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LOCATION AWARENESS FOR INTERFERENCE MANAGEMENT IN 5G NETWORKS

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ABSTRACT

Mohammad Mahadi Hasan Foad: Location awareness for interference management in 5G networks
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The deployment of the ultra-dense network in next generation 5G new radio (NR) offers better network capacity and higher data rates. However, the ultra-dense network also causes numerous interferences, such as inter-cell, intra-cell, and inter-user interference. Interferences degrade SINR performances. Furthermore, the next generation 5G NR also suffers in higher path loss which degrades the SNR performances. On the other hand,5G networks will enable high accuracy positioning that can be leveraged to design and optimize wireless networks. In this thesis, we utilize this location information feature of 5G NR for managing the interference. Moreover, different existing interference mitigation approaches are described as background information of interference management. In this thesis beamforming technique has been considered to achieve higher location accuracy and to compensate the path loss. The aid of using beamforming is to achieve the higher antenna gain which enables to steer the transmit signal directly towards the desired user. The simulation result shows that the beamforming technique by using multiple antenna arrays significantly improves the SINR performance along with the SNR performance.

Keywords: 5G NR, Interference management, beamforming, SINR, SNR, CoMP, ICIC, Coordinated scheduling, HetNet and D2D.

PREFACE

This master thesis, “Location awareness for interference management in 5G networks” was conducted to fulfil the requirement of Master of Science degree in Electrical Engineering, with a specialization in Wireless Communication and RF Systems.

All my gratitude and thanks to ALLAH, who is the heavenly power of the Earth and the store of every information and knowledge.

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Tampere, 28 October 2020

Author

Mohammad Mahadi Hasan Foad

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LIST OF SYMBOLS AND ABBREVIATIONS

2G	second generation
3G	Third generation
4G	Fourth generation
5G NR	Fifth generation new radio
3GPP	Third generation partnership project
ABS	almost blank subframe
AoA	Angle of arrival
BS	Base station
CoMP	Coordinate multipoint
CCI	co-channel interference
CS	Coordinated scheduling
DoA	Direction of arrival
D2D	Device-to-Device
DIS	Dynamic information selection
eMBB	Enhanced mobile broadband
FDD	Frequency Division Duplex
GSM	Global system for mobile communication
HSPA	High Speed Packet Access
HetNet	Heterogeneous network
ICIC	Inter-cell Interference Coordination
IMT	International mobile telecommunications
ICI	Inter cell interference
IoT	Internet of things
LS-CMA	Least square constant modulus algorithm
LCMV	Linearly constrained minimum variance
LMS	Least mean square
LTE	Long term evolution
LPDC	low-density parity-check
MIMO	Multiple-Input Multiple-Output
mm-wave	millimetre wave
MVDR	Minimum variance distortion-less response
mMTC	Massive machine type communication
OFDM	orthogonal frequency division multiplexing
Rel	release
RAT	radio access technology

RAN	Radio Access Network
SNR	Signal -to-noise ratio
SINR	Signal-to-noise-plus-interference ratio
TDD	Time Division Duplex
ToA	Transmission of arrival
UE	User equipment
URLLC	Ultra reliable low latency communication
UDN	Universal Domain Network
V2V	Vehicle to vehicle
W-CDMA	Wideband Code Division Multiple Access
WLAN	Wireless local area network

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1. INTRODUCTION

Present demands for fast data speeds for broadband users call for the expansion of the 3rd Generation Partnership Project (3GPP) communication networks to be competitive with new technologies [1]. Several scientists, mobile operators and other stakeholders collaborate with the 3GPP to achieve more user performance. 5G NR non-standalone is supposed to be available by next year. The data rate of the 5G NR is expected to be about 100 Gbps shortly. In addition, 5G NR promises to offer better user capacity and extended battery life with the relevant 1 ms latency [2]. Over the last two decades, the use of mobile communications has grown exponentially due to the introduction of wireless radio connectivity technology for voice communication. The 3GPP and Long-Term Evolution (LTE) [3, 4], one of the widely advanced fourth-generation (4G) wireless connectivity standards, offers consumers access to mobile services reaching more than 2 billion around the world by 2018.

Research regarding interference management on the UE side has been initiated, but it is still premature. However, it has been pointed out in some current study that interference management on UE-side can provide significant cooperative interaction with the network-side counterpart [5, 6]. Moreover, considering the local user's demand extensive fundamental changes are expected for 5G networks. Besides on, in the 5G network, the data demand for control plane (CP) and user plane (UP) will likely increase at a different speed. Therefore, alongside the intolerance of users to underperforming applications, an independently scalable solution and the demands of users are increasing [7]. 5G networks will follow a more organized approach to radio access network (RAN) technology based on CoMP transmission and Inter-cell Interference Coordination (ICIC) for optimal efficiency, as already demonstrated in the recent release-15 systems. It expressed that a solitary UE can be served by numerous BS of various backhaul innovations in an organized way with less interference [8]. Based on the recent research, we strongly believe that interference management which consists of a network side, as well as UE side techniques, will be the key driver in the 5G network, especially on location awareness system.

5G networks are supposed to have a comfortable positioning environment due to massive antenna arrays and wide bandwidths, which will play a tremendous role in future 5G networks, allowing the highly accurate direction of arrival (DoA) and Transmission of

Arrival (ToA) positioning in general. In addition, location-based information can be used in the 5G NR to mitigate various interferences, which will increase the SINR performances.

In the first chapter, the term interference as a key challenge of 5G NR and the possible mitigation scheme through the location information has been introduced. In the second chapter, some research background about the implementation aspects of 5G NR such as beamforming, latency etc will be widely discussed. In the third chapter location awareness of 5G NR, beamforming classification will be discussed briefly. In the fourth chapter different interference and interference management scheme will be presented. In the final chapter, we will analyse simulation outcomes based on SNR and SINR performances and conclude the thesis with some discussion.

1.1 Motivation

Although the introduction of new features and advantages in new launches 2015, the LTE standard meets the revolutionary criteria for a better quality of service and newly thriving forms of service. Nonetheless, as the LTE standard extends with new updates, we are envisaging more and more tacit restrictions, which prevent more performance improvements. Because of the fundamental shortcomings of 4G systems, our inclination toward the dawn of 5G NR systems is growing. Interference is one of the main issues among all the drawbacks of 4G networks, as the densely laminated heterogeneous network extension with complete resource reuse is assumed unavoidable in additional cellular communication systems. The problems of interference on 5G NR, however, remain. While, because of the vast number of obstacles existing in a tiny area, consumers in the wireless urban environment network are going down with more nuisance problems. In addition, weak signals were received by users located at the edge of the cell, as set alongside the minimum acceptable signal level necessary for communication [9].

The need for greater bandwidth is non-negotiable to provide the appropriate Quality of Service for the growing number of communication equipment. Hence, an acceptable method will be developed with an emphasis on providing reliable system performance which spectral efficiency is much better than the existing one. Wider bandwidth will provide the mobile devices with a bigger throughput. However, the range of transmission in the high frequency ultra-dense network is becoming shorter due to the smaller bandwidth and suffered extensively from interference problems [10]. Basically, the interference management in a previous cellular system is mostly a network side operation. Additionally, to make sure backward compatibility with legacy users, network- side interference management is advantageous. Moreover, it is easy to dispose of by extending the succession network. However, interference management on the network has some practical issues and limitations like backhaul and feedback overheads. At that case, the interference management at user equipment (UE)-side can be an accomplishment to reduce the network-side interference management related issues [11].

2. RESEARCH BACKGROUND

2.1 Implementation aspects of 5G NR

Work into the underused millimetre wave (mm-wave) frequency range for future broadband cellular communication networks has been inspired by the scarcity of wireless carriers facing global bandwidth. Growing the exponential growth of mobile data and using smartphones are growing unprecedented challenging situations for wireless service providers to overcome a shortage of worldwide bandwidth [12]. Cellular networks are currently limited to a carrier frequency range ranging from 700 MHz to 2.6 GHz to provide low latency, high-quality video, and wireless multimedia applications. Mobile broadband networks, however, need to direct ever-increasing customer data rate demands and tackle the growing rise in projected visitor volumes. To meet the ongoing demands faced by wireless carriers, efficient radio access technology mixed with extra spectrum availability is key. First-generation mobile systems were designed for a fundamental analogue method of radio communication. For 2G networks, an improved spectrum efficiency was achieved by the use of digital modulations and multiple access time division or code division. Along with Wideband Code Division Multiple Access (W-CDMA) and High-Speed Packet Access (HSPA), technically sophisticated video, high-speed Internet connectivity, and music streaming capabilities are included in 3G.

The International Mobile Telecommunications Advanced (IMT-Advanced) defines the next generation of mobile communications technology. IMT-Advanced is listed by ITU as a 4G mobile communications platform. Through means of the 3GPP, LTE radio connectivity infrastructure was developed to deliver a completely 4G-capable mobile cell network [13]. LTE provides a network access system based on orthogonal frequency division multiplexing (OFDM) that allows bandwidth up to 20 MHz. In addition, in LTE, Multiple-Input Multiple-Output (MIMO) enables multi-stream transmission for high spectrum performance, differences of radiation patterns for signal advantage, enhanced communication quality, and reduction of interference by adaptive beaming the use of antenna arrays [14].

However, the capacity to demand mobile broadband communications grows significantly each year. Therefore, in order to enhance the prevailing LTE network, the development plan for wireless technology now extends to IMT-Advanced with LTE-Advanced described in order to meet IMT-Advanced requirements in order to be theoretically capable of maximum throughput rates exceeding 1 gigabit per second (Gbps). In LTE Advanced, heterogeneous networks are enabled with coexisting large macro, nano, and picocells, and Wi-Fi access points. 5G NR would have greater spectrum allocations at unused mm-wave frequency bands, lower likelihood of outage, especially in highly directional beam-forming antennas on both the cell phone and base station, significantly maximum data rates in greater amounts of the coverage area, better battery life, reduced maintenance cost and increased aggregate efficiency for all of us simultaneously.

5G NR spectrum is normally classified in two types: sub 6 GHz frequencies wherein the traditional cellular bands are covered and for the mm-wave bands above 6 GHz is considered. However, a common system architecture will be considered for both low and high band in order that devices are able to connect to both accesses simultaneously. The primary motive that fascinated the operators to steer the mm-Wave is a larger amount of available spectrum in higher bands. Moreover, the under-consideration mm-Wave offer much larger channel bandwidth of 500 MHz, whereas lower band (sub 6GHz) provide channel bandwidth of up to 20MHz today. In wireless systems to generate economies of scale, harmonization is the key factor. It is particularly true in mm-Wave, on the ground that an antenna array's technical implementation can vary significantly among bands which are numerous GHz apart. Spectrum sharing schemes are also introduced in mm-Wave, in which the cellular users can coexist with other users, such as satellite operators. In mm-Waves, higher frequencies suffer from greater path loss in the event of obstructions such as buildings, rain, obstruction by oxygen, foliage and by convention are considered useful for short-range applications.

The key feature of 5G NR is the challenging situation that offers a thousand times higher amount of traffic and a hundred times increased rates of user data. This exponential increase in traffic and the user data rate can be managed by the use of several technologies, but we should be mindful of the three that can handle such a high ratio. Those are the Physical Layer (PHY) systems consisting of Massive Multiple-Input and Multiple Output (MIMO) [15], Filter Bank Multi-Carrier (FBMC) [16], Non-Orthogonal Multiple Access (NOMA) [17], Multiplexing General Frequency Division (GFDM) [18] etc. Those specialize primarily in decorating the network power by enhancing the spectrum efficiency. In addition, leveraging the bandwidth at the millimetre (mm) wave frequency can be very useful in improving network efficiency. Better branding, however, is the most dominant aspect which contributes to wireless connection device capability. It is assumed that the network's potential via Universal Domain Network (UDN) can expand in the linear ratio of the cell quantity. Heterogeneous network (HetNet) composed of macro ENodeB (eNB) and low strength eNB micro eNb, pico, eNB, etc., considering group densification. In addition, Device-to-Device(D2D) Communication, an alternative to HetNet, is capable of rising the maximum data rate and the performance of the spectrum efficiency. The computation offloading between multi-radio access technology (RAT) [19] systems is still capable of enriching network capability by improving network resource performance. While network densification may intensify network capacity by minimizing the effect of the path between the client and the core network. It tends to increase the interference as well as the desired warnings and effectively mirror the thermal noise effect. It could be taken equal to suggest the systems are constrained in interference, and the transfer of interference could be an increase in the efficiency of the connections.

However, the intrusion will become more complex as the density of the complex cells increases. Hence the advanced cancellation of interference on the receiver side is necessary. In addition, network architecture often needs to support the efficiency and synchronization of a variety of different cells. Because the quantity of signalling management in the distributed coordination mechanism will be quadratically enhanced by increasing the small cell intensity. The first important priority feature of 5G NR infrastructure would be unified management. The network output can be similarly improved by integrated resource planning and management through multiple cells and multiple RAT systems, based on centralized processing. In fact, due to the restricted geographic area of small cell mobility and device versatility, fast-moving users would be regularly handed over. Rather than one small cell should be handled centrally to provide the value of seamless mobility. It is clear that centralized planning and control is essential for the 5G mobile network's Radio Access Network (RAN). In the meantime, consideration should also be given to the Mobile Core Network (CN) for exploiting the explosive increase in traffic capacity.

