Coordinated Multipoint Transmission and Reception in LTE-Advanced

A Thesis Submitted for Partial Fulfillment of Requirements of the M.Sc Degree in Electronic Engineering (mobile systems)

By:
Eng: Yousif Ahmed Elsidig Elhadi

Supervisor:
Prof. Amin Babikr Abdal-nabi Mustafa

December 2019
بِسْمِِ اللهِ الرَّحْمنِ الرَّحِيمِ

قال تعالى:

{يَرْفَعِ اللَّهُ الهذِينَ آمَنُوا مِنكُمْ وَالهذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ}

صدق الله العظيم

سورة المجادلة(11)
إهداء

إلي من ربياني و سعيا و شقيا لأنعم بالراحة والهناء اللذان لم يبخلا بشيء من أجل دفعي إلى طريق النجاح الذي علمني أن أرتقي سلم الحياة بحكمة و صبر إلىأمي وأبي

إلى من سرنا سويا ونحن نشق الطريق معا نحو النجاح والإبداع و التميز في مختلف دروب الحياة

أصدقاني

إلي من علمونا حروفًا من ذهب وكلمات من درر و نسجو لنا علمهم و فكرهم ليكون واضحا و جليا لنا ، نسمو به في حياتنا العلمية و العملية إلى؛

أساتذتنا الأعزاء

إليهم جميعا نهدي عملنا المتواضع هذا سألين الموالي عز و جل أن يقبل منهم ما قدموه و يجعله في ميزان حسناتهم
شكر و تقدير

في حيز الشعوب ومضات مشرقة يسطرها التاريخ بأحرف من نور ؛؛؛؛؛؛؛؛؛؛؛؛؛؛ يباهى و يفاخر بها لتكون صفحات في سجل الوطن أقل الوفاء كلمات نسوقة فمن أعطى ومبذل شكرا و تقديرا ؛؛؛؛؛ الي من كانو بجانبنا و كانو يرافقونا فواجب علينا شكرهم و وداعهم و نحن نخطو خطوتنا الأولى في غمار الحياة و نخصص بالجزيل الشكر والعرفان إلى كل من أشعل شمعة في دروب عملنا و وإلى من وقف على المنابر وأعطى من حصيلة فكره لينير دربنا

إلى الدكتور:
امين بابكر عبدالنبي
ABSTRACT

Coordinated multi-point (CoMP) transmission and reception is a network multiple-input multiple-output (MIMO) technology considered in 3GPP LTE-Advanced systems. In order to improve reliability and capacity of the services for the user equipments (UEs) at the cell edges.

CoMP utilizes cooperation among neighboring enhanced node Bs (eNBs). When a mobile station is at the cell edge, it may be able to receive signals from multiple cell sites, and the mobile station’s transmission may also be received at multiple cell sites. If the data transmission and signaling from multiple cell sites can be coordinated, the downlink performance can be significantly improved. This coordination can be similar to the interference avoidance techniques or the case where the same data is transmitted from multiple cell sites.

CoMP is very different for the uplink and downlink. DL CoMP is divided into ‘Coordinated Scheduling and Beamforming’ (CS/CB) and ‘Joint Transmission (JT)’ and UL CoMP is divided into ‘Coordinated Scheduling (CS)’ and Joint Reception and Processing (JR)”.

The goal of this search is to evaluate the potential performance benefits of JT-CoMP techniques and the implementation aspects including the complexity of the standards support for CoMP, also this project discusses and compare scenarios in which JT-CoMP techniques and without JT-CoMP By using Matlab Program the results are show that data rate, throughput especially cell-edge throughput, spectral efficiency, delay and SNR after coordination have been formed.
المستخلص

يعتبر تنسيق الشبكات متعددة الارسال والاستقبال من التكنولوجيا متعددة المدخلات والمخرجات وهي من الانظمة المتقدمة للجيل الرابع. لأجل تحسين الموثوقية والخدمات لمعدات المستخدم على حواف الخلية.

الشبكة المنسقة تستخدم لتعزيز التعاون بين الخلايا المجاورة، وفي حالة أن المستخدم موجود في حافة الخلية قد يكون قادرًا على تلقي إشارات من عدة خلايا في مواقع متعددة ويمكن أيضًا أن يرسل المستخدم إلى عدة مواقع، إذا كان نقل البيانات والاشارات من خلية المواقع متعددة يمكن تنسيقها، واداء الاستقبال يمكن أن يحسن بشكل كبير. هذا التنسيق يمكن أن يكون مماثل لتقنيات تجنب التداخل أو في حالة يتم نقل نفس البيانات من مواقع متعددة.

التنسيق متعدد النقاط يختلف في عمليات الارسال والاستقبال بالنسبة للمستخدم. في عملية الاستقبال يقسم إلى منسق الجدولة والتشكيل والمعالجة المشتركة أما في عملية الاستقبال يقسم إلى منسق الجدولة والاستقبال المشترك.

الهدف من هذا البحث هو تقييم فوائد الأداء المحتملة لتقنيات التنسيق متعدد النقاط وجوائز التنفيذ بما في ذلك تعقيد المعايير لبرامج التنسيق متعدد النقاط، كما نناقش هذا المشروع ويقارن السيناريوهات التي تستخدمها تقنيات التنسيق متعددة النقاط بدون استخدام بروتوكول التنسيق متعدد النقاط باستخدام نموذج المحاكاة الماتلاب واظهار النتائج في كل من معدل نقل البيانات، الإنتاجية في حافة الخلية، الكفاءة الطيفية، التأخير ونسبة الإشارة إلى الضوضاء المستخدمة بعد عملية التنسيق.
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Arabic</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>الآية</td>
<td>I</td>
</tr>
<tr>
<td>الإهداء</td>
<td>II</td>
</tr>
<tr>
<td>الشكر والتقدير</td>
<td>III</td>
</tr>
<tr>
<td>Abstract</td>
<td>IV</td>
</tr>
<tr>
<td>المستخلص</td>
<td>V</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>VI</td>
</tr>
<tr>
<td>Abbreviations</td>
<td>IX</td>
</tr>
<tr>
<td>List of Figures</td>
<td>X</td>
</tr>
<tr>
<td>List of Tables</td>
<td>XII</td>
</tr>
</tbody>
</table>

#### 1 Chapter One: Introduction

1.1 Preface 1
1.2 Problem Statement 2
1.3 Problem Solutions 2
1.4 Objectives of Project 2
1.5 Methodology 3
1.6 Research Layout 3

#### 2 Chapter Two: Literature Review

2.1 Backgrounds of LTE-Advanced 4
2.2 Features of LTE 5
    2.3 Features of LTE-Advanced 7
    2.4 Technologies of LTE advanced 9
        2.4.1 Enhanced MIMO 9
        2.4.2 Relay Nodes 10
        2.4.3 Coordinated Multipoint (CoMP) 11
        2.4.4 Carrier Aggregation 12
2.5 OVERVIEW OF GENERAL COMP TECHNIQUES 14
    2.5.1 CoMP architecture 15
    2.5.2 CoMP scenarios 16
    2.5.3 CoMP types 17
3 CHAPTER THREE : METHOTOLGY
3.1 Joint transmission 29
3.2 Simulation Scenario 31
3.3 Mathematical Model of Performance Method 32
   3.3.1 Signal Interference Noise Ratio 32
   3.3.2 Data Rate 33
   3.3.3 Throughput 34
   3.3.4 Spectral Efficiency 34
3.3.5 Delay 35
3.4 Simulation Parameters 36

4 CHAPTER FOUR : RESULTS AND DISSCION
4.1 The Performance Metrics 37
   4.1.1 Signal to Noise Interference Ratio result 37
   4.1.2 Data Rate result 38
   4.1.3 Throughput result 39
   4.1.4 Spectal Efficiency result 40
   4.1.5 Delay result 41
4.2 Discussion 42

