Declaration of Authorship

This is to confirm that the study given in this dissertation is the result of the author's assessment and experimentation; Tahmina Khanom Tandra, Fehima Tajrian, and Afia Hossain, under the supervision of Dr. Mohammad Tawhid Kawser, Professor, Department of Electrical and Electronic Engineering, Islamic University of Technology (IUT), Dhaka, Bangladesh. It has also been proclaimed that no portion of this project has been presented anywhere else for any degree or certificate. A list of references has been included in the narrative to recognize the use of materials from various sources, both published and unpublished.

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Impact of Joint Transmission (JT) Coordinated Multipoint (CoMP) on Mobile Users in 5G Heterogeneous Network

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List of Acronyms

3GPP	3rd Generation Partnership Project
1G	1st Generation
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
5G	5th Generation
FDMA	Frequency Division Multiplexing Access
TDMA	Time Division Multiplexing Access
OFDMA	Orthogonal Frequency Division Multiplexing Access
CDMA	Code Division Multiple Access
LTE	Long Term Evolution
gNB	Next Generation Node B
eNB	Evolved Node B
MIMO	Multiple Input Multiple Output
PS	Packet Switching
CS	Circuit Switching
HetNet	Heterogeneous Network
HomNet	Homogenous Network
SNR	Signal-to-noise-ratio
SINR	Signal-to-interference-plus-noise-ratio
BS	Base Station
UE	User Equipment
CDP	Call Dropping Probability
HDP	HandoVER dropping probability
CoMP	Coordinated Multipoint
UDN	Ultra Dense Network
IoT	Internet of Things

List of Acronyms

JT	Joint Transmission
IP	Internet Protocol
IMSI	International Mobile Subscriber Identity
GPS	Global Positioning System
D2D	Device to Device
ULL	Ultra Low Latency
TDD	Time Division duplexing
NOMA	Non Orthogonal Multiple Access
UWB	Ultra Wideband Spectrum
mmWave	Millimeter Wave
FWA	Fixed Wireless Access
MEC	Multi-access Edge Computing
NFV	Network Function Virtualization
ICI	Inter Cell Interference
CLSM	Closed Loop Spatial Multiplexing
RR	Round Robin
ClIP	Control Link on Uplink Power
HCP	Handover Control Parameters
SON	Self Optimatization Network
PUSCH	Physical Uplink Control Channel
DL	Downlink
ZF	Zero Forcing
CQI	Channel Quality Indicator
CSI	Channel State Information
PMI	Precoding Matrix Index
DC	Dual Connectivity

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We want to express our grateful appreciation for **Professor Dr. Mohammad Tawhid Kawser**, Department of Electrical and Electronic Engineering, Islamic University of Technology (IUT), Dhaka, Bangladesh. This study would not have been accomplished without his help and supervision. Throughout our thesis work, he offered us excellent advice, time, and insight, all of which helped us complete the assignment in a timely manner. We are grateful to him.

Abstract

The vision to ensure ubiquitous connectivity with ultra-reliable low latency, inconceivably high data rate, and support a myriad of data-hungry devices is foreseen with the widespread rollout of the 5G network. Ensuring seamless connectivity at the cell edge amidst the significant prevalence of Intercell Interference (ICI) and path loss proves to be complicated. In addition, the impact of mobility poses particular challenges to the wireless network and the high frequency of 5G networks limits the coverage area. With increase in UE mobility, Doppler effect becomes significant enough to impair the mean data rate and induce call drops. Joint transmission Coordinated (JT CoMP) is a promising ICI mitigation technique where several eNBs coordinate to create a virtual antenna array and transmit downlink (DL) data simultaneously to serve the UEs with strong radio signal links. The transmitted signals from the coordinated eNBs act as the desired signal for the UEs, reducing the interference of undesired signals. This paper examines the influence of JT CoMP technology on user velocities by incorporating closed loop spatial multiplexing (CLSM) into the Heterogenous Network (HetNet) with the aim of improving signal reception at cell edge and minimizing the effect of ICI for mobile users. To realize the effectiveness of inter-site and intra-site JT CoMP schemes in ICI mitigation and boosting cell edge throughput for mobile users in HetNet, the simulation was conducted for HetNet with CoMP and non-CoMP deployment. With the proliferation of UE velocity, the performance of CLSM degrades and less detailed feedback is reported. On the contrary, the simulation results reveal that CLSM integrated intrasite based JT CoMP offers better signal reception for low velocities and intersite based JT CoMP provides better throughput at high velocities.

Chapter 1

Introduction

1.1 Overview

Transmission across a distance without the need of "wires" or upgraded electrical conductors is known as wireless communication. Shorter (a few meters, as with a television remote control) or lengthy lengths might be included (thousands or millions of kilometers for radio communications). Since the early 1970s, the mobile wireless business has been creating, revolutionizing, and evolving its technologies. There has been an explosion in mobile phone use since the mid-1990s. [1] Voice calls were only possible on the first generation (1G) of mobile wireless networks. Text messaging is supported by the second generation (2G) of digital technology. Enhanced data transfer, expanded capacity, and audiovisual support were all offered by the third generation (3G) of mobile innovation. The fourth generation (4G) combines 3G and stationary internet to offer wireless mobile internet, which is a development in mobile technology and overcomes the limits of 3G. Increases bandwidth and lowers the cost of resources are also a benefit. The term "5G" refers to the latest upheaval in mobile technology, which has altered how people may use their phones at very high bandwidths. 5G technology is one of the most powerful and will be in greater demand in the near future, and users have never encountered such high-value technology prior.

Figure 1.1: Evolution of Mobile Technology.

To better serve customers, fiber and wireless infrastructures will be more closely integrated, resulting in higher QoS and more nimble resources deployment. There is a specialized topology in conventional networks where a network function correlates to a certain kind of equipment. To accommodate new capabilities, new specifications must be implemented, which results in a lengthier development period and greater customization costs since the equipment operates in closed-source. Wireless system performance is affected by mobility since most of the time users are moving around. As the subscriber goes from one cell to the next cell, the UE must be supplied by the new cell, which necessitates handover. Handover raises network demand as signaling overhead grows. The rising demand for wireless communications has necessitated the expansion of wireless network capability. Due to the restricted quantity of accessible spectrum, cell sizes have been reduced in order to enhance spectrum utilization and subsequently wireless network capacity. Nevertheless, the handover rate, the average number of handovers per unit time, rises as cell size and mobility decrease. [2]

Challenges in 5G:

- **Integration of numerous standard:** Standardization is one of the greatest problems for 5G. Several organizations are actively attempting to develop protocols for interoperability, backward compatibility with existing networks (4G, 3G), and future-proofing of the infrastructure.

- **Common Platform:** In terms of linking engineering processes, there is no standard architecture. It is necessary to establish a single regulatory organization that will serve as a common platform for the regulation of interconnection concerns and the exchange of information.

- **Obstacles:** Trees, terrible climate, and even skyscrapers may all conflict with one other. Carriers will need to construct additional base stations and employ antenna technologies like MIMO in order to counteract this.

- **Installation and Administration of Complicated Networks has Become More Difficult:** Low electromagnetic thresholds in combination with the high density of low-powered gNBs; mm-wave technologies; frequency chunks' accessibility; reforming; the technology alternatives for fronthaul and backhaul; and the intensively variable radio environment, make access network planning and deployment exceedingly difficult or even impossible in some cases.

- **Issues Related to Spectrum:** A variety of radio frequency bands are used to achieve quality, reliability and accessibility in the 5G network. One of the most pressing issues is the distribution and administration of spectrum resources small cell infrastructures will continue to need huge amounts of spectrum (i.e., 66–71 GHz and 40.5–43.5 GHz allotment) notwithstanding developments in the access network**.**

Heterogenous Network: In the current cellular network, a significant increase in data traffic necessitates careful consideration of spectral efficiency allocation and architecture. The notion of frequency reuse is critical to 4G, 5G, and upcoming cellular networks; nevertheless, researchers in LTE (Long-Term-Evolution) wireless network have focused a lot of emphasis on HetNets. [3]

Nodes and connections of various kinds are linked in a heterogeneous system. It is possible to utilize these linked structures to increase nodes and linkages and spread data from one kind of data to another. It is not always the case that the UE with the best signal-to-noise ratio (SNR) would also have the maximum total throughput in wireless heterogeneous environments. HetNets can also aid with adaptive IP traffic routing and monitoring, effective load balancing and resource allocation, and unloading and loading chosen or bulk packet-switched/circuit-switched (PS/CS) traffic between the HetNets.

1.2 Problem Statement

Cellular networks are impacted by user movement. However, due to the intricacy of the analysis, there are currently no solutions to this issue. Existing research only looks at how often a user switches base stations and how long their average trip is. Hot-spots (such as workplaces, shopping centers etc.) and phone devices account for the majority of traffic. An automobile traveling at a reasonable speed passes cells every few seconds due to the cell's size. Since there are a lot of handovers, the service provided to customers is affected; as fast handover is required.

One of the most critical configurations QoS parameters in cellular networks is the Call Dropping Probability (CDP). The chance of a call being dropped due to a handoff failure is shown below. To ensure greater bandwidth consumption or reduce blocking rates for new calls, practically all admission control techniques aim to restrict the CDP to a certain desired level. The Handoff Dropping Probability is another relevant element (HDP). If the destination cell does not have enough facilities allocated, the handoff will fail. When it comes to cell edge UEs, they suffer the most because of ICI and distance from the BS. In our work we are trying to present an architecture using CoMP technology to mitigate the call drop issues as well as interferences. Our problem statement can be stated as follows: This study of ours would be able to make a simpler, efficient and accurate similar to modern state-of-the art solution for mobile users, mostly who are moving with a very high velocity; the study would also present argumentative result about the benefits of our CoMP implemented architecture over a simple HetNet.

1.3 Motivation and Objective

Cellular networks were first modelled using queueing structures. There would be a lineup for each cell, and handoff would be portrayed as a user being transferred from one queue to another in those representations. [4] Unfortunately these findings do not convey the BSs geometric layout in the plane.

As scientific knowledge progresses and the world's inhabitants grows at an accelerating rate, there will be an ever-increasing need for greater wireless technology capabilities. Intercell and intracell interference are only two of the many variables that affect network performance. Including both static and dynamic subscribers in a het network, intercell interference remains to be a hindrance to cell edge performance. As resources for cell-edge users are allocated with a high frequency reuse factor, there is no overlap with nearby cells resources in 2G. 1 (or close to 1) re-allocation per cell-center user is the standard. There is hence a reduction in power sent towards the cell center from spectrum resources that are not used by cell edge users. There can be only one frequency reuse factor in 3G. All base stations (BSs) in CDMA utilize the same frequency and are differentiated by various pseudo-random spreading codes, which are not perfectly orthogonal, in order to identify them from each other. Because of this, there are cross-interferences between all BSs, and these cross-interferences are directly connected to the power output. This means that power management is a crucial interference mitigation strategy in CDMA systems.

The ICI in a HetNet with macro and tiny cells is very different from that in Homogeneous networks (HomNet) with just macro cells. Ultra dense networks (UDNs) are a viable method for future 5G networks (UDN). - The UDN's irregular network architecture will exacerbate ICI, and present management approaches may not be adequate to counteract it. CoMP permits simultaneous connections to several base stations to improve service at the cell edge by enhancing the signal and eliminating distortion. 5G CoMP will provide capacity increases in small cell-based entity installations, as well as reduced latency in industrial IoT.

Consequently, our primary goal is to integrate JT CoMP on a heterogeneous network to provide uninterrupted connection and higher performance for at cell boundaries, thereby enhancing entire system effectiveness in a mobile framework. Also, presenting an ideal option that can be incorporated in Dhaka Metro Rail system, so that fast handover occurs and no call drops happen.

1.4 Thesis Outline

In Chapter 1, we talk about how we're going to approach this course of study. Chapters 2, 3, and 4 cover the literature review and the steps we took to get to where we are now as a result of that investigation. Our skeleton for our suggested technique, algorithm, and methods we followed was laid forth in Chapter 5 and 6. The ensemble technique, which we use, is explained in depth here. Outcomes and comparisons of our suggested method's effective execution are shown in Chapter 7. The conclusion and all of the cited sources are included in the last section of this report.

Chapter 2

Synopsis of 5G Technology and Architecture

2.1 Introduction

5G and digitalization are often linked, and since location information is fundamental to digitalization, introducing 5G mobility is a critical phase. The LTE positioning function is expanded in Release 16 to suit 5G technologies such as wideband transmissions, larger frequencies, numerous antennas, low latency, and flexible architecture. 5G infrastructure simplifies greater data rates, ultra-low latency, increased dependability, huge network capability, and improved availability. There are some difficulties involved from migrating to 5G from 4G, such as:

- Consumer Terminals with Multiple Modes: Through 4G, there will be a need to plan a solitary client terminal that can perform in different distant businesses and eliminate plan inconveniences like device size constraints, cost, and power utilization. This problem may be solved by using programmed radio methodology.
- Choosing between several remote architectures: Each remote framework has distinct characteristics and functions. The selection of the best technology for a certain administration at a specific location and at a specific time. This will be accomplished by making a selection based on the best attack of customer QoS (Quality of Service) requirements.

- Security: Insured devices that are flexible, adaptable, and lightweight should be designed.

- Support towards the organization's framework and QoS: Linking existing non-IP and IP-based frameworks and providing QoS assurance through start to finish benefits that lock in diverse structures is a challenge.

- Data Encryption: If a GPS receiver communicates with the main transmitter, the communication link between these two is easily broken, and the client should use ciphertext. [5]

5G employs 5G new radio techniques, which is built on orthogonal frequency division multiplexing (OFDM). To decrease distortion, a technique of modulating digitized signals over many channels is used. It also features solutions with a greater bandwidth i.e., mmWave. It is also intended to achieve a peak transmission capacity of 10 Gbs. Following these characteristics, a 5G radio access technology is capable of realizing greater data speeds, more capacity, and less latency than present 4G radio access technologies (LTE/LTE Advanced) will be developed.

2.2 Existing Technology of 5G

The authenticity and confidentiality of information being transported from a broadcaster to a recipient is critical in a cellular communication equipment. To ensure 5G reliability, a scheme that processes ciphered messages in mobile communication devices could be used. The signal will be encoded and will contain the encrypted substance as well as the encryption accessing information, so that when a mobile device acquires a signal, it can hold the encryption accessing information in its ram and extract it when needed, allowing the message to be decoded and interpret. This might be advantageous if there are several recipients, since the recipient will check the authenticity before decrypting the signal, resulting in secured data key caching in a mobile communication equipment.

A mobile terminated communication technique enables wireless users to interact with a safe equipment as a payment system agent over a cellular network from a destination in a common IP address web. It necessitates a mobile network host receiving the device's IP address from a cellular telecommunication channel juncture. More contact phone numbers or emails may be stored on a smart phone. Due to security concerns, this feature has been preserved. Whether a mobile communication device is stolen or lost, and the sim card is replaced, the mobile will check to see if the sim card is the same as the owner's sim card. The IMSI numbers of the owner's sim card and the modified sim card are compared. A surveillance function is enabled if the numbers deviate from one another. The biggest challenge for their consumers is that 4G service is becoming more sluggish, thus they are upgrading services and technology by concentrating on their key goals in the impending 5G era. As they are striving to strengthen their design and concentrate on the most critical elements, 5G is highly beneficial owing to its wireless network. Due to various failures in the 4G networks, 5G has become the fastest-growing technique in the contemporary period. It enables device-to-device interaction in real time (D2D). New technology, such as real-time video streaming systems, have been adopted. It uses 5G radio antennas to record and notify mishaps such as stealing, accidents, and other similar actions to local ambulances, police stations, and government authorities. By using the GPS tracking mechanism, they are able to address the issue in a shorter amount of time. [6]

The 5G architecture enables for the simultaneous transmission of multiple upstream and downstream links. Today's technology is really not built with low latency in mind, and as a consequence, it might add seconds or even more of delay, resulting in bad consumer interactions and oscillations. Because many implementations need ultra-low latency, "ULL networking mechanisms" have made a significant contribution to the upcoming 5G connectivity sequence, which includes "mobile technologies," "accessibility," and "core networks." Some Technologies presented by 5G innovations are:

- **Massive Multiple-Input Multiple-Output (Massive MIMO):** Multiple input multiple output technology (MIMO) has become one of the most prominent networking techniques since 5G debuted wireless communication advancements. A user-centric approach has been presented to increase user Quality of Service (QoS) in 5G networks, which is attaining the predictability of the subscriber everyday notions. To identify these concepts agglomerative clustering is used by the help of cells. [7] MIMO is widely used in WIFI, LTE, and other wireless networks. The basic notion is to equip base stations with many antenna arrays, including a massive amount of broadcast and reception antennas. The capability of a MIMO network will rise linearly, roughly proportional to the number of antennas at the minimal level. The LTE module may be used with up to four antennas. Further on, there will be up to eight antennae. The downstream ray generation takes use of massive MIMO in TDD mode and the uplink-downlink reciprocity of radio communication. The BS array, in particular, learns the channel in both directions using spectrum estimations received from upstream pilots broadcast by the terminals. Massive MIMO is entirely adaptable in terms of the number of base station antennas. Adoption of the peak interface level in large MIMO spectrum sharing networks may be of relevance in the long term.

