



**Enhanced Coordinated Multipoint Transmission based on
Parameter Selection and Scheduling Technique for LTE-
Advanced Network Optimization**

by

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LIST OF ABBREVIATIONS

3GPP	Third Generation Partnership Projects
CDMA	Code Division Multiple Access
CoMP	Coordinated multi point
CSI	Channel State Information
DRR	Discrete Round Robin
EPC	Evolved Packet Core
E-UTRAN	Evolved-Universal Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FFR	Fractional Frequency Reuse
GSM	Global System for Mobile communication
HRPD	High Rate Packet Data
ICIC	Inter-cell Interference Coordination
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
MAC	Medium Access Control layer
MAXCI	Maximum of Carrier to interference
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
NIC	Network Interface Card
OFDMA	Orthogonal Frequency Division Multiple Access
PF	Proportional Fair
PHY	Physical layer
QoS	Quality of Service
RRE	Remote Radio Equipment
SAE	System Architecture Evolution
SINR	Signal-to-Interference-and-Noise Ratio
SISO	Single Input Single Output
TDD	Time Division Duplex
UE	User Equipment
VoIP	Voice over Internet Protocol
WiMAX	Worldwide Interoperability for Microwave Access

**Transmisi Penyambungan Berbilang Penyelarasan yang Dipertingkatkan
berdasarkan Pemilihan Parameter dan Teknik Penjadualan untuk
Pengoptimuman Rangkaian Evolusi Jangka Panjang Lanjutan**

ABSTRAK

Peningkatan permintaan terhadap Internet dan penghantaran data membawa kepada evolusi kelajuan tinggi, kadar tinggi senibina sistem komunikasi mudah alih tanpa wayar yang dikategorikan sebagai generasi keempat dan melebihi teknologi generasi keempat. Senibina baru yang dinamakan Evolusi Jangka Panjang (LTE) dan Evolusi Jangka Panjang Lanjutan untuk trafik suis paket, menawarkan pengalaman perkhidmatan dan pengalaman pengguna yang hebat, serta memberikan perkhidmatan di atas protokol Internet. Untuk penggunaan LTE yang cekap, peruntukan sumber adalah parameter penting untuk memastikan pengguna mendapat kepuasan dengan perkhidmatan yang diberikan oleh rangkaian. Pelbagai strategi peruntukan sumber boleh digunakan untuk meningkatkan prestasi rangkaian. Penjadualan adalah salah satu proses untuk memperuntukkan sumber fizikal kepada peralatan pengguna menggunakan algoritma penjadualan yang efisien. Kajian ini menyiasat prestasi parameter terpilih untuk rangkaian persediaan untuk pelbagai aplikasi. Kerja penyelidikan ini menyediakan rangka kerja pengoptimuman untuk peruntukan sumber pautan bawah dalam satu sel dengan sistem berbilang pengguna kemudian dilanjutkan untuk sistem pelbagai-sel. Algoritma yang dibangunkan, dikenali sebagai Algoritma Pengoptimuman Iteratif (IOpA) menggunakan teknik pengoptimuman berasaskan "array ortogonal" untuk meningkatkan pilihan parameter untuk prestasi rangkaian. Rangka kerja ini digunakan untuk simulator berasaskan OMNeT sebagai alat simulasi. Kriteria prestasi yang diukur adalah berdasarkan kepada celusan, lengahan dan kualiti pengalaman untuk aplikasi trafik suara IP (VoIP). Pelbagai algoritma penjadualan yang dikenal pasti dalam rangka kerja yang merupakan Skema Maksimum Pengangkut untuk Interferensi (MaxCI), skema Diskrit Disiplin Robin (DRR) dan skema Berkadar Adil (PF). Tetapan reka bentuk yang optimum mencadangkan gabungan terbaik pada "Bilangan Pengguna", skim penjadualan, jalur lebar dan kedudukan pengguna yang diperlukan untuk menyediakan rangkaian. Konsistensi prestasi diperolehi dengan membuat skim penjadualan tidak mempengaruhi pengaruh faktor yang tidak terkawal seperti kelajuan mobiliti pengguna dan saiz paket data. Indeks nilai skor tertinggi dan indeks skor pendapat diperolehi dari skema MaxCI dan juga memberikan nilai terendah lengahan kerangka dan variasi lengahan paket dalam senario rangkaian yang dinilai. Penilaian lanjut mengenai skim penjadualan diperluaskan kepada persekitaran pelbagai-sel. Mekanisme baru mengenai penjadualan terkoordinasi telah diperkenalkan untuk sistem pelbagai-sel. Algoritma penjadualan yang diselaraskan telah meningkatkan kira-kira 30.8% untuk parameter indeks skor pendapat purata VoIP, 88.9% untuk variasi lengahan paket VoIP, 89.7% untuk variasi lengahan bingkai VoIP dan 26.8% untuk celusan yang diterima VoIP. Mengguna pakai penghantaran berbilang diselaraskan, algoritma penjadualan yang diselaraskan telah dilaksanakan dengan baik berbanding skema MaxCI, yang lebih munasabah dalam sistem sel tunggal.

Enhanced Coordinated Multipoint Transmission based on Parameter Selection and Scheduling Technique for LTE-Advanced Network Optimization

