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# Dynamic Resource allocation in Millimeter wave technology


**By**

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# Abstract

In this project, dynamic resource allocation in millimeter wave system that holds the effect of millimeter-wave. It also gives the understanding of directivity of antennas as transmitter and receiver side. In addition to this, it is clearing the idea path-loss of signal due to obstacles and molecular absorption and blockage of radiation that are on high frequency. Main focus is to explore the effect of blocking and propose a resource allocations scheme that tries to avoid it.

# Preface

I would like to express my special thanks of gratitude to my teacher (Dmitri Moltchanov) who gave me the golden opportunity to do this wonderful project on the topic (Dynamic Resource Allocation of Millimeter Wave Technology), which also helped me in doing a lot of Research and I came to know about so many new things I am really thankful to them. Secondly I would also like to thank my parents and friends who helped me a lot in finalizing this project within the limited time frame.

Tampere, 08.05.2017

Khaza Towfik Akbar

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| GSM | Global System for Mobile communication |
| 2G | Second-Generation wireless telephone technology |
| 3G | Third Generation technology |
| LTE | Long Term Evolution |
| 4G | Fourth Generation technology |
| NTACS | Narrowband Total Access Communication System |
| ETACS | Extended Total Access Communications System |
| CDMA | Code-Division Multiple Access |
| TDMA | Time-Division Multiple Access |
| ITU | International Telecommunications Union |
| 3GPP | 3rd Generation Partnership Project |
| 3GPP2 | 3rd Generation Partnership Project 2 |
| HSPA | High Speed Packet Access |
| UMTS | Universal Mobile Telecommunications Service |
| HSDPA | High Speed Downlink Packet Access |
| HSUPA | High Speed Uplink Packet Access |
| TDD | Time Division Duplex |
| WiMAX | Worldwide Interoperability for Microwave Access |
| OFDM | Orthogonal Frequency Division Multiplexing |
| MIMO | Multiple-Input and Multiple-Output |
| EHF | Extremely High Frequency |
| THF | Tremendously high frequency |
| 4G+ | LTE-Advanced |
| 5G | 5th generation wireless systems |
| Tx | Transmitter |
| Rx | Receiver |
| LoS | Line- Of- Sight |
| NLOS | Non-Line-Of-Sight |
| mm-W | millimeter Wave |
| AWGN | Addictive White Gaussian Noise |
| IEEE | Institute of Electrical and Electronics Engineers |
| HDTV | High Definition Television |
| RAN | Radio access Network |
| SINR | Signal-to-Interference-plus-Noise Ratio |
| MAC | Medium Access Control |
| BCQI | Best Channel Quality Indicator |
| TTI | Transmission Time Interval |
| RB | Resource Block |
| RR | Round Robin |
| UE | User Equipment |
| QoS | Quality of Service |
| CQI | Channel Quality Indicator |
| SNR | Signal-to-Noise Ratio |

| | |
|---|---|
| dB | decibel |
| exp | Exponential function |

# 1. INTRODUCTION

The chapter mainly focuses on the evolution of the mobile communication; this chapter also discusses the history traces along with the architecture overview and the LTE technology. The steps of the 4G and 4G+ are also discussed in the chapter as the state of the art. The document has a short past of the wireless communication system that usually includes the essence of the emergence of the cellular systems from the beginning to the present times. Furthermore, the chapter will explain the outline related to the topic and the reasons for choosing this particular topic for thesis.

## 1.1 The wireless network evolutions

In the modern times of the technological advancements, the communication services are increasing at a high level. In 1983, Ameritech established the first cellular telephone in Chicago. The concepts of the analog technology were used by the service, however, the name of the concept was AMPS which is “Advanced Mobile Phone Service”. In this late century the mobile or cellular services are very common in the world, whole world is using the cellular systems and the users and services are also eased. Many surveys were done in the context and one survey that was conducted in March 2010 displayed that, the mobile subscriber as increasing on daily basis and the fixed line subscribers are decreasing and the mobile subscribers at that time increased to 4.8 billion all over the world. Similarly, like the wireless and the fixed line, the trend of wireless systems is increasing.