The traditional method of centralizing the information plan function at the Internet boundary and requiring all site traffic to pass through the P-GW in the LTE environment complicates the realization of P-GW and yields the P-GW bottleneck. In addition to the information-plane function, P-GW also plays a broad range of features such as tracking site visitors, billing, authentication, etc. Despite so much versatility in P-GW, flexibility and scalability resulting in a decrease. Then the user can't individually update the records and control functionality. In addition, the traditional community no longer directs a designated sub-set of traffic through the essential middle boxes in compliance with the specific circumstances of the communist country and the client. Therefore, separating the control plane from the statistics plane and centralizing the control plane logically is important.

Clearly, it can be inferred that keeping the control plane separate from the data plane and centralizing are critical aspects of 5G mobile society to boost network capacity in a similar way.

One of the most revolutionary aspects of 5G is lower latency. It is one of the finest challenging demand for the fifth-generation wireless network technology which is 1 ms. However, lower latency service is highly critical for some application like robotics, v2v communication, education, automated industrial production, entertainment, healthcare etc. It is a true fact that IoT will become a reality very soon and everything is connected with other things without any certain time and location. In particular, all of the smart wearable gadgets like watches, smart glasses, bracelets etc, smart home appliances like television, advanced lighting system, sensor, drones, robots, automated operating vehicles as well as with smartphones are adjacent to constantly affiliate world to enhance our lifestyle [20, 21].

Several highly recommended 5G NR supported latency-critical services are discussed as follows:

- Factory Automation
- Autonomous transportation systems
- Robotics
- Healthcare

Factory Automation: In Factory automation the machines and systems will be real-time controlled for short manufacturing lines and constrained human participation. At these cases, the manufacturing lines will be sufficient and adjacent. In reliability and latency point of view establishing smart factory automation system is truly challenging. Since the acceptable E2E latency for factory automation application is within 0.25 ms to 10 ms with a packet loss rate 10-9 [22].

Autonomous transportation systems: For establishing expert road traffic system and intelligent V2V communication ultra-reliable low latency is unavoidable. For efficient traffic services, intelligent transportation systems set a different value for several issues [23]. Some research shows that autonomous cars will highly intellectual to coordinate in alliance with themselves for overtaking [24]. In that case, the maximum acceptable E2E latency for exchanging message is 10 ms [25]. On the other hand, for avoiding collision and warning purposes the required latency is 10ms to 100 ms with packet loss rate from 10-3 to 10-5.

Robotics: Inside the close to destiny, remote-controlled robots may have applications in various sectors including production and upkeep in dangerous regions. A prerequisite for the utilization of robots and telepresence packages is far off-control with actual-time synchronous visible-haptic remarks. In this situation, system response time have to be less than some milliseconds along with network delays [26].

Healthcare: Tactile internet brings a massive breakthrough in medical science. Tele-diagnosis, telesurgery and telerehabilitation are the throughputs of such kind of low latency tactile internet. Nowadays, we are considering a telesurgical operation, where a robotic device is commanded by the surgeon. However, to adapt with this sophisticated technology the major challenge is lower latency which is from 1 to 10 ms with ultra-reliable data transmission [26].

2.2 Beamforming

Nowadays, we are highly optimized about to achieve noble throughput and establish long-range communication link in the next-generation radio network system. Where beamforming will be the foremost technique to adopt optimization to reality. Moreover, beamforming technology will be the key factor for the efficient utilization of the available spectrum. Basically, beamforming is a special kind of pattern of antenna radiation. It is a strategy to focus the radiated omnidirectional power of the antenna in one or more particular directions. Beamforming in the 5G NR framework refers to the propagation of a signal from the base station to the receiver in a narrower shape in such a way that only the targeted recipient can retrieve the information while rejecting interference from all other directions. Multiple antenna elements are changing their phases to provide the desired directivity. Therefore, the devices experience a better-quality signal.

In MU-MIMO networks, a large number of UEs are served simultaneously by a large number of antenna element base station, while the BS is equipped with a huge number of antennas. As a result, we can experience a better beamforming accomplishment. Range of BS and capacity are significantly improved by the revolution of beamforming. Figure 1 represents how beamforming in 5G NR increase the BS range along with the increase in the number of connected devices.

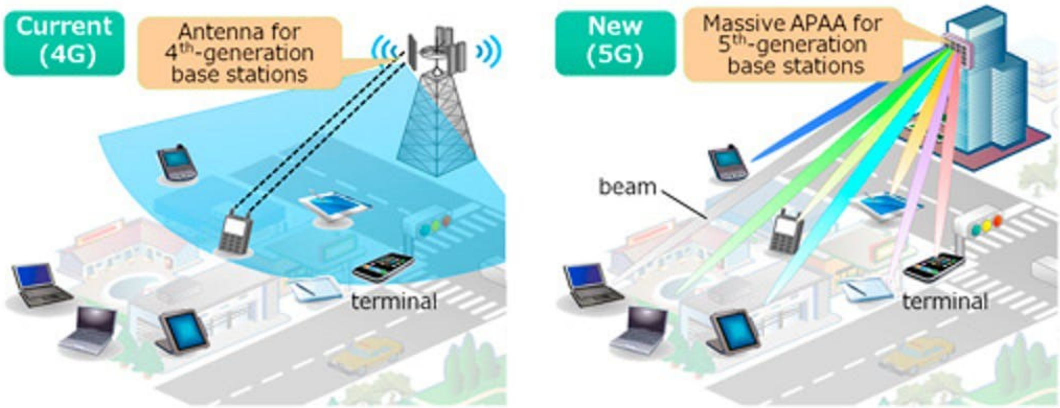

Figure 1 How beamforming achieves the goal

In general, beamforming utilizes multiple antennas to ensure the correct direction of a wave whereas an array of different antennas play an important rule to appropriately weight out the magnitude and phase of each antenna signals. In point of fact, the same signal is sent from multiple antennas to transmit the same signal by ensuring enough space between them. Therefore, in any given location, the receiver receives several replicas of the identical signal. Simply, beamforming redresses the interference issues and improves signal quality, which especially highly desirable for the cell edge user.

3. LOCATION AWARENESS

Location awareness has a great aspect in order to accomplish very effective and systematic traffic management, improve spectral efficiency, provide higher data rate, and manage the Bs power in cellular communication. Current study about developments of 5G networks shows that the positioning accuracy is much higher than the previous network technology. Researchers state that positioning accuracy of the 5G network would be in the order of one meter or even below [27]. Whereas in long term evolution (LTE) systems furnish the network with the accuracy of a couple of tens of meters observed in a time difference of arrival-based methods, which is a positioning feature introduced in realese19 (rel9). This is not sufficiently precise for some special communications performance, but now this accuracy will significantly better in 5G technique. It has been promised that the 5G networks positioning accuracy will outperform the conventional commercial global navigation satellite systems (GNSSs) which provide the accuracy in around 5 m [28], and 3 m –4 m accuracy is triggered by the wireless local area network (WLAN) fingerprinting. In terms of marketing endeavours, location awareness plays an important role such as information about the sequence of user movement. It has been expected very highly that network-based localization will be available in 5G NR. This enables the 5G network to provide high energy efficiency in positioning. In addition, the enhanced energy efficiency accuracy of 5G localization methods can provide lower UE power consumption while exploiting network-centric positioning.

However, while those signals are considered for positioning in a network-centric manner then the UE position can be considered either individually in the ANs or a centralized fusion centre. As a consequence, no estimations are required for mobile UEs. However, it is a matter of concern how we ensure the precise location awareness for the furnish 5G network system. 5G devices completely rely on universal location awareness system. The location accuracy will be provided by the conventional global navigation system along with the global navigation system where GNSS will dominate. In order to provide higher location accuracy, the ground support system and multiband operation are operated combinedly. These systems provide location accuracy around one meter in the open sky [30].

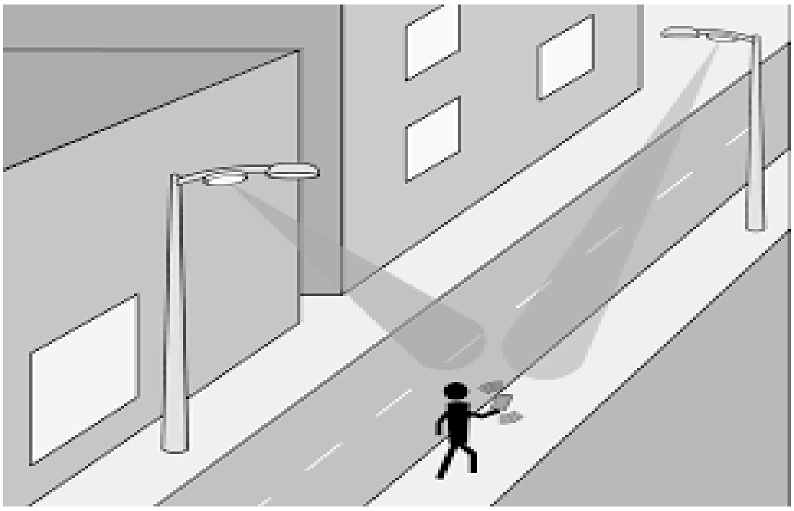

Figure 2 Network-centric localization in an ultra-dense small cell network where ANs receive uplink pilot signals [29].

In the opposite scenario where the GNSS is unavailable, other local radio-based technologies such as ZigBee, ultrawideband (UWB), RFID, and Bluetooth will provide current Wi-Fi-based positioning. Communication systems are related in several ways to location information, including distances, delays, velocities, angles and predict-able user behaviour. For a location awareness system, the BS needs cognition about the user position, velocity and angle to estimate the path loss, doppler effect, shadowing and required antenna radiation angle.

3.1 Pathloss

When a signal travels from the transmitter to receiver the power of the propagate signal reduce with the distance due to the reflection, diffraction and scattering the receiver does not receive the signal with the actual transmitted power of that signal. The reduction of the propagate signal with distance is referred to as path loss. Path loss of a given channel can be calculated by using the following formula:

$$L = n10log10\ (d) \tag{1}$$

Where L is the calculated path loss in dB with a given distance d and n is the path loss component.

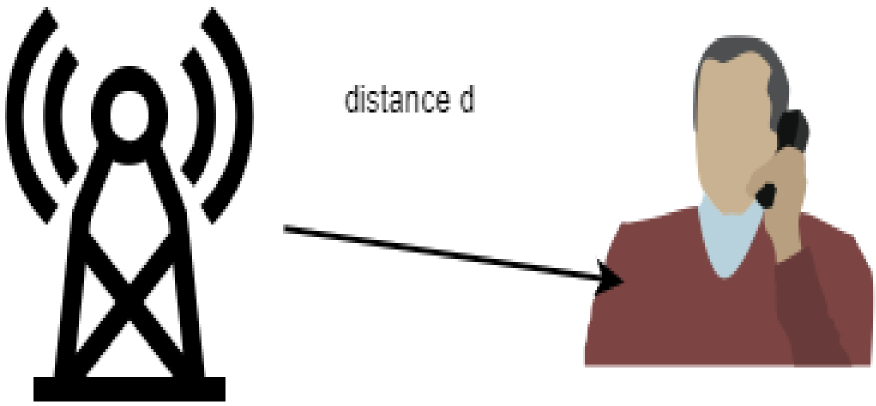

Figure 3 Path loss

Reflection: When a signal between the transmitter and receiver impinges by an obstacle and reached at the receiver is called a Reflected signal.

Diffraction: When the transmitted medium is obstructed by an edge surface diffraction is occurred.

Scattering: When the transmission medium dimension is smaller than the wavelength of the radio then scattering occurred.

3.2 Doppler effect

Doppler shifts are caused by relative motion between the transmitter and the receiver, for example, by the motion of an object from where the radio signal is reflected or scattered. Usually, local scattering originates from several angles across the mobile. This situation triggers a sequence of Doppler changes, known as the doppler spectrum. The maximum Doppler change refers to the components of local scattering whose direction is precisely in opposition to the mobile trajectory. Even fading effects can be categorized as fast fading and slow fading due to doppler distribution. The cell site transmitter and the mobile receiver also have relative motion. Doppler frequency is the region over which the transmitted signal intensity fluctuates. The Doppler effect results in system inaccuracy. To mitigate this effect, proper compensation technique must be put in place.