ABSTRACT

The increase demand on Internet and data transmission leads to the evolution of high speed, high data rate of wireless mobile communication architecture which is categorized as fourth generation and beyond fourth generation technologies. The new architectures called Long Term Evolution and Long Term Evolution Advanced support for packet-switch traffic, offer great quality of service and user experience, as well as provide services on top of internet protocol. For efficient utilization of LTE characteristics, resource allocation is a significant parameter to ensure the users satisfy with the services granted by the network. Various resource allocation strategies can be adopted to increase the performance of the network. Scheduling is one of the process to allocate physical resources to the user equipment using an efficient scheduling algorithms. This research work investigates the performance of selected parameters to setup network for various application. This research work provides an optimization framework for downlink resource allocation in a single cell with multi-user system then extended for multi-cell system. The developed algorithm, which is known as Iterative Optimization Algorithm (IOPa) used orthogonal array-based optimization technique to enhance the parameter selections for network performance. The framework applied to the OMNeT-based simulator as the simulation tool. The performance criteria measured are based on throughput, delay and quality of experience for voice of IP (VoIP) traffic application. Various known scheduling algorithms are evaluated in the framework which are Maximum of Carrier to Interference (MaxCI) scheme, Discrete Round Robin (DRR) scheme and Proportional Fair (PF) scheme. The optimal design setting suggests the best combination on “Number of User”, scheduling scheme, bandwidth and user’s position required to set up the network. The consistency of performance are obtained by making scheduling schemes unaffected for the influence of the uncontrollable factors such as user mobility speed and data packet size. The highest value of throughput and mean opinion score index are obtained from MaxCI scheme and also provides the lowest value of frame delay and packet delay variation in the evaluated network scenario. Further evaluation on scheduling schemes is extended to multi-cells environment. A new mechanism on coordinated scheduling has been introduced for the multi-cells system. Coordinated scheduling algorithm has improved about 30.8% for average mean opinion score index of VoIP parameter, 88.9% for VoIP packet delay variation, 89.7% for VoIP frame delay and 26.8% for VoIP received throughput. Adopting the coordinated multipoint transmission, the coordinated scheduling algorithm is performing well as compared to MaxCI scheme, which is more reasonable in single-cell system.

CHAPTER 1 : INTRODUCTION

1.1 Background

The remarkable evolution in wireless cellular business extended to 4 billion over the past decades (Dahlman, Parkvall, & Skold, 2011). In 1981, the primary global mobile communication system, namely the Nordic Mobile Telephony (NMT) system, was broadcasted in the Nordic countries. At the same time, the analogue mobile service network with the name as Advanced Mobile Phone Service (AMPS) was introduced in North America. The first generation (1G) analogue network only sustained voice with restricted roaming. With the introduction of digital communications during 1980s, the awareness in emerging a replacement to the analog communication system appeared and delivered the basis in the direction of the advancement of the Second Generation (2G) mobile communication systems. The second generation digital network sustained better quality voice, improved capacity and extensive roaming as compared to the analogue system. Improvement in roaming part was due to few standards and mutual spectrum distribution predominantly in Europe.

Global System for Mobile communication (GSM) and IS95 standards, Second Generation (2G) technologies are two commonly used cellular systems. GSM is established based on Frequency and Time Division Multiple Access (FDMA/TDMA) whereas IS95 is based on Code Division Multiple Access (CDMA) technique. The 2G cellular networks are essentially intended for voice communication; in advanced releases they are completed for data transmission but still data rates were poorer than dial up. Both GSM and CDMA systems molded their own standards, 3G partnership projects (3GPP)

and 3GPP2 separately so that to cultivate advanced technologies constructed on CDMA technology. The International Telecommunication Union-Radio (ITU-R) project on International Mobile Telecommunication IMT-2000 flattened the approach for 3G networks, the key characteristics were higher data rates and the concept definition for vehicular movement.

In 1980s, ITU-R originated the Universal Mobile Telecommunications System (UMTS) which is raised to as the Third Generation (3G) mobile communications systems. 3G system is established on Wideband CDMA (WCDMA). The standard technology in 3GPP for 3G system is raised to WCDMA which customs of 5 MHz bandwidth while in 3GPP2, CDMA2000 technology uses 1.25 MHz bandwidth. Far along 3GPP2 also established its own standard and the frequency band was stretched to 5 MHz composed of three 1.25 MHz which is then entitled as CDMA2000-3x. To distinguish both standards, 5 MHz CDMA is called CDMA-3x and single carrier of 1.25 MHz CDMA is called CDMA-1x or 3G-1x (Dahlman et al., 2011).

The first release of these standards did not accomplish their targets and the expected data rates was lower than the applied one. After thoughtful determinations, 3GPP2 announced High Rate Packet Data (HRPD) service which practices improvement methods for data optimization such as channel sensitive scheduling, fast link adaptation and hybrid ARQ etc. Nevertheless, HRPD obligated an isolated 1.25 MHz subcarrier for data transmission only with no voice on the same carrier. Therefore, originally it was called CDMA2000-1x EVDO (evolution data only). 3GPP trailed the similar approach and enriched WCDMA; established HSPA (High Speed Packet Access) which used the identical access methods, the only modification was that the voice and data uses the same

bandwidth of 5 MHz. They are multiplexed in downlink. 3GPP2 also developed CDMA2000-1x EVDO to CDMA2000-1x EVDV which means (evolution data and voice). Both data and voice used the same subcarrier on 1.25 MHz but not ever commercially released. Later on, in HRPD Voice over IP (VoIP) was introduced to take care both voice and data on the same carrier. Both of these innovative technologies satisfied the need of high data transmission for 3G and used in major markets of world (Dahlman et al., 2011).

In the meantime, IEEE 802 LAN/MAN Standard Committee (LMSC) presented a new standard, namely IEEE 802.16e for mobile broadband wireless access which is the superior version of IEEE 802.16 for fixed wireless broadband. This standard uses new access technology which is known as Orthogonal Frequency Division Multiple Access (OFDMA) and delivers better data transmission than HSPA and HRPD technologies. The IEEE 802.16 family of standards is officially entitled as WirelessMAN in IEEE. It is also entitled as Worldwide Interoperability for Microwave Access (WiMAX) by a commerce group known as WiMAX forum. The responsibility of WiMAX forum is to check the compatibility and interoperability of WiMAX system. The WiMAX reinforced mobility just as in IEEE 802.16e standard is called mobile WiMAX. With the introduction of new standard specifically Mobile WiMAX directed both 3GPP and 3GPP2 to their specific fresher type further than 3G by employing new access technology OFDMA and comparable network architecture like Mobile WiMAX. Those past 3G in 3GPP standard is called Evolved Universal Terrestrial Radio Access (UTRA) technology. This technology in 3GPP is commonly recognized as Long Term Evolution (LTE). Whereas in 3GPP2 standard is known as Ultra Mobile Broadband (UMB) (Dahlman et al., 2011). Figure 1.1 illustrates the evolution of 3GPP, 3GPP2 and mobile WiMAX standards.