People are becoming more social these days and trying to communicate with each other more than ever and this is made possible by the wireless technology and this technology is ultimately fulfilling the preferences of the people. The wireless system is revolutionizing and the humans are at the doorstep of that revolution (Petrov, 2016).

### 1.1.1 First Generation Cellular Systems

In 1979, Telephone Company of Japan applied the cellular systems which were commercial and international as well, this was a unique step. In the time period of two years in 1981, the Nordic Mobile Telephone NMT-400 successfully developed the system which supported the roaming outside the country or can be said as international roaming along with the handover of the calls inside the Europe, the process was automated and was implemented for the first time (Petrov, 2016). The countries which enjoyed the deployment of NMT-400 were Denmark, Austria, Spain, Sweden, Norway, and Finland. Even more the NMT-400 subscribers had the car phones which were able to transfer the 15 watts power. Japan, United States, and the Europe were the pioneer in developing the wireless cellular system.

The basic characteristic was the Analog modulation scheme of the first generation systems; the scheme was solely designed to deliver the services of voice. The system consisted of the different bandwidth and was similar to radio stand point. The NTACS and ETACS normally use the size of channel 1.25 kHz and 25 kHz, however AMPS channel size was the 30 kHz (Takano, 2016). The concept of the cellular devices allowed the automated switching and ongoing call delivery and these are the factors differentiating the systems. AMPS was the system which reached the highest success levels in the first generation inside the United States with the different total access systems of communications that are, NTACS and ETACS in the Europe and Japan.

### 1.1.2 2G Digital Cellular Systems

The 2G wireless systems were developed with the improvement in the abilities of the processing of the platforms commonly hardware. Basically the objectives backing the 2G systems development was the voice marketing and it was different from the first generation on the basis of the digital modulation (Petrov, 2016).

The new techniques such as time division or multiplexing many users were able to multiplex at the same frequency. The tighter frequency coding was used again and again, error performance and the equalization techniques were also enabled and this allowed the ratio to fall from 18 dB to less dbs. The digital modulations allowed a lot of improvements in the system performance.

The security problems included misrepresentation dropping that are of fundamental worry in the first generation then the 2G system utilized the straightforward encryptions. The most well-known cases of the 2G cell systems incorporate the IS-136 TDMA systems, IS-95 CDMA and the Global System for Mobile interchanges (GSM). Furthermore, out of every one of these frameworks the most used so far is the GSM while the IS-95 and IS-54 are conveyed in the North America on starting stages, after some time it was upgraded to IS-136 and assist ended and substituted by the GSM. Moreover, the upgrade of the system to the digital system changed many features like the digital speech codes; it increased the spectral efficiency of the system and increased the capacity as well.

Good speech codes usage and processing signals usage allowed to level the quality of voice was improved. A portion of the individual convenient telephone sets otherwise called PHS that were conveyed in a portion of the Asian nations including China, Japan and Taiwan and so forth are likewise viewed as 2G systems. These PHS are, really, computerized upgraded cordless phones having the capacity of giving over starting with one cell then onto the next cell worked inside the recurrence band of 1880–1930MHz. 2G has empowered numerous new applications apart from the security, limit and enhanced voice quality,. The most imperative of them was the short messaging service or SMS that was right off the bat sent in 1991 in the Europe and bit by bit turn into the most critical and prominent instrument for the discussion in this modern era.

### 1.1.3 3G Broadband Wireless Systems

After the success of 2G, it was later followed by a new service and still it is the most commonly used wireless service and that is 3G or the third generation technology. These systems were better than the 2G systems for having higher rates of information exchange and a fundamentally expanded limit of the voice supporting more propelled applications and administrations relying on with the interactive media. Among the mid-90s, the improvement on the third era has started. This was the time when the International Telecommunications Union (ITU) began the solicitations for the 3G proposition alongside the recognizable proof of the range for it that is otherwise called IMT-2000. The prime goal of the ITU was the worldwide harmonization of the versatile correspondence and to encourage the worldwide interoperability that could give the lower cost also.