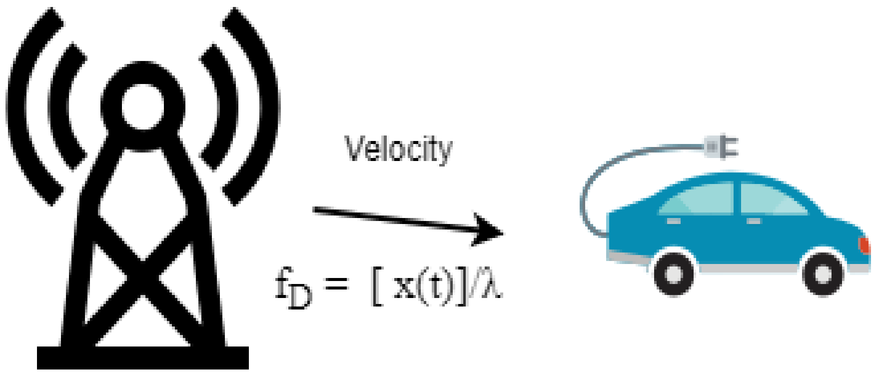

Figure 4 Doppler effect

3.3 Shadowing

If an object obstructs the transmission path between the transmitter and the receiver the transmitted signal power has fluctuated, the fluctuation is called shadowing. As a consequence of the shadowing, therefore, the signal shifts are primarily due to reflection and scattering during handover. The shadowing effects often cause the wave lights to bend, i.e. the transmission does not follow a straight line

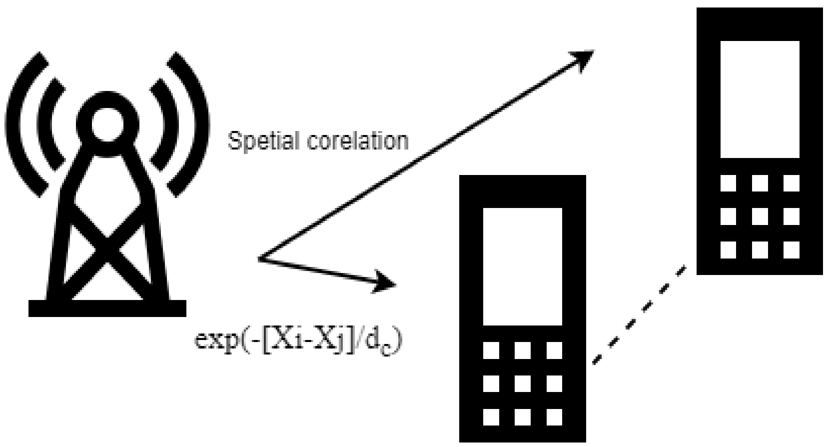

Figure 5 Shadow effect. Xi and Xj are the two-user locations and dc is the correlation distance.

3.4 Massive MIMO scheme

An integral part of the upcoming 5G new radio (NR) system is a massive multiple-input multiple-output (MIMO) antenna system. Numerous experiments have in modern times focused on multiple input multiple output platform (MIMO), which is believed to perform a significant part in 5G NR. Massive MIMO structures are MIMO services where there are multiple antennas in precoders and/or detectors. A higher number of antennas allow for better spectral performance and energy performance. A variety of antennas, one of which is considered a smart antenna, can be used for this reason. Smart antennas are entities with multiple base station (BS) antenna components and wireless transmission facilities, where the signal is properly controlled to improve cellular network coverage and to improve the device efficiency. This antenna allows the ability to be increased in the wireless communication systems by the effective decrease in the multi-path fading and channel distortion which can be accomplished by directing signal radiation only in the anticipated direction. For signal propagation from BS multiple different antennas to one or more pieces of consumer equipment to be shielded, beamforming is used in wireless communication systems.

Radiation aims to maximize the signal power of each user while reducing the signal interference strength of other users, thereby increasing efficiency. The same signal can be received from all broadcasters with completely separate amplitudes and phases. Such various variations of the signal propagation are distributed through numerous MIMO channels in order to be constructively applied to the intended applications and other devices. Because of the growing number of users serving and the increased need for vast volumes of data, MIMO systems gained tremendous attention. Multi-user MIMO systems could offer a revolutionary strategy for enhancing wireless spectral performance. Nowadays MIMO technology is an automatic choice for future communications networks as the number of wireless service demands keeps rising, with the bandwidth finite. Throughout the field of multi-user MIMO connectivity, several in-depth experiments have recently been performed in which specific systems are pointed to as massive MIMO or large-scale MIMO schemes. Massive MIMO systems are classified as MU-MIMO systems in which large amounts of antenna elements are deployed on BS and large amounts of the antenna are used on terminals.

In massive MIMO schemes, large amounts of antennas associated with the BS are concurrently used for slightly fewer terminals with the same time and frequency and carrier resources [31]. Due to its characteristics and energy efficiency, massive MIMO systems will increase the performance of wireless communications systems 10 or more times over.

3.5 Developments of Beamforming in MIMO

Having a large number of antennas creates an opportunity to generate different type of interference which can be mitigated by installing beamforming antennas rather than traditional antennas. In Beamforming technique multiple arrays of antennas can be used on both transmitter side and/or receiver side which concurrently delivers or tracks multiple signals from multiple desired terminals to improve the efficiency and output of the devices. Beamforming can be achieved by arranging the components in an ordered array, adding beams oriented to a certain target and neglecting the other beams. While this strategy is not modern, it continues to be improved by the developed Organizations of cellular communication systems, including specialized carriers of long-term evolution (LTE) and LTE. Such operators are based on incorporating techniques of beam shaping into cellular networks. The energy performance of massive MIMO systems could be significantly improved by the installation of a significant number of beam shaping antenna components at the BS [31].

3.6 Beamforming makes Massive MIMO efficient

In beamforming technique, multiple arrays of antennas can be used on both transmitter side and/or receiver side which concurrently delivers or tracks multiple signals from multiple desired terminals to improve the efficiency and output of the devices. Beamforming can be achieved by arranging the components in an ordered array, adding beams oriented to a certain target and neglecting the other beams. While this strategy is not modern, it continues to be improved by the service provider of cellular communication systems, including specialized carriers of long-term evolution (LTE) and LTE. Such operators are based on incorporating techniques of beam shaping into cellular networks. The energy performance of massive MIMO systems could be significantly improved by the installation of a significant number of beam shaping antenna components at the BS [31].

Beamforming is a method designed to generate the antennas' radiated beam patterns by building up the transmitted signals fully in the direction of the target terminals and cancelling disrupting signal beams. The use of beamforming in massive MIMO systems has the following advantages: enhanced energy performance, improved spectral quality, in-creased system stability, and mm-wave band applicability can be achieved by using the beamforming technique in the massive MIMO system.

The reduced power demands of beamforming antennas for signal delivery to the target customer and cost savings result in the reduced power usage and amplifier costs of massive MIMO systems. A beam shaping procedure is used to minimize power consumption in the entire system by calculating the optimum number of antenna elements that meet certain fundamental requirements for the operation of large MIMO energy-efficient systems [32, 33.] The overall energy efficiency is essentially unchanged by the number of the working antenna array in the cell for each particular electricity usage of each BS, a standard number of working antennas can be applied for the entire cell of the device to achieve high levels of cost-efficiency and total energy performance.

Utilizing the antenna arrays of uplink and downlink signals power management and signal quality can be improved. In wireless communication systems, the potential performance of spectral efficiency can be accomplished by using massive MIMO systems. Coherent precoding and detector processing along with the large numbers of antenna elements of beamforming antenna arrays at BSs are designed to improve spectral performance efficiently [34]. In other words, multiple antenna arrays help to focus the energy in a smaller region which increases the spectral efficiency of the system [35].

3.7 Security

The main purpose of beamforming is to transmit the signal to the desired user. Therefore, it creates a high opportunity for the users to receive the desired signal by only the desired user. Physical protection is accomplished as a broadcast signal becomes less likely than with traditional antennas to attract the eavesdropper [36].

3.8 Applicability for mm-wave bands

Another useful aspect of beamforming, which encourages the researchers to step towards it, is highly adaptable with mm-wave bands. The suitable frequency spectrum for urban cellular communication is limited and already licensed in previous communication systems like GSM and LTE, therefore if we want to increase the data rate in the frequency domain the only choice is to move forward into the mm-wave. Since the mm wavebands have low propagation characteristics but it is unavoidable that it provides higher bandwidth at the same time.

3.9 Beamforming technique classifications

Beamforming, diversity and spatial multiplexing are the three different categories of the smart antenna system. Diversity is used in for ordinary fading reduce purposes in both transmitting and receiving side. On the other hand, spatial multiplexing is used to parallelly transferring multiple data stream for increasing data rate purposes.

However, beamforming can be classified in different ways. Switched beamforming and adaptive beamforming are the two primary categories. On the other hand, based on antenna array beamforming technique can be classified into the following categories: linear arrays, circular arrays, and rectangular arrays etc. Moreover, based on signal processing beamforming techniques are classified into three different categories they are analogue beamforming, digital beamforming and hybrid beamforming [37, 38, 39].

However, several researchers have proposed many algorithms to increase the performance of adaptive beamforming antennas. There are two main algorithms, one of them is blind adaptive algorithms and another one is non-blind adaptive algorithms. It is very important in the non-blind adaptive algorithm that it already has the statistical information of the transmitted signal. On the other hand, the blind adaptive algorithm totally avoids the statistical knowledge of the transmitted signal. The blind adaptive algorithm mainly emphasizes on maximizing the signal on the predefined terminal. Moreover, it also focusses on minimizing the interference. Based on the bandwidth of the signal beamforming technique can be classified into two different categories: wideband beamforming and narrowband beamforming. Although, the researchers are still highly dependable on narrowband beamforming which is enough to fulfil the current wireless communication requirement.

However, in near future for upcoming wireless communication technique wideband beamforming will be a hot topic as extended frequency band and high data rate are two most important requirement of the upcoming 5G technique. In general beamforming scheme can be classified into two categories which are switched beamforming and adaptive beamforming. Switched beamforming scheme is highly dependable on switching network. The main purpose of this scheme is to select a competent beam to acquire the desired signal from a specific terminal. The selected beam of the switched beamforming scheme might not be pointed to the desired direction [40]. On the other hand, in the adaptive beam-forming technique a singular beam has been produced to serve for each user. In this technique, it is possible to form a specific beam shape towards the signal in a specific direction where the mobile user is located. In this technique mainly emphasise on forming the main lobe as desire shape and consequently try to nullify the interference sequences. Therefore, the interference between the users can considerably reduce in adaptive beamforming technique. Moreover, this technique offers considerably improve power resources [41].

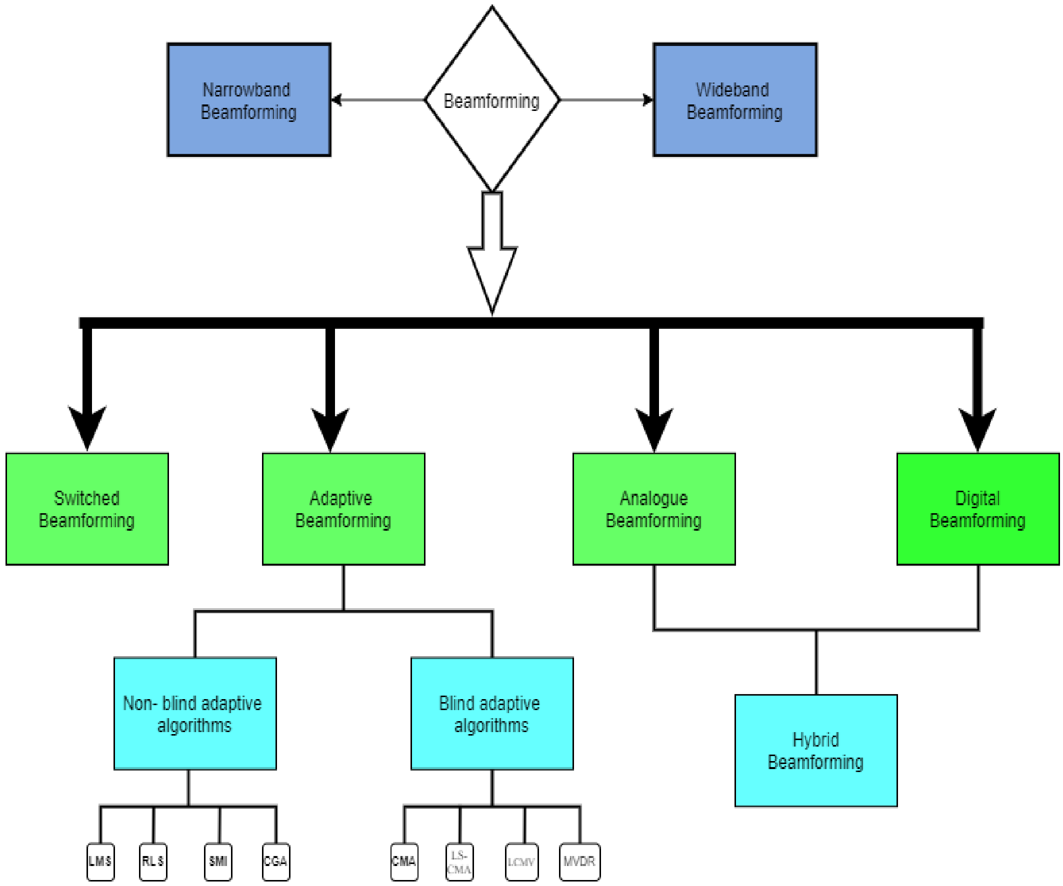

Figure 6 Beamforming Classification

3.9.1 LCMV

Many beamforming algorithms are highly dependent upon the reference signal information and strength of the desired signal. Linearly constrained minimum variance beamforming (LCMV) is one of the effective techniques which help to overcome this kind of limitation. The principal concept that defines the LCMV beamformer is to use a spatial filter that chooses the optimum weight vectors to minimize the filter's response, whereas the reducing of filters response are depends on power limitations. Together with other limitations, this constraint ensures signal safety at the desired position while minimizing the variance effects of the generated signals. The greater achievement of LCMV technique in the direction of arrival information is enough to maximize the SNR, but at the same time, it suffers a lot in massive MIMO system for its very poor convergence rate performances [42]. The key driving forces of these algorithms are based on their conversion rate level, the number of iterations performed, and precise SNR resolutions. To achieve improved performance, new methods and algorithms are developed and integrated with the current algorithm. For example, to increase its weight, particle swarm optimization (PSO), dynamic mutated artificial immune system (DM-AIS) and gravitational search algorithm (GSA) have been integrated into LCMV.