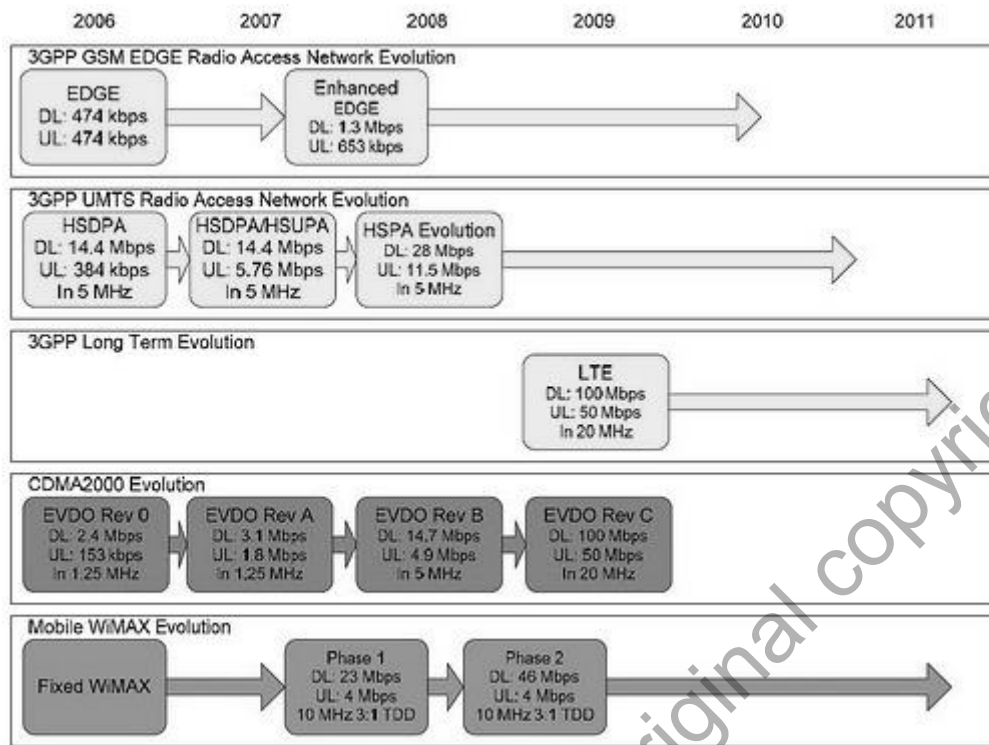


Figure 1.1 3GPP, 3GPP2 and WiMAX standards evolution (Ghadially, 2008)

1.1.1 Long Term Evolution (LTE) Technology

HSPA is handled as 3.5G or beyond 3G. LTE is considered as a pre-4G as it does not satisfy the International Telecommunication Union (ITU-R) prerequisites for transmission rate and diversity of networks. Nevertheless, commercially LTE is frequently named as 4G. LTE can function in the frequency range from 900 MHz to 2.6 GHz. LTE is expected to afford high data transmission rate, low delay and packet enhanced radio access technology with flexible bandwidth distribution. LTE supports a flexible bandwidth from 1.4 MHz to 20 MHz (Seyedbrahimi, Peng, & Harrison, 2013). 20 MHz bandwidth gives peak data rate of 326 Mbps using 4x4 Multiple Input Multiple Output (MIMO). For uplink, MIMO is not yet implemented so the uplink data rate is limited to 86 Mbps (Dahlman et al., 2011). LTE deploys Orthogonal Frequency Division Multiple Access (OFDMA) which gives high robustness and spectral efficiency counter

to multipath fading (Cardona, Monserrat, & Cabrejas, 2013). While associating to HSPA, LTE offers high spectral efficiency of two to four times. Furthermore, LTE system is proficient of providing low latency for packet transmission of 10 ms from Network to User Equipment (UE). LTE-Advanced (LTE-A) is the extended version of LTE system with more features added to provide higher spectral efficiency and to improve data rate.

Figure 1.2 shows the network architecture for LTE/LTE-A cellular system. LTE/LTE-A adopts System Architecture Evolution (SAE), which is an evolved network architecture that consists of a core network and a radio access network. The core network is known as the Evolved Packet Core (EPC), which is formed by the serving gateway (S-GW), the mobility management entity (MME) and the packet data network gateway (P-GW). The MME is responsible on user mobility, intra-LTE handover, and tracking and paging procedures of UEs upon connection establishment. The SGW is responsible to route and forward user data packets among LTE nodes and to manage handover among LTE and other technologies. The PGW interconnects LTE network with the rest of the world, provides connectivity among UEs and external packet data networks.

The radio access network, known as the Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) can host only two kinds of node: the UE and eNodeB (known as base station in previous mobile network architectures). In LTE/LTE networks, eNodeB is the only device in charge of performing both radio resource management and control procedures on the radio interface.

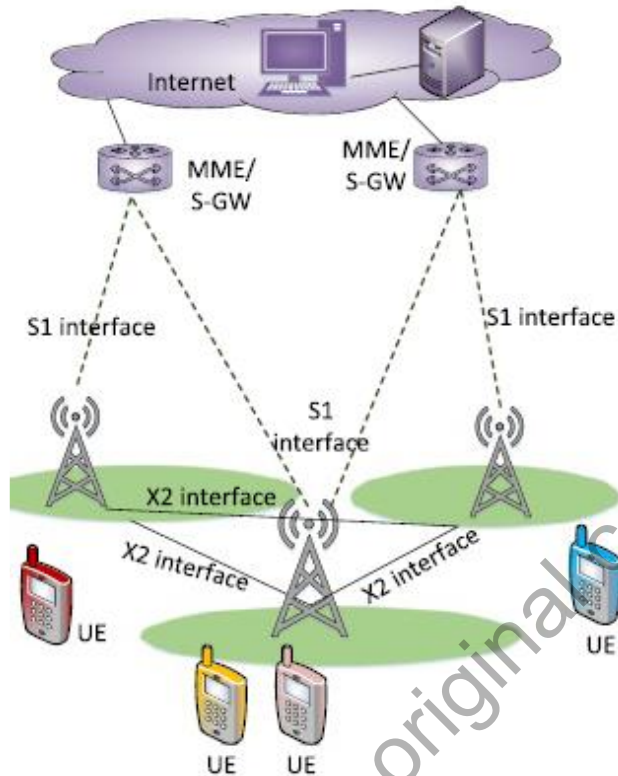


Figure 1.2 LTE network architecture which consists of a core network (gateways and mobility management) and a radio access network (Mehmood, Görg, Muehleisen, & Timm-Giel, 2015)

Table 1.1 shows several fundamental LTE specifications which include bandwidth allocations, supported antenna system and peak data rate achieved at 20 MHz. LTE system also supports Frequency Division Duplex (FDD) and Time Division Duplex (TDD) (Eluwole & Lohi, 2012).