Eliminating the reality of high information rates 3G has given the best quality and better administrations that have custom-made numerous applications including the voice quality, email, intelligent gaming and diverse interactive media applications. Among the traverse of 15 years, numerous proposition were put together by ITU and just six of them were affirmed. The best get to method that the 3G systems had was CDMA. CDMA2000 additionally a 3G innovation that is started by IS-95 and wideband CDMA was proposed by GSM (Group Special Mobile).

| | W-CDMA | CDMA2000 W-CDMA 1X | EV-DO | HSPA |
|---|---|---|---|---|
| Standard | 3GPP Release 99 | 3GPP2 | 3GPP2 | 3GPP Release 5/6 |
| Typical User Rate | 150–300kbps | 120–200 kbps | 400–600kbps | 500–700kbps |
| Channel Band-width | 5MHz | 1.25MHz | 1.25MHz | 5MHz |
| Multiple Access | CDMA | CDMA | CDMA/TDMA | CDMA/TDMA |

Table 1. Summary of Major 3G Standards (Takano, 2016)

### 1.1.4 Beyond 3G

3G proposed their first arrival of standard by 3GPP and fruition year was 1999, however appropriately discharged it in the year 2000 and refer to it as 3GPP Release 99. In the world huge numbers of the UMTS monitor that standard. Moreover, their discharge is perceived by the attaching discharge year with it. Each discharge confers a few upgrades of various perspectives. Long haul Evolution (LTE) was a venture identified with media transmission in 2004 and called to be Third Generation Partnership Project (3GPP).

The new stride of advancement happens in 2009 arranged by the mobile operators and their decision relies on upon the present condition of improvement. It's sensible to presume that for the most part administrator would additionally take a shot at the accompanying alternatives. HSPA (High-Speed Packet Access) that expression present the blend of two noteworthy enhancements that is finished by 3GPP to UMTS (Universal Mobile Telephone Service i.e. in view of GSM) - WCDMA High-Speed Downlink Packet Access (HSDPA) that was available in 2002 and fast Uplink Packet Access (HSUPA) that was available in 2004 Establishment of HSPA and their up and coming advances and potato to move to LTE, foundation of WiMAX that is intentionally for broadband information.

This probability is for the most part pleasing to CDMA administrators, Green-field administrator, and furthermore to the administrator who yearnings to send a TDD system. 3. Set up of LTE. The greater part of the CDMA administrators don't depend on HSPA and WiMAX so they float towards LTE.

After incredible foundation that happened over the most recent couple of decades and the high information rates and idleness, the LTE can give up to 326 Mbps. One of the significant objectives of LTE was to proper portable web involvement and improved versatile web than broadband get to (Vasilakos, 2015). To experience the execution necessity their plan approves radio and system advancements. LTE utilize the innovation OFDM (Frequency Division Multiplexing) in UMTS to vanish the impact of multi way blurring and furthermore for down connection it really transmit information from base station to terminal crosswise over restricted band bearers having 180 KHz on the other hand the total entire signal of 5MHz.

To multi-carrier move information OFDM use limit sub-transporters in substantial sum. OFDM experience the LTE interest for allow savvy and range adaptability for high pinnacle charge transporters (Vasilakos, 2015). The principle standpoint of OFDM is chipping away at single carrier plan without utilizing composite equalization filter amid extraordinary channel condition. The real disadvantages are High top to-normal proportion and because of Doppler move OFDM is delicate to the balance of frequency.

## 1.2 The current state-of-the-art: 4G and 4G+

The downlink of peak spectral and basically the spectral proficiency of 15bps/Hz and 2.6bps/Hz are being imagined alongside the phone edge effectiveness of 0.075bps/Hz per client. Besides extraordinary systems like higher MIMO and request regulations are utilized for expanding top frequency. However the instability of the necessity for the normal and cell edge spectral productivity from the progressed IMT keeps on existing. Around there a testing situation exists for the specialists and developers.