- **Non-orthogonal multiple access (NOMA):** Orthogonal multiple access (OMA) techniques such as time division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA) are used in all existing wireless networks. Neither of these solutions, however, can match the high demands for radio access infrastructures that exist now and in the long term. NOMA is substantially distinct from these multiple access methods, which give subscribers with orthogonal access in time, frequency, code, or space. In NOMA, every subscriber runs in the same frequency range at the very same time, distinguishable only by their power levels. NOMA employs superposition coding at the transmitter, allowing the successive interference cancellation (SIC) receiver to distinguish between users in both the transmitting and receiving systems. [8] NOMA has been presented as a radio access development contender for 5G telecommunication infrastructure. The practical application of NOMA in cellular networks requires a significant amount of computer capacity in order to execute real-time power allotment and subsequent error control techniques.

- **Ultra Wide-band Spectrum (UWB):** Ultra wide band (UWB) is a critical crucial enabler for higher bandwidth utilization and more precise positioning in high-speed wireless network applications. Sensory data collecting, precise locating, and monitoring capabilities are available. Very minimal energy values may be employed for short-range and high-bandwidth communications throughout a broad area of the wireless spectrum. The signal-to-noise ratio determines channel capacity and bandwidth. UWB technology allows mobile connectivity equipment to interact over a broad variety of radio frequencies while requiring minimal energy. The front-end antenna is critical in Ultra Wide Band communication systems. UWB and MIMO innovations have recently been implemented into cellular connections to boost performance in terms of high data levels.

- **Millimeter Wave (mmWave):** Since it contains a large unregistered accessible spectrum, migrating to the millimeter wave (mmWave) band, i.e., 60 GHz band, seems to be a potential contender for enabling 5G infrastructure. mm Wave technique can handle extremely high broadcast rates, narrow beams, and the connection of multiple components. However, it is hindered by a number of technological difficulties. Due to propagation and penetration losses, the MmWave signal is greatly weakened in space. Additionally, mmWave has a significant obstructing chance due to human shadowing. One of the earliest mmWave antenna modules developed particularly for 5G Fixed Wireless Access (FWA) CPE configurations, the Qualcomm QTM527 antenna subsystem, was released.

- **Device to device communication (D2D):** A new paradigm network is one of the essential advancements supplied by 5G to boost its functionality. Two people may communicate with each other at the same time since it is based on spectrum sharing. For 5G to work, a slew of brand-new innovations is required. That technique enables UEs to interact with one other without the need for network architectures to connect them to one another. Access points or BS are examples of this. Another benefit is that D2D will minimize backhaul requirements while improving spectral performances and cellular connectivity. HetNet was developed using D2D transmission. Interference occurs in three forms in an underlying D2D network connection; disturbance from D2D to M-UE, M-UE to D2D, and D2D to D2D. [9]

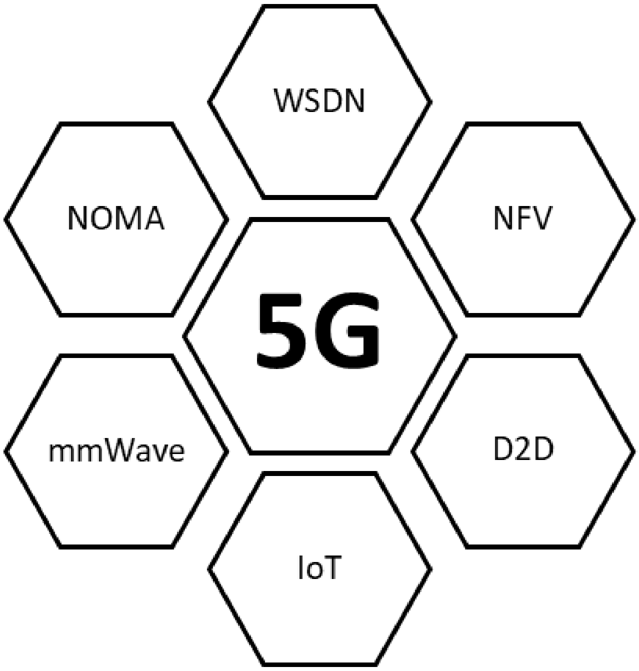

Figure 2.1: Key Enabling Technologies in 5G.

2.3 5G Network Architecture

The construction and modeling of a micro strip patch antenna operating system at 28GHz is part of 5G networking. The antenna's operating environment is that it runs in the regional multipoint transmission platform spectrum at 27.91 GHz with a maximum reflection coefficient of 12.59 dB. It has a "bandwidth" of 582 MHz and a high efficiency of 6.69 dB, and the supply is the antenna's transmission line. The base is the "Rogers RT Duroid 5880," that has a "dielectric" constant of 2.2 and a 0.25mm in height. HFSS shows the simulation outcome, analyzes it, and estimates the antenna dimensions. [10] According to prior and recent studies, 5G infrastructures should enable very rapid data transfer and handling. Understandings of network functionalities inside the radio protocol stack enable for quick device access for mMTC with little administrative layer signaling overhead. Also, moving network operations near to the access network's edge is being researched for low-latency alternatives. The Mobile Edge Computing (MEC) platform also helps address critical needs for expanding the notion to the final leg.

When all conceivable aggregation and core network combinations were studied by the 3GPP, there were initially eight design alternatives on the plate. However, as work advanced, the following two major architectural possibilities formed. With LTE as the primary connecting point, and combining the preexisting LTE cores with 5G radio as a secondary cell, this strategy was first in the finalization timeline for implementation (Architecture option 3). Afterwards, the 5G radio with the new 5G core was finished (Architecture option 2).

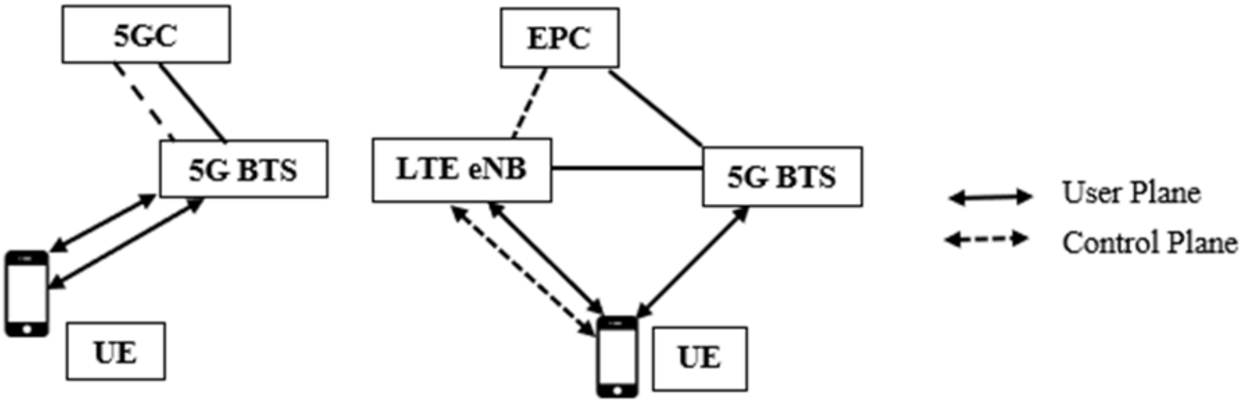

Figure 2.2: For the first phase of 5G deployments options.

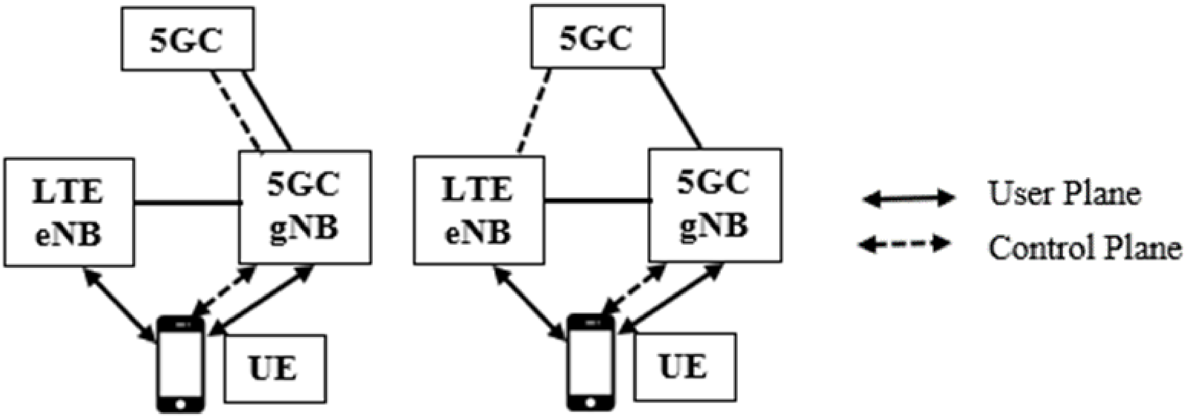

Figure 2.3: Release 15 "Late drop" includes more 3GPP architectural choices.

Numerous architectural alternatives for supporting a double connection were completed in June 2019 seen in **Figure 2.3** and are summarized in the following. First-phase UEs for 5G system deployments are not expected to accommodate them, since they were completed as part of "late drop" in Release 15. In architectural option 4, the 5G gNB serves as the interconnection anchor. The LTE connection is the secondary link on the interface, with the control plane traveling through the 5G gNB to the 5G core network. This is appropriate for circumstances when there is adequate range for a 5G connectivity, either by establishing a dense enough network or by employing a low enough frequency range. Next option 7, in which the LTE eNB serves as the connection anchorage. The 5G interface is now the auxiliary one on the link, with the control plane traveling through the LTE eNB to the 5G core network. This presupposes that the LTE eNB has been upgraded to provide connection to the 5G core network. This is appropriate for situations when LTE service is likely to be significantly greater than existing 5G reception, such as when employing 5G on mmW bands with a very limited cell area.

The core network must allow fluid communication services in which the computing and memory resources are separated. The split of compute and storage allows for infinite linear development and high robustness. Subscriber data, session data, policies, operational data, charging, and accounting data would all be stored in the 5G architecture's Unified Data Management (UDM). This will allow an unrestricted data exposure and analytics platform. In contrast to EPC, multi-access compatibility is incorporated in from the start, allowing for the optimal use of various static and wireless infrastructure to deliver access-independent value-added products, maximum data rates, greater dependability, and improved user experience. These enhanced features will facilitate end-to-end network slicing, allowing public and private operators to flexibly adjust infrastructures to unique vertical demands. Network slices may be connected and resource allocated independently, forming “virtual private service networks.” A network infrastructure slice may be added quickly through automated processes, allowing new business models that were not possible with specialized access devices.

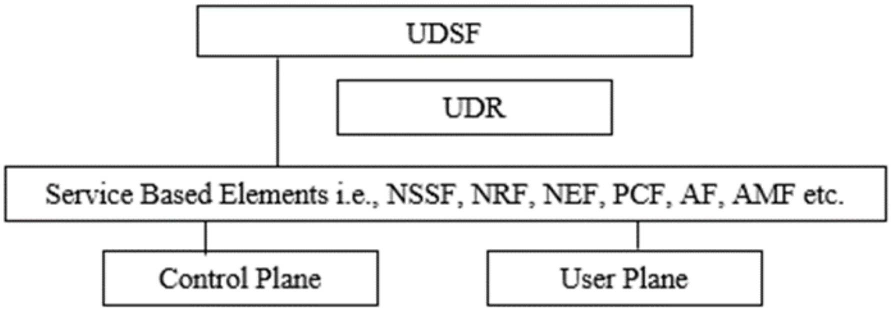

Figure 2.4: Simplified 5G Core Network Architecture.

Figure 2.4 depicts the simplified 5G core architecture. Some connections in 5G still use the point-to-point architecture that was used up until 4G, and will continue to do so. It's called the point-to-point framework because various network activities are linked to each other over standard interfaces that allow for multivendor networks to be set up. The point-to-point design has the disadvantage of having numerous distinctive (or nearly distinct) connections amongst operational parts, each of which is linked to several neighboring units. Administrators must adjust numerous nearby operations and verify the new configuration before going live if a new element is added or an established activity is enlarged or updated. This increases the bar for experimenting with and deploying novel services in applications.

- **5G mmWave Range:** The region of the radio spectrum with frequencies between 30 GHz and 300 GHz is known as the mmWave. The 5G new radio is now using multiple spectral scopes.

- **Multi-access Edge Computing (MEC):** It is a crucial component of 5G architectural features of the MEC comprise low latency, high bandwidth, and real-time access to RAN information. The operator's approach to network testing and validation would be altered as a result of this RAN and core infrastructure convergence. 5G networks based on 3GPP 5G requirements are an ideal framework for MEC implementation. The dispersion of processing resources will make it easier to support a large number of linked devices.

- **Network Function Virtualization (NFV):** By virtualizing activities inside the 5G network, NFV enables the 5G technology. Network slicing innovation is included in this. It enables the operation of numerous virtual connections at the same time. Storage and network resources are modified depending on the activity using virtualized computation.

- **Slicing of Network:** The entire potential of the 5G architecture can be utilized thanks to network slicing. This technique provides a new depth to the NFV realm. By constructing end-to-end virtualization that incorporate both networking and storage capabilities, this becomes critical to 5G design. As a result, network slicing has become a major design issue for 5G networks, allowing for anticipated testing of novel 5G services.

Chapter 3

Interference Management of 5G

3.1 Introduction

Voice over IP (VoIP), online video, web browser, social networking, P2P video sharing, and other services are projected to be supported by fifth-generation wireless communication networks (5G). Because these services have differing uplink and downlink traffic demands, asymmetrical traffic is one of the distinguishing features of upcoming wireless connectivity. Starting with the 3GPP development plan in 2004, the first version of the LTE protocol was released in 2008. Release 8 was completed in 2008, and discussions on Release 12 were underway with a deadline of 2014 for implementation. The LTE protocol responds to rising requests for greater QoS and additional service kinds by including new capabilities in newer versions. However, as the LTE standard advances with new versions, we're running across far more fundamental constraints that prohibit from improving efficiency further. The understanding of the 4G system's inherent shortcomings ushers in the fifth generation of technologies.

Due to the characteristics of each low power node, multi-tier discrepancies are created in a small cell mobile infrastructure. Because it is sent and received at the same frequency, the HD (Half Duplex) configuration restricts the operation of a radio communication network. In contrast to HD, FD (Full Duplex) transmission concurrently transmits and receives signals on the same frequency and is supported by a multi-antenna system that increases infrastructure capability and reduces round trip packet transfer duration. The FD enables faster speed with reduced latency and more effective band use. It also improves ergodic capabilities and system confidentiality; yet, its effectiveness is severely degraded owing to interferences as a consequence, in order to offer substantial benefits for the realistic forthcoming cellular network system, a strong and tangible interference reduction method in FD transmission is necessary. [11] [12] Interferences caused by their various installation and distribution scenarios have an impact on each infrastructure. The main interferences in communication systems are thoroughly discussed by scholars in different publications, and some noteworthy study topics are as follows.

- **Adjacent Channel Interference:** When the targeted broadcast is interrupted with by the neighboring frequency band (channel) in the same coverage region, this is referred to as adjacent channel interference, as followed in **Figure 3.1**. When the transmission of a small or macro base station breaches while broadcasting on a band, its energy and signal are added to the neighboring frequency band. [13] The primary cause of neighboring interference is an inadequate receiver's filtration, which allows surrounding bands to seep into the passband. Nevertheless, it may consist of a passband filter's physical construction that allows just the needed spectrum to pass. Consequently, a dependable interference prevention strategy aids in mitigating the damage.
- **Cross-Link Interference:** Cross-link interference occurs when adjoining cells send information in opposite paths at the same or partly overlapping time parameters, **Figure 3.2**.

- **Inter-Channel Interference:** Inter-channel interference occurs when two distinct spectra (channels) interact. Multiple wireless and digital communication devices in a HetNet platform. Inter-channel interference occurs when a high-power broadcast interacts with a weak signal reception. The vast variety of transmission and reception strengths of these instruments produces numerous interference difficulties such as inter-channel interference. [14]

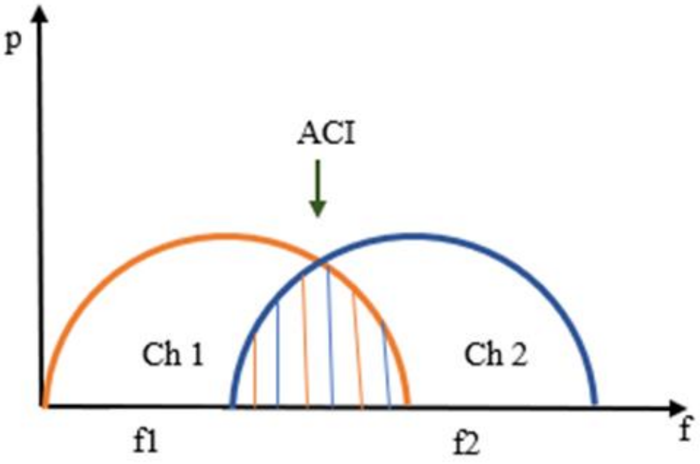

Figure 3.1: Adjacent Channel Interference.