Table 1.1 Some fundamental LTE system features

Parameters	Features
Bandwidth	1.4 – 20 MHz
Duplexing	FDD, TDD, Half-duplex FDD
Highest Mobility Speed	350 km/h
Multiple access	OFDMA (Downlink) SC-FDMA (Uplink)
Multiple antenna supported	2 x 2, 4 x 2, 4 x 4 (Downlink) 1 x 2, 1 x 4 (Uplink)
Peak data rate (at 20 MHz)	173 Mb/s with 2 x 2 MIMO (Downlink) 326 Mb/s with 4 x 4 MIMO (Downlink) 86 Mb/s with 1 x 2 MIMO (Uplink)
Modulation	QPSK, 16-QAM and 64-QAM

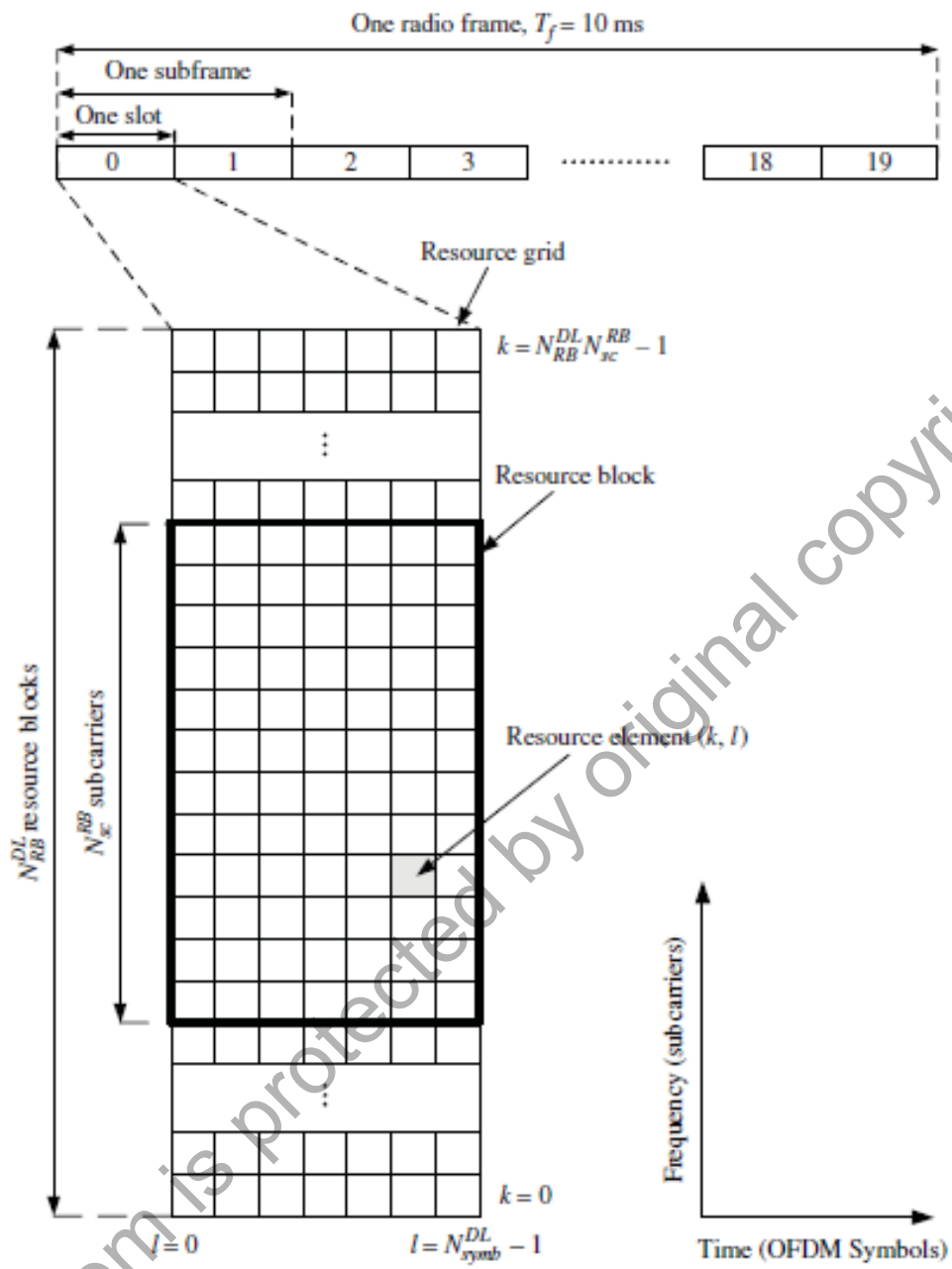


Figure 1.3 The LTE frame structure and downlink resource grid (Ghosh, Zhang, Andrews, & Muhamed, 2011)

Figure 1.3 illustrates the structure of the downlink resource grid for LTE FDD system. The channel bandwidth is allocated into small orthogonal resource blocks (RB), which is the smallest unit of radio resource to be assigned to UEs. Each RB comprises of 12 successive subcarriers and seven orthogonal frequency division multiplexing symbols

which be vested in a 180 kHz spectrum bandwidth and holds a time slot of 0.5 ms. In general, LTE is adjusted for vehicular mobility about 15 km/h but can be used up to 350 km/h with approximately acceptance to performance degradation. For its uplink it uses Single Carrier FDMA (SC-FDMA) access technique which provides better coverage for uplink with the fact of low Peak to Average Power Ratio (PAPR). For this perseverance new network architecture is deliberated with the purpose to provision packet switched traffic with continuous mobility, small latency and great quality of service (QoS).