3.9.2 MVDR

Minimum variance distortion less response (MVDR) beamforming algorithm is used to minimize the variance of beam response. This algorithm is proposed to achieve a desired antenna gain by selecting the proper antenna element which steers the beam towards the desired direction. In wireless communication minimum variance distortion less response (MVDR) procedure helps a lot to eliminate the unwanted signals, which are responsible for the possible interference, from several undesired directions. Study shows that the MVDR algorithm has significant improvements over the conventional adaptive antenna, which also meets the 5G NR requirement in the massive MIMO system [41, 43].

3.9.3 Analog beamforming

With one RF chain and several phase shifters around the antenna components, an analog beamformer is constructed. Advanced hardware and advanced precoding algorithms monitor the process of each element. Steering the beam is responsible for the phase shifters. In analogue beamforming, the phase of each transmitted signal has been controlled by using the low-cost phase shifters. Basically, each antenna element received a single signal. Furthermore, those signals pass through a phase-shifter where the signal amplification and selecting the desired direction processed has been accomplished. Nowadays, among all of the beamforming technique, analogue beamforming is the most cost-effective technique, it is just because of using simple low-cost phase shifter.

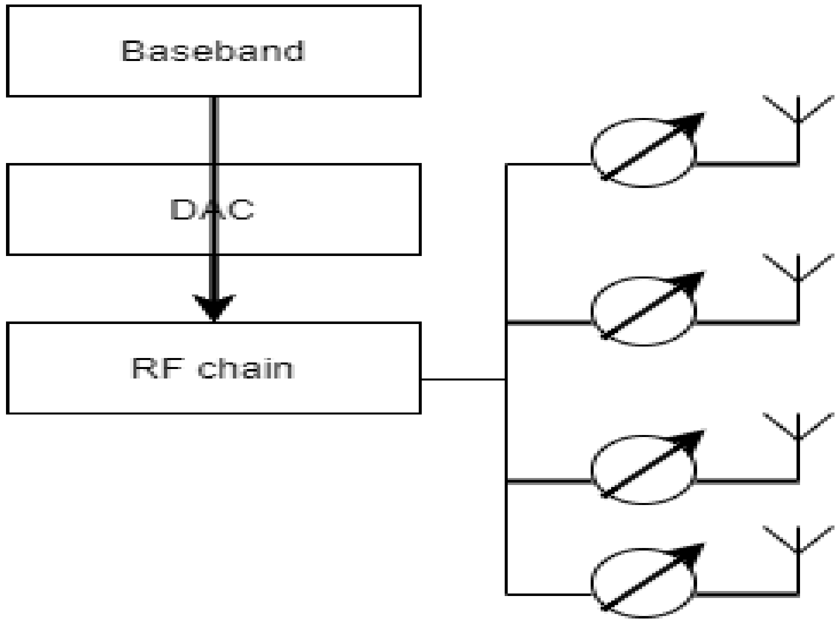

Figure 7 Analogue Beamforming Architecture

3.9.4 Digital Beamforming

On the other hand, the predominant purpose of the investigation of a digital beamformer requires the passing of each antenna with the same information symbol, but with sufficient modification to both the amplitude and the signal phase at each of those antenna components. However, the number of RF chains is fully digital beamforming is the same as the antenna components. That means that a dedicated RF chain and phase shifter are fitted with each antenna element. This allows for shaping and directing the appropriate radiation pattern of the entire array to the particular recipient. More recent digital beamforming designs implement self-forming schemes aimed at optimizing signal power at the position of the intended consumer. Therefore, the cell range is increased as transmission power is focused after deciding the channel's own path wherein the RF channels have the best directions. However, conventional beamforming is used at base band in digital beamforming system to control the phase and amplitude of the signal. Moreover, in digital beamforming, the carrier frequency of the processed signal needs to be upconverted.

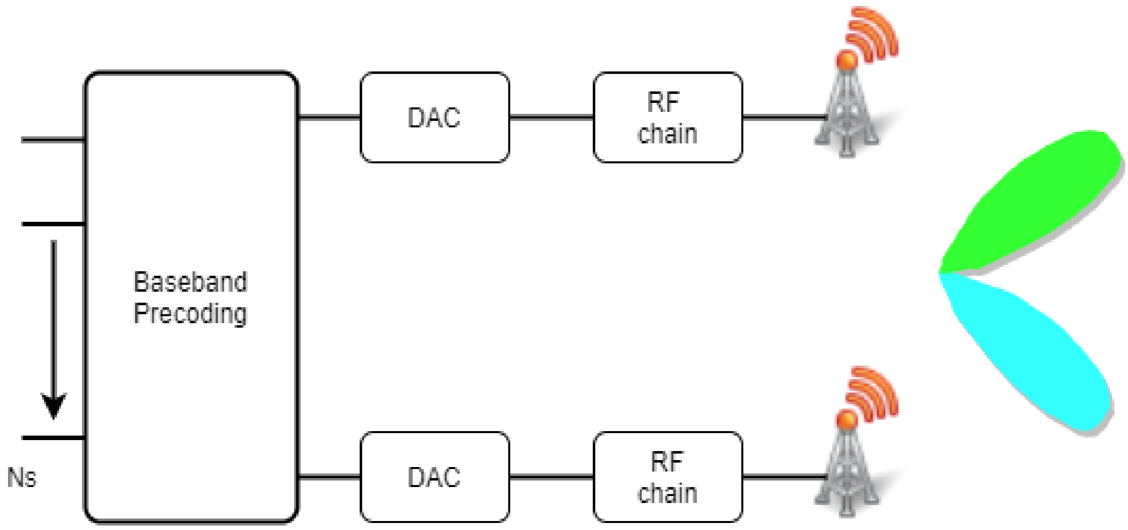

Figure 8 Digital Beamforming architecture

3.9.5 Hybrid analogue/digital beamforming

The hybrid beamforming technique combines the analogue and digital beamforming technique. Digital Beamforming performs the generation of the baseband signals. The analogue beamforming component, on the other hand, tackles RF chain yielding by limiting the number of ADCs / DACs that boost power amplifier outputs or modify the mixer design and thus provides cost savings.

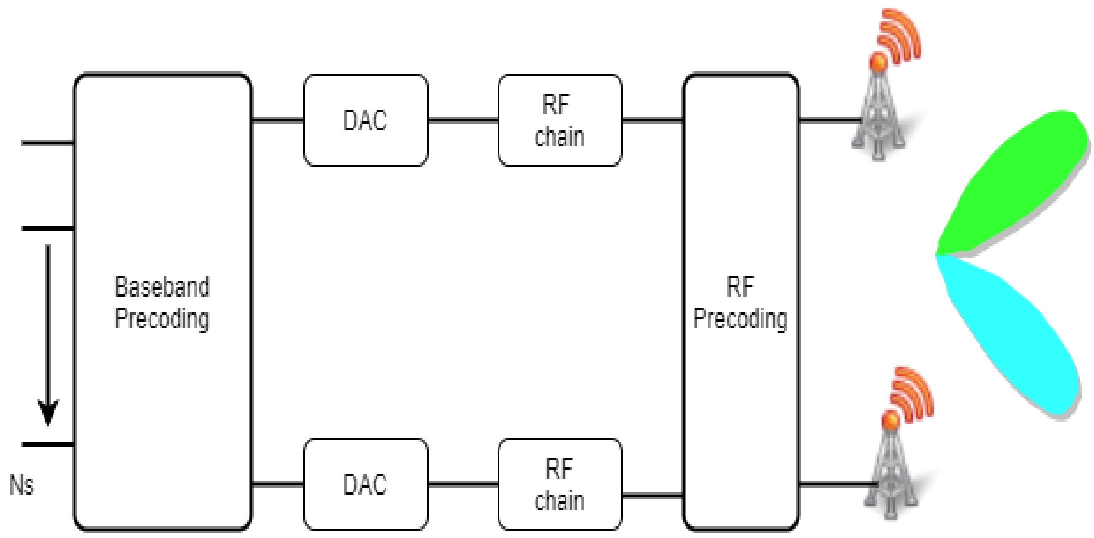

Figure 9 Hybrid Beamforming architecture

4. INTERFERENCE

One of the most common issues of the radio access network (RAN) is interference in cellular networks. Independent mechanisms and facilities such as mobile phones, cell radios, paging, wireless LAN, and online image broadcasting each use an allocated spectrum to prevent the transmission of different signals at the same frequency resulting signal disruptions or interference. Fortunately, even though unique wireless networks do not produce harmonics, frequency drifts, or RF leakage, but on cell sites, there is a chance to generate internal interference due to the inappropriate capacitance of passive components, such as connectors, wires, or antennas. This intrinsic interference can produce relatively similar frequency band intermodulation signals. However, one common scenario of intrinsic interference with the RAN occurs from frequency reframing. Providers developing their own wireless technologies to LTE use reframing to produce a higher performance for smart devices while retaining current technologies such as GSM and WCMDA as well. This approach is tolerant of incremental LTE acceptance. The coexistence of several technologies in a minimal spectrum is pressuring service providers to expand the number of carriers and to reuse frequencies, generating an internal interference-sensitive RAN.

4.1 Intercell interference

Intercell interference mitigation is one of the biggest challenges for the future cellular communication especially when we consider about the full reuse of available frequency in the multi-cell cellular environment [44]. The cell edge clients of the cellular network are the major sufferer of inter-cell interference just because of it avowedly degrades the spectral efficiency and the energy efficiency of a system [45]. The spectral efficiency is described as measuring how efficiently the obtainable spectrum is used in the system, whereas energy efficiency is measuring the system's effective energy consumption [46].

Several other mitigation strategies based either on dynamic or static strategies to resource distribution is being used to boost spectral performance and energy quality improvements across the cells [47]. A few of these approaches, however, may not always work optimally as planned, and appear to narrow the base station's available bandwidth resulting in spectral loss of performance. The trade-of-information between spectral efficiency and energy efficiency is important for efficient device design in a multi-cell cellular network [48, 49].

However, in practice, cancelling interference may be done indirectly by eliminating or separating the maximum interferers or by increasing the distance between base stations to separate. It might be an effective strategy to ICI minimization that can help attain optimal signal gain than the trigger value [50]. In order to effectively minimize interference, several strategies like cooperative propagation, resource clustering, beamforming, and interference alignment (IA) were developed and implemented by various literature's [51–56].

Several of these strategies has its own successful conditions for benefit and adaptability. In recent researches, several sophisticated approaches to reduce ICI are described in the below sections. Cooperative beamforming is top of them. Cooperative beamforming approach is focused on redistribution of resources and selection of beams has been utilized to obtain substantial outcomes for significantly greater cluster size. In [57] the authors mainly concentrated on limiting the inter-cell interference of the indoor environments through the use of a network framework described as a digital cellular network. According to their proposed method, the virtual cell can be designed in several groups depending upon the user distribution. Their findings have shown that the implemented method has decreased inter-cell interference with better spectral efficiency.

In addition, a study in [58] proposes an energy-effective system for the framework of the high-density cell in an attempt to obtain effective energy consumption with a minimal interference consequence. This strategy, while maintaining the base station in idle mode, dynamically distributes the spectral resources equally between consumers. Compared with conventional 'interference monitoring only' and 'idle mode only' systems, it provides better energy efficiency performance. In addition, research in [59] is intended to mitigate the impact of inter-cell interference on adjacent cells particularly for cell edge clients. Another research is addressed at [60] to improve the QoS for self-organized HetNet. It proposes a new concept relying on game theory which developed the muting of cell time transmission. It allows transmitting better quality of service assure more consumers have equivalent satisfaction levels.

We know that there are some critical issues for cellular communication in terms of the use of the same frequency band in neighboring cells and ICI is one of them. We need to mitigate these issues, but we cannot afford any loss of user’s information mainly for the next generation 5G network that may transform to more complex and vastly concentrate communicating devices. To understand this procedure practically we need to use various interference management schemes. For instance, we may face high ICI issues by using more compound cooperative networks such as resource partitioning, IA, beam-forming, and cooperative transmission.