The test is of building up an effective remote framework. This remote framework needs to have an overwhelming impact, on account of the capacity of the most recent advanced mobile phones which have the profoundly differing applications and processing powers. As expressed in 2011 by Cisco the portable information movement has grown up to 2.3 folds that are even more than two times as recorded continuously since 2008.

The endeavors are now being made for the advancement of a framework past the LTE. Albeit the majority of them call it as 4G systems however in truth it doesn't meet the genuine necessities of the fourth era remote system gauges set by the ITU. The ITU characterizes the 4G framework regarding IMT which is exceptionally best in class with the necessity of focused peak data rate of very nearly 1Gbps for high and low portability applications separately. In addition the progressed IMT has likewise set the prerequisites for the peak data rates identified with the normal, phantom, peak and cell edge productivity.

As indicated by a forecast the normal increment in the information movement is up to 18 overlays between the years 2011 to 2016 with a normal of 1.3 GB era information by an advanced cell. The prompt answer for this information blast is the overhauling of versatile information towards the 4G LTE however even with this up degree the portable applications have turned out to be more differing with the more information utilization alongside the expansion in the quantity of savvy cushion clients. In this way it appears that the client movement request will even surpass the limit of 4G in the coming future and system suppliers should look for alternate choices with the goal that they ought to have the capacity to meet the prerequisites of the information blast.

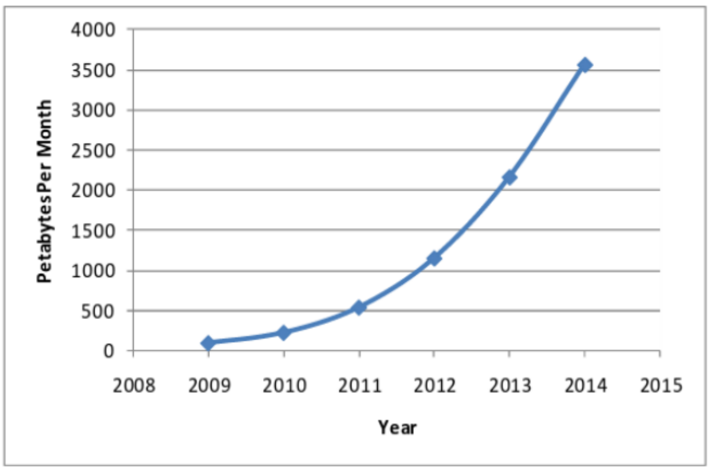


Figure 1. Global mobile data growth (Takano, 2016).

As it is observed from the previous records and keeping in mind the end goal to build a limit of the information movement up to 1000X, the emotional increment in the utilization of versatile information which roughly multiplied and is still increasing. The accomplishment towards the 1000x ability to expand the ghastly effectiveness of the portable information will make utilization of numerous innovation upgrades (Vasilakos, 2015). Be that as it may, the accomplishment of 1000x activity pick up will likewise require the accessibility of range.

## 1.3 Millimeter waves as 5G enabler

Millimeter waves are stretched out waves when contrasted with the infrared waves. Their scope of band range lies between 30 GHz to 300GHz.Moreover there range infrequently liken with radio band of 30GHz to 300 GHz and reaches up to the traverse of Extremely High Frequency (EHF) which is pressed amongst infrared and microwaves, the vast majority of the territory for fast is given through this range. Wavelength of radio wave in this band is from one to ten millimeter, otherwise called millimeter band and millimeter wave and is curtailed as mm-W. Moreover in 1890, Jagadish Chandra Bose was the primary individual to explore this study.

As per the Organization of Federal Communication Commission and studies led, this can be considered as "5G" that give quick and good administrations. To permit this innovation to spread into the market, millimeter wave system work into the range traverse of EHF (30 to 300GHz) that is purposely to investigate in coming years. Besides, a hefty portion of the gatherings beforehand investigated the higher recurrence that is in Terahertz band. Some logical variables, for example, those which impacts the proliferation of waves in the Extremely High Frequency and Tremendously High Frequency traverses that shape the obstruction into 5G frameworks.