5 CHAPTER FIVE : Conclusion and Recommendations
5.1 Research challenges 43
5.2 Recommendations 44
5.3 Conclusion 44
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>3GPP</td>
<td>Third Generation Partnership Project</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency Division Multiple Access</td>
</tr>
<tr>
<td>IMT-A</td>
<td>International Mobile Telecommunication-Advanced</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>CoMP</td>
<td>Coordinated Multipoint</td>
</tr>
<tr>
<td>SC-OFDMA</td>
<td>Single-Carrier Frequency Division Multiple Access</td>
</tr>
<tr>
<td>QPSK</td>
<td>Quadrature Phase-Shift Keying</td>
</tr>
<tr>
<td>16QAM</td>
<td>16 Quadrature Amplitude Modulation</td>
</tr>
<tr>
<td>64QAM</td>
<td>64 Quadrature Amplitude Modulation</td>
</tr>
<tr>
<td>DL</td>
<td>Downlink</td>
</tr>
<tr>
<td>UL</td>
<td>Uplink</td>
</tr>
<tr>
<td>UE</td>
<td>User Equipment</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
</tr>
<tr>
<td>PAPR</td>
<td>Peak-to-Average Power Ratio</td>
</tr>
<tr>
<td>FDD</td>
<td>Frequency Division Duplexing</td>
</tr>
<tr>
<td>TDD</td>
<td>Time Division Duplexing</td>
</tr>
<tr>
<td>AMC</td>
<td>Adaptive Modulation and Coding</td>
</tr>
<tr>
<td>FEC</td>
<td>Forward Error Correction</td>
</tr>
<tr>
<td>E-UTRAN</td>
<td>Evolved UMTS Terrestrial Radio Access</td>
</tr>
<tr>
<td>FTTH</td>
<td>Fiber to the Home</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality-of-Service</td>
</tr>
<tr>
<td>RAN</td>
<td>Radio Access System</td>
</tr>
<tr>
<td>PUSCH</td>
<td>physical uplink shared channel</td>
</tr>
<tr>
<td>TP</td>
<td>Transmission Point</td>
</tr>
<tr>
<td>CS</td>
<td>Coordinated Scheduling</td>
</tr>
<tr>
<td>CB</td>
<td>Beamforming Coordinated</td>
</tr>
<tr>
<td>JT</td>
<td>Joint Transmission</td>
</tr>
<tr>
<td>CSI</td>
<td>Channel State Information</td>
</tr>
<tr>
<td>TPS</td>
<td>TP choice</td>
</tr>
<tr>
<td>ICIC</td>
<td>Inter-Cell Interference Coordination</td>
</tr>
<tr>
<td>eNB</td>
<td>Evolved Node B</td>
</tr>
<tr>
<td>HP-RRH</td>
<td>High-Power Remote Radio Heads</td>
</tr>
<tr>
<td>LP-RRH</td>
<td>Low-Power Remote Radio Heads</td>
</tr>
<tr>
<td>JR</td>
<td>Joint Gathering and Handling</td>
</tr>
<tr>
<td>JP</td>
<td>Joint Processing</td>
</tr>
<tr>
<td>RI</td>
<td>Rank Pointer</td>
</tr>
<tr>
<td>PMI</td>
<td>Pre-coding Metric Record</td>
</tr>
<tr>
<td>PDCCH</td>
<td>Physical Downlink Control Channel</td>
</tr>
<tr>
<td>PUCC</td>
<td>Uplink Control Channel</td>
</tr>
<tr>
<td>PDSCH</td>
<td>Physical Downlink Shared Channel</td>
</tr>
<tr>
<td>PUSCH</td>
<td>Physical Uplink Shared Channel</td>
</tr>
<tr>
<td>SINR</td>
<td>Signal to Noise Interference Ratio</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
</tbody>
</table>
## List of Figures

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>MIMO 4x4</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Relay node and donor eNodeB</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>A) Joint transmission B) Dynamic point selection</td>
<td>12</td>
</tr>
<tr>
<td>2.4</td>
<td>Carrier Aggregation concepts</td>
<td>13</td>
</tr>
<tr>
<td>2.5</td>
<td>General classifications of CoMP techniques</td>
<td>15</td>
</tr>
<tr>
<td>2.6</td>
<td>CoMP architecture</td>
<td>16</td>
</tr>
<tr>
<td>2.7</td>
<td>CoMP Scenario</td>
<td>17</td>
</tr>
<tr>
<td>2.8</td>
<td>CoMP types</td>
<td>18</td>
</tr>
<tr>
<td>2.9</td>
<td>The JT and CS/CB modes of CoMP</td>
<td>20</td>
</tr>
<tr>
<td>2.10</td>
<td>Almost blank sub-frame technique for HetNet</td>
<td>21</td>
</tr>
<tr>
<td>2.11</td>
<td>CS-CoMP</td>
<td>23</td>
</tr>
<tr>
<td>2.12</td>
<td>PMI coordination to reduce interference</td>
<td>24</td>
</tr>
<tr>
<td>3.1</td>
<td>Intra-eNB joint transmission</td>
<td>30</td>
</tr>
<tr>
<td>3.2</td>
<td>Inter-eNB JT: Inter-eNB JT: distributed coordination</td>
<td>31</td>
</tr>
<tr>
<td>3.3</td>
<td>Inter-eNB JT: centralized coordination</td>
<td>32</td>
</tr>
<tr>
<td>3.4</td>
<td>Downlink CoMP (JT)</td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Compared SINR Between With and Without (JT) CoMP</td>
<td>37</td>
</tr>
<tr>
<td>4.2</td>
<td>Compared Data Rate Between With and Without (JT) CoMP</td>
<td>38</td>
</tr>
<tr>
<td>4.3</td>
<td>Compared Throughput Between With and Without (JT) CoMP</td>
<td>39</td>
</tr>
<tr>
<td>4.4</td>
<td>Compared Spectrum Efficiency Signal Between With and Without (JT) CoMP</td>
<td>40</td>
</tr>
<tr>
<td>4.5</td>
<td>Compared Delay Signal Between With and Without (JT) CoMP</td>
<td>41</td>
</tr>
</tbody>
</table>
### List of Tables

<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>LTE release8 major parameter</td>
<td>5</td>
</tr>
<tr>
<td>2.2</td>
<td>LTE and LTE advanced comparison</td>
<td>8</td>
</tr>
<tr>
<td>2.3</td>
<td>LTE and LTE-Advanced capacity comparison</td>
<td>9</td>
</tr>
<tr>
<td>3.1</td>
<td>Standard SNR, Modulation and Coding</td>
<td>34</td>
</tr>
<tr>
<td>3.2</td>
<td>The Simulation Parameters…..</td>
<td>36</td>
</tr>
</tbody>
</table>
CHAPTER 1

Introduction
CHAPTER ONE

Introduction

1.1 Preface

After the advancement of the 3G group of measures, the Third Generation Partnership Project (3GPP) began dealing with Long Term Evolution (LTE) frameworks aimed to Release 8 (Rel-8) standard. Being the principal cell framework in the light of Orthogonal Frequency Division Multiple Access (OFDMA), it spoke to a notable achievement regarding accomplishing maximum rates of 300 Mbps and 75 Mbps for downlink and uplink, respectively. In order to take care of the developing demands for rapid and various remote broadband services, the fundamental goal of International Mobile Telecommunication-Advanced (IMT-A) is now, to achieve 1Gbps and 500Mbps maximum rates for DL and UL respectively. In LTE-A network, the main objective is to achieve better network capacity as compared to LTE network. The main motive is to maximize the system throughput at minimum cost and to satisfy the necessities set by the International Telecommunication Union (ITU) for IMT-A Standard. [1]

One of the key enabling technologies of LTE-Advanced is coordinated multipoint (CoMP) that targets to improve the cell-edge performance as well as overall network spectral efficiency through eNBs coordination. (CoMP) is an advanced wireless mechanism in mobile communication transmission and reception which proposes a better solution to overcome the inter-cell interference and enhance the cell edge data rates.
1.2 Problem Statement

In a conventional cellular system, the BS is located in the cell center and it only serves the users in its coverage area. The signals transmitted from, serving BS decreases as the user moves towards cell edge this will lead to poor SINR and hence the throughputs, spectral efficiency, worsen for cell edge users.

The signal received by the subscriber at cell edge is very poor and hence low data rates and limited qualities of services are provided to them. In addition there may be some unused resources in adjacent cell.

1.3 Proposed Solutions

Cell coordination has been proposed as an efficient way which allows several base stations to transmit data simultaneously to the same user. By using Joint transmission CoMP technology.

1.4 Objectives of Project

The main objective of this research is to:

- Constructing deep background in the LTE advanced and Study LTE advanced vs. LTE.
- Show LTE advanced: features and coordinated multipoint transmission and reception (CoMP) technology.
- Improve the performance of the cell edge users through the efficient utilization of unused resourced at neighboring cells.
- Compare the performance of two approaches: one is No-CoMP Network and other one is CoMP Network.
1.5 Methodology

The Methodology of this research divided into following stages:

Stage 1: mathematically formulates operation of coordinated multipoint transmission and reception scheme with the relation between different parameter.

Stage 2: include the simulation over a MATLAB platform. A MATLAB code has been written to simulate the system performance with and without coordination.

There are many parameters that can measure the system performance like (signal to interference ratio, throughput, delay, spectral efficiency and bandwidth utilization) due to their huge effect on the system performance and their relation with each other, they have been selected in this project to verify the enhance of the system. The output of the simulation is in graphs form, it shows the amount of improvement in each parameter.

1.6 Research Layout

This project contain five chapters their details are as flows:

Chapter 1: introduction, the problem statement, proposed solution, objectives and the Methodology of the research.

Chapter 2: literature review, which covers the LTE and LTE advanced features, technologies of LTE advanced, overview of CoMP technique and Joint transmission CoMP technology.