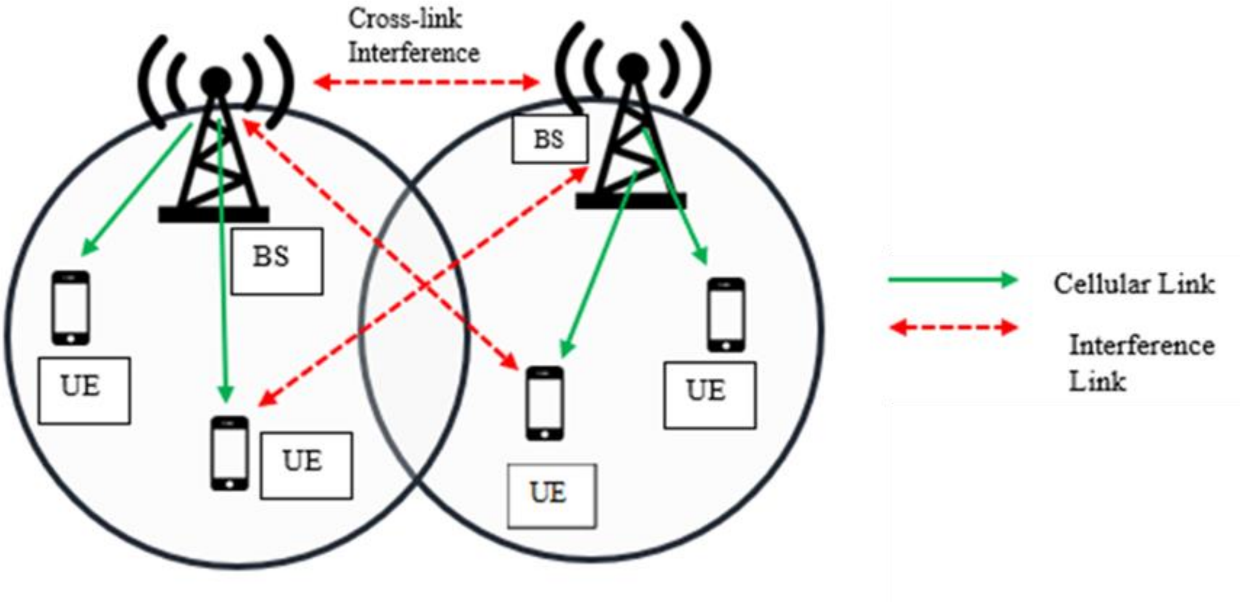

Figure 3.2: Cross-Link Interference.

- **Intra-Channel Interference:** Intra-channel intervention is common in multi-low power cells within a mobile network. It mainly happens in mm-wave HetNet distributed architecture scenarios. This infrastructure is based on mm-wave self-backhauling, in which each small cell BS interacts and sends backhaul information to the closest BS. The content is then sent to the gateway through this multi-hop mm-wave connection. This results in quick shifting and, in addition to transmission losses, limits transmission delay. Nonetheless, intra-channel interferences were introduced and influenced the relevant stream. [15]

- **Inter-cell and Intra-Cell Interference:** Inter-cell interference (ICI) is one of the major reasons of system deterioration. When users from two adjacent cells tried to utilize the same spectrum range, they experienced overlapping signals. The ICI also affects users at cell boundaries since they get a high-power signal from their cell macro-BS and surrounding cells owing to frequency reuse. **Figure 3.3** illustrates that macro-BS connects directly to consumers and uses little power to transmit. Many subscribers' real data interact with other transmissions due to simultaneous uplink and downlink broadcast. Intra-cell interference is the disturbance induced by the user to extra apparatus inside the same cell. [13]

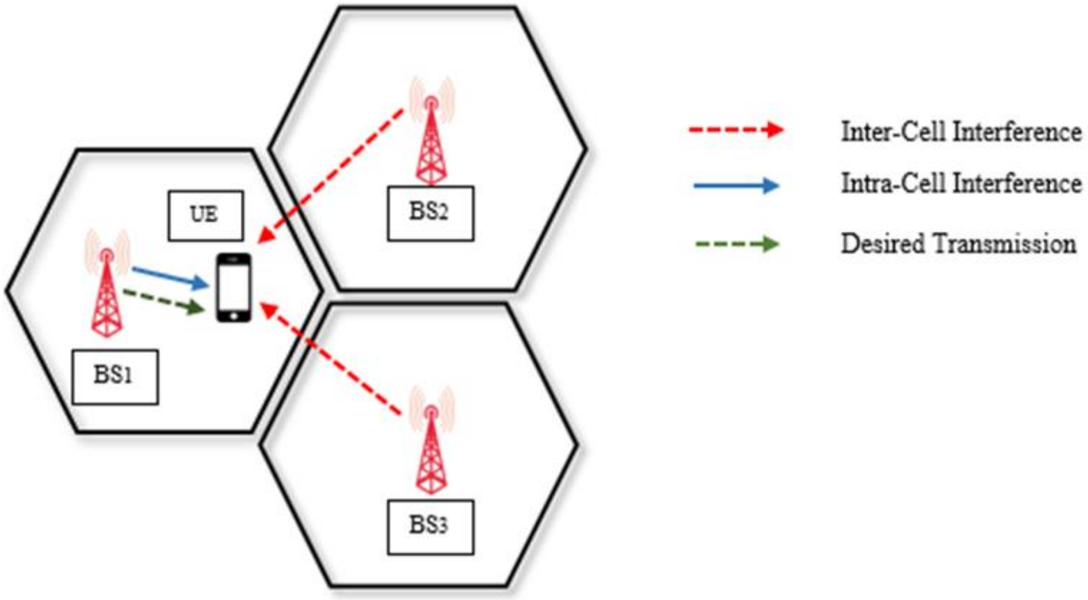

Figure 3.3: Inter-Cell and Intra-Cell Interference.

- **Multiple-Access Interreference:** In a variety of small cell cellular networks, the same frequency resource blocks were used by BS emitters for the concurrent broadcast of meaningful data. Numerous radio streams are used to send the required information, which induces interference in the delivered signal. Multiple access interference is a mix of multi-user interference and co-channel interference (CCI). [16]

3.2 Interference Management for Different Technologies

- **Cognitive Interference Management:** Typically, the channel coherence time of a communication connection determines the rate of power regulation. In a macro cellular network, wireless devices are often very dynamic, necessitating a quicker power management based on user path variance. Cognitive broadcast techniques have the potential to significantly boost cellular network throughput. In contrast to more typical monitoring systems that solely permit the secondary user to communicate when the main user is inactive, the cognitive strategies that permit the superposition in time and frequency of primary and secondary user broadcasts.

- **Macro Aware-noise Rise Settings:** Femtocells are low-power cellular base stations that may be used in household, corporate, or hotspot environments. Femtocells are often linked to the Internet and the cellular operator's infrastructure through a DSL gateway or wired network. Femtocells help both customers and administrators. Users may benefit from improved phone reception and increased internet performance. Operators may divert congestion from the macro network to enhance macro user performance without raising network investment expenses.
  Uplink noise surge is managed in macro cell systems to assure UL accessibility at the cell border (greater noise rise demands more UE Tx power) and to maintain efficient UL function and avoid instabilities. If the noise increase threshold is surpassed, the UL scheduling algorithm will attempt to reduce the noise rise by lowering the transmission rates of serviced customers in the Dedicated Channel (DCH). Typically, the same noise increase threshold is applied to all macro cells in a network.

- **Control Link on Uplink Power (CLIP):** Controlled Limit on Uplink Power (CLIP), which reduces the disturbance induced at macro cells by restricting Femto User Equipment (FUE) Tx strength, is another solution for dealing with femto-to-macro uplink interference. Without CLIP (blue curves), the FUE transmits at maximum capacity. The high Tx power creates a noise spike at the macro cell, which is usually above the normal macro cell noise rise threshold (e.g., 6 dB), affecting all UEs in the macro cell. Whenever CLIP is activated, the effect of FUE on macro distortion growth is fully removed. [17]

- **Self Organized Networking (SON):** Recent interest in LTE SON algorithmic research has focused primarily on downlink-related issues. Supervision of the underlying SON architecture is spread over the wireless infrastructure, while intensive algorithmic calculations are performed centralized manner by the Network Management Servers. Many administrators favor the hybrid SON model over completely distributed (across eNBs) computing for two main factors: the flexibility to operate across base stations from various suppliers, and the lack of a convergent problem (due to asynchrony and message latency).

- **Joint Scheduling:** Releases 8 and 9 of the LTE protocol did not examine any sophisticated co-channel noise control solutions other than the randomness of disturbances by scrambling transmission packets. Subsequently, in 3GPP LTE-Advanced, i.e. Releases 10 and 11, it was determined via feasibility studies that there was sufficient potential for additional enhance capability, particularly at the cell edges, by coordinating transmission among many transmitters located at separate cell sites. In September 2011, a work item on Coordinated Multiple Point (CoMP) transmission was thus launched. The goal of joint scheduling is to jointly decide serving UEs and transfer methods for a group of numerous transmit points (TPs), referred to as a cluster, in order to improve the cluster's entire utility function. Relying on the particular method, this collaborative scheduling may be accomplished either centrally or dispersed. [18]

Interference control in 4G LTE is primarily network-side and invisible to consumers. For legacy users, network-side noise control is helpful and straightforward to adopt by stretching the old infrastructure. Nevertheless, placing all interference control responsibilities on the infrastructure raises several operational concerns, such as backhaul and feedback overheads. [19] Furthermore, previous studies shows that UE-side interference management may offer substantial symbiosis with network-side, and a study on UE-side interference management backing began in Release 12, but it was somewhat in preliminary state.

3.3 Interference Management Available for 5G

In the context of the 5G and beyond HetNet framework, 3GPP has provided several techniques and processes for mitigating numerous sorts of interferences under development for next-generation mobile communication.

- **Pilot Contamination:** The orthogonal uplink pilot signal assists the subscriber in determining the path within the same cell. The identical pilot sequencing might be utilized by the nearby cell subscriber for optimal assets allocation. Although frequency reuse has shown considerable promise for making optimal use of the available spectrum range, it is greatly hampered by the unavoidable CCI.
  Since M-MIMO is one of the primary underlying technologies for the 5G multi-cell system. Due to the utilization of resources, the pilot symbols in M-MIMO TDD configuration are very susceptible to corruption and generate ICI. The noise impact in a signal reduces the spectrum's attainable throughput and ultimate performance. [20]
  Mitigation Methodology: Zero Forcing (ZF) Precoding.
  Limitations: Problems with transceiver hardware and multi-user multi-cell transceiver degradation, as well as phase noise in the oscillators.

- **Base Station Identification:** In high-density HetNets, a BS must be conscious of, competent of and connected to its surrounding BSs and any subscribers linked with them. Data about the interfering base station is crucial for handling ICI and making handover choices. However, identification, transmission, and detection of an interferer BSs over an air interference is a difficult job, but it may be mitigated by varying propagation strength, BSs triggering, and advance reference signal layout.
  Mitigation Methodology: DL Coordination Scheme.
  Limitations: Real-world execution effects like as latency, packet loss, and jitter.

- **Control Channel:** Control channels are an integral component of both uplink and downlink data transfer. Physical uplink control channel (PUCCH) sends information about

CQI, ACK/NAK, and the HARQ protocol, for example. Channel estimation, signal synchronization, cell seeking, and other processes all rely on control channels. Nevertheless, keeping these uplink and downlink control channels separate is critical. As a result, 3GPP suggested that MBS's power intensity be lower than the specified cutoff power, to reduce unwanted shifts. [21] In the setting of the control channel, several studies have demonstrated the occurrence of transmission gaps when femtocells are installed in a macro-cell overlay wireless network. To limit the impact of control channel interferences, 3GPP recommended that femtocells be executed in solely closed access mode, i.e., each femtocell should develop and manage a database of permitted user equipment (UEs) that may access the facilities.
Mitigation Methodology: Cross Carrier Scheduling.
Limitations: Gaps in network access, flexible eNB dependability, UE channel estimation side effects, seamless eNB synchronization, and joint optimization of control and data channels are some of the challenges that must be overcome.

- **Rank Calculation:** The degree of separate transmission stream used to equalize the exchange of many received signals at the receiver is defined by rank adoption. It aids in increasing spatial gain and improving noise resistance. 3GPP has suggested many efficient approaches, with an emphasis on an interference-aware inter-cell rank coordination algorithm to decrease computing complexity. It also necessitates a rank selection approach depending on immediate CSI for the interference covariance matrix (ICM). [22]

- **Receiver Designing:** To effectively manage interference, the 3GPP has suggested a user-side interference suppression and rejection approach; nevertheless, it is confined to a single recipient station. Multipath noise reception deterioration is the problem that may generate significant signal attenuation in 5G networks. [23] The 3GPP came up with a method called Code Word Level Interference Cancellation (CW-IC) to stop interference between users and within a cell at the subscribers' terminal. The group in charge of making standards also said that ICI could be reduced with Minimum Mean Square Error-Interference Rejection Combining (MMSE-IRC) in an ultra-dense multiple small cell domain. [24]
Mitigation Methodology: CW-IC.
Limitations: The channel's Eigen phase and the distance between antenna modules.

- **Reference Signal:** The architecture of a reference signal is one of the most important difficulties to deal with since the transmission channel state for sending signal is always changing and unexpected. To distinguish between the data signal's and interference signal's BS, you may use this technique. A new reference signal (dubbed Demodulation Reference Signal) has been created for both the time and frequency downlink and uplink channels in the forthcoming 5G infrastructure, notwithstanding 3GPP's suggestion that no specific reference signal is required.

- **Cellular-V2X:** In version 14 of the LTE specifications, the 3GPP added two protocols, i.e., BS scheduled and direct scheduled, enabling cellular-vehicular-to-everything (C-V2X)

transmission. Mobility management and channel estimation are two possible obstacles to vehicular networks effectiveness in rapidly moving vehicles. V2X innovations in an Intelligent Transportation System (ITS) reveal end-to-end transmission latency and viability, compromising traffic safety and bandwidth efficiency in response to climatic variations. [25]
Mitigation Methodology: V2V sidelink/PC5.
Limitations: High latency, ultra-high dependability, consistent conflict, and reasonable commercial installation likelihood make it unusable in a densely packed traffic condition.

- **Narrow Beam Link:** Because of the enormous antenna arrays and the mm-wave propagation, narrow and concentrated beams become even more critical. When it comes to mm-wave communication, beam synchronization is critical. As a result, Beamforming and Beam-steering, were developed by investigators and standards bodies.
  Mitigation Methodology: Hybrid Beam Synthesis.
  Limitations: Level of excitation in amplitudes.

Chapter 4
Mobility Management of 5G

4.1 Introduction

The fully accomplished standardization of the new mobile generation has led to the deployment of fifth-generation (5G) wireless networks to gratify enormous traffic volume for cellular and Internet services. Current 5G and future wireless networks are expected to simultaneously support billions of smart devices while maintaining reliability and QoS for each product, especially those residing on cell edges or in motion. The current centralized mobility systems discussed extensively is not sufficient to manage an explosive increase in data volume and is therefore, a steadily growing concern in modern communication. A new technique that can affluently handle traffic problems and completely avoid network breakdown chances is highly crucial.

In this chapter, the issues that crop up due to mobility as well as the current mobility management schemes of 5G cellular networks are discussed.

4.2 Problems in Mobile Environment due to Mobile UEs

Mobility refers to the ability to maintain a UE's connection with the serving wireless network during the UE's movement within cells without any disruption in the ideal scenario. The movement of UE leads to a continuous change in the received signal strength level. Once the received signal strength falls below an acceptable level or below the Received Signal Strength Indicator (RSSI), which is the received signal strength threshold level, at any specific location, a handover procedure is triggered. The procedure begins by sending a request from the serving eNB to the target eNB with better network gain to switch the UE's connection to the target BS that provides a good signal strength. Therefore, the UE connection will be maintained with the serving networks during mobility without any disruption in the ideal case. [26]

In 5G technology, the use of high frequency is the dominant factor affecting performance of network. High path loss is observed when high frequency bands are employed thereby reducing the cell coverage. The issue is further exacerbated by the motion of users. One of the main distinguishing factors of high mobility communications is the fast time variation of the fading channel caused by the large Doppler spread caused by high velocities. Doppler effect causes two problems: Doppler frequency offset (FO) and fast fading. Due to the movement between transmitter and receiver, the carrier frequency of the received signal will be shifted from its original value. It is extremely difficult to accurately estimate, track, and predict the fast time-varying fading coefficients. Multi-user interference and many other interferences discussed extensively in Chapter 2 pose tremendous problems to service provisioning when high mobility is involved.

This leads to a significant increase in the handover probabilities, which leads to increased mobility problems, such as high handover failure, handover Ping-Pong effect, and radio link failures. Moreover, new types of mobile connection systems are expected to be established in future networks. Implementing these systems will contribute to the increase of mobility issues as well as it will lead to congestions in the network. Therefore, leading to increased problems due to interference.

Handover interruption time is another critical issue to be considered in 5G networks since the 5G cell size is incredibly small and the handover probability for moving UEs will be very high, leading to a significant increase in the interruption time which is especially important for UEs with high velocities. 5G networks are deployed overlapping the current HetNets (2G, 3G, and 4G networks) as well as future IoT networks. Femtocells and mesh Wi-Fi are widely deployed and overlapping cellular networks with all networks expected to be capable to serve both static and mobile UEs, and handover can be performed from one network to another. Since HetNets are overlapping, and ultra-dense the types of handover scenarios are also high. This contributes to soaring handover rates during UEs' mobility, which will increase the handover probability, causing a significant escalation in Handover Failure Probability (HFP), Handover Ping Pong Probability (HPPP) effect, radio link failure, interruption time, throughput degradation, as well as overhead and overall communication performance quality. [27] The drawbacks become more severe through high mobility speeds, particularly when there are no mobility robustness optimization techniques or efficient handover decision algorithms used.