Tentatively, it has been demonstrated that mediations have an impressive impact in this specific region. Notwithstanding the use of propel system plans and the extending organizing buildup, guide correspondence of gadget to gadget and customer transmission may at some point obstruction happen when the directional radio wires are utilized as a part of activity. The effect that is utilized as a part of this record is line-of-sight blockage. Many papers have tended to this case as a component of microwave correspondence system, where basic units are impeding transmitter and beneficiary.

When contrasted with the microwave cell frameworks, millimeter-wave and THz framework are dealt with on substantially more compact separation thus in the yield organization, structures are not accepted as a noteworthy issue. In spite of the fact that, client is allowed to hinder the LoS way between the transmitter and beneficiary at these frequencies, if the wavelength is bigger than the protest volume then it goes about as a hindrance. As per the present day figuring beam following reenactment inquire about, at recipient side (Rx) accessible vitality is 60-80% that originates from the LoS components and can control the channel quality.

Electromagnetic waves (EM) are exceptionally impacting at these frequencies and results in a high way misfortune. Reliance of way misfortune is on EHF/THF reception apparatuses to such an extent that littler the measure of radio wires bigger the way misfortune. Additionally, signal transmission exhibits the procedure through which dynamic vitality is changed in inside vibrating particles by the proliferating some portion of electromagnetic vitality (EM). As oxygen is plentiful in nature it influences the way misfortune in EHF band. In the event that the spongy component is disregarded, the yield of got power at a separation from transmitter is very mind boggling, which incorporates type as well as power law work.

Exceedingly directional radio wires and power transmission checks are required at both Receiver (Rx) and Transmitter (Tx) side to disperse the intense spread misfortune. Conceptually, the directivity of the transmitter/recipient receiving wire is high that gradually elevates to clamor restricted heading correspondence framework. Despite the fact that impedance free correspondence by dangerously sharp-shaft is not on the moment horizon, subsequently the fundamental driver of synchronization issues presented by the intricacy of high directivity of pillar framing reception tool's transmission framework the activity of LoS conceivable blockage has additionally be thought about (Vasilakos , 2015).

## 1.4 Aim of the thesis

Into the huge network of the modeling of multiuser interference, it is witnessed that the work is done on the particular topic and it helped a lot in doing the research as well. Additionally, knowing about the aim of the thesis is to construct the concept and get the effects of the millimeter wave. The knowledge about the directivity of the antennas was also given as the receiver and the transmitter side. The blockage effect is not visible when the frequency is not suitable like in LoS; the major effect is caused by the interruptions. To control the effects another communication system needs to be proposed. The particular approach will allow handling the network performance problems effectively and intelligently.

## 1.5 Organization of the thesis

The following paper is divided in five major components. Section 1 of the paper dealt with the basic introduction of the subject and the topics related to this particular field. Different technologies from the past and the future were discussed to introduce them as a part of the research. In section 2, millimeter wave technology is the basic component of the research. Additionally, the section discusses on the use of mm-W in 5G. Furthermore, there are discussions on the blockage schemes and model illustrations related to the situation.

The third section of the thesis is about the performance evaluation model and investigates the performance metrics and implementation details. Section 4 deals with the calculations and numerical results while the section 5 concludes the thesis.

# 2. MILLIMETER WAVE TECHNOLOGIES

Millimeter wave’s communication system employs small scale technology in the upcoming and future technology of 5G. In this chapter the discussion will be based on the guiding principles of the protocols and structural design of the millimeter wave technology. In addition to this, terms will also be a part of the discussion which is linked to the propagation model. The concept of this chapter will prove the idea of the proposal given and presented.