Chapter 3: discuss the equations and operation method of coordinated multi point transmission and reception for LTE advanced network.

Chapter 4: Show the simulation, in addition the results and discussions construction procedure highlighted.

Chapter 5: conclusion and Recommendations are stated in this chapter.
CHAPTER 2

Literature Review
CHAPTER TWO

Literature Review

2.1 Backgrounds of LTE-Advanced

Mobile communications has become an everyday commodity. In the last decades, it has evolved from being an expensive technology for a few selected single to today’s ubiquitous systems used by a majority of the world’s population. From the first experiments with radio communication by Guglielmo Marconi in the 1890s, the road to truly mobile radio communication has been quite long.

To understand the complex mobile-communication systems of today, it is important to understand where they came from and how cellular systems have evolved. The task of developing mobile technologies has also changed, from being a national or regional concern, to becoming an increasingly Complex task undertaken by global standards-developing organizations such as the 3GPP and involving thousands of people. [2]

Mobile communication technologies are often divided into generations, with 1G being the analog Mobile radio systems of the 1980s, 2G the first digital mobile systems, and 3G the first mobile Systems handling broadband data. The LTE is often called “4G”, but many Also claim that LTE release 10, also referred to as LTE-Advanced, is the true 4G evolution step, with The first release of LTE (release 8) then being labeled as “3.9G”. This continuing race of increasing Sequence numbers of mobile system generations is in fact just a matter of labels. What is important is the actual system capabilities and how they have evolved.[3]
2.2 Features of LTE

LTE is a mobile broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings. Some of the most important features that deserve to highlight are as follows Table 2.1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access scheme UL</td>
<td>SC-OFDMA</td>
</tr>
<tr>
<td>Access scheme DL</td>
<td>OFDMA</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>1.4, 3, 5, 10, 15, and 20 MHz</td>
</tr>
<tr>
<td>Minimum TTL</td>
<td>1ms</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>15 KHz</td>
</tr>
<tr>
<td>Cyclic prefix long</td>
<td>16.7 Ms</td>
</tr>
<tr>
<td>Cyclic prefix short</td>
<td>4.7MS</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK-16QAM-64QAM</td>
</tr>
<tr>
<td>Spatial multiplexing</td>
<td>Single layer for UL per UL, up to four layer for DL per UE, MUMIMO supported for UL and DL</td>
</tr>
</tbody>
</table>

OFDM for high spectral efficiency is the basis of the physical layer: OFDM is used in downlink in order to obtain robustness against multipath interference and high affinity to advanced techniques such as frequency domain Channel-dependent scheduling and MIMO, while Single-Carrier Frequency Division Multiple Access (SC-FDMA) is used in uplink in order to get a Low Peak-to-Average Power Ratio (PAPR), user orthogonally in frequency Domain and multi-antenna application. [4]
Support for TDD and FDD: LTE supports both Time Division Duplexing (TDD) and Frequency Division Duplexing. TDD is favored by a majority of Implementations because of its advantages:

(1) Flexibility in choosing uplink to-Downlink data rate ratios.
(2) Ability to exploit channel reciprocity.
(3) Ability to implement in non-paired spectrum.
(4) Less complex transceiver design.

Adaptive Modulation and Coding (AMC): LTE supports a number of modulation and Forward Error Correction (FEC) coding schemes and allows the scheme to be changed on per user and per frame basis, based on channel conditions. AMC is an effective mechanism to maximize throughput in a time-varying channel. The adaptation algorithm typically calls for the use of the highest modulation and coding scheme that can be supported by the signal-to-noise and interference ratio at the receiver such that each user is provided with the highest possible data rate that can be supported in their respective links.

Support of variable bandwidth: E-UTRA shall operate in spectrum allocations of different sizes, including 1.25, 1.6, 2.5, 5, 10, 15, and 20 MHz in both the uplink and downlink (Table 2.1). Operation in paired and unpaired spectrum shall be supported. This scaling may be done dynamically to support user roaming across different networks that may have different bandwidth allocations.

Very high peak data rates: LTE is capable of supporting very high peak data rates. In fact, the peak PHY data rate can be as high as downlink peak data rate of 100 Mb/s within a 20 MHz downlink spectrum allocation (5 bps/Hz), while it provides uplink peak data rate of 50 Mb/s (2.5 bps/Hz) within a 20MHz uplink spectrum allocation.[6]

Mobility: E-UTRAN should be optimized for low mobile speed from 0 to 15 km/h. A higher mobile speed between 15 and 120 km/h should be supported with high performance. Mobility across the cellular network shall be maintained at speeds from 120 to 350 km/h (or even up to 500 km/h depending on the frequency band).
2.3 Features of LTE-Advanced

LTE-Advanced should be a real broadband wireless network that provides peak data rates equal to or greater than those for wired networks, i.e., Fiber to the Home (FTTH), while providing better QoS. The major high-level requirements of LTE are reduced network cost (cost per bit), better service provisioning, and compatibility with 3GPP systems LTE-Advanced being an evolution from LTE is backward compatible. In addition to the advanced features used by LTE Release 8, LTE-Advanced enhanced these features that can be found in the following:

**The peak data rate:** LTE-Advanced should support significantly increased instantaneous peak data rates. At a minimum, LTE-Advanced should support enhanced peak data rates to support advanced services and applications (100 Mbps for high and 1 Gbps for low mobility were established as targets for research) (Table 2.2)

**Mobility:** The system shall support mobility across the cellular network for various mobile speeds up to 350 km/h (or perhaps even up to 500 km/h depending on the frequency band). System performance shall be enhanced for 0–10 km/h and preferably enhanced but at least no worse than E-UTRA and E-UTRAN for higher speeds.

**Enhanced multi-antenna transmission techniques:** In LTE-A, the MIMO scheme has to be further improved in the area of spectrum efficiency, average cell throughput, and cell edge performances. With multipoint transmission or reception, the antennas of multiple cell sites are utilized in such a way that the transmitting/receiving antennas of the serving cell and the neighboring cells can improve quality of the received signal at the user equipment and reduce the co-channel interferences from neighboring cells Peak spectrum efficiency is directly proportional to the number of antennas used. [10]
Layered Orthogonal Frequency Division Multiple Access (OFDMA): OFDMA is utilized for radio access system for LTE-Propelled (Table 2.3). A strategy known as bearer collection is utilized by the layered OFDMA to join different LTE part transporters (from LTE Discharge 8) on the physical layer to give the essential data transfer capacity. Therefore, the layered OFDMA radio access can accomplish fundamentally higher prerequisites regarding the framework execution and capacity parameters when contrasted with the radio access approach utilized in LTE Discharge 8. The persistent range portion idea (utilized by layered OFDMA for LTE-Progressed) was embraced by the 3GPP Radio Access Working Group1, as the methodology is in reverse good with the LTE Discharge 8 client gear and can be sent with IP usefulness abilities, low inertness, and minimal effort with the current Radio Access System (RAN). [11]

**Table 2.2 LTE and LTE advanced comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LTE</th>
<th>LTE advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak data rate downlink DL</td>
<td>300Mbps</td>
<td>1Gbps</td>
</tr>
<tr>
<td>Peak Data rate uplink UP</td>
<td>75Mbps</td>
<td>500Mbps</td>
</tr>
<tr>
<td>Transmission bandwidth DL</td>
<td>20 MHZ</td>
<td>100MHZ</td>
</tr>
<tr>
<td>Transmission bandwidth UP</td>
<td>20MHZ</td>
<td>40MHZ</td>
</tr>
<tr>
<td>Mobility</td>
<td>Optimized for low speed (&lt;15km/h)high performance at speed up 120km/h and maintain link at speed up to 350km/h</td>
<td>Same as that in LTE</td>
</tr>
<tr>
<td>Coverage</td>
<td>Full performance up 5km</td>
<td>Same as LTE Requirement</td>
</tr>
<tr>
<td>Scalable Bandwidth</td>
<td>1.4,3,5,15 and 20MHZ</td>
<td>Up to 20-100MHZ</td>
</tr>
</tbody>
</table>
### Table 2.3 LTE and LTE-Advanced capacity comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Antenna Configuration</th>
<th>LTE</th>
<th>LTE Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (bps/Hz/Cell) DL</td>
<td>2-by-2</td>
<td>1.69</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>4-by-2</td>
<td>1.87</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>4-by-4</td>
<td>2.67</td>
<td>3.7</td>
</tr>
<tr>
<td>UL</td>
<td>1-by-2</td>
<td>0.74</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>2-by-4</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Cell edge user throughput</td>
<td>2-by-2</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>DL (bps/Hz/Cell/User)</td>
<td>4-by-2</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>4-by-4</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>UP</td>
<td>1-by-2</td>
<td>0.024</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>2-by-4</td>
<td>-</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**2.4 Technologies of LTE advanced**

Introducing the following key technologies into LTE-A realizes these requirements:

**2.4.1 Enhanced MIMO**

MIMO support has been enabled since the LTE Release 8, but LTE-A has advanced MIMO schemes as an enhancement. MIMO is based on transmitting and receiving using multiple antennas, and utilizing communication channels which are uncorrelated. The multiple transmissions can share the same frequency resources and if the system can utilize the communication channels efficiently for multiple transmissions, the system is capable of providing higher capacity.
There are various subjects regarding MIMO performance. One of them is the number of antennas in the transmitter and in the receiver. The LTE Releases 8 and 9 allow the use of four transmitter and receiver antennas in the DL, but only a single antenna in the UL. In Release 10, this is enhanced by supporting up to four transmitters and eight receiver antennas in the UL. Downlink supports eight transmitters and receiver antennas. Release 10 also introduced new reference symbol design, which enables better performance if the number of antenna branches is high. Higher peak data rate is achieved by enabling more parallel transmission streams. For example, with 20 MHz carrier 150 Mbps is achieved with 2x2 MIMO [10]. Theoretically 600 Mbps can be achieved with 8x8 MIMO.