If Handover Control Parameters (HCP) settings are adjusted to fixed settings, ongoing communication will be negatively affected as the network architecture varies significantly inside the network, especially when the UE speed is high. Thus, HCP settings has to be suitably adjusted to address this shortcoming. However, performing this manually will increase management and maintenance complexity. According to existing studies in the literature, algorithms that provide efficient optimization for HCP settings are available, but no optimal solution exists. Some proposed algorithms only adjust HCP settings according to a single parameter, such as distance or velocity.

Most of the challenges for mobility can be summarized under 4 categories:

1. Accurate Channel Estimation
2. Advanced signal processing
3. Optimized network deployment
4. Effective mobility management

4.3 Mobility Management

The 5G network and the upcoming 6G network is thus considered to be an extremely heterogeneous ecosystem of various technologies, including: ultra-dense networks (UDN), device- to-device (D2D) communication mmWave approach, low-power nodes (LPNs) [28], multitier network architecture [29], vehicular networks [30], multiple-input and multiple-output (MIMO) platforms [31] to name only a few of them. The wide variety of many use cases in the 5G heterogeneous network increases the load on mobility management functions significantly as compared with 3G and 4G long-term evolution (LTE).

Mobility management refers to the procedures that maintains data information at the location of UEs and controls their link connections when commuting between coverage areas. [32]

In 5G, mobility management is done with consideration to two major limiting factors that determine link performance for mobile UE scenarios for both uplink and downlink: [33]

- Receiver’s capability to track the fast time-varying channel with Doppler shift:
  Due to severe time and frequency spreading in high mobility wireless communications, channel estimation is very difficult. In OFDM systems, the rapidly time-varying channel may change over several symbols or even one symbol, which costs large frequency resources to accurately estimate the channel state information.
- Inter cell interference (ICI):
  ICI due to the carrier frequency offsets caused by Doppler shift will become severe which significantly affects the overall system performance.

Doppler effect is dealt with in 3 ways:

1. **Doppler planning:**
   Doppler planning can alleviate Doppler effect for both CFO and fast fading. However, in practical systems, the configuration for parameters is constrained by many factors, thus the benefits from Doppler planning are limited.

2. **Doppler Compensation:**
   Doppler estimation and compensation are effective means to deal with the FO, e.g. auto frequency correction (AFC) [33] can support a system operating at the speed up to 350 km/h. However, to combat the fast fading issue,
   Doppler estimation and compensation are not efficient.

3. **Doppler Utilization/ Diversity:**
   Doppler diversity was proposed to take advantage from the potential mobility gain inherent in the time-varying channels and improve the reliability of transmissions, even for high mobility communication systems with imperfect channel estimation.

Mobility management in high speed scenario faces the challenges of frequent handovers, high penetration loss, heavy signaling overheads due to group mobility, and fast mobility management procedures such as cell selection.

There are four available solutions, which will be discussed as follows:

1. **Self-Optimization Network (SON):**

   Mobility functions under the SON are an important feature that has been implemented to alleviate mobility concerns in 4G and 5G networks, which may further be developed and kept as one of the main components in the 6G system as well. The SON feature is one of three main sub-networks that has been introduced under the Self-Organization Network in 4G and 5G networks.
   The SON's major goal is to automate the management process by adapting system parameters dynamically. Automatic adaptation of system parameters is accomplished by integrating a variety of self-optimizing functions to improve system quality and reduce network complexity. Handover Parameter Optimization (HPO) and LBO are among the significant algorithms introduced in the SON.
   The existing HPO algorithms developed for 4G networks may not be efficient for use in 5G networks. One of the reasons is due to the central optimization operation and in part

due to the partial optimization. The core optimization procedure is one of the explanations, while partial optimization is another. Furthermore, some of the present methods in the literature use inefficient input parameters in their design, resulting in inaccurate HCP estimates. [34] The LBO function adaptively adjusts HCP settings to balance the unequal load between neighboring cells. Although this function has been introduced to contribute to solving mobility issues, the need for more efficient LBO algorithms is still required. [35]

2. **Enabling Dual Connectivity (DC):**

   Although DC is one of the elements that increases the likelihood of a handover, it also helps to solve mobility concerns. In DC, the UE can simultaneously be connected over multiple carriers to two varied eNBs of different technologies. By allowing UEs to use two separate bands over two different technologies, this will help to provide high data rates. However, the mobility issue will not be solved entirely.

3. **Conditional Handover (CHO):**

   CHO is a new technique that has been introduced as a part of mobility functions in 3GPP's Rel.16. Its aim is to enhance the mobility robustness of UEs. It is a handover that is executed by the UE when one or more handover execution conditions are met. This technique specifically aims to decrease the occurrences of handover failure, which leads to the reduction of the interruption time. CHO contributes to reducing the need for the re-establishment procedure. On the other hand, CHO will contribute to increasing the signaling overhead and buffering storage since the mobile must establish monitoring in advance, while sometimes it may be unnecessary.

4. **Dual Active Protocol Stack Handover (DAPS):**

   DAPS is a proposed solution introduced by Ericsson to mainly contribute to reducing the interruption time during UE's mobility. Once the UE receives the request to execute the handover procedure, it continues to send and receive UE data in the serving eNB. Simultaneously, the UE establishes a new connection for synchronizing random access to the target eNB. There are no simulation or measurement results that have been published for this solution and is not in deployment.

4.4 Closed Loop Spatial Multiplexing (CLSM)

Spatial Multiplexing is a multiplexing technique in which a high-rate input data stream is split into multiple parallel lower-rate independent data streams to boost data rate by enabling transmission over spatially isolated MIMO channels. The unpredictability of the wireless environment characterised by scattering, reflections, diffraction and other effects of multipath propagation leads to channel distortion and signal propagation gets impeded. To counter the effects of multipath propagation, LTE introduced CLSM transmission scheme to facilitate multi-layer transmission via precoding to enhance the multiplexing capabilities of LTE. In CLSM, after successful data reception, the UE sends feedback to the base station on channel condition parameters. UE evaluates the received data stream and delivers CSI, RI, and PMI estimates. The CSI (Channel State

Information) provides the base station with recommendations for the optimal modulation scheme and code rate to be used in the downlink (DL). The RI (Rank Indicator) indicates the maximum number of spatial layers that a UE can handle based on channel quality. BS utilises PMI (Precoding Matrix Index) to choose the precoding matrices for DL transmission.

4.5 Resource Scheduling

Round Robin (RR) is a popular scheduler that prioritizes fairness when allocating resources to UEs. Due to its channel independent resource scheduling technique, RR scheduler ensures better throughput and fairness index (FI) at high mobility compared to conventional schedulers.

Priority function (P) is utilized to allocate resources in RR. [36]

$$P = \frac{T^{\alpha}}{R^{\beta}} \tag{4.1}$$

Here α and β are parameters that are used to control the FI. For RR α=0 and β=1, T stands for throughput and R for data rate.

Chapter 5
Proposed Interference Management Scheme

5.1 Introduction

The demand for better performance for wireless technologies is ever-increasing with the advancement of science and the exponentially increasing nature of the population. Network performance is influenced by various factors, including intercell and intracell interference and UE velocity fluctuations. In a Heterogenous network (HetNet), intercell interference (ICI) continues to be detrimental to cell edge throughput for both static and dynamic users. Due to the proximity and varied power classes of macrocells and small cells, the ICI in a HetNet is quite different and significantly prevalent compared to Homogenous Network (HomNet). In future 5G networks, dense deployment of small cells has been widely accepted as a promising technique to boost the network capacity, known as ultra densification of network (UDN). - ICI will be extremely severe due to the irregular network topology of UDN. Existing management schemes may not be sufficient to combat the ICI. The impact of high mobility leads to substantial degradation in throughput, making it challenging to provide the minimal throughput required to avoid call drops while handover is sought. A potential solution to the problem is Coordinated multipoint (CoMP), which can improve cell edge throughput and lessen the effect of ICI. This chapter contains a detailed explanation of the operation of CoMP technology in ICI mitigation.

5.2 Coordinated Multipoint (CoMP):

CoMP is a foreseen technology that allows dynamic transmission and reception across several BSs to improve overall service quality for UEs while increasing system capacity. Multiple coordinated eNBs serve a single UE in the best possible way via CoMP, resulting in improved received signal quality. CoMP's performance boost is contingent on successful information coordination among eNBs via the backhaul link. CoMP considers the transmitted signals from coordinated eNBs to be desired signals, reducing ICI and increasing cell edge throughput.

5.3 Prime Motivations of CoMP :

The primary driving force behind the origin of CoMP technology is the reduction of the effect of the signals transmitted from the non-serving eNBs. A few of the motivations of CoMP are listed below:

1. To improve the coverage
2. To improve the cell edge throughput
3. To increase overall system throughput

4. Interference management
5. Improve spectral efficiency

5.4 Types of CoMP:

There are **two types** of CoMP:

1. **Intrasite CoMP:**

   In intrasite CoMP technique, multiple sectors of the same eNB coordinate among themselves to serve the UEs with no excess burden on backhaul links, giving the advantage to exchange volumes of information among the coordinated eNBs belonging to the same cell.

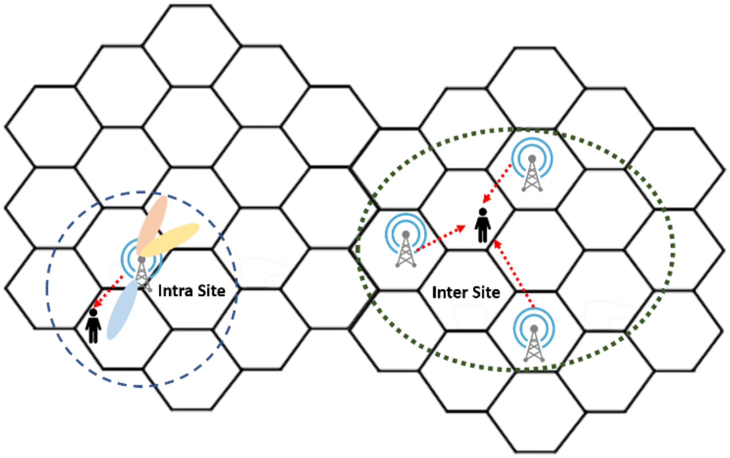

Figure 5.1: Intersite and Intrasite CoMP

2. **Intersite CoMP:**

This process involves coordination among multiple eNBs located at different cell sites to take the UE scheduling decisions putting a significant load on the backhaul links as a lot of info needs to be exchanged in distant cell sites via the backhaul. A limited number of eNBs participate in intersite CoMP operations.

The inter-site (inter-cluster) CoMP can be expressed by,

$$y_m = \sum_{\mathrm{l \in Bm}} H_{l,m} d_{l,m} + \sum_{\mathrm{l \in Bm}} H_{l,m} \sum_{\mathrm{i} \in U_{\mathrm{l}} \backslash \mathrm{m}} d_{l,i} + x_m \qquad (5.1)$$

$$x_m = \sum_{\mathrm{l}\in \mathrm{B}\backslash \mathrm{Bm}} H_{l,m} \sum_{\mathrm{i}\in U_{\mathrm{l}}} d_{l,i} + n_m \tag{5.2}$$

Here, $d_{l,m}$ is transmitted signal , $H_{l,m}$ stands for the channel matrix, where l *and* m specifies the particular eNB and UE; n_m stands for additive noise vector and the normalised complex data symbol is presented through x_m. [37]

5.5 CoMP operation:

CoMP operation involves cooperation and coordination among the eNBs primarily. There are two main parts: centralized coordination and decentralized coordination.

The central unit (CU) of centralized combination houses the CSI and data received from the UE feedback, pre-calculates all the frequencies and forwards to the coordinated eNBs via a star-like network system as remote radio heads (RRHs). But the size of overhead for the users' data in the entire network increases.

In decentralized coordination, a limited number of eNBs coordinate among themselves within specific cells via a mesh network topology, reducing the size of overhead.

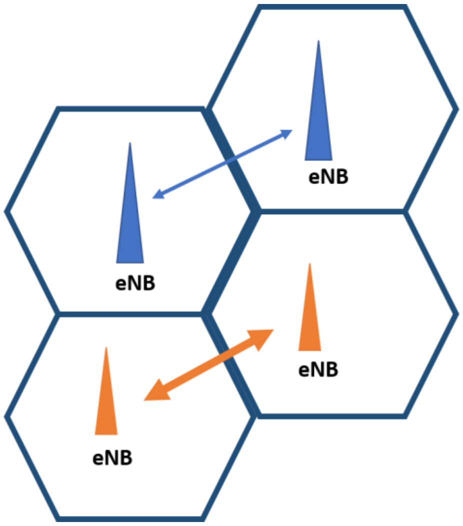

Figure 5.2: Decentralized network

Downlink CoMP operation takes place in 2 ways: Joint Transmission (JT) CoMP and Coordinated Scheduling (CS) CoMP

JT CoMP:

This is the process where the coordinated eNBs form a virtual antenna array to transmit DL data simultaneously to a UE to improve received signal quality and strength. This type of transmission can be coherent (in which case it's known as Network MIMO) or non-coherent.

The capacity to precode in a manner that takes use of the phase and amplitude relationships across channels associated with distinct transmission points is referred to as coherency. This technique allows signals which are low in strength and masked by errors to be received with few errors but place a heavy demand on the backhaul network.

For effective operation of JT CoMP, low latency fronthaul or backhaul, accurate estimates of CSI and efficient scheduling decisions have to be maintained.

Smooth exchange of user data and CSI needs to be ensured among the coordinating eNBs for CoMP operation at very low latency. The additional requirement of multiple site reception and transmission can add significantly to any delays.To overcome this problem the different sites can be anticipated to be connected together in a form of centralised RAN (C-RAN) Which is available in the network architecture of 5G. 5G is expected to have ultra reliable low latency of less than 1ms .CoMP implementation in 5G is beneficial and practical.

JT CoMP employs a combination of constructive and destructive signal superposition with the purpose of maximizing the intended received signal while minimizing mutual interference. Higher transmission bandwidths are envisaged in the 5G era, which indicates that higher-resolution channel estimates may be required.Additionally, the higher carrier frequencies employed will result in more frequency-flat channels, which can be calculated more precisely and transmitted back to the BS side more effectively. Transmission Time Interval (TTI) lengths in 5G will be shorter than in legacy systems, allowing for speedier CSI feedback. Even with precise channel estimate, however, feedback and exchange between collaborating nodes may cause the latency between channel estimation and application for precoding to be so long that JT CoMP performance is obviously harmed. [37]

CS CoMP:

In CS CoMP, UE receives data transmitted from a single eNB determined through coordination within the CoMP cooperation unit. The coordinated UEs cooperate to determine the UE scheduling decisions beforehand. This process reduces the load on backhaul links but has multiple challenges such as efficient feedback compression, reduced feedback delay, efficient channel prediction at precoder, handling of outer interference within the cluster, flexible networking behind Co-ordinated Multipoint and integration of CoMP in higher layers etc.

CLSM in JT CoMP :

In practice, users move around the cellular network and depending on user location the signal reception varies diversely. Accurate estimates on CSI become difficult to be provided with changes in user velocity. CLSM enables the transmitter to have momentary estimates on channel conditions and detailed feedback on user data. The reports on CSI received from the UE are shared among the coordinated eNBs to take the scheduling decisions on UE and enhance the network gain accordingly to combat throughput degradation. In MIMO antenna system, the transceivers are configured with multiple antennas to increase data rate and spectral efficiency immensely. CLSM transmission ensures additional increase in system capacity.

At high velocities, the wireless environment encounters various unpredictable challenges. The frequent occurrences of scattering, reflection, diffraction and other multipath events degrades the signal quality intermittently and channel conditions rapidly changes making it difficult to estimate the channel condition.

In this paper, we have implemented a CSLM enabled JT CoMP network model to analyse the DL performance for mobile users in HetNet. The impact of mobility on the DL performance of CoMP is one of the focuses of our work. Detailed explanation of the results are discussed at chapter 7.

Chapter 6

Overview of Millimeter wave (mmWave) technology

6.1 Introduction

The skyrocketing market demands and technological advances fuel the research for 5g framework of communication which is still ongoing alongside the vision of 6G.The targets set for 5G standard are support system capacity (100–1000x) than current 4G system, data rates of several Gbps with lower order modulation, very low latency(<1ms) and support wide range of devices and applications. [38]

With the exponential rise of users and devices and the frequency spectrum in use being crowded with existing data traffic, it has become urgent to use new frequency spectrum and so researchers are now broadcasting using millimetre waves having frequency range of 30-300 GHz.mmWave is emerging as most promising solution to meet all these targets.

6.2 Potentials of mmWave technology

The wide unused frequency spectrum of mmwave is expected to offer an increase in system capacity greater than conventional network . According to Shannon’s capacity theorem, data rate is proportional to bandwidth. So wide BW of mmWave is expected provide data rate in the order of several Gbps. The equation for theoretical data rate is as follows:

$$C = B \log_2(1 + \frac{S}{N}) \qquad (6.1)$$

C stands for data rate, *B* for channel bandwidth and signal-to-noise ratio*, S/N.* [36]

The untapped potential of mmWave is capable of the following:

1. **Huge bandwidth availability :**

   The abundant bandwidth of mmWave can achieve higher data rate with lower modulation levels and has the capability to support high speed devices and applications such as short range communication, vehicular networks, wireless in-band front hauling/backhauling, high definition video streaming in mobile environments etc. [39]

2. **Support system capacity greater than 4G system:**

   mmWave is expected to provide system capacity hundred folds greater than 4G system. With mmWave massive MIMO system huge volumes of information can be transferred at very low latency(<1 ms) and signal coverage can be significantly increased.