## 2.1 Characteristics of millimeter waves

The basic characteristics of the millimeter wave communication system will consider the structure of the network and the protocols that are able to use the elements of this type of network structure. The spectrum band that has been provided for the technology is wide enough for the researcher to do the experiments and it is around 30 GHz to 300GHz. The basic element of mm-wave communication system is that they have a short wavelength which has a range of 1-10 mm only. The atmosphere also plays a vital role as they face attenuation due to the high atmosphere. Furthermore, the strength of these waves is weak and is disrupted due to the absorption of the gases in the atmosphere. Rain Fade is the term that is used in this case and it is because of the humidity in the atmosphere. Moreover, the signal strengths are severely affected because of this effect. Because of the scope of mm W being around just a kilometer so they continue through the pathway that is in the sight and on at high recurrence structures and distinctive material articles are able to come in their way blocking them. While contrasting with the radio waves and different groups of bands, they seem to have a high extent of retention and consideration by gasses. In particular, the traverse of 57-64GHz is much and in which they are lessened and influenced more towards reverberation. In addition, the rain fade keeps on being the principle issue as the distance is not much to care about. The impacts of stickiness on the signs that retain the proliferation are exclusive of the desert areas. Henceforth the correspondence gets constrained because of this ingestion.

As indicated by another study which was led in New York for the aggravation and interference in signals, receiver was able to catch the signal at a 200 meter distance. Furthermore, over half of the regions that are influenced by the intrusions are because of the prevention that happened past the 200 meter from the transmitter. In the event that more separation is secured, an increase in the antenna gain can easily be seen as well the decrease in the path loss variable. The New York City's urban condition demonstrates that significantly more excellent outcomes have been accomplished by utilizing of profoundly directional antennas. This alters the course of the signals to different ways at any area arranged and having a normal signal of 2.5 lobes. The details for this noteworthy research directed by Akdeniz et al are given.

Zhao et al examined the most extreme separation a signal goes in the high unsettling influence regions is 200 meter, just when the transmitter and the receiver pick up is 49 Db. Estimating a channel for mm-Wave cell can be characterized in another band like 28 GHz band, 38 GHz, and the 73 GHz and as introduced in a study, the 28 GHz urban spread development that happened in New York, the separation between the transmitter and recipient is extended from 75 m to 125 m. The outcomes obtained from this path loss demonstrate that the way loss exponent is 2.55 from the estimation measured. The decent path loss is 5.76 as the case of NLOS suggests. Furthermore, the sorted out intrusion and reflection is 28 GHz. In addition, the outcomes suggest that the glasses in the territory are tinted and the mainstays of blocks have high entrance loss of 40.1 dB to 28.3 dB individually. The lossless is low at the point when the indoor material is in contact with the drywall and non-tinted glass and that is 3.6dB and 6.8 dB individually. Besides the edge of entry and flight of the signal are computed in the study. Subsequently the arrangement found with the assistance of which any NLOS condition and their solid signal can be established at the scope of 100-200 m from the cell that bolster a wide range of areas with numerous accumulation ways. The following subsection of the paper exhibits an outlined exchange on the qualities of millimeter wave correspondence innovation.

### 2.1.1 Wireless Channel Measurement

Employed with the lower carrier frequency, the other communication system compared to mm W shows, mm W has a large propagation dropping. The characteristic of mm W of atmospheric molecular absorption the reason for which is rain, limits the mm W communication.

As the attenuation in the atmosphere at sea areas is quite low the spectrum of frequency spectrum of the microwave is also low at 38 GHz. Furthermore the peaks inside the diagram represent the level of absorption of oxygen molecules and the water vapor. The transmission of waves starts to be affected by other things as well after the 100GHz span. Providing with the results of condition for favorable propagation of waves when the attenuation is lower, due to this reason; the data is transmitted by e-band above the miles.

Rain is the cause of attenuation as well as some other weather conditions that affects it. In the above figure, the idea of attenuation caused by rain can be seen clearly. These days small cell are the cause of the upgrades in the generous effectiveness of proliferation of waves. Therefore, the sizes of cells arrange 200m in the arrangement and the path loss does not leave because of ecological ingestion and rain constriction. Consequently it has been stated by the scientists that mm-wave is appropriate for the indoor condition and cell measurements utilized by backhaul is 200mm (Jung, 2016).

The magnificent work and explorations should be possible on the mm-Wave proliferation at the frequency of 60 GHz. Frequency squared is corresponding to the free space promulgation and with the wavelength of around 5 mm and it is further concluded that the free space engendering loss is around 28 dB at 60 GHz. Moreover, it can be said that when talking about the oxygen ingestion has a peak extending from 15 - 30 dB/km, at the recurrence of 60 GHz, as observed. This way of portrayal exhibits non-line-of-sight (NLOS) path that experiences the higher constriction conversely of line-of-sight (LOS).