1.1.2 LTE Issues and Challenges

One of the main concerns headed for the utilization of LTE technology is the inter-cell interference (ICI) affected by adjacent base stations (BSs) that can significantly worsen the performance of nearby mobile User Equipments (UEs). In the following illustration of Figure 1.4, as a user moves towards its cell-edge, he experiences from high inter-cell interference from neighboring cells (BS2, BS3). This occurs due to the signal reduction the user bears in long distance from its allocations BS as well as the strong nosiness by nearby cells. This problem basically demands employing operational radio resource management approaches to reduce ICI and instead transform it into functional signal by implies of coordinated processing. The significance of inter-cell interference in multi-cells has also been emphasized in recent literatures (J. Li, Chen, Botella, Svensson, & Eriksson, 2012; Y. Li, Zhang, Chen, & Peng, 2013; Afroz, Sandrasegaran, & Kim, 2015). As discussed there, interference be able to be a key dispute that worsens the whole execution in a tiered multi-level network. Consequently, stringent interference management is essential to enhance spectral efficiency all over the network.

In general, interference management and resource management can be inter-related. Both are concerning on improving the performance of the networks. There are many techniques and strategies have been formulated to manage the resources and reduce the effect of interference in the network. Scheduling is one of the way that can be used to manage the resources in the networks and handling inter-cell interference. In multi-cell scheduling, another cells channel information and factors are acquired to moderate interference. In this approach, multi-cell scheduling can be deliberated as a higher level on top of conventional inter-cell scheduling policies.

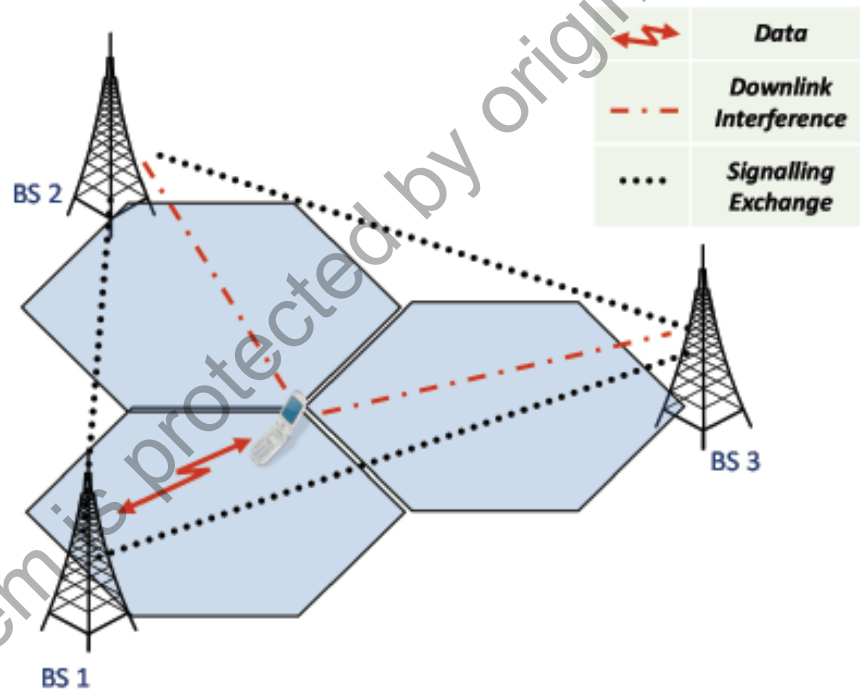


Figure 1.4 Interference in multi-cell network (Pateromichelakis, Shariat, Quddus, & Tafazolli, 2013)

Optimizing the multiple objectives of the network, which are related to Quality of Service (QoS) requirements is another challenge in enhancing the network. A set of LTE service classes with the QoS requirements has been translated to guide the standard behaviours of data transmission with distinctive application data it carries. The related

parameters are summarized in Table 1.2. Each QoS class identifier (QCI) is categorized by its resource type (Guaranteed Bit Rate, GBR or non-Guaranteed Bit Rate, non-GBR), a priority level, the maximum admitted delivery delay and the acceptable packet loss rate (Capozzi, Piro, Grieco, Boggia, & Camarda, 2013).

Table 1.2 LTE service classes with QoS requirements (Ameigeiras et al., 2016)

QCI	Resource Type	Priority	Packet Delay Budget (ms)	Packet error loss rate	Example services
1	GBR	2	100	10^{-2}	Conversational voice
2		4	150	10^{-3}	Conversational voice (live streaming)
3		3	50	10^{-3}	Real-time gaming
4		5	300	10^{-6}	Non-conversational video (buffered streaming)
5		1	100	10^{-6}	IMS signaling
6	Non-GBR	6	300	10^{-6}	Video (buffered streaming), TCP-based (e.g.: web browsing, e-mail, chat, ftp, p2p file sharing and progressive video)
7		7	100	10^{-3}	Voice, video (live streaming), interactive gaming
8		8	300	10^{-6}	Video (buffered streaming),
9		9			TCP-based (e.g.: web browsing, e-mail, chat, ftp, p2p file sharing and progressive video)

Therefore, to address the issues on inter-cell interference and QoS requirements, this thesis provides the research work on optimizing the performance of the LTE networks through iterative optimization method. Further, a new method to coordinate the resources in the multi cells network through X2 interface is discussed. Coordinated scheduling for multi-cell network is highlighted and compared with single-cell network.

1.2 Problem Statement

Telecommunication network providers are searching for cost effective infrastructure and a favourably most efficient system in order to meet the expectation of higher data rate and quality of service (QoS) especially for the users at the cell edge. The evolution of LTE to LTE-A is based on the requirements of improving the data rates (Toskala, 2012). One way to increase the data rates is by increasing the transmission power (Elhamy & Ibrahim, 2014), but this technique induces more eminent interference in the network and shortens the battery lifespan in the terminals. Another way of achieving higher data rates with minimum power is by reducing the cell size (Bagaria & Shahnasser, 2015). However, this technique does not only increase the number of base stations but its effect on handover performance too. Further, coordinated multipoint (CoMP) transmission and reception technique is introduced as one of the important features in LTE-Advanced network (Dahlman et al., 2011). CoMP can be viewed as an inter-cell interference coordination (ICIC) techniques which utilize multiple transmit and receive antennas from multiple antenna site locations to mitigate ICI and increase the cell edge throughput (Jungnickel & Forck, 2010).