3. **Significantly reduces the physical size of antenna array:**

   At mmWave frequencies, antenna elements have very small dimensions rendering it possible to fit a large number of antennas in small space, so a large number of MIMO antenna systems can be deployed which enhances the transmission distance of mmWave and improves cell edge reception quality.

4. **Boost data rate and mean spectral efficiency of the wireless system**

   With its high multiplexing gain and large spectrum, mmWave has the potential to vastly improve user throughput, spectral efficiency, and energy efficiency. mmWave is expected to provide 0.1- 1 Gbit/s of user data rate, a hundredfold increase in energy efficiency. It Fixed access, cellular apps, gaming technologies, massive file transfer, and other applications all can be benefitted from it. [39]

6.3 Challenges and limitations of mmWave

mmWave is not without its drawbacks. Susceptibility to path loss , huge penetration loss and high polarization mismatch etc. factors contribute to the rapidly fluctuating SINR of mmwave.[20] The system link budget is badly affected and throughput degrades by a huge margin. Hence the massive potential of mmwave gets bounded within small cells.

Significant challenges of mmWave include:

1. **Vulnerability to path loss:**

   The high frequency of mmWave acts as a double-edged sword making it susceptible to high path loss but providing a high data rate as well. The mmWave spectrum is subjected to relatively high propagation loss due to the free-space path loss being proportional to the square of the link distance and carrier frequency. [39] In fact, a 10-meter link in mmWave technology will result in a free-space path loss of about 82dB.

2. **Non-static blockages:**

   Due to its short wavelength, mmWave gets easily obstructed by buildings, trees and other materials etc. and cannot diffract properly around the objects it would ideally bend around. Owing to its low transmit power,mmWave has a narrow beamwidth directed towards a particular direction, so mmWave is less likely to avoid strong blocking. [40]

3. **Dominant in-channel interference :**

   Despite the availability of wide bandwidth spectrum, the channel numbers in mmWave is restricted. In other words, in-channel interference will become more significant, necessitating the use of interference management and mitigation strategies. [39]

4. **Rapidly fluctuating SINR:**

   The SINR of mmWave undergoes rapid fluctuations, taking an "On/Off" pattern primarily determined by beam steering efficiency, the presence or absence of blockages, and the random alignment of interfering beams. [38]

5. **Polarization mismatch:**

   The susceptibility of mmWave to blockages causes the polarization of the transmitted signal experiences several reflections and scattering and other multipath events while reaching the receiver via the multipath channel resulting in high polarization mismatch.

6. **Hardware Complexity:**

   With mmWave technology, it has become possible to fit a large number of antenna elements within a limited space. But Phase noise (PN), non-linear PAs, I/Q imbalance, and low ADC resolution all degrade practical transceiver hardware. The mixers used in the mmWave communication system deviate their output upon slight variations in the carrier frequency used in the transmitter and receiver. mmWave is very sensitive to PN which can alter the phase of the carrier frequency which must be kept the same at both transmitter and receiver. [41]

7. **Power Consumption:**

   A highly directional antenna system is required to counterbalance the severe effect of path loss in the mmWave channels and maintain a consistent Signal to Noise Ratio (SNR). So the transmitted power needs to be increased to tap the potential of mmWave signals, which is not energy efficient.

6.4 mmWave operation with JT CoMP operation

Users in the cell edge experience negligible throughput in mmWave technology owing to its short wavelength and sensitivity to path loss. So the potential of mmWave remains restricted within small cells. To improve the service quality at the cell edge in mmWave technology, JT CoMP operation is a viable solution. The cell sites in mmWave are significantly small in size so the eNBs are in close proximity to one another to exchange significant amount of information via the backhaul links. The load placed on backhaul links is less for JT CoMP in the mmWave network compared to the conventional network. The incorporation of CLSM in JT CoMP in the mmWave network is expected to give a significant boost to the network capacity and provide decent enough throughput to avoid call drop during handover at the cell edge. In our work, we have compared the performance of CLSM integrated JT CoMP in mmWave operated HetNet with a conventional mmWave based HetNet. The detailed analysis of the work is presented in chapter 7.

Chapter 7

Simulation

7.1 Introduction

For the purpose of demonstration of the complete impact of Joint Transmission Coordinated Multipoint on mobile users in 5G heterogeneous network and therefore, provide concrete proof of our research, a number of simulations have been conducted as follows:

- JT CoMP Basic Simulation,
- JT CoMP Simulation with varying antenna configuration,
- Visualization of Antenna Coverage,
- JT CoMP with MM wave implementation.

All the results obtained as well as analysis of said results of all the simulations conducted during our research is thoroughly examined and explained in this chapter.

7.2 Network Architecture

For our research, we have considered a heterogeneous network consisting of a mixture of macro and femto cells for CoMP implementation that mimics real world 5G network architecture.

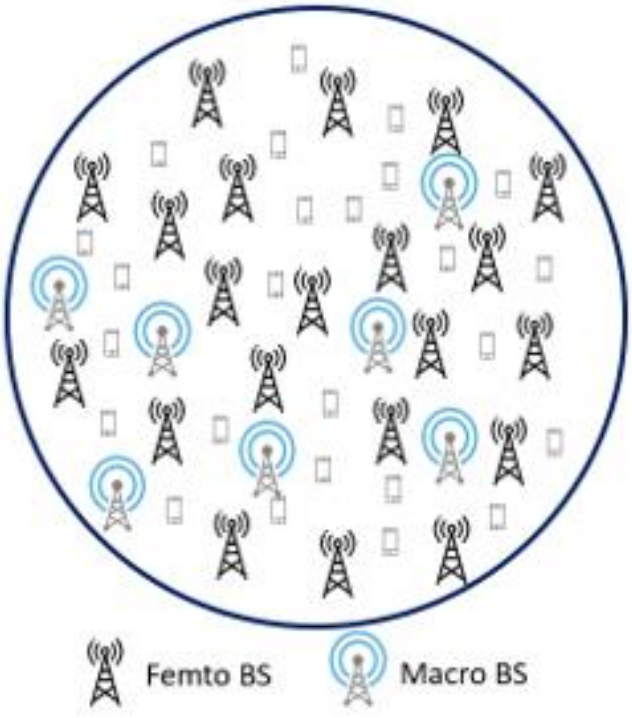

Figure 7.1: Network Architecture.

- There are 7 macro eNodeBs and 21 femtocells for a cell radius of 1 km with a total of 210 mobile users randomly scattered in the wireless environment. Every eNB is comprised of a tri-sector antenna. CLSM was used a transmission mode for proper feedback coordination required by CoMP and allows estimations of the radio link channel to be shared between the eNBs.

- All simulations used Round Robin (RR) scheduler.

7.3 Key Performance Indicator

Three parameters were used as key performance indicators were used to measure the quality of service and performance of the network: average UE throughput, cell edge throughput and spectral efficiency.

Average UE Throughput: Under a certain eNB coverage, distance of all the UEs from that certain eNB is different. This results in a wide range of SINR and throughput specific to each user. Thus, measuring the average UE throughput can express much about the present channel quality of the network, determined by [42]:

$$T_{avg} = \frac{\sum_{k=1}^{n} T_k}{n} \qquad (1)$$

Where the total throughput is defined by T_k for the k^{th} user while n is the total number of users.

Cell Edge Throughput: For a UE situated at the edges of a cell, the huge distance along with ICI degrades the system performance. In this scenario, providing a minimum data rate necessary to avoid call drop occurrence during handovers. The cell edge throughput is measured from the 5th percentile of the UE throughput ECDF.

Spectral Efficiency: This parameter is the measure of how the data is being transmitted over a certain bandwidth with due efficacy. The spectral efficiency depends on the bandwidth and data rate and it can be expressed by [43]:

$$S = \frac{\sum_{k=1}^{n} T_k}{BW} \qquad (2)$$

Where T_k is the total throughput for the k^{th} user and BW is the network system bandwidth.

7.4 Joint Transmission Coordinated Multipoint (JT-CoMP)

7.4.1 Simulation

A simulation has been conducted to soundly ascertain the effectiveness of inter-site and intra-site JT CoMP schemes in the mitigation of ICI and enhancement of cell edge throughput for mobile users in a HetNet compared to a HetNet without any CoMP implementation. Vienna advanced system level simulator has been used for this purpose. [44]

The simulation considers the use of Closed Loop Spatial Multiplexing in the HetNet to analyze the impact of JT CoMP technology for numerous user velocities. For this simulation, both the cases of static UEs and mobile UEs has been taken into consideration.

The simulation assumptions are effectually summarized in **Table 7.1**.

Table 7.1 JT-CoMP Basic Simulation Assumptions

No. of macro eNBs per cluster	7
No. of femto eNBs per cluster	21
MIMO Configuration	4x4
Transmission Mode	CoMP
Velocity	0-120 kmph
Resource Scheduling	Round Robin (RR)
Transmission Bandwidth	20 MHz
Distance between eNBs	1730 m
No. of UEs	210
Simulation Time	30 TTI

The results obtained has been illustrated clearly using graphs for concise and clear understanding.

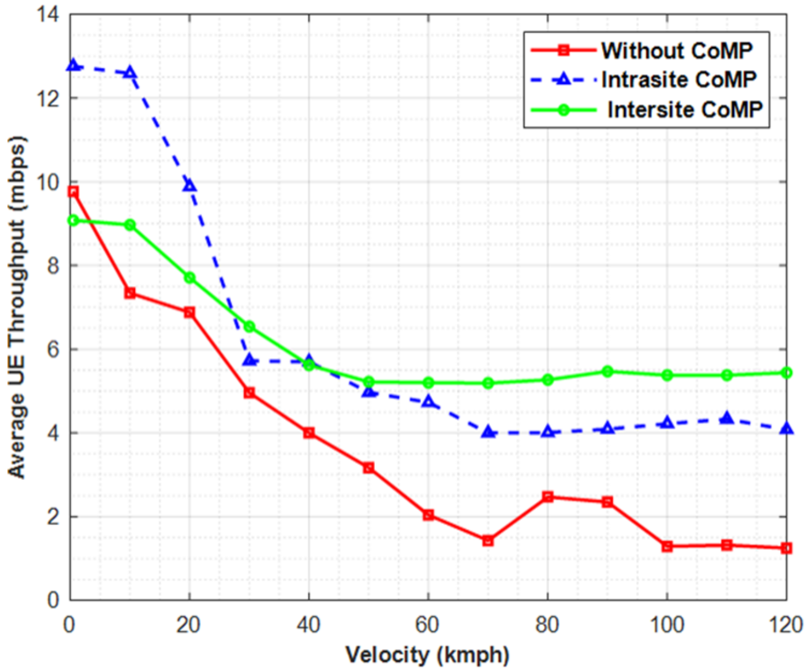

Figure 7.2: Average UE Throughput Vs UE Velocity

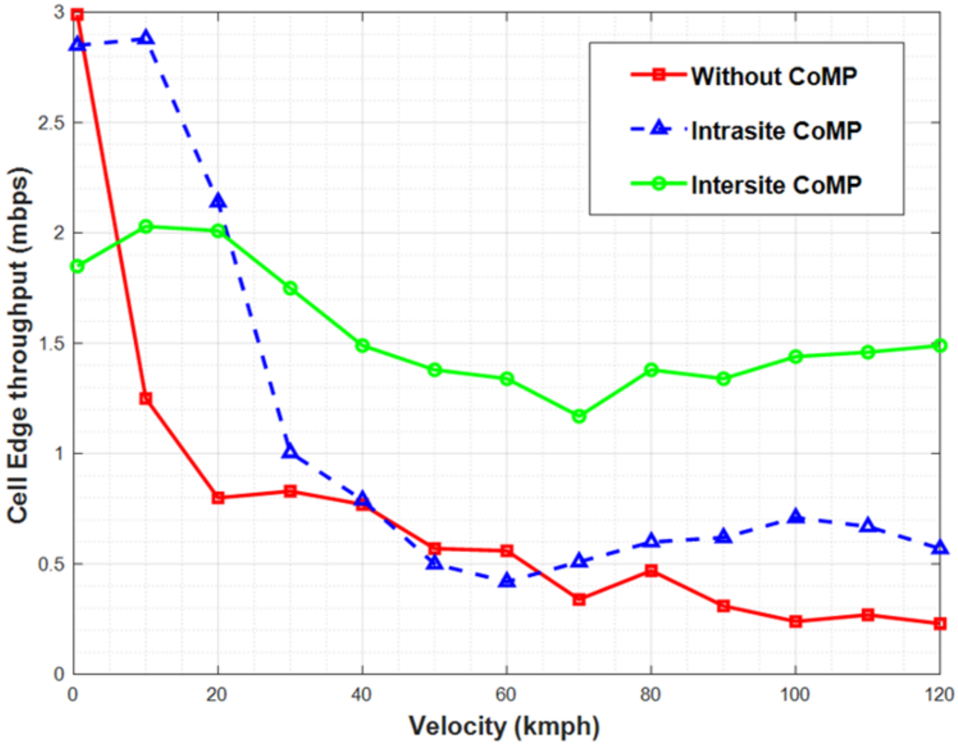

Figure 7.3: Cell Edge Throughput Vs UE Velocity.

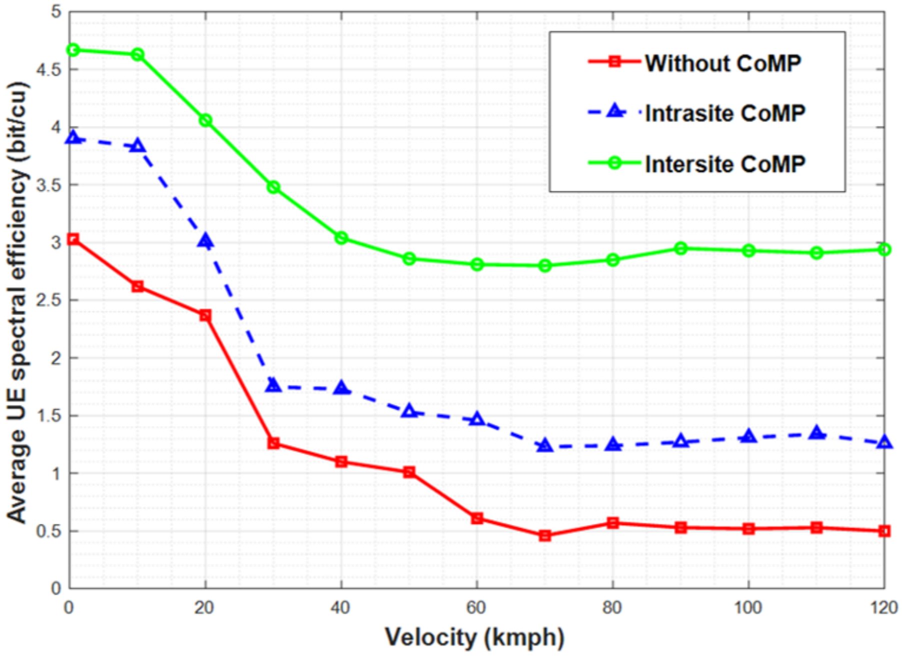

Figure 7.4: Average UE Spectral Efficiency Vs UE Velocity**.**

7.4.2 Analysis

The simulation compares the performance of HetNet with CoMP implementation and that without CoMP implementation. The CoMP implementation was considered for both intersite and intrasite CoMP schemes. The comparison was made in terms of the following key performance indicators with variation of the UE velocity:

- average UE throughput,
- cell edge throughput,
- spectral efficiency.

In **Figure 7.2** it can be seen that for all three schemes, the average UE throughput decreases with increase in UE velocity. This overall decreasing trend can be attributed to a number of different factors: CLSM, Doppler spread, etc.

Utilization of CLSM in the simulation allows approximations of UE channel state information that is shared between eNBs to enhance downlink performance. However, at higher UE speeds, CLSM is found to degrade the overall performance. This is because the feedback is far less detailed and lacks accuracy with respect to existing channels due to continuous fast change of multipath environment when the UE velocity is high.

Moreover, the Doppler spread increases at higher user velocities. The Doppler spread results from both the effects of Doppler shifts in the transmitted signal as well as the Doppler shifts in the interference signals. Other phenomena such as scattering, reflection and multipath fading further degrades the system throughput. As a result, causing signal distortions and packet losses leading to decline in throughput.

Downlink transmission in HetNet without CoMP is heavily affected by Intercell interference and therefore, as shown in **Figure 7.2**, it exhibits the poorest performance. In this case, fluctuations can be observed in throughput at higher UE velocities whereas in CoMP schemes, there is an overall decreasing trend without any fluctuations. This phenomenon is due to the random nature of ICI causing inconsistent DL performance and it is not present in CoMP schemes due to their effectiveness in the reduction of ICI.