4.2 Interference management in Heterogeneous networks

Simultaneous functioning of macrocells, microcells, picocells and femtocells is reported as HetNet. The biggest drawback of HetNet deployment is its uncoordinated nature. Interference management for such kind of uncoordinated HetNet always challenging for the researcher. A handover edge power offset is implemented in typical HetNet arrangements between macro base stations and pico base stations or between macro base stations and other less power base stations. It allows us to accomplish highest offloading and expands the service area of low power base stations elsewhere their actual coverage threshold [61].

However, individuals (UEs) at the cell borders within the service range of the relatively lower power base stations are extensively interfered by macro-cell downlink data transmissions and experience extreme inter-cell interference, ensuing in lower UEs performance [62]. Limiting inter-cell interference to enhance cell-edge efficiency is critical in a single frequency network as it is often difficult to maintain synchronization between neighboring base stations [63]. However, Inter-cell Interference Coordination (ICIC) technique is initially implemented to limit the inter-cell interference in multi-cell networks [64]. There are two different categories of ICIC, one of them follow the static coordination and its called simple ICIC whereas others follow the dynamic coordination technique and referred to as enhanced ICIC. dynamic coordination such as the enhanced ICIC (eICIC).

In the simple ICIC technique, the macrocell base station transmits and receives the relevant network management information. It allows coordinating the transmitted power and resource allocations for either the cell-center or the cell edge UEs together [65]. Whereas 3GPP presents an improved version of ICIC, also known as eICIC technique, to reduce the complex overhead coordination encountered in ICIC norm [66].

The eICIC procedure involves coordination among two cells as minimally as possible. However, a single frequency network is typically implemented to significantly improve the usage of available spectrum in time division-based multi-cell networks [67]. In the eICIC case, where adequate feedback information was provided, the multi-cell will be performed as an independent cell. To put it another way, multiple base stations will communicate and obtain statistics to optimum output together [68].

The eICIC implies a new scheme for the macro-cell downlink subframe called almost blank subframe (ABS). It helps minimize UEs interference within the scope of lower-power base stations [69]. As the name suggests (ABS), in certain subframes, the MBS does not send any data and control signal to enable lower power base stations to synchronize with UEs within that subframe.

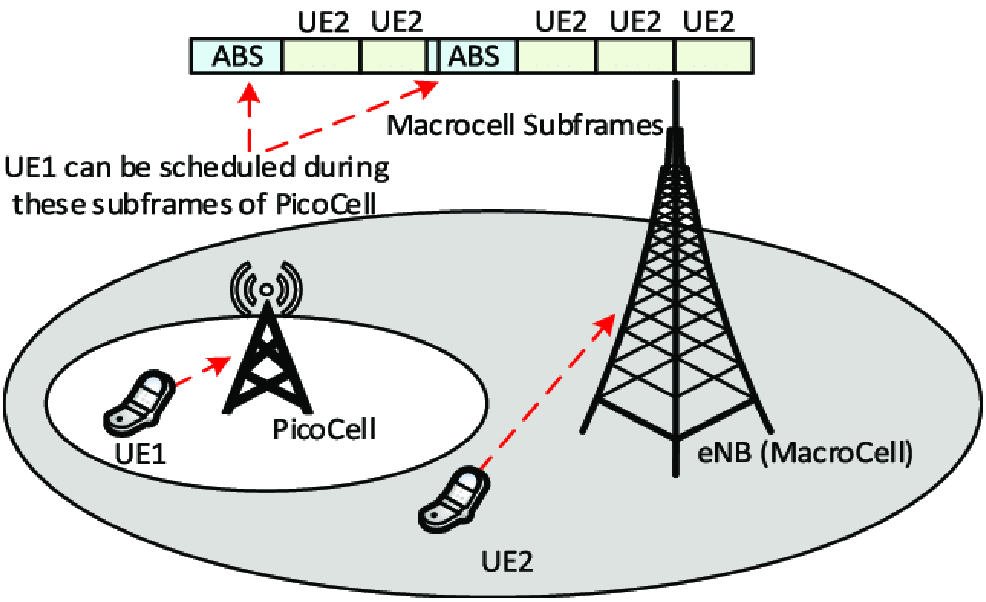

Figure 10 Almost blank subframe technique for HetNet [70]

This concept can result in the loss of some resources, but it definitely enhances the efficiency of the lower power base stations, thus improving the overall gained through the system-wide evaluation [71, 72]. In addition, Time Division Duplexing (TDD) is a well-known coordinated strategy for multi-cell heterogeneous 5G infrastructures. Since 5G NR is supposed to work in a large MIMO antenna scheme, TDD allows duplexing to get optimum system efficiency [73]. Several existing studies are discussed below which has been conducted to mitigate the HetNets interference.

An inter-cell interfering coordination study that uses soft frequency reusable strategy for cellular network focusing on relay [74]. The outcomes demonstrate that the proposed technique provides better performance for cell-edge clients with an efficient and equitable allocation of resources between users. A further resource sharing method that uses soft frequency reuse for inter-cell interfering coordination is described in [75]. The outcomes of this approach are that it provides better performance for both uplink and downlink network while the researcher efficiently uses the spectrum for cell-edge clients. Another power coordination scheme for intercell interference is presented for the uplink network in [76]. It follows the transmission power control based Intercell interference strategy, where the interference impact is the equivalent for the strategy of reuse of fractional frequencies. Compared to the conventional method user throughput is improved which clearly demonstrate on [76]. It also emphasized to explore more realistic traffic model to achieve sophisticated performance for overall users. Another study that illustrated some of the specific issues such as power ratio and traffic loads based on the utilization of the soft frequency reuse method is discussed in [77]. Desired signal-to-interference-plus-noise ratio (SINR), block error rate and throughput can be archived by this method.

On the other hand, to ensure better picocell and macrocell performance through interference aware slot allocation technique is conducted in [78]. It is an improved inter-cell coordination technique relying on an almost blank subframe that uses an untouched spectrum and offers better spectral efficiency compared to the current almost blank fixed subframe ratio concept. Another enhanced inter-cell interference coordination scheme based on dynamic load balancing algorithm for non-homogenous users' distribution is proposed on [79]. The outcomes provide improve spectral and packet delay performance compared to the conventional inter-cell interference coordination approach.

Another enhanced inter-cell interference coordination scheme based on base stations coordination by horizontal beamforming technique is proposed in [80]. The proposed method offers significantly improve outcomes. However, at the same time on the antenna side, precise codebook-based precoding algorithm is appeared to ensure the desired outcomes. A study about cell association and the interference management technique for HetNet provide some significant outcomes in terms of archiving higher bandwidth [81]. Outcomes reveal that the demonstrated approach provides superior results compared with the fixed cell range deployment and fixed almost blank subframe techniques. However, the author agreed that this technique is limited for fewer RBs sharing and a more complex algorithm is needed to accomplish the larger bandwidth.

A study to increase the performance of femtocell in HetNet is compiled in [82] which also follow the enhanced inter-cell interference coordination (eICIC) scheme. The most optimistic outcomes of this study are that it is backwards compatible, and it offers that the approach is adaptable with Long Term Evolution Advanced (LTE Advanced) Frequency Division Duplex (FDD) and Time Division Duplex (TDD) scheme. However, when interference from the same frequency signal is received its performance is degraded to a single time slot. A study focusing to mitigate the interference has been conducted in [83]. The study highly emphasized to measure the SINR for the heterogonous Poisson fields of the transmitter and interferes. The authors were able to prove that the demonstrated approach provides better SINR performance.

We know that higher ICI issues are some significant problems for heterogeneous networks causing by different small cells like femtocell and picocell. But we can solve these problems using different frequency and time division techniques. We can use ICIC and eICIC schemes to reduce the amount of network influenced traffic and cooperation. It will give liberty to every end-user who is connected to each BS which is permitted only information related channel state. We know that, in terms of imperfect channel conditions and time variations, IA is not an efficient solution. If we use a limited degree of freedom (DoFs), it is suggested to design with minimum feedback to use the possibility of IA. We can also go forward with another efficient approach such as ABS approach, but it needs more CSI value. In terms of the good outcomes with high interference, we can also study the FDD and TDD approaches. But, if we consider the future generation 5G HetNets multi-cell networks, then it will be critical because of the possibility of using the scheme of massive MIMO antenna for optimal system performance operating in TDD mode.

4.3 Interference management in the D2D network

A recent study shows that the requirements for modern innovations are the higher data rate, low latency, increased capacity and excellent QoS for long term wireless networks [84]. In this aspect, 3GPP developed a new technology which is known as D2D communication, where consumers independently communicate with each other in the same shared access network over multiple interfaces [85]. It is a radio access platform that allows users with the opportunity to connect with each other in limited vicinity, without any need to transmit data via the cloud infrastructure. D2D enabled system uses WLAN, WiMAX, LTE-A services to establish communication within the long-range devices. On the other hand, to continue connection within the short-range devices it uses Bluetooth protocols or other proximity services [86]. When short-range communication is possible D2D uses the Bluetooth or limited ranges Wi-Fi transmission protocol for data interchange purpose [87]. However, the transmission capacity is limited on these network protocols where LTE-A, WLAN, or WiMAX network protocols offers comparatively higher transmission capacity. The optimistic result comes from the recent research where it reveals that the unlicensed spectrum of LTE-A network can be shared by the D2D users within the existing network [88, 89]. The study also shows that the performance of the core network of a cellular system has been improved by utilizing the D2D [90]. Moreover, D2D networks allow maximizing the scarce spectrum resources. In this process, coordinated radio resource management is appreciated to utilize the unlicensed spectrum [91, 92]. coordinated radio resource management is the principal solution for avoiding the problem of high cellular network activated intercell interference in D2D. Interference was frequently encountered between separate neighboring D2D networks and between D2D and cellular networks. Users mobility and D2D Network Boundary instability are primarily responsible for this form of interference [93]. Additionally, it is compiled in [94] that implementing a wide range of spectrum bands to support single D2D systems (Figure 11) offers essential performance improvements to the capability of the cellular network system.

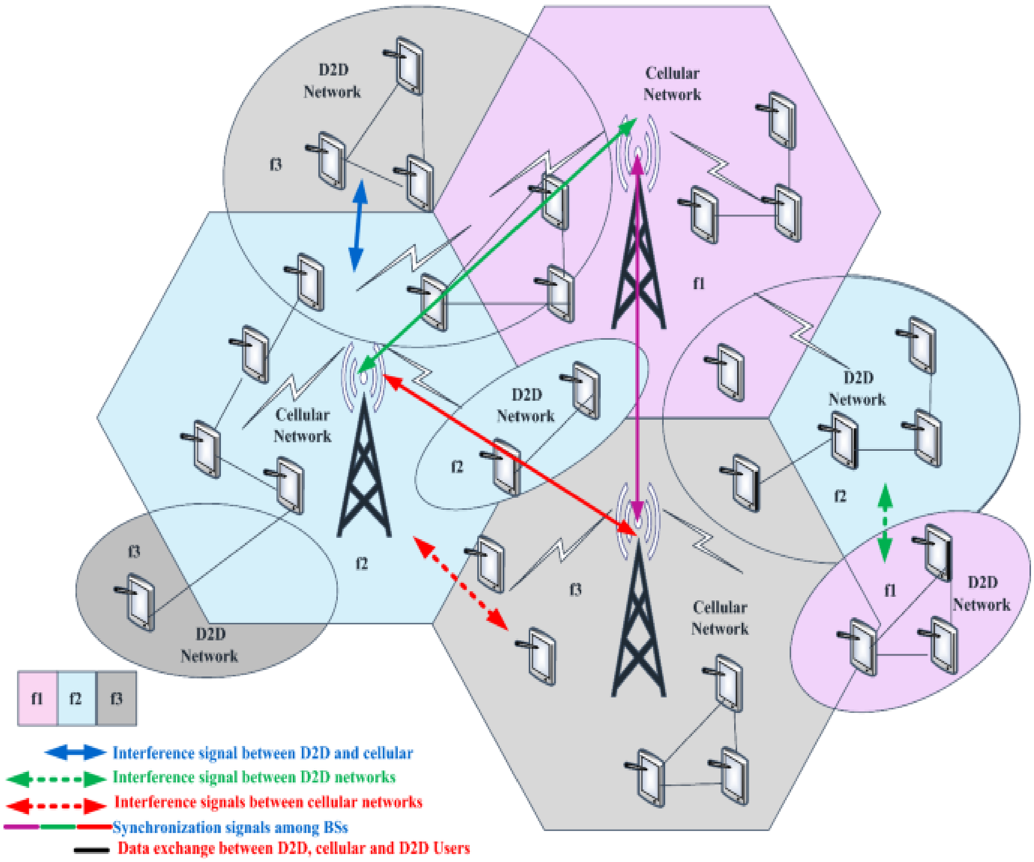

Figure 11 Reuse of spectrum and interference inside a converged cellular and D2D network [70].

Researchers also investigate that D2D network will play a significant role in the future 5G network. In order to ensure low latency, higher spectrum efficiency and power efficiency, augmentation of network capacity and comparatively larger network coverage researchers are highly focused on D2D network [95–97]. However, an effective interference management framework is required to significantly improve the overall efficiency of the network [98]. Several of the relevant methods for addressing below which have already investigated to mitigate the interference in D2D communication.