Figure 2.1. Simplified illustration of 4x4 MIMO (Spatial Multiplexing). Four different data streams are transmitted on four TX antennas and received by four RX antennas, using the same frequency and time, separated only by the use of different reference signals.

![Figure 2.1 MIMO 4x4](image)

### 2.4.2 Relay Nodes

The Relay Nodes are low power base stations that will provide enhanced coverage and capacity at cell edges, and hot-spot areas and it can also be used to connect to remote areas without fiber connection. The Relay Node is connected to the Donor eNB (DeNB) via a radio interface, Un, which is a modification of the E-UTRAN air interface Uu. Hence in the Donor cell the radio resources are shared between UEs served directly by the DeNB and the Relay Nodes. When
the Uu and Un use different frequencies the Relay Node is referred to as a Type 1a RN, for Type 1 RN Uu and Un utilize the same frequencies, see figure 2.2. In the latter case there is a high risk for self interference in the Relay Node, when receiving on Uu and transmitting on Un at the same time (or vice versa). This can be avoided through time sharing between Uu and Un, or having different locations of the transmitter and receiver. The RN will to a large extent support the same functionalities as the eNB, however the DeNB will be responsible for MME selection.

Figure 2.2. The Relay Node (RN) is connected to the DeNB with the radio interface Un. UEs at the edge of the donor cell are connected to the RN via Uu, while UEs closer to the DeNB are directly connected to the DeNB via the Uu interface. The frequencies used on Un and Uu can be different, out band, or the same, in band. In the in band case there is a risk for self interference in the RN. [7]

![Figure 2.2 Relay node and donor eNodeB](image)

2.4.3 Coordinated Multipoint (CoMP)

CoMP is a technique that enables the nearby antennas to cooperate, reduce the interference and improve the average cell efficiency for cell-edge users. Cooperation allows the sharing of user data, scheduling information and channel quality. The term point is defined by 3GPP specification as a set of geographically co-located transmit antennas.
CoMP improves the performance of a network near the edge of a cell by assigning points that provide coordinated transmission and reception. The points may belong either to the same or to a different eNodeB and provide coverage to different sectors, thus allowing operators to utilize network resources efficiently. CoMP can be implemented in several ways, for example by joint transmission or dynamic point selection. Joint transmission means that the data transmission to UE is simultaneous from multiple points, which improves the quality of received signal and data throughput. Dynamic point selection schedules the data transmission to be sent from one point rather than transmitting simultaneously. These two methods are illustrated in Figure 2.3.

![Figure 2.3](image)

Figure 2.3. A) Joint transmission B) Dynamic point selection

### 2.4.4 Carrier Aggregation

To reach the required peak rates, LTE-A supports a maximum bandwidth of 100MHz. Such high bandwidth is hard to find in the available spectrum resource, and also poses a great challenge to hardware design of eNodeB and User Equipment (UE). Moreover, a key technique is needed to fully utilize spectrum scattered on various frequencies bands. To meet these requirements, CA has been introduced into LTE-A. Carrier Aggregation (CA) is one of the Long Term Evolution Advanced (LTE-A) features that allow mobile network operators (MNO) to combine multiple
component carriers (CCs) across the available spectrum to create a wider bandwidth channel for increasing the network data throughput and overall capacity. CA has a potential to enhance data rates and network performance in the downlink, uplink, or both, and it can support aggregation of frequency division duplexer (FDD) as well as time division duplexer (TDD). The technique enables the MNO to exploit fragmented spectrum allocations and can be utilized to aggregate licensed and unlicensed carrier spectrum as well.

To allow compatibility with LTE, LTE-A Rel-10 specifies that each adopts existing LTE bandwidth and is backward compatible with LTE. In LTE-A Rel-11 or above, other non-backward compatible carriers will be introduced. In practical scenarios for carrier aggregation, one or more CCs can be scheduled per UE depending on the transmission requirement and capability.

**Figure 2.4** Carrier Aggregation concepts
2.5 OVERVIEW OF GENERAL COMP TECHNIQUES

Traditionally, a lot of geologically gathered receiving wires that compare to a specific sectorization are arranged as a phone. A UE terminal is associated with a solitary cell at a given time dependent on related most extreme got flag control. This cell at that point turns into its serving cell. Given the new meanings of CoMP situations as presented before, the reception apparatuses designed as a phone may not be topographically gathered. The term transmission point (TP) would then be able to be utilized to allude to a lot of assembled receiving wires, and a cell can relate to at least one of such TPs. Note that a solitary land site area may contain various TPs if there should be an occurrence of sectorization, with one TP relating to one division. CoMP systems can likewise be characterized in a progressively direct way as the coordination between TPs. CoMP thinks about performed in 3GPP by and large sorted three distinct kinds of CoMP strategies relying upon the required limitations on the backhaul interface between composed focuses and the dimension of booking multifaceted nature. These kinds of CoMP methods can be comprehensively arranged into composed booking and facilitated beamforming (CS/CB), joint transmission (JT), and TP choice (TPS). CS/CB can be portrayed by various facilitated TPs sharing just channel state information (CSI) for numerous UE terminals, while information parcels that should be passed on to a UE terminal are accessible just at one TP. JT can be portrayed by similar information transmission from different facilitated TPs with fitting beamforming loads.

TPS can be viewed as a unique type of JT, where transmission of beamformed information for a given UE terminal is performed a solitary TP each time occasion, while the information is accessible at various facilitated TPs.

Figure 2.5 outlines the standards of CoMP CS/CB, JT, and TPS. A strong red bolt alludes to the solid obstruction acquired by the transmission in a neighboring cell, while specked red lines speak to generally bring down impedance accomplished with coordination. CS/CB decreases the obstruction level experienced by a UE terminal by suitably choosing the beamforming
loads of meddling focuses to direct the impedance toward the invalid space of the meddled UE as spoken to by the spotted red bolt. JT enables at least one neighboring focuses to transmit the ideal flag as opposed to impedance signals from the perspective of the chose UE. TPS empowers UE to be powerfully planned by the most proper TP by abusing changes in the channel blurring conditions. A specked green bolt alludes to a meddling cell that could possibly be transmitting wanted signs to the UE in resulting time allotments. Half and half techniques may likewise be executed in a system to adapt to various kinds of impedance.

Figure 2.5 General classifications of CoMP techniques

2.5.1 CoMP architecture
The classification is depending on the way eNBs perform Inter-Cell Interference Coordination (ICIC) among them. Therefore, two diverse approaches, Centralized and Distributed Coordination is taken into consideration to categorize the CoMP architecture. In Centralized Coordination, with the use of feedback information from different eNBs, it reduces ICI [20]. All administration tasks are controlled through a central unit as shown in Fig. 2.6 a. Advanced resource management and scheduling techniques are executed, and Channel State Information (CSI) along with user information is being
transmitted on the star-like structure to the targeted eNB. Delay factor and large backhaul overhead are the main significant concerns of this design. As it shows in Fig. 2.6 a, a feasible but expensive way to facilitate eNBs is to link them with the central unit via delay-less optical fiber path. A case of Distributed Coordination is represented in Fig. 2.6 b, by utilizing the X2 interface over a meshed based architecture. All neighboring eNBs trade CSI and UE information among them, where the S1 interface is used to link between eNBs and central unit. In this decentralized methodology, out of several eNBs in the cluster, one of the cooperated eNB acts as a master cell which performs all resource management and communication tasks. [21]

![CoMP architecture](image)