For both CoMP schemes, it is noted that the average UE throughput is much higher than HetNet without CoMP implementation with intrasite CoMP scheme giving superior performance at lower velocities and intersite CoMP showing better results at higher velocities. This higher throughput for CoMP schemes can be attributed to the intense ICI management capabilities.
Use of CLSM is also generally expected to give poor results at higher velocities. Contrary to that, implementation of CoMP along with CLSM in this simulation has yielded better DL performance as illustrated in **Figure 7.2**, **Figure 7.3** and **Figure 7.4**. User velocity and the multipath environment differ with UE position with respect to different eNBs.

For Joint Processing CoMP, there is coordination between multiple eNBs that are simultaneously transmitting or receiving to or from UEs. eNBs share all transmit data and channel state information (CSI) of users through the backhaul links. Multiple BSs transmit simultaneously on the same frequency. In the case of intersite CoMP, there is coordination between eNBs of multiple different cells. The eNB most qualified to provide the best service can be identified by the sharing of CSI among the eNBs. The UE can then be handed over to an eNB from a different cell where the network gain is higher and therefore, can provide better service. For intrasite CoMP scheme, communication between multiple eNBs in the same cell is necessary for the creation of antenna array to provide better performance. This communication creates backhaul thereby causing it to have poorer than Intersite CoMP scheme at higher velocities but showing superior performance at lower velocities.

UEs at the cell edges are subject to heavy interference from neighboring cells. As seen in **Figure 7.3**, while HetNet without CoMP implementation had the greatest cell edge performance for static UE but showed a massive decline in cell edge throughput with UE starts moving due to delays due to limited frequency resource. One way to overcome the effects of ICI would be to increase transmission power which will in turn increase transmission cost. Therefore, it is not an economically efficient solution and less desirable compared to implementation of CoMP schemes.

Once again, intersite CoMP offers the best results at higher velocities used in this simulation as the rate of decrease of cell edge throughput is the lowest out of the two CoMP schemes. In case of intersite CoMP, interference at the cell edge due to neighboring cells is easily identified through the sharing of UE CSI between eNBs of different cells and therefore, easily mitigated. Intrasite CoMP initially suffers massive degradation of radio link quality when UEs start moving due to increased distance from serving eNB. It has comparatively poorer performance at the cell edge as the coordination is between eNBs of different sectors of same cell; it is less adept at reduction of interference from neighbouring cells.

Coordination between eNBs in CoMP schemes results in choice of best eNB for DL transmission such that maximum signal power is achieved and ICI is minimized allowing for notably high spectral efficiency as illustrated in **Figure 7.4**. Overall, through this simulation it has been observed that implementation of CoMP boosts signal strength and upgrades coverage with intersite CoMP having the most successful results at high velocities and intrasite CoMP at lower velocity.

7.5 Antenna Configuration for JT-CoMP

7.5.1 Simulation

A simulation has been conducted to study the DL performance of mobile users in 5G heterogeneous network with intersite and intrasite CoMP implementation with respect to different antenna configurations by varying user velocity.

The comparison between the DL performance between different antenna configurations were made with respect to average UE throughput, cell edge throughput and average UE spectral efficiency.

The simulation assumptions are summarized in **Table 7.2**.

Table 7.2 Simulation Assumptions

No. of macro eNBs per cluster	7
No. of femto eNBs per cluster	21
MIMO Configuration	2x2, 2x3, 2x4, 4x2, 4x3, 4x4
Transmission Mode	CoMP
Velocity	0-120 kmph
Resource Scheduling	Round Robin (RR)
Transmission Bandwidth	20 MHz
Distance between eNBs	1730 m
No. of UEs	210
Simulation Time	30 TTI

The results are summarized clearly in the following graphs.

- **Intersite CoMP Implementation**

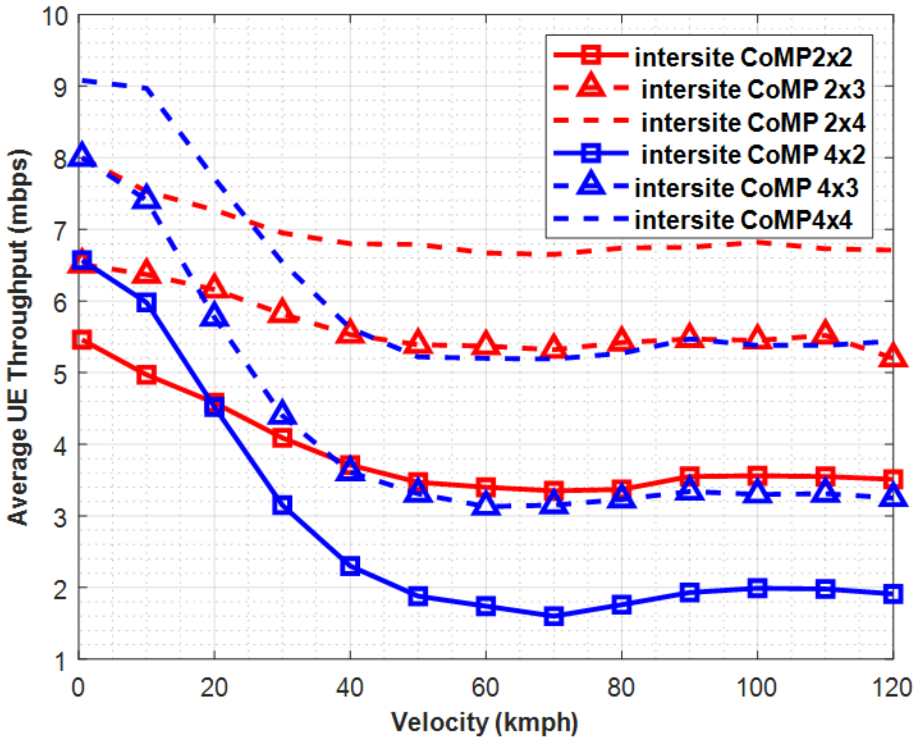

Figure 7.5: Intersite Average UE Throughput Vs UE Velocity.

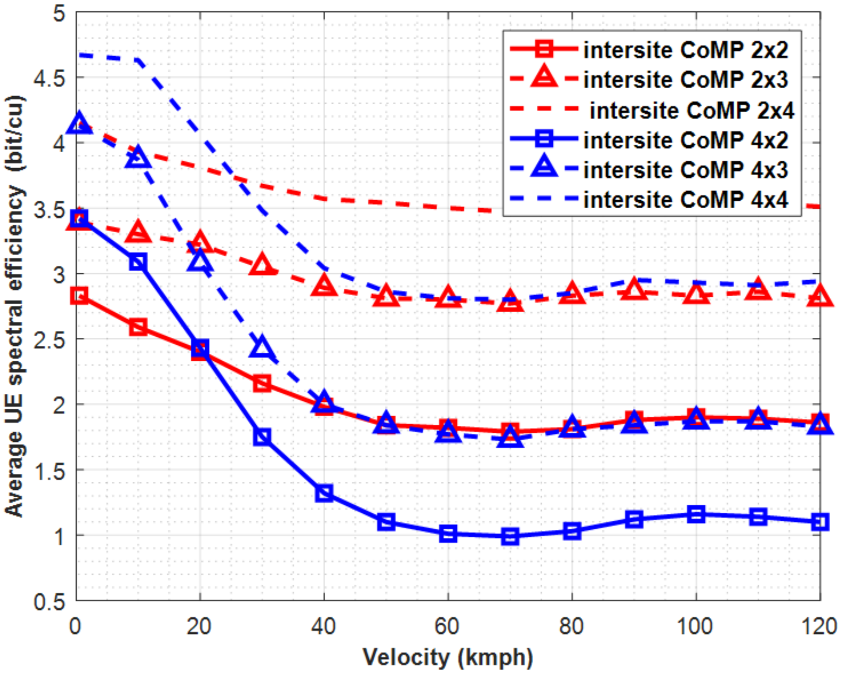

Figure 7.6: Intersite Spectral Efficiency Vs UE Velocity.

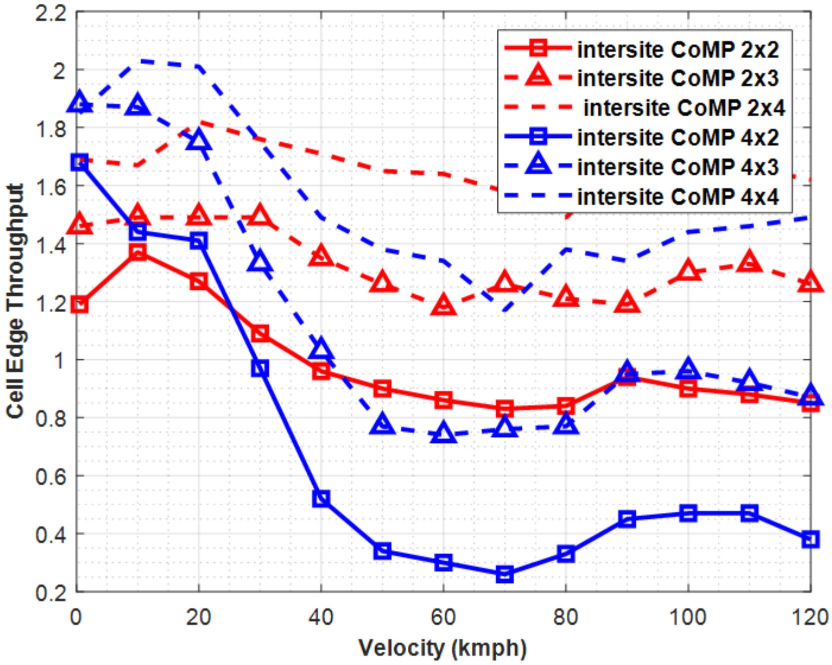

Figure 7.7: Intersite Cell Edge Throughput Vs UE Velocity.

- **Intrasite CoMP Implementation**

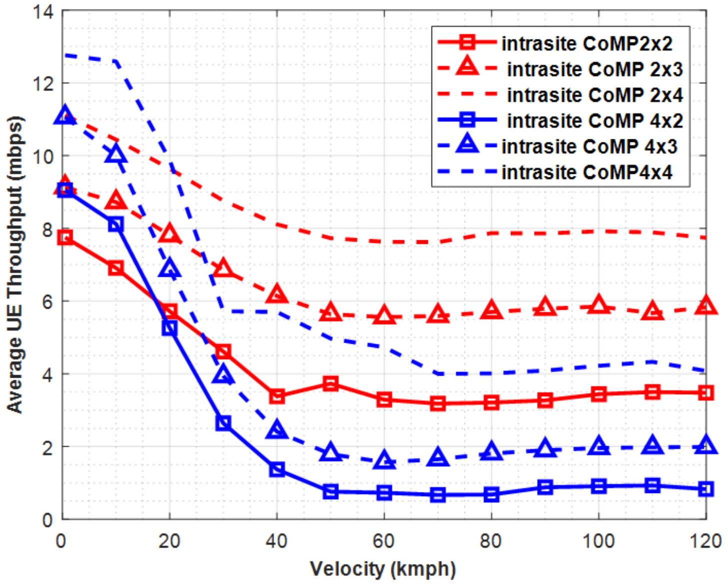

Figure 7.8: Intrasite Average UE Throughput Vs UE Velocity.

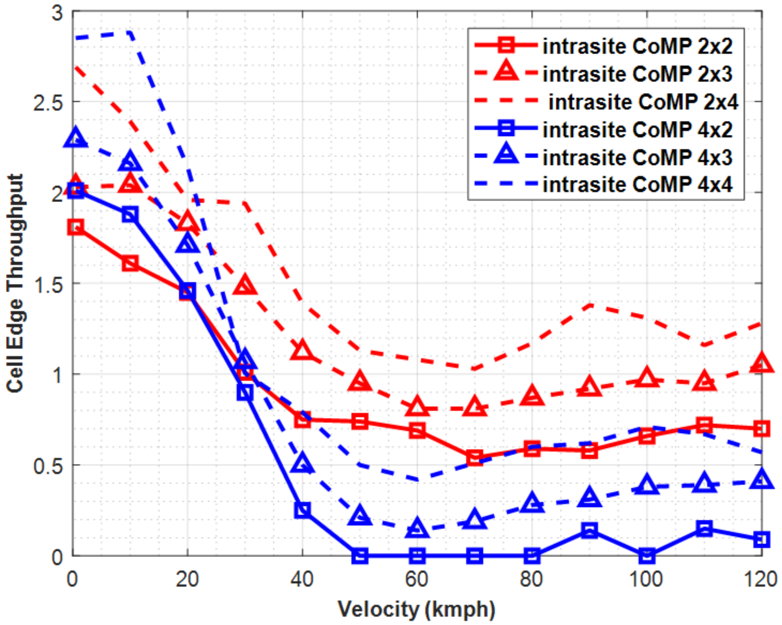

Figure 7.9: Intersite Cell Edge Throughput Vs UE Velocity.

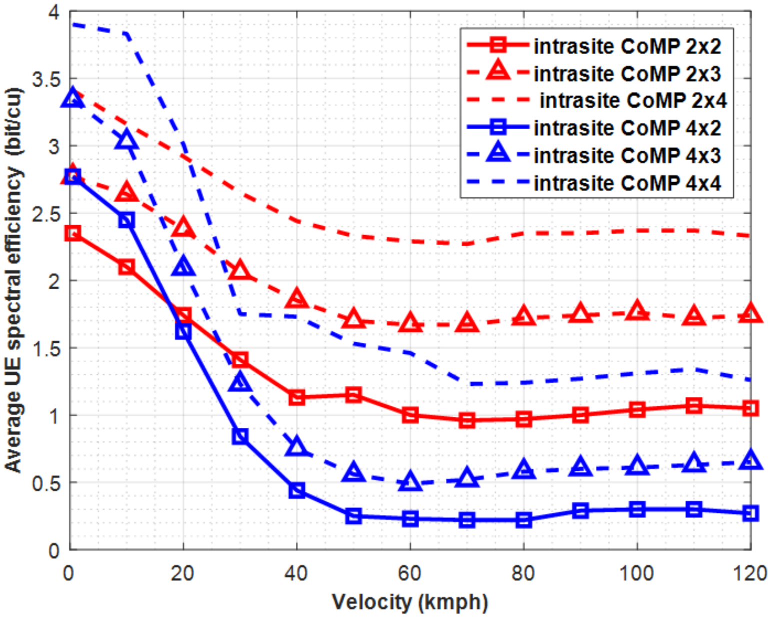

Figure 7.10: Intrasite Spectral Efficiency Vs UE Velocity.

7.5.2 Analysis

The ever rising data rate in current times is mostly tackled by the increase in the number of antenna. However, this solution comes at the price of a higher energy consumption which is undesirable. Moreover, the high velocity users experience a frequent unpredictable change in the channel conditions that degrade its downlink performance. Therefore, for the sake of good DL performance, a proper number of antenna selection is of paramount importance.

For intersite CoMP, as depicted in **Figure 7.5**, at low velocity with better SINR, the 4×4 provides the best average throughput outperforming 2x2, 2x3, 2x4, 4x2 and 4x3. But the velocity increases, the 2×4 combination outperforms other diversities, due to the fact that the more receiver antennas are active than transmit antennas, the higher the probability of successful reception for receiver UE at poor channel quality.

In the case of cell edge throughput, depicted in **Figure7.6**, combinations with higher number of transmitting antennas provide decent throughput initially but after a while, drastic decline occurs as SINR worsens at high velocity. The cell edge throughput drops with velocity increment but ultimately, it provides sufficient throughput to conduct successful handover, with that, the 2×4 combination triumphing over all. It provides greater spectral efficiency for a given bandwidth with higher throughput at high velocity as illustrated in **Figure 7.7**.

For the case of intrasite CoMP, we have observed similar patterns of results as in seen in intersite CoMP implementation. As seen in **Figure7.8**, At low velocities, higher number of transmitting antennas give better average throughput as illustrated by the antenna configuration 4x4. However, at higher velocities, antenna sets with greater number of receivers show better DL performance where 2x4 combination outperforms all other antenna sets which includes 2x2, 2x3, 2x4, 4x2 and

4x3. It should be noted that while the pattern of results is similar, the values of average throughput is greater than that of intersite CoMP.

Similar conclusions can be drawn from **Figure 7.9** and **Figure 7.10** where once again 4x4 combination can be seen performing best in terms of both cell edge throughput and spectral efficiency at lower velocities. However, at higher velocities, sets with higher number of receivers take over with 2x4 triumphing over all.