To mitigate the interference and increase the performance of a D2D network an effective approach is discussed in [99]. The authors concentrate on beamforming and IC technique along with multiple antenna based base station. The outcomes of this investigation provide higher SNR Performance. Another heuristic approach based on resource allocation technique is proposed in [100]. The authors state the estimation interference thresholds set by the base station and cellular users. The outcomes from the proposed scheme provide better interference performance between D2D and cellular users. In [101] the zero-forcing beamforming approach is implemented along with the D2D pair associate vector search algorithm to overcome the optimization issue and maximize the overall cellular and D2D user performance.

Compared to the traditional concept, the approach was substantially successful in providing better performance in terms of sum rate. An-other proposed scheme described in [102] which considered as an optimal solution to mitigate the mutual interference between the cellular and D2D networks. An effective power control method is introduced to get the desired D2D transmit power. In addition, it is recommended to improve interference efficiency by enhancing the distance-based re-source allocation scheme for the cellular user to the D2D receiver. Another interference management approach is described for D2D MIMO HetNet at [103]. This approach mutually develops precoders and receives filters for the interference of co-tier and inter-tier levels which involves lower channel state information (CSI). Two effective frameworks are proposed in [104] to mitigate the interference. The first framework provides an interference-free system, in which the base stations are orthogonally aligned. on the other hand, the second framework offers limited interference.

However, the results show that interferences are well regulated with the appropriate QoS, it is only true for a small number of D2D users within a cell. In [105] another framework for D2D underlined MIMO cellular systems from a unique outlook of interference-aware is implemented. The article presents an interference-free system by accepting the degree of liberty with a liner interference framework as the mode selection criterion. The findings of the article demonstrate that it can obtain significant SNR for massive MIMO-based small-cell networks with comparatively lower interference. Some interference occurred when the resource is shared between D2D and cellular users. An approach is proposed in [106] to mitigate these kinds of interference. A power control algorithm is investigated to achieve the desired cellular and D2D users' power. However, the authors consider the minimum SINR. The findings from the research indicate that a significantly greater sum rate can be achieved with an appropriate power optimization scheme.

When cellular network communicates with the same frequency channel and D2D has converged with it, then we face some primary challenges in D2D. In this situation, we cannot reduce the transmission power of the cellular system, we must reduce the transmission power of users within the enclosure of the D2D area of the network. We need to consider another problem of this scheme, such as it can reduce the overall network performance because it is not always an efficient approach. We need to use more advanced Stochastic geometry based (SIC) approaches, it inclines to produce a disparity among uplink and downlink coverage for D2D adapted cellular network with great spectrum efficiency.

4.4 Coordinated multipoint (CoMP) Technique for controlling interference

In the wireless communication when we consider especially for high density heterogeneous multi-cell networks Coordinate multipoint (CoMP) technique is one of the strongest candidates to ensure limited intercell interference [107]. Moreover, when the frequency reuse situation appears CoMP helps to control the co-channel interference (CCI). Therefore, the system enables multiple users to connect via a single channel [108]. Additionally, coordinate multipoint technique plays a pioneering role to ensure the limited interference between D2D and cellular transmissions networks [109]. CoMP techniques are expected to establish the ground for a potential converged network typically consists of different interfaces. Moreover, through this technique, cellular networks and D2D communications can coexist across the same frequency spectrum [110]. CoMP is an inimitable choice to hold the pledge that the next generation 5G wireless networks will have greater cellular coverage and improve the spectrum utilization efficiency [111, 112].

The number of co-located antennas interconnected via a high-speed X2 interface is installed at separate transmitting positions in CoMP systems [113]. The utilization of X2 interface to interconnect co-located antennas allow the coordination of multiple cells transmissions. This is the way how the CoMP ensures the lower transmission delay and minimum intercell interference [114]. Coordinated scheduling (CS) or coordinated beamforming (CB) and cooperative transmission or cooperative processing techniques are the widely used CoMP transmission schemes.

CoMP scheme in 3GPP Rel-13 and 14 for LTE-A is premised on the theory of multiple transmission nodes at different territorial locations. It offers a special operation mode called interference avoidance mode, which enables it to cooperate in the joint transmitting and receiving of data from UEs [115]. The transmission nodes involve with the joint transmission can be referred to as several remote radio units (RRU) and/or normal base stations (BSs) [116]. Several researches conclude that four types of downlink transmission are supported in the CoMP system [117]. They are:

(a) Dynamic transmission point blanking as shown in Figure 12. In this transmission system for the desired UE, the best transmission point is chosen for data transmission while blanking possible high-interference transmissions from other transmitters.

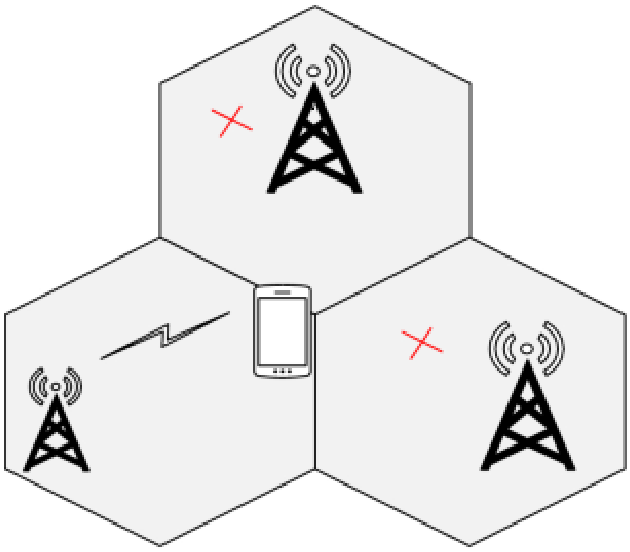

Figure 12 Dynamic transmission point blanking

(b) Coordinate scheduling or Coordinated beamforming is shown in Figure 13. Where beamforming or scheduling intelligence is typically shared among multiple coordinated interference-reducing transmission nodes.

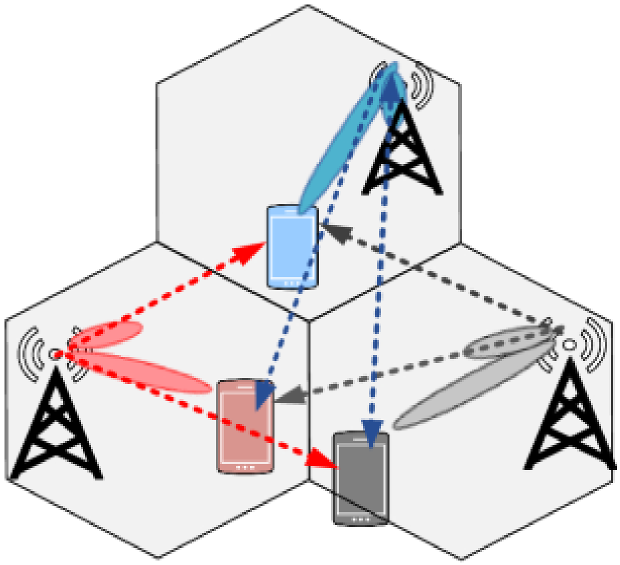

Figure 13 Coordinated Beamforming

(c) Joint transmission is shown in Figure 14. Where several transmission nodes transmit data jointly to the desired UE.

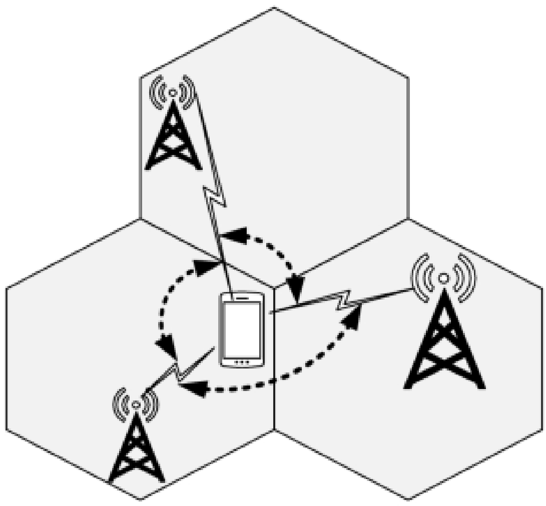

Figure 14 Joint Transmission

(d) Dynamic transmission point switching is shown in Figure 15. In order to transmit data to a specific UE through this technique, the best transmission node is chosen dynamically among several cooperated transmission points.

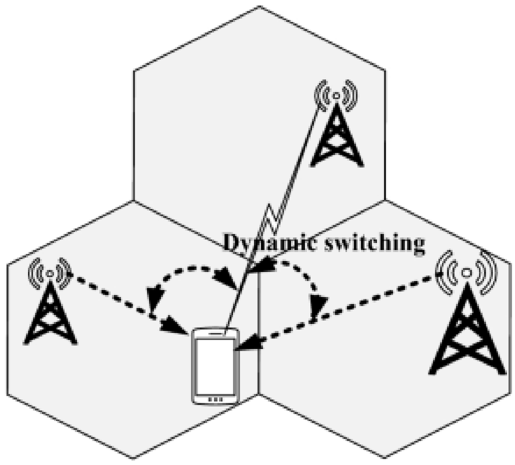

Figure 15 Dynamic transmission point switching

Several studies were performed to limit interference at an acceptable level. Some recent study to mitigate the interference through CoMP is compiled below. A well-established approach is described in [118]. The research proposal was based on the OFDM modulation technique along with higher-order constellations. Moreover, the researchers were forced to utilize the high-performance low-density parity-check (LPDC) code to establish the proposal. The results prove that both IA and CoMP offer better performance for SIMO as well as for MIMO case. A study to reduce the interference of a time asynchronous OFDM CoMP system has been described in [119]. The study was successful to provide consistently better average error probability in Rayleigh fading channel for the high number of base stations.

Considering the LTE-A uplink path another IA analysis is discussed in [120] which offers three different dynamic information selection (DIS) techniques to improve the performance. They are a) higher the sum rate ii) limiting the out-age probability iii) maximizing SINR value. The findings demonstrate that the sum-rate can be increased while reducing the risk of outage probability relative to a traditional UL CoMP system. An interference management scheme based on frequency reuse technique is discussed in [121]. The paper briefly addresses adaptive spectrum allocation and interference limiting through the hybrid dynamic frequency reuse technique. The outcomes demonstrate that the implemented technique will increase both the cell-edge performance and the efficiency of adjacent sector transmission. A technique for limiting local cooperation to distribute the incoming data in an efficient way is proposed in [122]. The findings indicate that the zero-forcing beamforming technique is suitable for the minimum number of receivers. An application-based CoMP scheme is proposed in [123], in which each node is liable for defining unique active application. This procedure significantly reduces the communication link between coordinated nodes that provides greater efficiency and high network capacity.

We know that CoMP serves many different solutions with significant network performance to mitigate interference issues. Some studies suggested and working with A-synchronized coordination system and some suggested synchronized coordination approaches. Sometimes we can implement effective beamforming techniques with the frequency reuse method. We can also use joint processing method to gain more network performance in the help of uplink CoMP which can coordinate with multiple BS coordination that can facilitate single targeted UEs. Finally, if we can utilize different channel interchanging properties what causes less computational complexity, then the performance of the whole system can be upgraded remarkably in the TDD system.

5. RESULT ANALYSIS AND DISCUSSION

In this chapter, SNR and SINR probability distribution in a beamformed system has been analyzed. Considering a new radio 5G network consist of numbers of BSs and UEs.

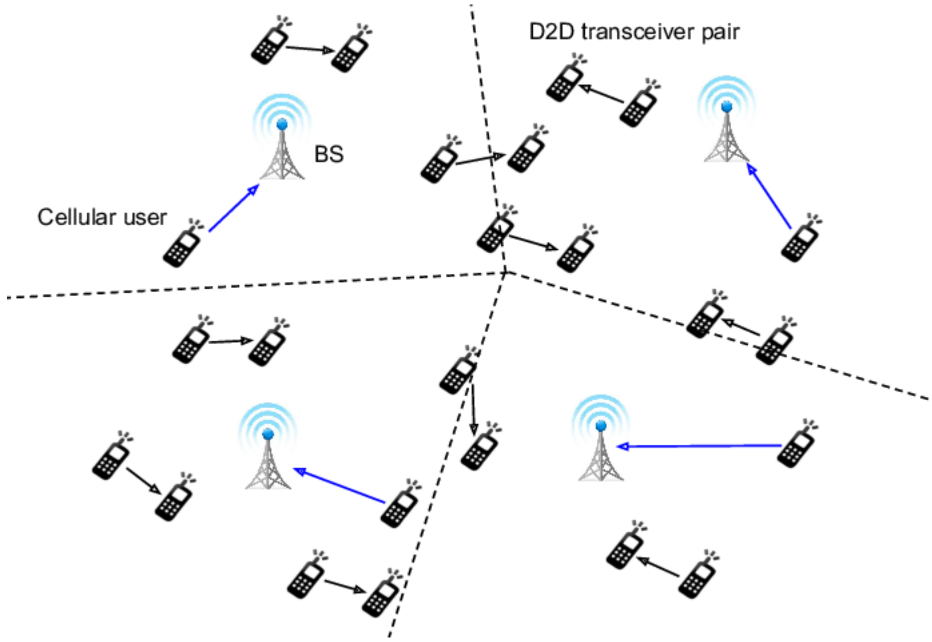

Figure 16 5G new radio network with multiple BSs and UEs [124].