**Figure 2.6** CoMP architecture.

### 2.5.2 CoMP scenarios

For both homogeneous and HetNets, diverse situations as introduced in Figure (2.7) proposed by 3GPP are as per the following: The primary situation is Intra-Site CoMP, actualized on a Homogeneous system, in which the single macro cell facilitates numerous eNBs of a similar cell, thusly, backhaul connect necessity for this situation is disregarded. The second situation is Between Site CoMP, as Intra-Site CoMP, it additionally executed on a homogenous net-work. It utilizes High-Power Remote Radio Heads (HP-RRH) so as to improve inclusion region. The third situation is actualized on HetNet and uses Low-Power Remote Radio Heads (LP-RRH) for the development of inclusion. For both second and third situations, it requires fast optical fiber backhaul connection to make the association between the full scale cell and their
particular RRH. CoMP can be composed of numerous perspectives relying upon the distinctive highlights, for example, the backhaul flawlessness, MIMO ability, and DL or UL transmission. [9]

![CoMP scenarios](image)

**Figure 2.7 CoMP scenarios**

### 2.5.3 CoMP types
For LTE-A network system, CoMP technique is intended to mitigate cell interference with better network capacity, especially for cell-edge UEs. Whenever eNB sends information to UE, it applies one of the associated CoMP types depending on the degree of coordination among cells and an active load, even though multiple types of CoMP can also be utilized together. CoMP techniques for the downlink (DL) and uplink (UL) are quite similar but with little difference which results from the fact that the eNBs are in a network, connected to other eNBs, whereas the UEs are individual elements.[22] As shown in Figure 2.8, DL CoMP is divided into ‘Coordinated Scheduling and Beamforming’ (CS/CB) and ‘Joint Processing’ (JP) and UL CoMP is divided into ‘Coordinated Scheduling (CS)’ and Joint Reception and Processing (JR)”.

The techniques used for coordinated multipoint, CoMP are very different for the uplink and downlink. This results from the fact that the eNBs are in a network, connected to other eNBs, whereas the handsets or UEs are individual elements.

2.5.3.1 Downlink LTE CoMP

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

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

  This form of coordinated multipoint places a high demand onto the backhaul network because the data to be transmitted to the UE needs to be sent to each eNB that will be transmitting it to the UE. This may easily double or triple the amount of data in the network dependent upon how many eNBs will be
sending the data. In addition to this, joint processing data needs to be sent between all eNBs involved in the CoMP area.

- **Coordinated scheduling and or beamforming:** Using this concept, data to a single UE is transmitted from one eNB. The scheduling decisions as well as any beams are coordinated to control the interference that may be generated.

  The advantage of this approach is that the requirements for coordination across the backhaul network are considerably reduced for two reasons:

  - UE data does not need to be transmitted from multiple eNBs, and therefore only needs to be directed to one eNB.
  - Only scheduling decisions and details of beams needs to be coordinated between multiple eNBs.

### 2.5.3.2 Uplink LTE CoMP

- **Joint reception and processing:** The basic concept behind this format is to utilize antennas at different sites. By coordinating between the different eNBs it is possible to form a virtual antenna array. The signals received by the eNBs are then combined and processed to produce the final output signal. This technique allows for signals that are very low in strength, or masked by interference in some areas to be receiving with few errors.

  The main disadvantage with this technique is that large amounts of data need to be transferred between the eNBs for it to operate.

- **Coordinated scheduling:** This scheme operates by coordinating the scheduling decisions amongst the eNBs to minimize interference. As in the case of the downlink, this format provides a much reduced load in the backhaul network because only the scheduling data needs to be
transferred between the different eNBs that are coordinating with each other.[23]

Figure 2.9 The JT and CS/CB modes of CoMP

2.5.4 Coordinated Scheduling and Beamforming

So as to decrease impedance between clients at the phone edge, DL CS/CB CoMP characterizes one of the sharing cells as a transmission cell it to interface with clients. The data information of a UE are constrained by the transmission cell just, notwithstanding, when the booking is done among eNBs in the CoMP set, the choice can be made commonly. Contingent on the land area of a UE, making of transmitter shafts is occurred to help the best serving set to the specific UE. While playing out the pillar to-asset portion process, all meddle eNBs together make sense of the most ideal way which can ready to improve flag quality while keeping the obstruction level at least. So starting here of view, CS/CB can be expressed as ICIC – CoMP, since it is the blend of two areas: ICIC part, for complex counteracting impedance and CoMP part, with respect to exacting coordination. There are a wide range of parameters proposed in the writing to satisfy the coordination procedure. An exceptionally fundamental yet compelling route is to utilize the SINR of a serving UE as a criticism flag. The fundamental detriment of utilizing it is that it builds the flag over-head estimate in uplink which makes delay amid
information transmission. Straight Pre-coding, a successful methodology is utilized to upgrade the execution in downlink and to limit the flag overhead among eNBs. This should be possible by describing the transmission channel by utilizing predefined pre-coding lattices. So as to choose the favored framework, CQI and MIMO Rank Pointer (RI) are accounted for by clients alongside Pre-coding Metric Record (PMI), which is expressed in the codebook network. RI shows the MIMO situating, which characterizes the quantity of data pillars required to transmit information in parallel over the transmission channel. As indicated by the got PMI report, which contains CSI of serving and interferes eNBs, the best CQI is determined for the UE and a criticism flag is utilized to screen the channel way from the serving eNB and UE. By and large, CS/CB are additionally separated in two essential part for example Facilitated Booking (CS) conspire and Composed Beamformng (CB) scheme.

Coordinated Planning plan The fundamental idea of CS-CoMP is comparable like ICIC which was a discharge 8 standard for LTE 3GPP. The fundamental working of ICIC is that lone two cells convey each other to make sense of the most ideal approach to dispense assets for the cell-edge clients with smaller than normal mum obstruction. This was finished by relegating different recurrence resources Asset Square (RB) to cell-edge clients, however soon it was not considered as a proper arrangement of obstruction.

Figure 2.10. Almost blank sub-frame technique for HetNet
3GPP Discharge 10 standard tended to this issue with some headway for example improved ICIC (e-ICIC) for HetNet, which works in both time and recurrence spaces. In the time space, as appeared in Fig. 2.10, the idea of Practically Clear Subframe (ABS) was presented. The thought is, right off the bat a full scale cell transmit clear sub-edges to the specific UE, at that point a little (femto/pico) cell can transmit their data pointed such casings to keep away from impedance. For the recurrence area alleviation conspire, cross-transporter booking is most normal and regularly utilized in con-intersection with bearer accumulation in the Essential cell (P-Cell). This P-Cell contains control channel named Physical Downlink Control Channel (PDCCH) and Physical Uplink Control Channel (PUCC). It likewise has shared channel called Physical Downlink Shared Channel (PDSCH) and Physical Uplink Shared Channel (PUSCH) including at least one optional cell (S-Cell) which contain just shared channel. Both large scale and little cell use P-Cell and S-Cell on various frequencies in this way helping it to moderate the impedance got from the control and information channel. From a viable execution perspective, CS-CoMP is a progressively prestigious development which outflanks the e-ICIC conspire with its shorter preparing time and less intricate calculation. Anyway e-ICIC, organizing cells offer impedance information of each cell, however in CS-CoMP they can convey channel information for each UEs. At first, sharing periods in CS-CoMP were significantly lesser than in e-ICIC, in spite of the fact that in e-ICIC, the measure of each sharing period is in many milliseconds. In this manner, when e-ICIC coordination results are updated, its booking relies upon the result for quite a while. On the other hand, in CS CoMP, with around 1-millisecond sharing period, new CS collaboration results are associated at each time interim when planning is executed. In this manner, assets can be without further ado conveyed even with brief changes in the state of clients channel. Further, in CS-CoMP, organizing cells offer a progressively noticeable proportion of information appeared differently in relation to those in e-ICIC. In e-ICIC, genuinely direct information like obstruction level and radio square data is shared.
Notwithstanding, CS-CoMP just offers client channel information (CQI, PMI, RI, SINR) among UEs and their partaking cells.

The CS-CoMP conspire is delineated in Figure 2.11 where clients A1 and A2 who are available at the cell-edge, are utilizing distinctive recurrence asset f3 and f2 separately, which will diminish impedance and improve client's ability. The two clients get signals from the different eNBs yet not meddling with one another because of various planning plan. There are a few proposals proposed in the writing for CS-CoMP to alleviate the issues like impedance taking care of, less cell-edge throughput, poor reasonableness among clients and low system execution gain. Following are some conceivable arrangements proposed to relieve these issues.

2.5.5 Interference handling

Interference is the most startling issue of CS-CoMP which not only decreases the UE’s data rate but also reduces the overall network throughput. To counter this, there are different strategies proposed in the literature. One of the most renowned techniques of CS-CoMP is Multi-cell PMI that can help to reduce the interferences and power the cooperation between neighboring cells. In PMI coordination, each UE transmits continuous information to the serving cell which is chosen according to the PMIs list. Good PMI and Bad PMI have been selected, when UEs reports the least and most interference PMIs from neighboring cell respectively. X2- the interface
is used to send a signal to communicate with the neighboring cell’s PMI for diminishing of interference as shown in Figure 2.12.