In order to optimize the network performance, many existing works has been presented in a variety of fields. There are number of factors affect the performance of the network such as infrastructures, cell environments, base station related factors (such scheduling algorithms, distance from eNodeB), UE mobility speed, multiple antenna configurations and others (Trivedi & Patel, 2014). The network performance is defined by the overall quality of service provided by a network. This encompasses numerous parameters and metrics that must be analyzed collectively to assess a given network. Network performance measurement is therefore defined as the overall set of processes

and tools that can be used to quantitatively and qualitatively assess network performance and provide actionable data to remediate any network performance issues. The demands on networks are increasing every day, and the need for proper network performance measurement is more important than ever before. The performance of a network can never be fully modeled, so measuring network performance before, during, and after updates are made and monitoring performance on an ongoing basis are the only valid methods to fully ensure network quality.

No standard works in the literature that tested on the best effort parameter combination to obtain the optimize network. Hence, this research work provides a platform to obtain the best parameter selection for selected environment tested in the simulation model based on OMNeT++ tool. Furthermore, different resource allocation techniques have been introduced in the literature to overcome the challenges faced when real time traffic is transmitted over an LTE networks. Scheduling techniques in Medium Access Control (MAC) layer and bandwidth partitioning in physical (PHY) layer are the example of resource allocation methods that received extensive concerns in the literature. Considering that the scheduling mechanism is not standardized but it is implementation specific, an efficient scheduling mechanism is a crucial differentiator among the different LTE network systems. Therefore, the proposed in this research work filling the gaps by combining heuristics optimization and frequency reuse method in obtaining enhanced coordinated scheduling algorithm for LTE networks.

1.3 Research Questions

The open issues described in the previous section lead to some research questions addressed in this research as follows:

- i) How to implement a proper parameter selection for LTE-Advanced network performance?
- ii) What is the effect of selected parameters such as bandwidth, number of users, distance of base station, mobility type and packet size to the network performance?
- iii) How to improve network throughput and delays using selected parameter setting?
- iv) How to enhance network performance in multi-cell network?

1.4 Research Objectives

The main objectives of this research are:

- i) To propose a parameter selection algorithm for LTE-Advanced network on coordinated multipoint system.
- ii) To optimize the LTE-Advanced network in term of throughput and delays using the proposed algorithm.
- iii) To enhance a scheduling technique for deployment in multi-cell network to improve the network performance.

1.5 Scope of Research

The study is based on a dense small cell scenario, which typically corresponds to urban conditions with a high density of base stations to ensure coverage continuity and user requirements.

The scope of the thesis covers the following:

- i) The simulation framework is developed and simulated based on SimuLTE, an OMNeT++ based discrete simulator.
- ii) The channel model employed is based on 3GPP standard using macro cell propagation model for urban area which is appropriate for scenarios in urban and suburban areas outside the high rise core where buildings are of nearly uniform height.
- iii) The evaluation of network is focused on downlink transmission of outdoor environment with hexagonal grid cellular layout.
- iv) The users distributed with uniform density within the macro coverage area.
- v) No power control in downlink is modeled, fixed power per frequency resource block is assumed.
- vi) The network performance that are evaluated are based on the network throughput, delays and quality of user experience index with the application of Voice over Internet Protocol (VoIP) as the traffic model.

1.6 Research Contributions

The following contributions have been made:

- 1) An enhanced parameter selection algorithm for LTE networks which name as Iterative Optimization Algorithm (IOpA) is proposed to overcome the limitation of the classical dependency on ordinary network setting. The algorithm quantifies the impact of network parameter to provide improvement in term of throughput, quality of user experience index and decreased response in delays.
- 2) An optimized LTE networks by using proposed Iterative Optimization Algorithm which resulted in the enhancement of network performance.
- 3) Further network improvement through Coordinated Scheduling technique in coordinated multipoint transmission system has been evaluated and applied for LTE-A environment. The scheduling technique provides appropriate network setting that resulted in the enhanced and improved LTE-A performance.
- 4) The evaluation of the performance based on measurements of significant parameters in LTE networks such as increase in term of throughput, quality of user experience index and decrease in delays.

1.7 Thesis Organization

The focus of the thesis is to investigate and evaluate the performance of LTE networks environments with realistic channel model in urban macro cell scenario based on iterative optimization algorithm and coordinated scheduling technique. The organization of the thesis is as follows:

Chapter 1 provides the introduction to the domain of the study, mainly mobile technology and the preliminaries of LTE/LTE-A features. This is followed by the discussion of the background of the problem, the statement of the problem, research objectives and contributions. The research scope is also been defined in this section.

Chapter 2 depicts an extensive literature review of the area of the study and focus more on CoMP characteristics. This includes the research area, network architectures, and coordination transmission schemes. This chapter also explains the resource and interference management in LTE/LTE-A CoMP systems which includes the optimization concepts and the use of iterative optimization technique as an optimization process. An overview of simulation tools and framework used for network research purpose has also been elaborated in this chapter.

Chapter 3 highlights the details of the research methodology used in this work. This is followed by the problem formulation based on the literature review and simulation set-up.

Chapter 4 presents the proposed technique, IOpA and the results obtained from the analysis of IOpA towards tested scenario of LTE model. Chapter 5 presents the development of coordinated scheduling algorithm and analysis of the scheduling schemes in improving LTE network performance.