The distance among each base station is calculated by the following equation.

$$d_{bs,i,j} = \sqrt{\left(x_{BS,i} - x_{BS,j}\right)^2 + \left(y_{BS,i} - y_{BS,j}\right)^2} \tag{2}$$

$$\theta_{bs,i,j} = \tan^{-1}\frac{\left(y_{BS,i} - y_{BS,j}\right)}{\left(x_{BS,i} - x_{BS,j}\right)} \tag{2.1}$$

where $d_{bs,i,j}$ is the distance between the ith and jth base station, and $x_{BS,i}$ and $y_{BS,i}$ are the x and y coordinate of the i^{th} base station and $x_{BS,j}$ and $y_{BS,j}$ are the x and y coordinate of the j^{th} base station. Equation 2.1 is considered to measure the angle between each base station.

Similarly, to calculate the distance among each user we consider the equation below

$$d_{us,m,n} = \sqrt{\left(x_{US,m} - x_{US,n}\right)^2 + \left(y_{US,m} - y_{US,n}\right)^2} \tag{3}$$

$$\theta_{us,m,n} = \tan^{-1}\frac{\left(y_{US,m} - y_{US,n}\right)}{\left(x_{US,m} - x_{US,n}\right)} \tag{3.1}$$

where $d_{us,m,n}$ is the distance between the m^th^ and n^th^ user, and $x_{US,m}$ and $y_{US,m}$ are the x and y coordinate of the m^th^ user and $x_{US,n}$ and $y_{US,n}$ are the x and y coordinate of the n^th^ user. Equation 3.1 is considered to measure the angle between each user along with other users.

Moreover, the distance and angle between each BSs to each UEs are calculated through equation 4 and 4.1 respectively.

$$d_{bu,p,r} = \sqrt{\left(x_{BS,p} - x_{US,r}\right)^2 + \left(y_{BS,p} - y_{US,r}\right)^2} \tag{4}$$

$$\theta_{bu,p,r} = \tan^{-1}\frac{\left(y_{BS,p} - y_{US,r}\right)}{\left(x_{BS,p} - x_{US,r}\right)} \tag{4.1}$$

where $d_{bu,p,r}$ is the distance between the p^th^ base station and r^th^ user, and $x_{BS,p}$ and $y_{BS,p}$ are the x and y coordinate of the p^th^ base station and $x_{US,r}$ and $y_{US,r}$ are the x and y coordinate of the r^th^ user.

Antenna power measurement is performed through the antenna gain function which represents in 4.2. Where AP represent the antenna power, AO_{angle} means the antenna orientation angle and N_{array} represent the number of antenna elements.

$$AP_{p,r} = ag\left(\theta_{bu,p,r}, beamangle, AO_{angle}, N_{array}\right) \tag{4.2}$$

The path loss measurement calculation is represented below

$$PL_{p,r} = -147.6 + 10 * n * log10 d_{bu,p,r} + 20 * log10(f) \tag{4.3}$$

Where n represents the path loss exponent. The receive signal power of UEs are calculated through the following equation (4.4)

$$PRx_{p,r} = PT - PL_{p,r} + AP_{p,r} \tag{4.4}$$

The interference signal power, SINR and SNR are calculated through the equation (5), (5.1) and (5.2) respectively. Where PI represent the interference power, PT is the transmit signal power, PR_x is the receive signal power and the required $Antenna_{gain}$ is defined similarly as in equation (2.4).

$$PI = PT - PL + Antenna_{gain} \tag{5}$$

$$SINR = 10 * log10\left(\frac{PRx}{Noise_{power} + PI}\right) \tag{5.1}$$

$$SNR = 10 * log10\left(\frac{PRx}{Noise_{power}}\right) \tag{5.2}$$

5.1 SNR and SINR performance analysis

One of the major drawbacks of 5G NR is higher path loss which degrades the SNR performance. However, higher path loss improves SINR due to lower interference power. To compensate for the path loss of 5G NR, directional antenna gain needs to be increased. Beamforming helps to increase the directivity of the antenna. Beamforming gain depends on the number of antenna arrays. Higher antenna arrays provide higher beamforming gain which results in lower path loss and increases the SNR performance along with SINR performance. For the simulation purposes, we have used six BSs and fifty UEs. UEs are uniformly distributed in the area and always served by the closest BS. and The simulation result shows that the beamforming technique influences the SNR and SINR performances by selecting the number of antenna array element and the path loss exponent. Moreover, the following histogram graphs represent the SNR and SINR probability distribution. In figure 17, it can be realized that the SNR performance is good enough. In the meantime, it also indicates that the interference power is also higher which causes lower SINR performance. In figure 17, when the selected antenna array is 1, the base station serves a single beam and at the highest SNR and SINR probability distribution, the SNR and SINR value is 45 dB and 3 dB respectively, which is a very poor SINR performance compared to the SNR performance. In this simulation, the beamforming occurs at the BS side, and the increasing number of antenna element enables the transmit signal more directive towards the desired user.

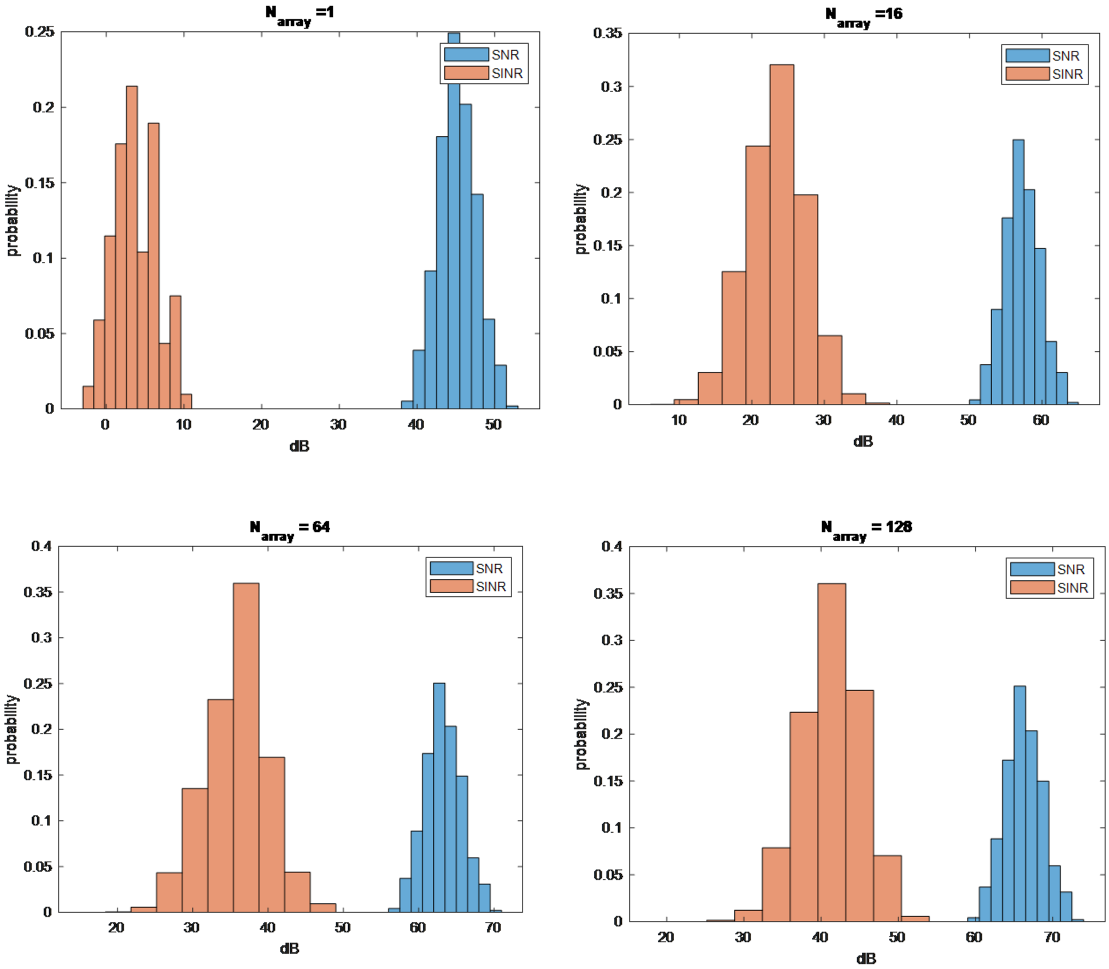

Figure 17 Path loss exponent n= 2 with selected antenna array.

Moreover, from Figure 17 it can be noticed that when the antenna array increases from 16 to 64 and finally to 128 the SINR performance is increasing significantly along with the SNR performance. In figure 17 at N_{array} 128 also shows that at the highest point of SNR and SINR probability, the SNR and SINR value is 65 dB and 45 dB respectively, which is 20 dB and 45 dB higher than the traditional antenna system.

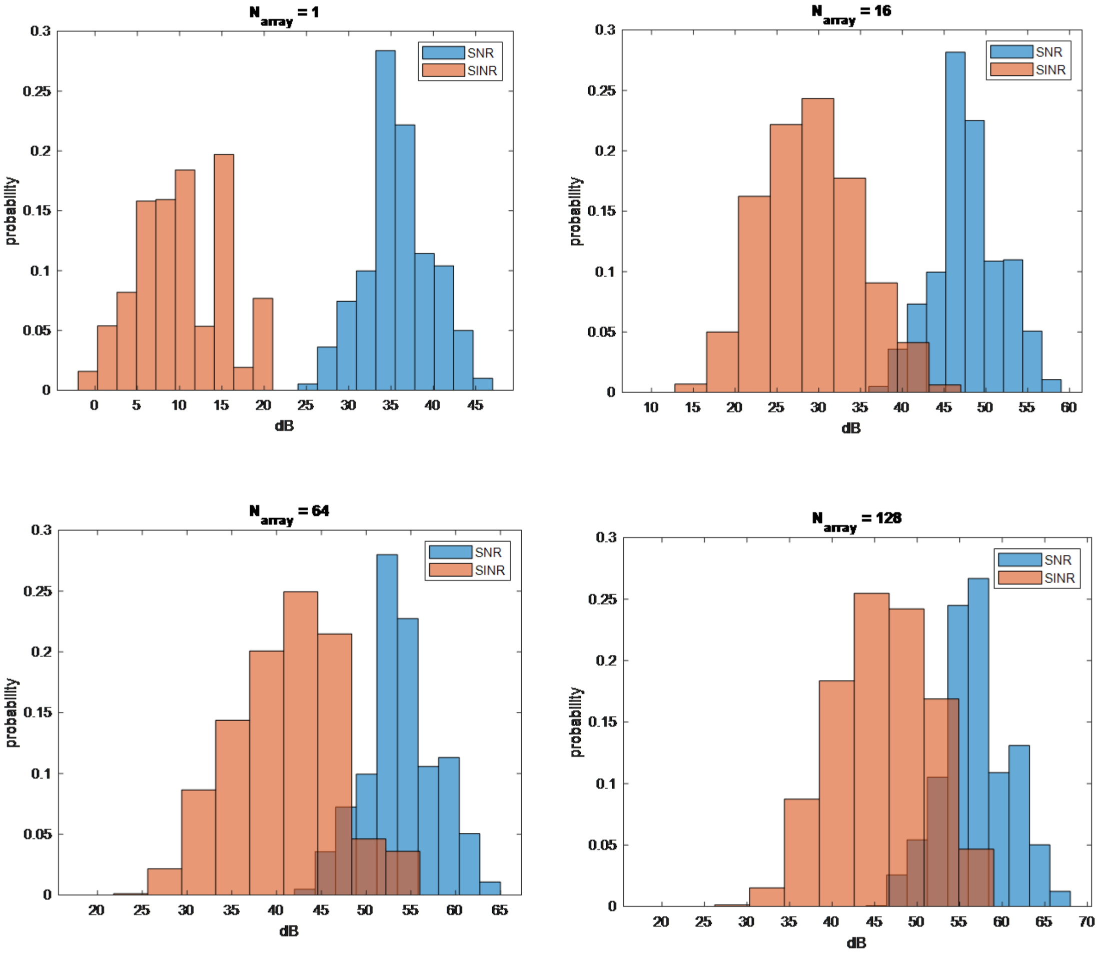

Figure 18 Path loss exponent n= 3 with selected antenna array.

Furthermore, Figure 18 also indicates the higher SINR performance along with the increase of N_{array} where the selected path loss exponent is 3. In this figure, at the highest SINR probability distribution, the SINR performance improves from 15 dB to 45 dB with the increase of N_{array} from 1 to 128 gradually.