7.6 Visualization of Antenna Coverage

7.6.1 Visualization

- **Outside Dhaka**

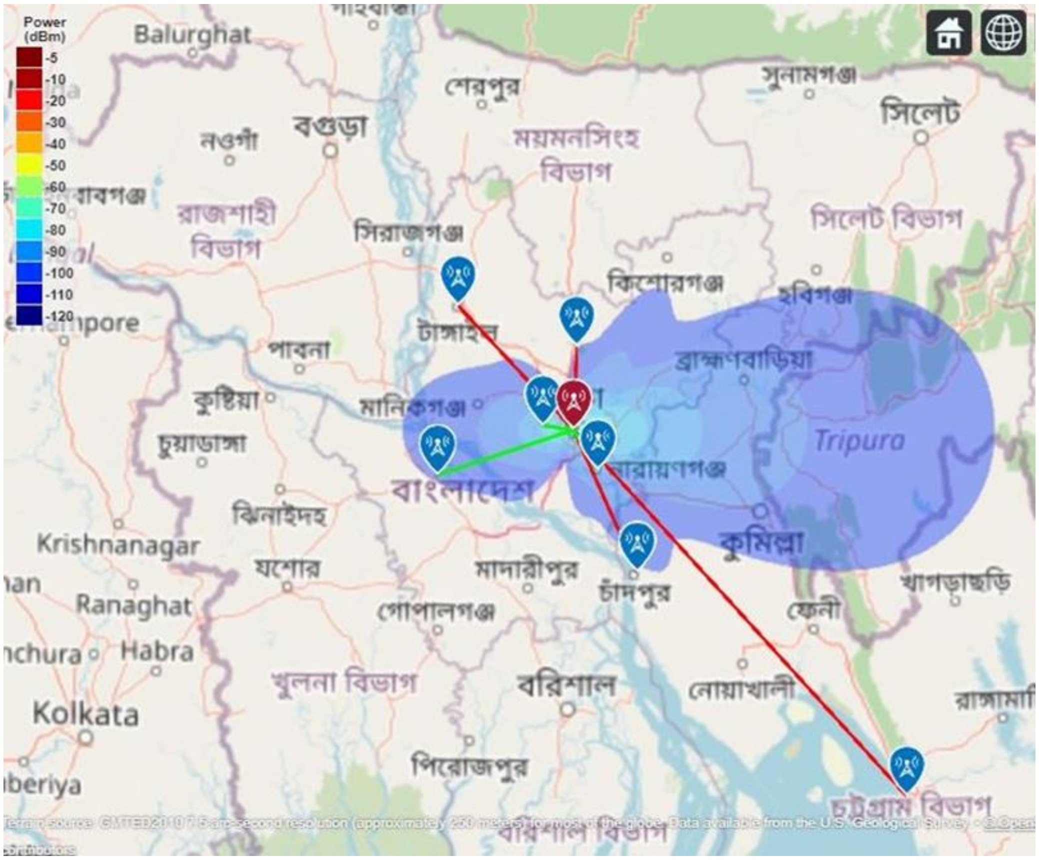

Figure 7.11: Visualization of coverage outside Dhaka at 6 GHz, 15 Watts.

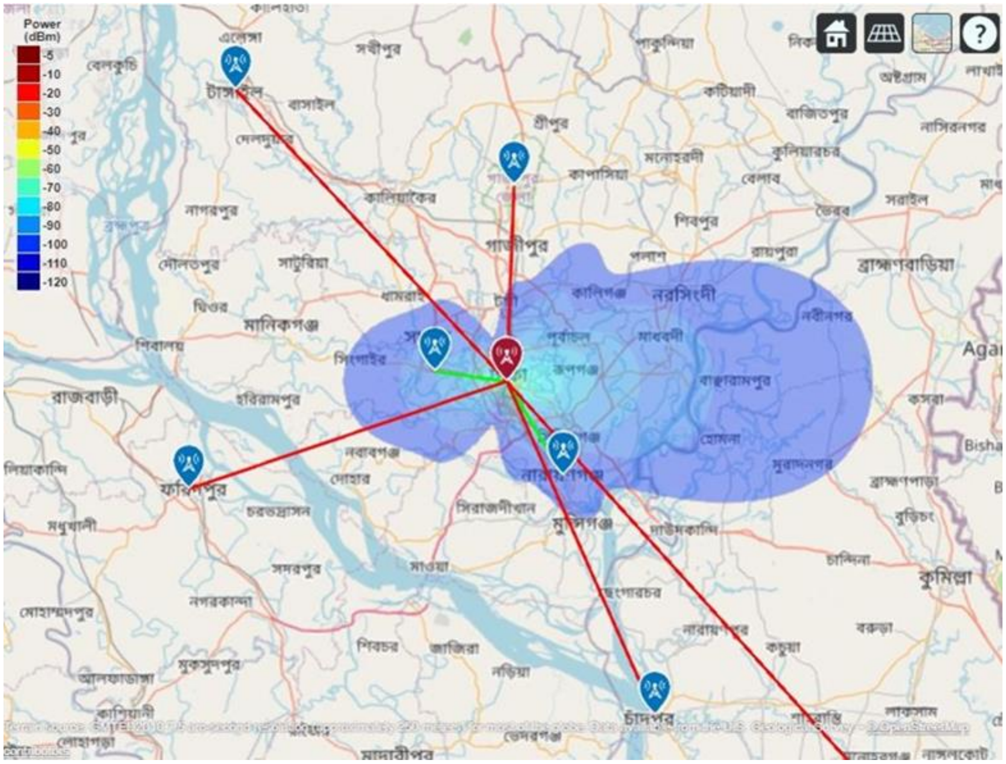

Figure 7.12: Visualization of coverage outside Dhaka at 6 GHz, 30 Watts.

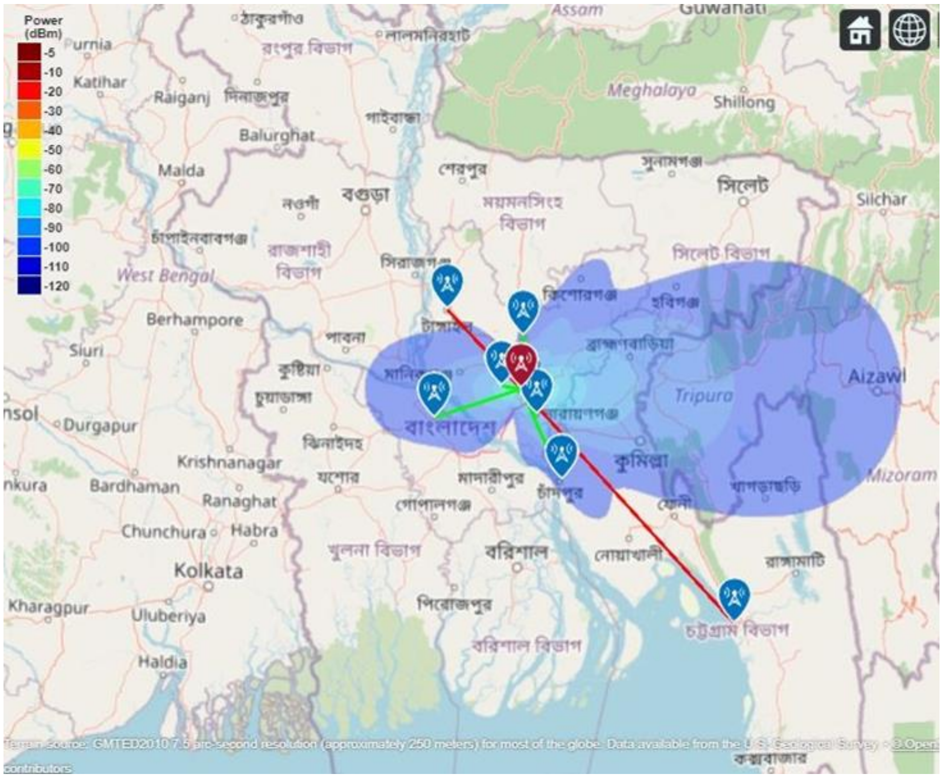

Figure 7.13: Visualization of coverage outside Dhaka at 9 GHz, 15 Watts

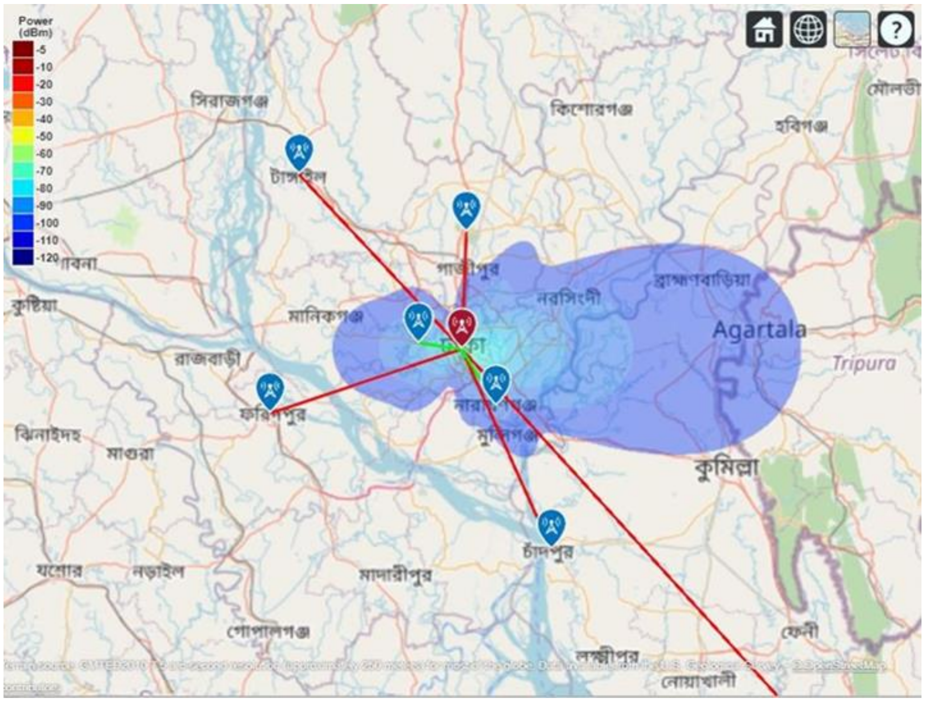

Figure 7.14: Visualization of coverage outside Dhaka at 9 GHz, 30 Watts.

- **Inside Dhaka**

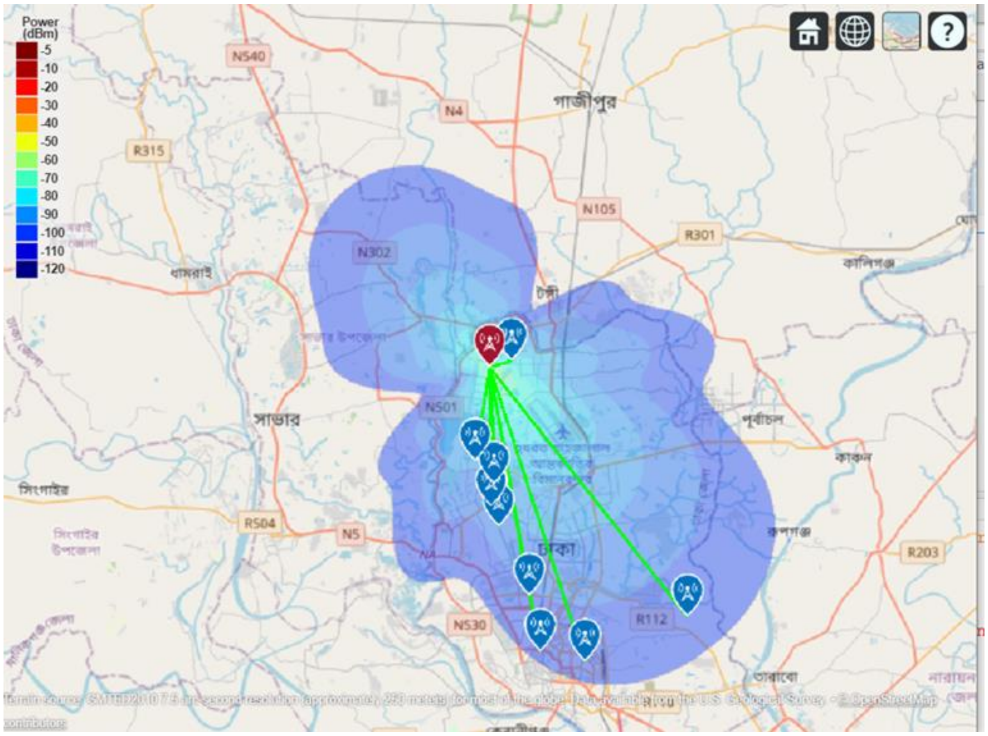

Figure 7.15: Visualization of coverage inside Dhaka at 15 GHz, 15 Watts

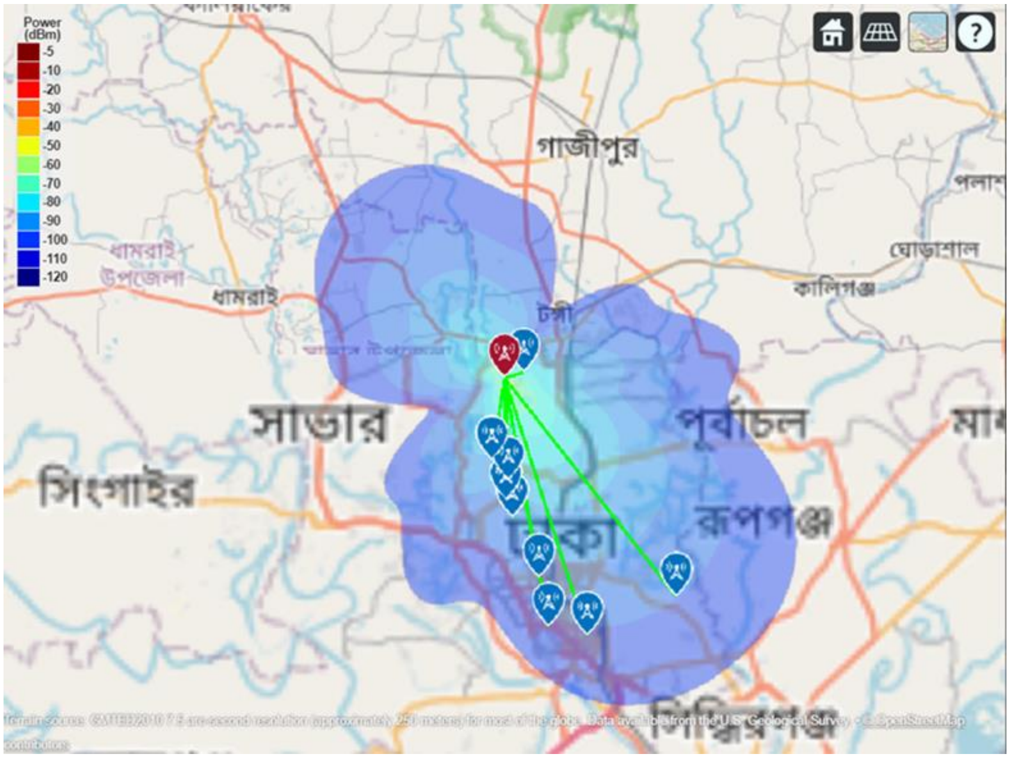

Figure 7.16: Visualization of coverage inside Dhaka at 15 GHz, 30 Watts.

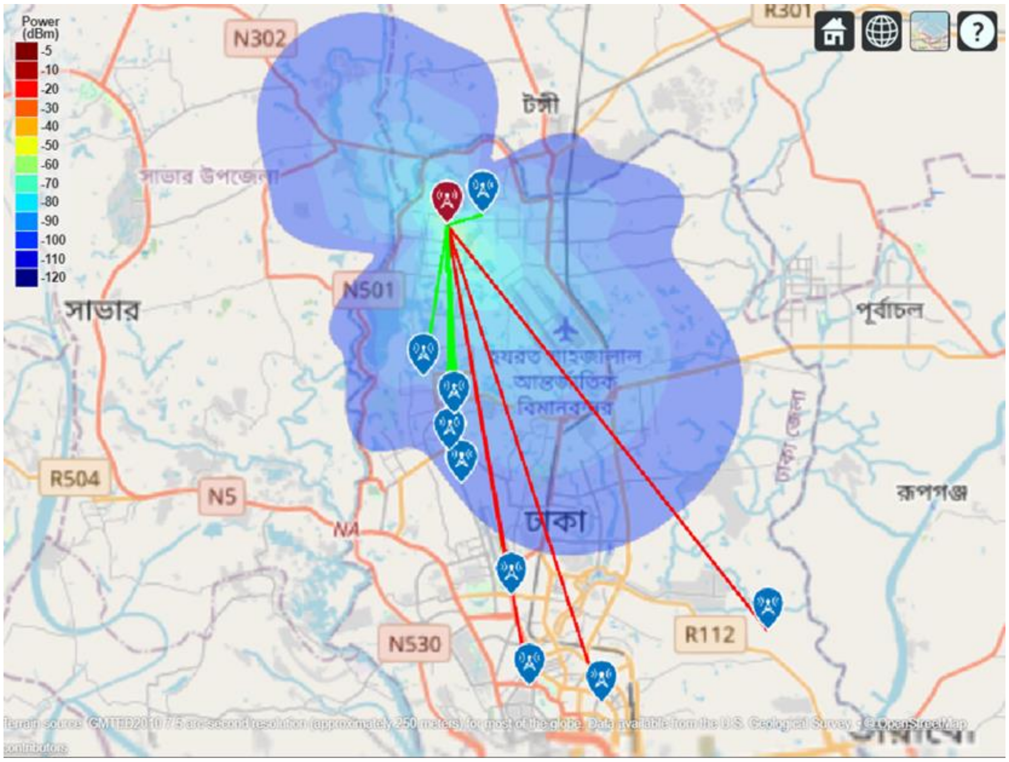

Figure 7.17: Visualization of coverage inside Dhaka at 28 GHz, 15 Watts.