Chapter 6 illustrates the summary of the thesis, the achievement of the study and re-affirms the contributions of the study. In addition, the suggestions and proposals for future research directions are discussed in this chapter.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

The growth of data over the cellular networks is increasing at an exponential rate as users transfer more data and use personal phones and tablets as their main access point for mobile communications. To meet the requirements for additional advancement of functionality, improved speeds and general enhanced performance in a new mobile telecommunication system are required. Few physical layer enhancement techniques such as carrier aggregation (CA), coordinated multiple point (CoMP) transmission and reception (Ding & Hanwen Luo, 2013), relaying as well as multiple antennas techniques (Cox, 2012) had been considered. The technology components are able to support a huge range of users with very high data rates and improvement in the capacity of the recent radio access system. The performance limitation of current cellular systems in term of interference is denying the operation to accomplish a very high data rate. By increasing the transmission power at each serving base station (denoted as eNodeB in LTE and LTE-Advanced) in order to fulfil serving user requirements basically inducing interference signal to the other users if the deployment of new sites is unplanned. Hence, increasing power itself does not solve the performance limitation problem and it is very expensive in terms of cost.

Another approach to increase the network capacity and meet data rates demands is by complementing the macro cell with low power nodes such as relay, pico and femto base stations. This approach, which is known as heterogeneous network (HetNet) has

been considered as a way to improve the capacity and data rate in the areas covered by these low power nodes. The low power nodes are mostly distributed in an unplanned manner depending on the areas that generate higher traffic (Dahlman et al., 2011). The specification and characteristics of different elements in heterogeneous network are summarized in Table 2.1 (Lopez-Perez et al., 2011).

Table 2.1 The characteristics and specification of elements in HetNet.

	Characteristic	Transmit power	Coverage	Backhaul
Macrocell	Conventional operator-installed base station, open public access and serving more customers	46 dBm	Few km	S1 interface
Picocell	Low-power base station, mainly utilized for capacity and in-building coverage	23-30 dBm	< 300 m	X2 interface
Femtocell	Home base station, user-deployed access points, open access or restricted for Closed Subscriber Group (CSG)	< 23 dBm	< 50 m	xDSL
Relay	Operator-installed access points, mainly utilized to increase signal strength and range extension in poor coverage areas	30 dBm	300 m	Wireless
Remote Radio Head (RRH)	Distributed base station, controlled by central macro base station	46 dBm	Few km	Fiber optic

Compared to homogeneous network, HetNet deployments, however impose more severe interference challenges to the network. In traditional networks, network frequency reuse schemes are successfully used to mitigate interference. In HetNet, the interference problems are challenging due to the existing of different types of cells in the network, which may have different bandwidth, restricted access control and latency constraints. Deployment of large numbers of low-power nodes limits the feasibility of centralized

radio resource management. To handle the challenge of interference in HetNet, the possibility of network-level multiple-input multiple-output (MIMO) technologies with cooperation between a set of network nodes is greatly studied (Gesbert et al., 2010). Such promising technique is referred as CoMP in LTE-Advanced. Various CoMP schemes are supported in the standardization and can be categorized by their processing control. This chapter will provide the taxonomy of CoMP system in LTE-Advanced as illustrated in Figure 2.11 and resource management in LTE-Advanced network as illustrated in Figure 2.5.

2.2 Coordinated Multipoint Transmission in LTE-Advanced

CoMP is considered for LTE-Advanced as a tool to improve the coverage of high data rates, the cell-edge throughput as well as to increase the system throughput. In a cellular deployment and specifically if frequencies are reused in each cell, other-cell interference traditionally degrades the system capacity. The aim in CoMP is to turn the other cell interference into a useful signal specifically at the cell border. CoMP transmission and reception is a structure that refers to a system where a number of geographically scattered antenna nodes work together with the mean of improving the execution of the users processed in the common collaboration area (Abe, Kishiyama, Kakura, & Imamura, 2011). It covers all required system architectures to accomplish tight coordination for transmission and reception. Cooperation among eNodeBs is categorized by the need of an interconnection among the different access points via dedicated backhaul links. These backhaul links should be a very high speed and low-latency link. The criteria are crucial for the accomplishment of the cooperative communication, even though its design will be very challenging due to the huge amount of information that

have to be interchanged between the nodes. LTE-A will utilize the standard interface X2 for these roles.

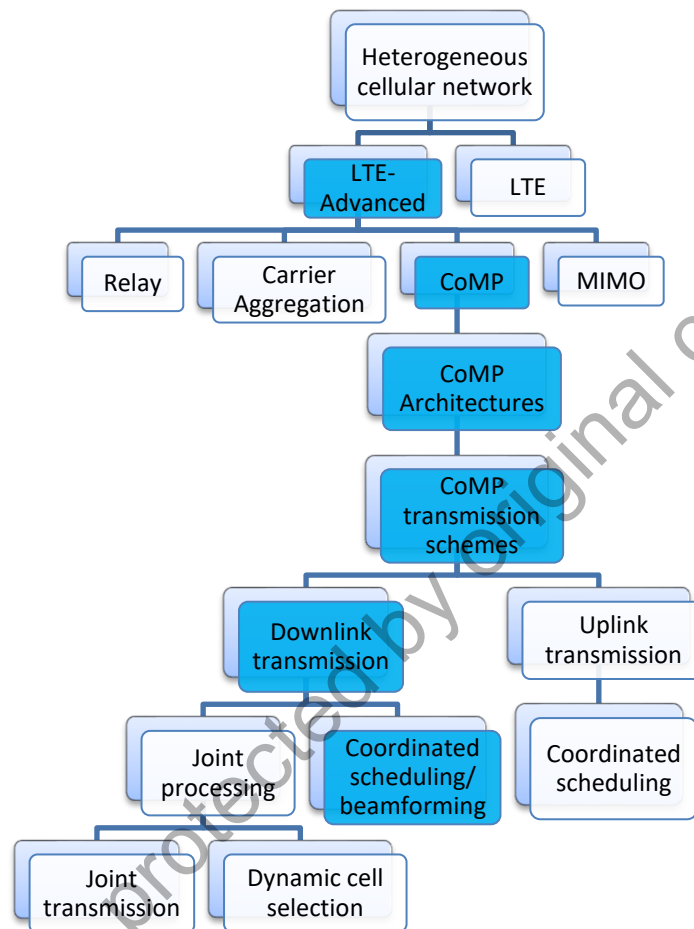


Figure 2.1 Taxonomy of CoMP system reviews in LTE-Advanced network.