![Figure 2.12 PMI coordination to reduce interference.](image)

At that point, each eNB chooses pre-coding matrices (i.e. the best path) in such way that the UE can able to enhance information signal and degrade the interference signal.

CoMP technology is one of the promising technologies in LTE-Advanced. We can summarize its main advantages as:
1. Base stations coordination is considered as an efficient solution to increase the average data rates and signal level in the UE which increase the total system capacity as well.
2. Interference mitigation, coordination between base stations converts undesired signals in conventional networks into useful signals that enhance the total throughput.
3. Network utilization, BSs that are exchanging the channel information using CoMP can send the data streams through the BS which has the lowest traffic load.

4. Enhancing the spectral efficiency, cell edge UEs spectral efficiency will be increased after applying CoMP due to receiving desired signals from more than one BS, as a result the number of dropped calls will decrease.

2.6 Related Works

In [13], the authors focus on downlink multi-point coordinated beamforming (CoMP-CBF), and study a particular multi-stream beamforming scheme. They also present detailed system level performance evaluation of the proposed scheme against a reference LTE Rel.8 non-cooperative scheme, which shows that CoMP-CBF transmission could achieve significant gains on both the average and the cell-edge user throughputs.

In [5], the authors characterize the SINR distribution when coordination multipoint is used and discuss some practical design problems. The main result of this work is that the SINR is increasingly improved, when the number of BSs increases in a ball with a fixed radius. Therefore the gain of cooperation, in terms of coverage, increases with the path-loss exponent.

In [8], the authors proposed the downlink CoMP-MU-MIMO transmission scheme for LTE-Advanced systems and present some performance evaluation which shows that Coordinated Multi-Point transmission/reception (CoMP) is one of the candidate techniques for LTE-Advanced systems to increase the cell average and cell edge user throughput.

In [12] the authors described uplink CoMP-MU-MIMO scheme and done system level performance evaluation for LTE-Advanced system. From the simulation results, we can see that CoMP-MU-MIMO is one of the candidate techniques for LTE-Advanced systems to increase both the average sector
Throughput and the cell edge user throughput. More cells jointly processed, bigger performance gains achieved, however, more complexity and more burdens on the backhaul are introduced. Further work is to estimate the time delay from UE to the multiple cells and to evaluate its impact on the CoMP performance.

In [14] the authors discussed CoMP techniques and the target deployment scenarios being considered as part of the LTE-Advanced radio technology standard development. Evaluation studies have shown that CoMP can greatly improve the cell-edge user experience. Similar conclusions were made in the LTE Advanced CoMP study item report, where CoMP performance benefits were observed in both homogeneous and heterogeneous networks the interest for the CoMP technology is expected to grow as new network topologies (e.g., heterogeneous networks) and geographically distributed antennas for single logical cell further demand solutions for interference mitigation. Lower cost radio nodes, improved backhaul connection links, faster processors at the base stations as well as user terminals, now allow CoMP to be considered as a viable technology for practical implementation and deployment.

The authors in [15] describes an overview of the key component in CoMP which includes architectures, scenarios, and approaches that can be employed in the future network. It also presents some well-known CoMP types with their practical challenges and possible solutions which can be considered as a major aspect of the LTE-A radio innovation standard development. Comprehensive literature shows that CoMP can incredibly enhance the cell-edge user’s throughput with better overall system capacity by dealing the interference exclusively. Comparative conclusions were made, where CoMP performances were analyzed for both perfect and non-perfect backhaul systems. The eagerness for the CoMP innovation is relied upon the development of new system networks (e.g., HetNets) and geographically distributed antenna are dependent on more advanced interference mitigation techniques. Lower cost radio nodes,
enhanced backhaul network path, high synchronization, low complexity and feedback accuracy among UEs as well as eNBs are allowing CoMP to be considered as a suitable innovation for practical deployment and implementation.

In [16] the authors investigated several CoMP schemes by combining flow-level analysis with network simulations. They evaluated the performance in terms of average user throughput achievable under different traffic intensities. Results with non-ideal beams showed that intra-site coordination achieves significant gains over the blind beamforming system and particularly the enhanced joint transmission scheme which improves the throughput as well as the system stability since each sector can help its neighbors while serving its own users. This can not the case with ideal beams, since intra-site interference is naturally avoided.

Cell edge users have always experienced degraded service due to two main factors: their distance to the cell tower and signal interference. To improve the user experience on the cell edge, LTE release- 10 introduced decode-and-forward relays to improve the user throughput on the edge. These specific types of Relay Nodes (RNs) are small nodes with low power consumption and do not suffer from limitations such as loop back interference between transmit and receive antennas LTE release- 11 introduced the concept of cooperative Multiple-Input and Multiple-Output (MIMO) also known as CoMP in which users are served by a group of BSs in a cooperative manner. [17]

A low-complexity resource allocation strategy in CoMP that aims to achieve high network throughput is presented. The resource allocation strategy consists of three modules which are performed sequentially; user allocation module, subcarrier allocation module and power allocation module. Our simulation study shows that the proposed strategy gives significant performance gain in CoMP LTE-Advanced network. the low-complexity resource allocation strategy for CoMP LTE-Advanced network is presented. The proposed strategy consists of
three modules; user selection module, subcarrier allocation module and power allocation module which are performed sequentially. The strategy exploits frequency and spatial diversities offered by the time-varying wireless channels to accomplish network performance gain. Simulation study shows that the proposed strategy enhances network sum-rate up to 36%, while reduces the average BS transmit power down to 24% compared to OPO strategy. [18]

Users located on the cell edge suffer from low data rates due to interference and poor reception. The Coordinated Multipoint technology targets this problem but it imposes over-head on the network, which can result in degradation of the Quality of Service. The Direct CSI feedback to Elected Coordination station architecture minimizes such overhead, resulting in improved data rates. Here, we analyze the performance of DCEC, Centralized, and Distributed control architectures for LTE-Advanced mobile networks in urban areas showing the advantages of the approach.

We presented new results highlighting the potential of the DCEC control architecture. The simulation results show that DCEC reduces the number of CSI feedback messages, resulting in lower delay and higher data rates. [19]
CHAPTER 3

Methodology
CHAPTER THREE
METHOTOLGY

3.1 Joint transmission

JT is one of the unique and efficient CoMP technique in which multiple cooperation cells altogether share UE information at the same time. Typically, in HetNets and small cell networks, users face more interference from neighboring cells. Therefore JT is a much-highlighted technique to enhance network capacity and user throughput. According to the preceding approach, JT is further divided into two types i.e. Coherent JT(CJT) and Non-Coherent JT(NCJT) [24].

CJT allow the receiver to achieve coherent combining of the transmission and jointly pre-codes transmissions procedures at multiple TPs. Each cooperating BSs receives CSI sent by a UEs which comprising of CQI, wideband RI and favored PMI. All eNBs mutually handle PMI-to-asset assignment and send it to the particular UE. This is because multi-cell precoding coordination is achieved among interferer eNBs which subsequent a distinct pre-coder for every communicating end of CoMP set.

While in NCJT, each TP pre-codes the transmission matrix independently therefore only a power gain is available to the receiver. Each eNBs receive CSI from UEs, which comprises of wideband RI and Sub-band CQI. It mainly focuses on increasing the diversity gains by utilizing the Cyclic Delay Diversity (CDD) or Single Frequency Net- work (SFN) plans.

In JT, transmission cells have been selected among coordinating cell, in order to provide better reception quality to the cell- edge users [25]. Various cells can transmit the similar information simultaneously by utilizing the similar time and frequency radio assets.

3GPP has released the two main architectures for JT-CoMP i.e. Intra-eNB and Inter-eNB.

In Intra-eNB, the transmission cells are located in the same eNB, and it is controlled by single Digital Unit (DU). It typically uses coherent transmission
mode in which, cell A and cell B cooperates with each other to allocate the same frequency resource (f3), same time resource (Subframe #n) to user A1, and share the same data (as shown in Fig. 3.1). In other words, user A1 receives the same data from Cell A and Cell B concurrently approaching from Serving Gateway (S-GW) to DU, then DU to Radio Units (RU1 and RU2) by allocating the same frequency and time resources.

While in Inter-eNB, transmission cells are present in different BSs and controlled by various DUs. According to the scheduling technique, it is subdivided into distributed and centralized coordination [26]. If scheduling and RB allocation process perform separately at the TP, the network is said to be in distributed coordination. It uses non-coherent transmission mode, and all precoding and scheduling (at CoMP coordinator) for Cell A and Cell B is processed separately at DU1 and DU2 respectively (as shown in Fig. 3.2).
Each CoMP coordinator is directly linked together via X2 interface, and the user data is routed from DU1 to RU1 (Cell A) and DU2 to RU2 (Cell B) simultaneously. However, in centralized coordination, each DU is controlled by a single CoMP coordinator, but user data transmission is same as in distributed coordination (as shown in Fig. 3.3) [27].