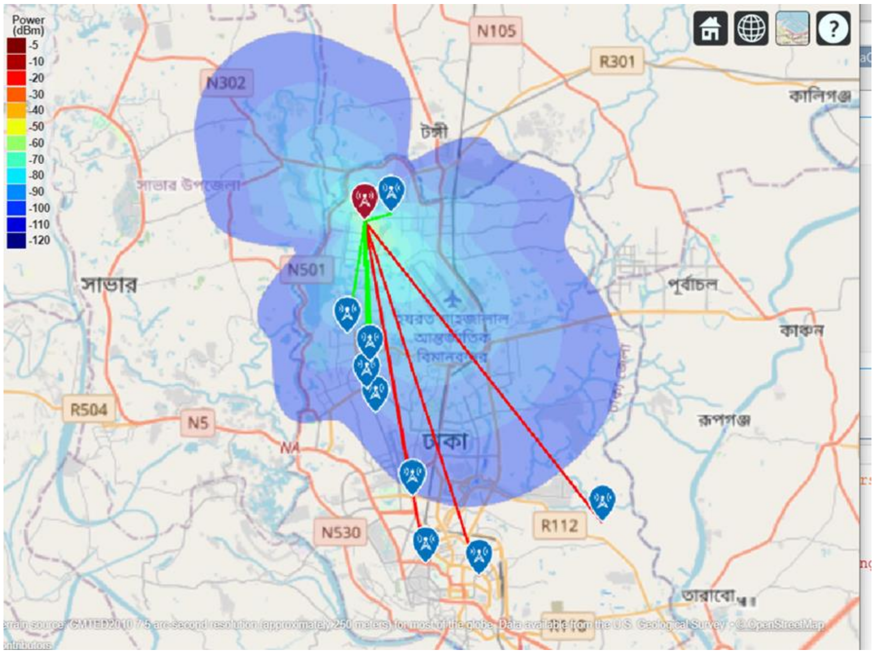

Figure 7.18: Visualization of coverage inside Dhaka at 28 GHz, 30 Watts.

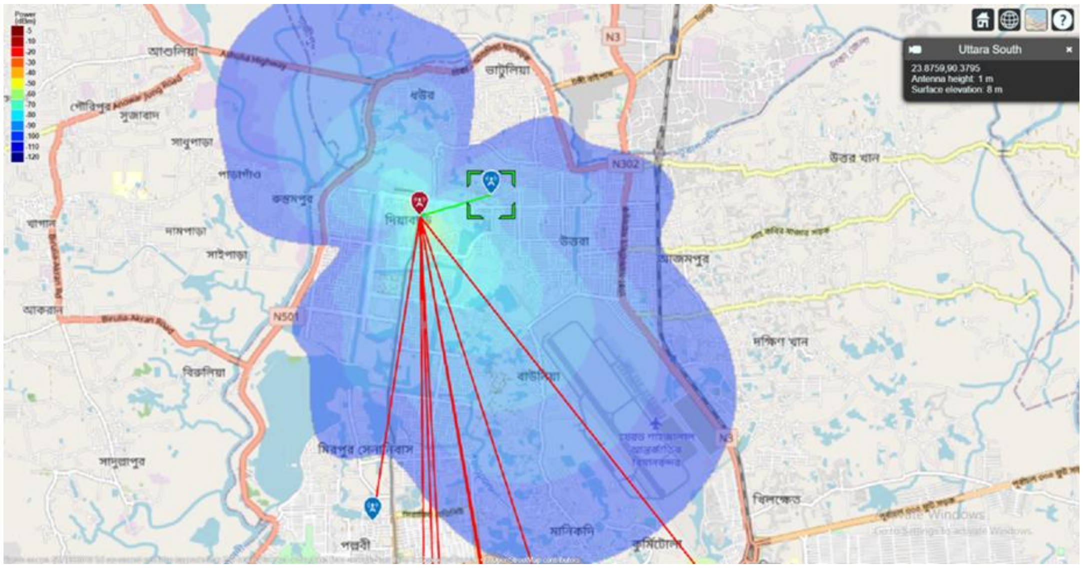

Figure 7.19: Visualization of coverage inside Dhaka at 30 GHz, 15 Watts.

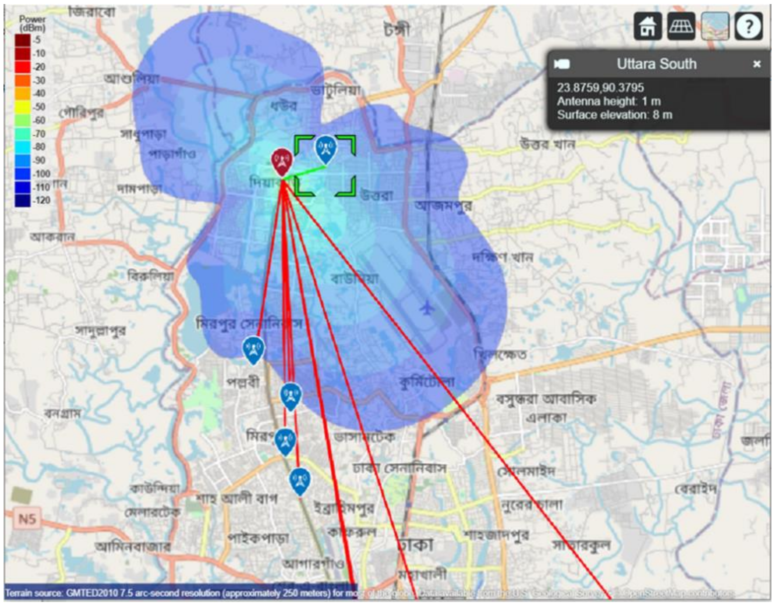

Figure 7.20: Visualization of coverage inside Dhaka at 30 GHz, 30 Watts.

7.6.2 Analysis

A simulation was conducted over a real-life environment to further visualize the connection between transmission and reception is occurring.

This simulation consists of two segments:

- Antenna coverage for areas outside Dhaka,
- Antenna coverage for areas inside Dhaka.

For this simulation, a Yagi-Uda antenna has been used which offers a unidirectional radiation pattern, thereby more adept at creating a transmission visualization than an omni-directional antenna. In both scenarios, Dhaka has been kept as the central transmission zone. The green line indicates a successful transmission whereas, red indicates failure.

For outside Dhaka, the visualization was done with two frequencies for two different power levels: 15 watts and 30 watts. For the case of 6 GHz, as depicted in **Figure 7.11**, it can be observed that when the power is 15 watts more eNBs are outside the coverage area. With the increase in power to 30 watts, the same signal now covers more area than previously as seen in **Figure 7.12**.

Increasing the frequency to 9 GHz, the coverage area can be seen to have been reduced as illustrated by **Figure 7.13** and **Figure 7.14**. This is due to the fact that higher frequencies attenuate more the further distance they travel. Moreover, higher frequency radio waves tend to be absorbed more readily by objects that is the penetration capability of high frequency signals is shorter. Wavelength of a signal is diminishing with increasing frequency. The lower the wavelength the lesser will be the distance covered by the signal the more it will be prone to blockages.

For the case of inside Dhaka, the visualization has been made for the mmWave ranges. As shown in **Figure 7.15** and **Figure 7.16**, in case of frequency 15 GHz, there was successful reception for all receivers for both power levels of 15 watts and 30 watts. However, as frequency is increased to 28 GHz and 30 GHz, radius of coverage decreases as depicted in **Figure 7.17** and **Figure 7.19**. This is because, mmWave is vulnerable to atmosphere and other environmental parameters. The operation of millimeter wave radar is also affected due to interference from nearby electric poles, cellular towers, Wi-Fi/cellular hotspots etc.

7.7 mmWave Implementation

7.7.1 Simulation

A simulation has been conducted to soundly ascertain the effectiveness of inter-site and intra-site JT CoMP schemes in the mmWave range. Vienna 5G SLS simulator has been used for this purpose. [3]

The simulation considers the use of Closed Loop Spatial Multiplexing in the HetNet to analyze the impact of JT CoMP technology for numerous user velocities. For this simulation, both the cases of static UEs and mobile UEs has been taken into consideration.

The simulation assumptions are effectually summarized in **Table 7.3**.

Table 7.3 mmWave Simulation Assumptions

No. of macro eNBs per cluster	7
No. of femto eNBs per cluster	21
MIMO Configuration	4x4
Transmission Mode	CoMP
Velocity	0-120 kmph
Resource Scheduling	Round Robin (RR)
Transmission Bandwidth	30 MHz
Frequency	28 GHz
Distance between eNBs	1730 m
No. of UEs	210
Simulation Time	30 TTI

The results obtained has been illustrated clearly using graphs for concise and clear understanding.

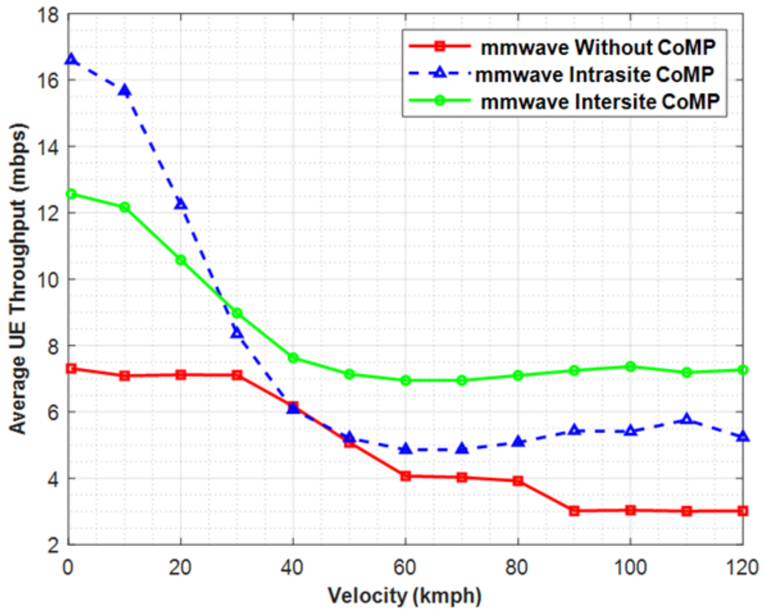

Figure 7.21: mmWave implemented Average UE Throughput Vs UE Velocity.

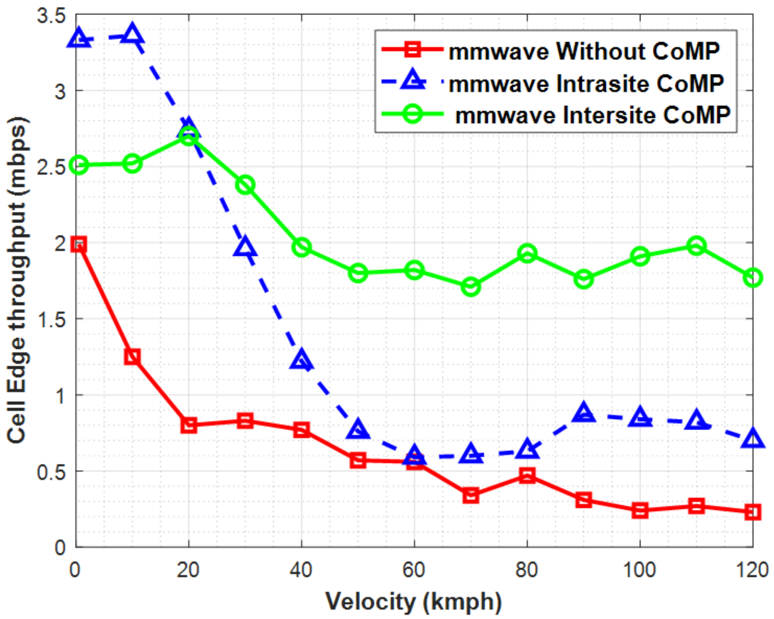

Figure 7.22: mmWave implemented Cell Edge Throughput Vs UE Velocity

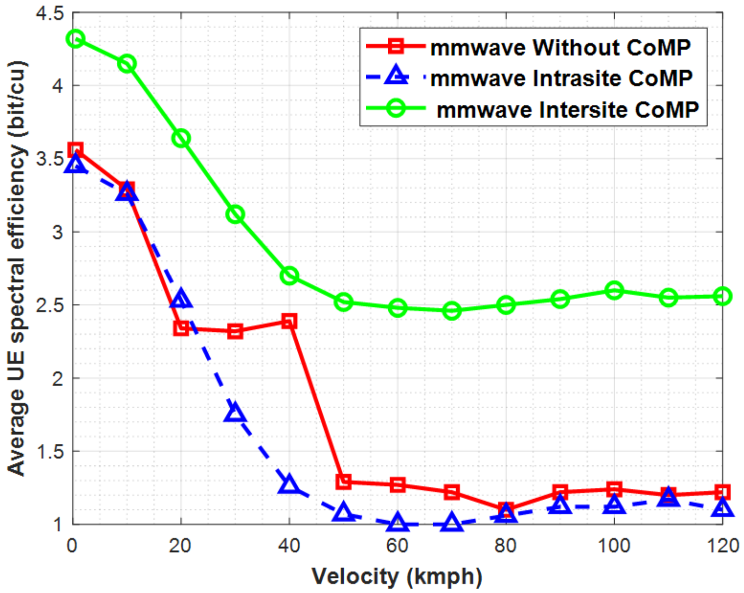

Figure 7.23: mmWave implemented Spectral Efficiency Vs UE Velocity.

7.7.2 Analysis

From the visualization of antenna coverage of mmWave, it can be concluded that it is highly suited to localizes areas. Therefore, this simulation was carried out to observe the DL performance of CoMP in the mmWave frequency range and compare the effectiveness of intersite and intrasite CoMP compared to mmWave performance without CoMP implementation.

5G millimeter wave (mmWave) technology is one of the prospective solutions for supporting traffic surge of 100-1000 times than 4G. The shorter wavelength of mmWave equips it with wide frequency spectrum making it suitable for achieving data rates of several Gbps. Extremely high frequencies allow multiple short-distance usages at the same frequency without interfering each other. Therefore, as observed in **Figure 7.21**, all three mmWave schemes have higher values of average UE throughput than all schemes in **Figure 7.2**. This trend also stays true for cell edge throughput and average UE spectral efficiency in **Figure 7.22** and **Figure 7.23**.

As depicted in **Figure 7.21**, average UE throughput decreases with increase in user velocity for all three schemes. At low velocities intrasite CoMP provides the best service but shows significant decline in throughput when velocity increases due to more frequent occurrences of scattering, reflection and other multipath events that decline throughput. In the case of intersite CoMP, there is coordination between eNBs of multiple cells and the UE can be handed over to an eNB from a different cell where the network gain is higher and therefore, can provide better service, thereby giving a somewhat constant figure. For scheme without CoMP implementation, the values of throughput are quiet relatively similar. However, they are on the lower side compared to CoMP schemes.

UEs located in the cell experience heavy inter cell interference from the neighboring cell and signal strength is weak due to the distance from the eNB. As a result, UEs located in the edge of the cell have a very poor data rate and this degrades the performance of the network. Both intersite and intrasite provides better cell edge throughput than mmWave without CoMP implementation as illustrated by **Figure 7.22**. For low UE velocities or unmoving UEs, intrasite provides better data rate than intersite at cell edges. Communication between several eNBs is required for the formation of an antenna array for greater performance in the intrasite CoMP system. This communication causes backhaul, making it perform worse than the Intersite CoMP system at higher velocities.

With increase in bandwidth, data rate will also be increased. With increase in UE velocity for a given system bandwidth, the efficiency of utilization of the spectrum decreases. Hence, there is a decline in data rate. Spectral efficiency that is dependent on both on bandwidth and data rate, has the greatest values and thereby, best DL performance for intersite CoMP as seen in **Figure 7.23**.

7.8 Practical Application of Our Work

Although Joint Transmission Coordinated multipoint is an existing technology in the management of inter cell interference in a 5G network, the effect of mobility of users in the network with CoMP implementation, both intersite and intrasite, has not been previously studied.

Our research meticulously examines the DL performance of JT-CoMP in a HetNet with mobile users providing a detailed report and analysis through extensive simulations using realistic network architecture and parameters. DL performance is compared using key performance indicators widely used to judge and evaluate network performance: average UE throughput, cell edge throughput and spectral efficiency.

Furthermore, our work also helps visualize the antenna coverage as well as evaluate the performance of CoMP schemes for mobile UEs (0-120kmph) using different antenna configuration. We have also determined the pattern and quality of DL performance for mmWave implementation with CoMP which is becoming a popular solution to deal with the ever increasing traffic surge in networks.

In general, our results can easily be interpreted for large scale systems and can be easily implemented in the existing network architectures with minimal complexity. It has the potential for solving real-life problems like call drops and low data rate to be frequently experienced by high speed users. This is especially useful for users in transportation systems like Dhaka MRT project. The results we have obtained from extensive simulations is also undoubtedly a valuable resource for use as reference for further research into mobility in 5G technology.

Chapter 8
Conclusion

To conclude all the works and simulation, it can undoubtedly be said that implementation of JT-CoMP will be beneficial for ICI management as well as for improving DL performance in 5G network including the mmWave frequency ranges as the results obtained in our simulations validates our claims. It improves cell edge throughput and system throughput, utilizes interference constructively. CoMP transmissions improve infrastructure utilization in mm-wave small cells, enhance reception quality, increase the chance of LOS paths, and reduce ICI for cell edge users. It helps service provider by improving network resource utilization i.e. spectrum efficiency. Subscriber notices higher bandwidth due to service provided by multiple eNBs at any given time.

Current and future wireless networks are expected to accommodate billions of smart devices at the same time while preserving reliability and quality of service for each product especially for users at cell edges or in motion. Our research distinctly establishes why JT-CoMP is a feasible solution for both scenarios from both technical and economical perspective.

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