There are several possible coordinating schemes available in the circumstance of LTE-Advanced. Coordinated beamforming/scheduling is a less complicated approach where only a single cell transmits user data to the user equipment (UE). Joint processing scheme, on the other hand, involves multiple nodes to transmit user data to the UE. There are two approaches being considered in the joint processing scheme: joint transmission, which needs multi-user linear precoding, and dynamic cell selection, where the data are

transmitted from only one cell that is dynamically selected. The transmission schemes can be implemented on any types of network configurations.

2.2.1 CoMP Network Architecture

There are different approaches possible for CoMP network deployment as illustrated in Figure 2.2: centralized control based on Remote Radio Equipment (RRE), or autonomous distributed control based on an independent eNodeB configuration (Sawahashi, Kishiyama, Morimoto, Nishikawa, & Tanno, 2010).

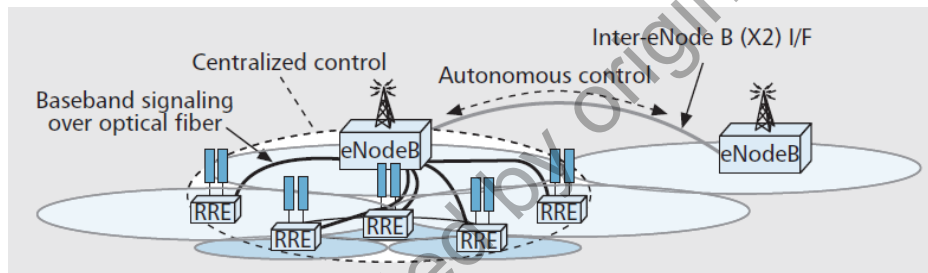


Figure 2.2 CoMP Network configuration. (Sawahashi et al., 2010)

2.2.1.1 Centralized Architecture

In this approach, multiples RREs are connected to the central eNodeB via an optical fiber carrying a baseband signal between cells and the central eNodeB. The central entity is required in order to collect the channel information from all the UEs in the area covered by the coordinating eNodeBs. This entity is also in charge of performing baseband signal processing and control, so the radio resources between the cells can be controlled accordingly. With this approach, the signaling delay and overhead between eNodeB are small and the control of high speed radio resources between cells is relatively easy. However, with high capacity optical fiber required, as the number of RRE increases,

the processing load on the central eNodeB will also increase. This would be the limitation for this network configuration (Sawahashi et al., 2010).

Further works on backhaul requirements and feasibility of CoMP for the centralized architecture have been reported by Irmer et al. (2011). The authors tested the principal feasibility of CoMP in two field testbeds with multiple sites and different backhaul solution between the sites. Key challenges and potential benefits of using CoMP in specific scenarios also have been presented by the authors. It has been concluded from the implementation of view, that intra-site cooperation is easier to be implemented. However, in order to benefit the potential of full interference reduction from base station cooperation, inter-site cooperation will still be needed. The logical X2 interface, either a direct physical link or a multihop link could be used to accomplish the backhaul requirements for inter-site cooperation.

2.2.1.2 Distributed Architecture

A distributed architecture is another method to carry out coordination that relieves the demands of a centralized approach. Based on the assumption that schedulers in all eNodeBs are identical and channel information regarding the whole coordinating set can be available to all cooperating nodes, inter-eNodeB communication links are no longer necessary to perform cooperation. Thus, this architecture has the great advantage of minimizing the infrastructure and signaling protocol cost associated with these links and the central processing unit, so conventional systems need not undergo major changes.

Furthermore, the radio feedback to several nodes could be achieved without additional overhead.

Regardless of different network configurations, the cooperation should be confined to a limited number of eNodeBs or RREs. This is due to the fact that as the number of users and eNodeBs or RREs increase, the signalling overhead demanded for the information interchange between eNodeBs and the amount of feedback required from the users also will be increased. To ease the network limitation, the network is thus fractioned into clusters of cooperative cells (Papadogiannis, Bang, Gesbert, & Hardoium, 2008). Cluster selection either a network-centric (executed by a central entity) or user-centric (per-user way) is apparently a key to cooperation algorithm's performance. Cluster formation can be either static or dynamic.

Marsch and Fettweis (2011) highlighted on a static clustering concept for CoMP in their research work. Their overlapping clustering scheme can be viewed as a type of fractional frequency reuse (FFR) but applied in such a way that the overall reuse factor is one using different subsets of system resources. The authors split the system resources into three equally-sized resource blocks each cell with three clusters having different partnering cells. Their work on finding the optimal choice of overlapping clusters is based on whether optimizing the mean signal-to-interference-and-noise ratio (SINR) or the outage measure. They have shown that clustering problems can be stated as binary linear optimization problems and that in particular concepts of overlapping clusters can lead to a performance close to that of UE-specific (ideal) clustering approaches, while requiring minimal signaling overhead between clusters. However, they did not specify whether their overlapping clusters are tested for centralized or distributed architectures.

Huang et al. (2010) proposed a novel multi-layered clustering method for the distributed cooperation. Their aim is to achieve better performance with limited overhead increment and low complexity compared with traditional static and dynamic clustering. They employed a scheme of double-layered clustering and extend to multi-layered clustering for distributed scheme aimed at rectifying the cooperation defects in static clustering with relatively low increment on complexity. Simulations showed that not only the average user rate, but also the fairness of the system are improved. Their research work also provides a new concept for the centralized scheme which use the omni-antenna cooperation concept. The new concept also improves the fairness of the system, but further modifications are needed by the current system structure since originally the oriented antennas which have a directional loss and sectorization are presented for the intention of cutting down interference and spatially reusing frequency resources. To get more effective operation for circular antenna array cooperation, antenna pattern should also be modified.

2.2.2 CoMP Transmission Schemes

In this section, the possible CoMP categories that are figured in LTE-A for both the uplink and the downlink are presented. The transmission schemes can be independently implemented whether the architecture is a distributed or a centralized one. The schemes necessities in terms of measurements, signaling, and backhaul are distinct, where usually the best performance achieving schemes demands the most complex system.