3.2 Simulation Scenario

Figure 3.4 shows the operating principle of CoMP (JT) in the downlink. In the CoMP (JT) transmission scheme, multiple eNBs in the network cooperatively transmit signals to a user-end terminal (UE). The main idea of this class of
transmission scheme is either to improve the received signal quality or actively cancel the interference to other UEs, or both. Data intended for a UE is shared and jointly transmitted from all eNBs in the CoMP network and the received signals at the UE will be coherently or non-coherently added up together. 

**Figure 3.4** Downlink CoMP (JT)

### 3.3 Mathematical Model of Performance Method

In this scenario we use Joint Transmission in downlink to measure the improvement in performance metrics for one user in cell-edge area and can be located at two base stations. Collected data about it and also mathematical equations which calculate the performance metrics of CoMP system after that we will evaluate by means of simulation code by using Matlab Program to calculate performance metrics of system such as data rate, throughput, spectral efficiency, delay, & SINR utilization with and without coordination scenarios. In without coordination our scenario contains Only (eNBs) that serves to one mobile station(UE), while the scenario of coordination of BS , the system have two eNBs to serve one UE. Both with &without coordination we calculate performance metrics.

#### 3.3.1 Signal Interference Noise Ratio

The signal to interference noise ratio is defined as the power of a certain signal of interest divided by the sum of the interference power (from all the other
interference signals) and the power of some background noise. In equation (3.1) calculate the SINR.

\[
\text{SINR} = \frac{P_{Rx1}}{P_{Rx2} + P_{N1}} \quad (3.1)
\]

- \( P_{Rx1} \) refers to the UE received power from eNodeB1
- \( P_{Rx2} \) refers to the UE received power from eNodeB2
- \( P_{N1} \) is the noise power at eNodeB1

As illustrated in Figure 3.4, assume that UE 1 is receiving signals from Cell 1 and Cell 2. In equation (3.2) calculate the SNR with Joint Transmission in downlink.

\[
\text{SNR}_{\text{CoMP}} = \frac{P_{Rx1} + P_{Rx2}}{P_{N1}} \quad (3.2)
\]

### 3.3.2 Data Rate

Required data rate is the main performance indicator for LTE. Cell edge is defined according to the Required SNIR for a given cell throughput. Data is every number of bits per unit time of a cell signals and have relation between these parameter SNR, coding, modulation and bandwidth, when any parameter of these increase the data are also increased as shown in Equation (3.3).

\[
\text{DR} = B \times R_c \times \log M \quad (3.3)
\]

Where:
- \( \text{DR} \) is Date Rate,
- \( B \) is Bandwidth
- \( R_c \) is Code Rate
- \( M \) is Logarithm of actual data rate.
They have a relation between the modulation and coding shows in a table 3.6

Table 3.1 Standard SNR, Modulation and Coding table

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Coding Rate</th>
<th>Receiver SNR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>½</td>
<td>6.4</td>
</tr>
<tr>
<td>QPSK</td>
<td>½</td>
<td>9.4</td>
</tr>
<tr>
<td>QPSK</td>
<td>¾</td>
<td>11.2</td>
</tr>
<tr>
<td>QAM-16</td>
<td>½</td>
<td>16.4</td>
</tr>
<tr>
<td>QAM-16</td>
<td>¾</td>
<td>18.2</td>
</tr>
<tr>
<td>QAM-64</td>
<td>½</td>
<td>22.7</td>
</tr>
<tr>
<td>QAM-64</td>
<td>¾</td>
<td>24.4</td>
</tr>
</tbody>
</table>

3.3.3 Throughput

The system throughput is the sum of data rates and essentially its bandwidth consumption as shows in Equation (3.4).

\[
TH = \sum B \times Rc \times \log M \quad (3.4)
\]

Where:

TH is Throughput

B is Bandwidth,

Rc is Code Rate

Log M is Logarithm of actual data rate

3.3.4 Spectral Efficiency

Spectral efficiency also called bandwidth efficiency refers to the data rate that can be transmitted over a given bandwidth in specific communication system shows in Equation (3.7). It is a measure of how efficiently a limited frequency spectrum is utilized by the media access control.
Information rate transmission over a given bandwidth, in wireless networks or cellular systems, the system spectral efficiency in bit/s/Hz/area unit, bit/s/Hz/site or bit/s/Hz/cell, is the maximum system throughput (aggregate throughput) divided by the analog bandwidth and some measure of the system coverage area.

\[ S = R_c \times \log M \quad (3.5) \]

Where:
- \( S \) is spectral efficiency
- \( R_c \) is code rate
- \( \log M \) is logarithm of actual data rate.

### 3.3.5 Delay

Delay is an important design and performance characteristic of a computer network or telecommunications network, the delay of a network specifies how long it takes for a bit of data to travel across the network from one node or endpoint to another, it is typically measured in multiples or fractions of seconds. Delay may differ slightly, depending on the location of the specific pair of communicating nodes. Delay is also called Latency refer to the total time of transmit a specific size of Data in Bit, can be measured by using Equation (3.6).

\[ D = \frac{N}{R} \quad (3.6) \]

Where:
- \( N \) is the number of bits
- \( R \) is the Data rate.
3.4 Simulation Parameters

The equations of this research are applied in MATLAB simulation to get results with constant parameter in this simulation show in Table (3.2).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW of eNB1</td>
<td>20 MHz</td>
</tr>
<tr>
<td>BW of eNB2</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Noise</td>
<td>2dB</td>
</tr>
<tr>
<td>Power gain</td>
<td>2dB</td>
</tr>
<tr>
<td>data</td>
<td>2</td>
</tr>
<tr>
<td>Interference by eNB2</td>
<td>25 dB</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK, 16QAM, 64QAM</td>
</tr>
<tr>
<td>Receiving Power from eNodeB1</td>
<td>Randi[10 20]</td>
</tr>
<tr>
<td>Receiving Power from eNodeB2</td>
<td>Randi[15 25]</td>
</tr>
<tr>
<td>Interference by eNB2</td>
<td>10 dB</td>
</tr>
<tr>
<td>Number of UEs</td>
<td>1</td>
</tr>
<tr>
<td>Antenna Height</td>
<td>30 m</td>
</tr>
<tr>
<td>User Height</td>
<td>0.5 m – 10 m</td>
</tr>
</tbody>
</table>
CHAPTER 4

Result And Discussion
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 The Performance Metrics

This chapter presents a part of the simulation results obtained by running the Matlab code program. The results include the performance metrics like SINR, delay, throughput….etc.

4.1.1 Signal to Noise Interference Ratio result

The figure 4.1 shows the signal to interference noise ratio (SINR) for the red curve represents the SINR with (JT) CoMP the SINR is fluctuated between 20 dB and 25 dB. while the other green curve represents the SINR without CoMP, SINR is fluctuated between 0.9 dB and 0.7 dB, From the comparison the signal to noise interference ratio increase than without coordinated signal to noise interference ratio, this increase due to the signal is shared between eNBs to send the frame for one user that mean the power of signal is double when compared with one eNB.

Figure 4.1 Compared SINR Signal Between With and Without (JT) CoMP
4.1.2 Data Rate result

The figure 4.2 shows the data rate for the green curve represents the data rate without (JT) CoMP, data rate fluctuated between 10 Mbps and 25 Mbps, data rate is affected by bandwidth, code rate and actual data rate according to the SNIR value. While the other red curve represents the data rate with CoMP, the data rate is fluctuated between 90 Mbps and 250 Mbps, these increases due to the rate send from two eNBs it adds together by summation method for one user.

![Figure 4.2 Compared Data Rate Between With and Without (JT) CoMP](image)

Figure 4.2 Compared Data Rate Between With and Without (JT) CoMP
4.1.3 Throughput result

Figure 4.3 illustrates accumulative throughput thus the green curve represents the throughput without (JT) CoMP, the throughput is reach 200Mbps in 0.2S and the other red curve represent the throughput with (JT) CoMP is increase to 500Mbps. the results in figure 4.3 below represent the throughput performance of the considered system with using (JT) CoMP is outperforming than the accumulative throughput performance without (JT) CoMP because the increase in Data Rate.

**Figure 4.3** Compared Throughput Between With and Without (JT) CoMP
4.1.4 Spectrum Efficiency result

Figure 4.4 explains the spectrum efficiency for the considered system with and without using (JT) CoMP. The results demonstrate that first red curve represent the spectrum efficiency of the scenario (JT) CoMP while the green curve represent the spectrum efficiency without (JT) CoMP. The results show the effective spectrum efficiency is improvement than the effective spectrum efficiency without (JT) CoMP deployment because the increase in Bandwidth.

![Figure 4.4 Compared Spectrum Efficiency Signal Between With and Without ( JT) CoMP](image-url)
4.1.5 Delay result

Figure 4.5 explains the delay for the system with (JT) CoMP and without (JT) CoMP. The results illustrate that the red curve represent the delay with (JT) CoMP while the other green curve represent the delay with (JT) CoMP. The results represent the delay after (JT) CoMP is decreased than the delay before (JT) CoMP with because of the increasing in Data Rate.

