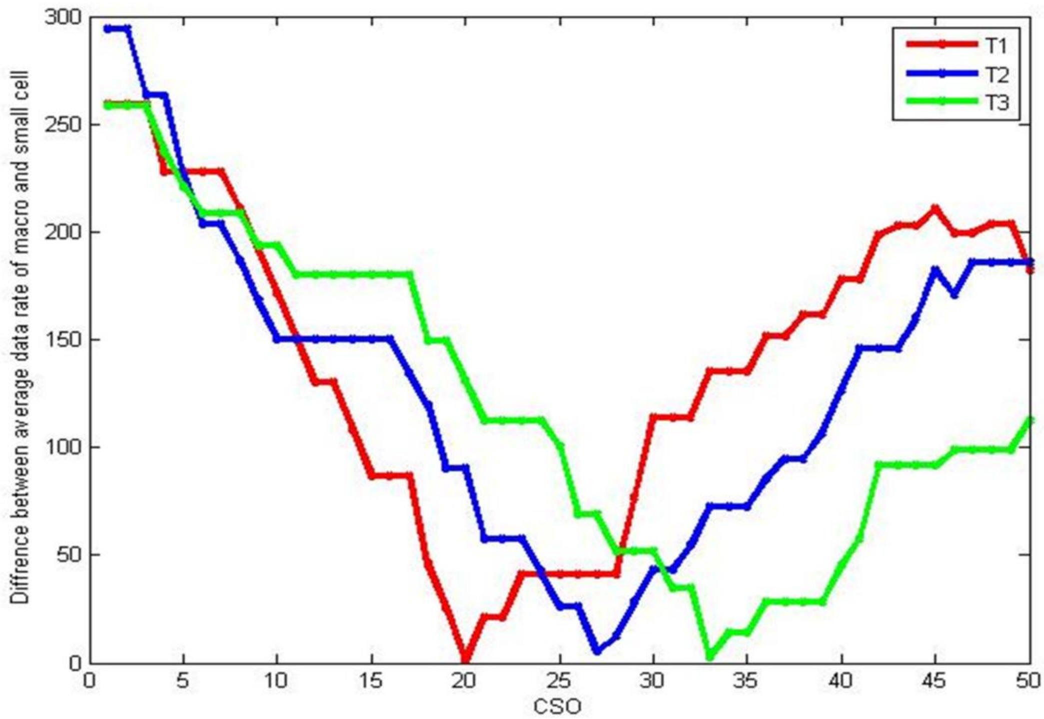

Figure 8.3: Difference of average data rates vs. CSO

Chapter 9

Conclusion

Conclusion:

CRE is an important feature in HetNets scenario to fully utilize the small cell resources.. Most of the previous works are based on round robin allocation. But here in this work we have simulated it by incorporating proportional fair resource allocation to obtain better results. However, we think that cell range extension may also play a positive role in balancing the loads. We first analyze the influences of different CSO values on average user throughput. As a result, the larger the CSO, the more UEs will transfer from macro cell to small cells. However, larger CSO value does not necessarily brings benefits to average user throughput. And we come up with a bias setting strategy to find out the optimal CSO value, thus enabling the equal average data rates for both small and large cell. The system-level simulation results indicate that our work can have tremendous effects on load balancing if it is implemented with proper functionality.

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