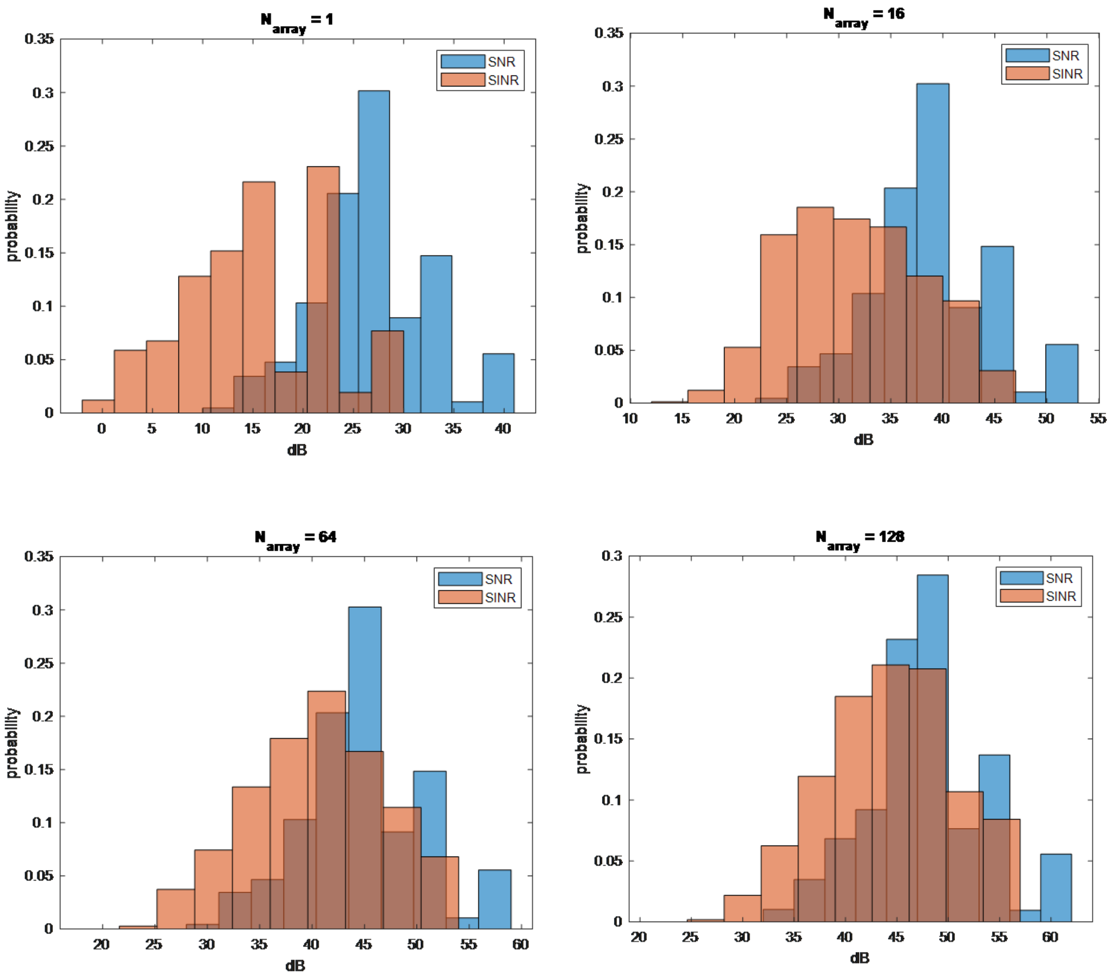

Figure 19 Path loss exponent n=4 with selected antenna array

Similar improvements of SINR with selected path loss exponent can be observed from Figure 19. Where at the highest SINR probability distribution, the SINR are 23 dB, 28 dB, 43 dB and 46 dB corresponding to the antenna array 1, 16, 64 and 128 respectively.

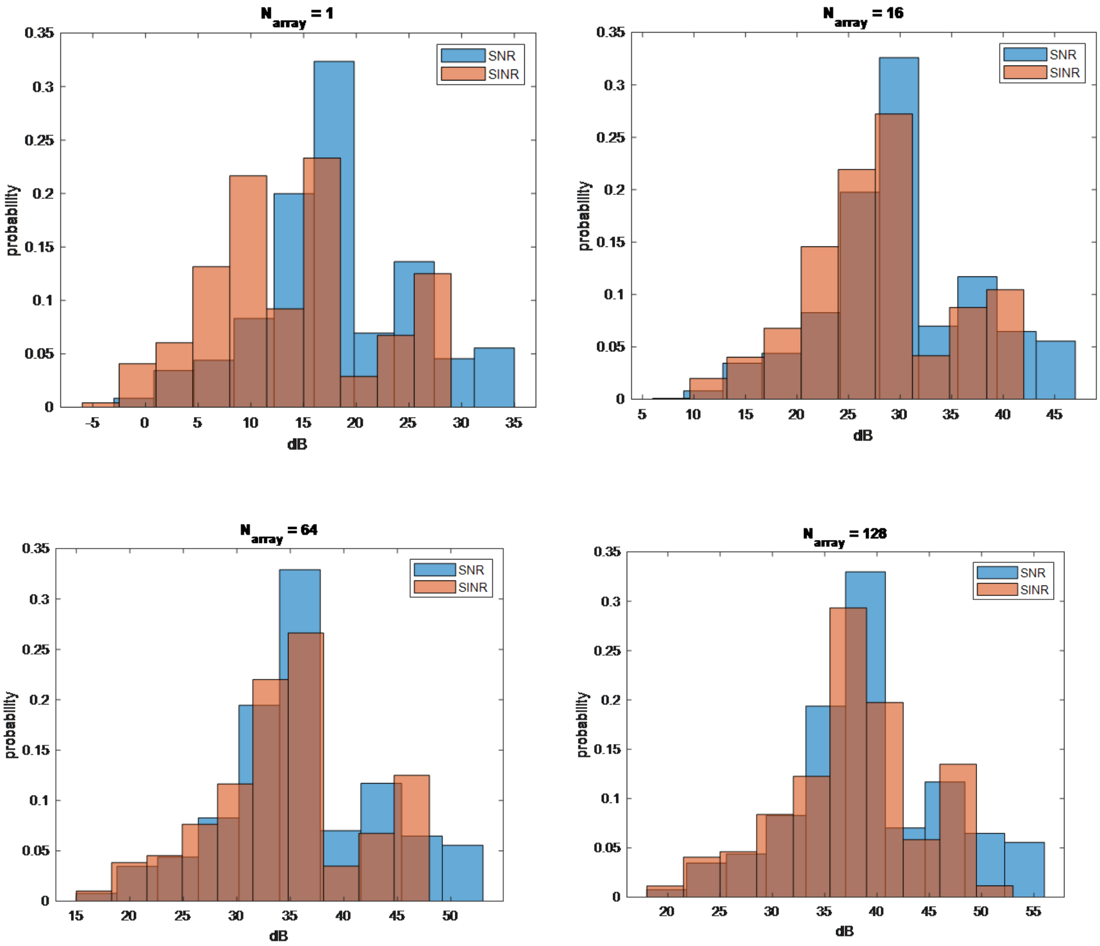

Figure 20 Path loss exponent n=5 with selected antenna array

Figure 20 shows that without applying beamforming at path loss exponent 5 there are some unaccepted SNR and SINR performances. In that case, we can get significant outcomes from the increasing the antenna array which helps to direct the signal towards the desired user. Moreover, increasing the antenna array reduces the number of interferer possibility and interference power which helps to achieve the acceptable SNR and SINR value.

In other words, where the interferer probability is higher, the signal power should be higher. Increasing the number of antenna element helps to achieve the desired SINR through directing the beam towards the desired user where the interferer probability is higher. Simulation results also indicate that increase of antenna array increase the SINR value along with increase the SNR performances.

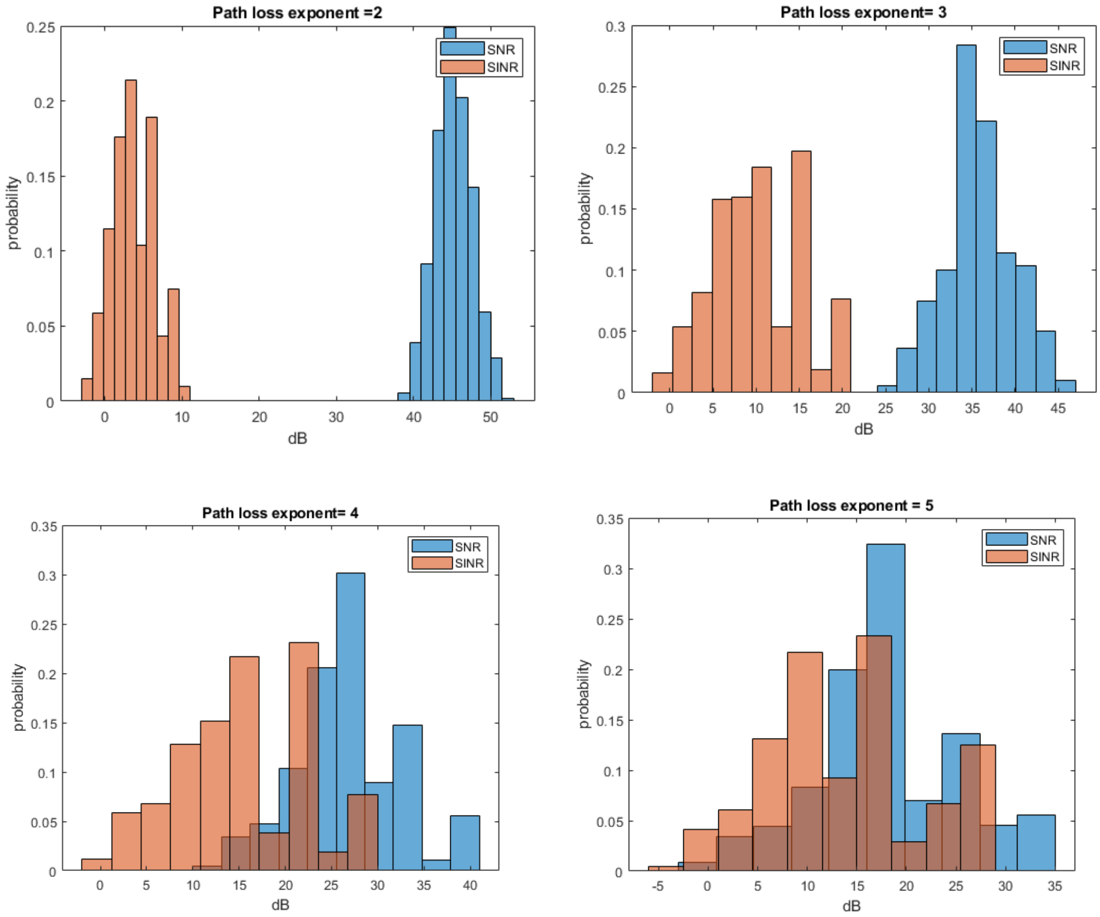

Figure 21 N_{array}=1 with selected Pathlos exponent

On the other hand, Figure 21 indicates that the SNR performance degrades radically with the increasing of path loss exponent from 2 to 5, but SINR only a little. This is because higher path loss also reduces the interference power.

6. DISCUSSION AND CONCLUSION

For the upcoming 5G NR wireless network, the number of users will rise exponentially, rendering the communication network an ultra-dense one. There are some high interference problems, such as ICI (which is triggered by signals from the neighboring sector of the same cell) and co-channel interference (CCI) due to the reuse of the same frequency in the adjacent cells. In addition, allowing D2D communications over cellular networks would provide greater capacity expansion, but many interferences, particularly in the ultra-dense network, have to be deal with.

SNR performances degrade with the increase of path loss. Proper location information and thus distance knowledge helps to get a clear idea of received signal power ant the interference level. Location knowledge is not only important for location-based services but also significant for robotics and intellectual transport system. Moreover, location-aware resource allocation technique has the ability to predict the channel quality. However, in order to make the location awareness possible to predict the position accurately consequential signal processing is needed.

Pathloss in 5G NR can be compensated through the beamforming by increasing the antenna elements, a large number of antenna elements increases the directivity towards the user. Especially in the cell edge where the highest number of interferers are appeared. Additionally, a huge number of antenna array allows more freedom to narrower the beam in order to ensure better throughput and spectral efficiency. Nowadays, beamforming is the automatic choice to the researcher, when approaching for mitigating the interference.

In this thesis, we mainly focus to increase the SINR performance of the cell edge users. Moreover, in this thesis, we deeply investigate the SINR performance of 5G network by selecting different antenna arrays. The main objective of our research was to achieve the desired SINR value where the user suffers in lowest signal power. The principal key challenge to get the desired performance was to measure the interferer probability. Beamforming technique with multiple antenna arrays is proposed to minimize the interferer probability. In order to increase the antenna array from 1 to 128 at the highest SINR probability distribution, the minimum SINR performance increase is 30 dB.

This thesis aims to provide additional insight to interference issues in 5G systems. After a brief overview of beamforming techniques together with location awareness aspects, different interference mitigation schemes are discussed. With the extensive literature overview and illustrative simulation results provided in the thesis, it is strongly believed that this thesis is able to help researchers working with the topic of location awareness and interference management.

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