Figure 4.5 Compared Delay Signal Between With and Without (JT) CoMP
4.2 Discussion

The simulation using mat-lab code calculate the signal to noise ratio (SNR), data rate, throughput and spectrum efficiency, delay between system with (JT) CoMP and another without (JT) CoMP.

The purpose of this project is to present a study on performance of LTE-Advanced feature referred as (JT) CoMP. In (JT) CoMP scheme, The results of the throughput is increased and delay time is decrease than without (JT) CoMP, Also (JT) CoMP increases data transmission rates, increases SINR and the spectrum efficiency also improved.
CHAPTER 5

Recommendations And Conclusion
CHAPTER FIVE
Recommendations and Conclusion

5.1 Research challenges

1. **Backhaul aspects**: Most BS cooperation schemes require information exchange over a backhaul infrastructure. Depending on the existing infrastructure of a mobile operator, both backhaul capacity and latency requirements of some CoMP schemes may be the principle cost drivers on the roadmap towards CoMP.

2. **Synchronization**: While utilizing the JP, data and UEs information sharing among eNBs are the continuous task which required highly accurate and precise synchronization among them. In order to minimize CCI and ICI, all neighboring eNBs must be synchronized in both time and frequency domain. Because of the several propagation delays on various terminals of eNBs, it leads struggle with the guard interval. This perspective might overcome through some fast packet buffer or exotic equalizer.

3. **Complexity**: Computational complexity always becomes a serious problem while it comes to the scheduling algorithm processing. It does not only increase the signal overhead delay but also decreases the overall network performance. Various significant enhancements are being considered, but still, Single Carrier FDMA (SC-FDMA) scheme suffers more complexity due to the enabling of MIMO equalization and additional sub carrier. More improved computational algorithm by using fewer reference parameters need to be designed to reduce complexity.

4. **Additional overhead**: exchanging the data CSI via the backhaul requires greater link capacity. More signaling overhead is required on air interface and through the backhaul.
5.2 Recommendations

This research explored high data rate and spectral efficiency by using coordinated multipoint transmission and reception for LTE-advanced network. There are some remaining issues can be continued as future research activities these include:

- Use another scenario to get different results by change parameters (number of BTS, height of antenna).
- Evaluating CoMP challenges, such as synchronization, backhaul, and Complexity.
- Evaluating CoMP practical network efficiency using Coordinated Scheduling/Beamforming scheme.
- Compare between CS/CB CoMP and (JT) CoMP in performance.
- Investigating the linear preceding methodology in CoMP and how can we decrease its complexity.

5.3 Conclusion

In this research, shown the performance metrics for one user to improve the signal received by user in the cell-edge from two base stations, to achieve this purpose (JT) CoMP technique is used. Evaluation studies have shown that (JT) CoMP can greatly improve the cell-edge user experience. Also (JT) CoMP increases SINR, data transmission rates is developed, the throughput is progressed, the spectrum efficiency also improved and delay was decreased. These results used MATLAB simulation.
References

[14] Volker Jungnickel, Konstantinos Manolakis, Wolfgang Zirwas, Panzner, Volker Braun, Moritz Lossow, Mikael Sternad Rikke Apellfröjd, and Tommy Svensson, LTE-Advanced systems are built upon the orthogonal frequency division multiple access (OFDMA) Technology.
[16] Analytical Modeling of Downlink CoMP in LTE-Advanced/ Ahlem Khlass Orange Labs & Telecom ParisTech France/ ahlem.khlass@orange
[18] Modeling Coordinated Multipoint with a Dynamic Coordination Station in LTE-A Mobile Networks Gabriel Wainer, Mohammad Etemad, Baha Uddin Kazi Dept. Systems and Computer Engineering Carleton University, Ottawa, ON, Canada {gwainer, mohammadetemad, bahauddinkazi}@sce.carleton.ca.
[19] RESOURCE ALLOCATION FOR DOWNLINK COORDINATED MULTIPORT (CoMP) IN LTE-ADVANCED/ Norshidah Katiran1, Norsheila Fisal2, Aimi Syamimi Abdul Ghaffar3, Siti Marwangi and Mohamad Maharum2 .
Appendix

%%% matlab code of COORDINATED MULTIPOINT TRANSMISSION AND RECESSION CoMP in LTE-A BY eng.yosif

clear all,clc, close all
Bw1=20;
Bw2=20;
Fc=500; %kHZ
hB=30; %meter
hM=2;%meter
Pt=30; %power tx(dB)
G=2; %power gain(db)
data=2; %the data 2k bps
N=2;
Result=zeros(10,12);
pr1=randi([10 20],1,10);
pr2=randi([20 30],1,10);
I1n=25;
I2n=10;
SNR1=(pr1+G)/(I1n+N)
SNR2=(pr2+G)/(I2n+N)
SNR3=(((pr1+G)+I1n)/N);
for n= 1:10
    time= n * 0.02;
    Result(n,1)=time;
Result(:,2)=SNR1
Result(:,3)=SNR2
Result(:,4)=SNR3
if ( SNR1(n) >=.43 & SNR1(n) < .49 )
    M1(n)=1;
    C1(n)=0.5;
elseif ( SNR1(n) >=.49& SNR1(n) < .57)
    M1(n)=1;
    C1(n)=0.5;
elseif ( SNR1(n) >=.57 & SNR1(n) < .66)
    M1(n)=2;
    C1(n)=0.5;
elseif ( SNR1(n) >=.66 & SNR1(n) < .75 )
    M1(n)=2;
    C1(n)=0.5;
elseif ( SNR1(n) >= .75 & SNR1(n) < .82 )
    M1(n)=2;
    C1(n)=0.75;
end;
DR1(n)=Bw1*M1(n)*C1(n);
DR1(n)=DR1(n);
Result(n,5)=DR1(n);
if ( SNR3(n) >=18.4& SNR3(n) < 19.5)
    M2(n)=4;
    C2(n)=0.5;
elseif ( SNR3(n) >=19.5 & SNR3(n) <20.4 )
    M2(n)=4;
C2(n)=0.5;

elseif ( SNR3(n) >=20.4 & SNR3(n) <21)
    M2(n)=4;
    C2(n)=0.75;
elseif ( SNR3(n) >=21 & SNR3(n) <21.8)
    M2(n)=6;
    C2(n)=0.5;
elseif ( SNR3(n) >=21.8 & SNR3(n) <23.6)
    M2(n)=6;
    C2(n)=0.75;
end;

DR3(n)=(Bw2+Bw1)*M2(n)*C2(n);

%DR
Result(n,5);
Result(n,6)=DR3(n)

%TH
Result(1,7)=DR1(1)
Result(1,8)=DR3(1)
if n >= 2
    Result(n,7)=Result(n-1,7)+DR1(n)
    Result(n,8)=Result(n-1,8)+DR1(n)
end

%SE
Result(n,9)=DR1(n)/Bw1
Result(n,10)=DR3(n)/Bw2

%DELAY
Result(n,11) = data/(DR1(n))
Result(n,12) = data/(DR3(n))
end;
Result(:,9)

%***************************************SNIR
semilogy(Result(:,1),Result(:,2),'g*-')
hold on
semilogy(Result(:,1),(Result(:,4)),'r*-')
grid
xlabel('time in s')
ylabel('SNR in dB')
title('SNR VS TIME')
legend('SNR ','SNR with (JT) CoMP ')

%**************************data rate
figure
semilogy(Result(:,1),Result(:,5),'g*-')
hold on
semilogy(Result(:,1),Result(:,6),'r*-')
hold on
grid
xlabel('time in s')
ylabel('data in Mpbs')
title('data rate vs time')
legend('data rate ','data rate with (JT) CoMP ')

%**************************throughput
figure
semilogy(Result(:,1),Result(:,7),'g*-')
hold on
semilogy(Result(:,1),Result(:,8),'r*')
axis([.02 .22 0 10^3])
hold on
grid
xlabel('time in s')
ylabel('throughput in Mbps')
title('throughput vs time')
legend('throughput ','throughput with (JT) CoMP')
%***********************spectrum efficiency
figure
semilogy(Result(:,1),Result(:,9),'g*')
hold on
semilogy(Result(:,1),Result(:,10),'r*')
axis([.02 .22 0 12])
grid
xlabel('time in s')
ylabel('spectrum efficiency in bph')
title('spectrum efficiency vs time')
legend('spectrum efficiency ','spectrum efficiency with (JT) CoMP')
%**************************Dealy
figure
semilogy(Result(:,1),Result(:,11),'g*')
hold on
semilogy(Result(:,1),Result(:,12),'r*')
grid
xlabel('time in s')
ylabel('Delay in s')

title('Delay vs time')

legend('Delay','Delay with (JT) CoMP')