This path way characterization demonstrates the non-line-of-sight (NLOS) path that goes through the higher attenuation in contrast of line-of-sight (LOS). The fading can be done on large spectrum is as follow (L. S. Rothman, 2014).

$$F(d) = PL(d_0) + 10_n \log_{10} d \frac{d}{d_0} - S\sigma$$

It can be seen from the above formula that PL (d0) denotes the path loss at the distance of do, and path loss exponent is shown by n, showing loss can be differentiated by Sσ. σ is the standard deviation of S σ (Athanasios)

| | $PL(d_0)$ [dB] | n | $\sigma$ [dB] |
|---|---|---|---|
| Corridor | 68 | 1.64 | 2.53 |
| LOS hall | 68 | 2.17 | 0.88 |
| NLOS hall | 68 | 3.01 | 1.55 |

Table 2. The statistical parameters in the path loss model (Yong, 2015).

In the above table there are constraint listed as the way loss of NLOS lobby, LOS corridor and hallway. It can be observed that the loss of LOS lobby is 2.17 while the NLOS corridor is 3.01 (Athanasios, 2015). The contention in the table that can be seen is the loss and the directional receiving wires which are incorporated at both transmitter and receiver to achieve at high reception gain. The scale engendering has a usage at 60 GHz traverse and it should be noted as well that scale is a compact one (Kim, 2016).

Generally the observations are that multipath impact is not discernible alongside the directional reception tool and that is antenna. In any case, on account of narrow beam width antenna at the receiver end is long with the utilization of the round polarization multipath can impact as well as it can be thrashing. As indicated by the gathering room of the condition, according to the situation, which is proposed in IEEE 802.11 advertisement, the level multipath segment exists in the immediate way and includes all the vitality. Addictive White Gaussian Noise (AWGN) can be translating all the things considered. There will be no immediate way all things considered and the arrangement of the way has in significant amount of energy. Control productivity can be augmented and to achieve high information rate, in mm-wave correspondence for the most part rely on upon the LOS transmission (Jung, 2016), (Athanasios, 2015).

### 2.1.2 Directivity

Millimeter wave connections are very directional, alongside the coordinated effort of little wavelength electronic antennas can be seen with the metal on the circuit board. The signal transmitted by the wire is maintained in the controlling stage so that high gain is secured at specific bearing radio wire cluster. The concept is that the coordinates their shaft towards any of its course, however in other directions the low increase contribution happens. The method for training is required when transmitter and collector coordinate bar toward each other and a considerable lot of the practicing calculations have been recommended (Tsang, 2011), (J.wang, 2009).

### 2.1.3 Sensitivity to Blockage

The electromagnetic waves that have the bigger wavelength quite have a noticeable capacity that needs to diffract around the hindrances. Wavelength having the range traverse is 60 GHz are effortlessly influenced by hindrances such as furniture and an individual. The scope of waves those human blocks is 20-30 db. In the study of (Collonge et al), it is suggested that channel is hindered by 1-5 people around 1 - 2%. This calculation result is finishing up as indicated by the reasonable indoor region. Millimeter wave connections are sporadic when considering the human portability with the goal that's the reason requires bona fide relationship for postponement delicate applications like an immense test for mm-Wave is HDTV.

## 2.2 The use of mm Wave in 5G

The present foundation that happens in the versatile correspondence framework is insufficient but rather the predetermination is very unique. As the request increment and it will keep expanding, so for the future foundation require a superior way to deal with video spilling innovation. As beforehand, the effect of developing human innovation shows us to associate more. To get off from the offload activity and with the remote framework to convey up or depend on the enormous number of cells that is incorporated into the fifth era. To allow this usefulness in real life the mm-wave and the THF band investigate this successfully. The band portrayal is one of a kind as far as engendering resources conversely with microwave framework. The resultant outcomes would demonstrate that at the lower frequencies their system would thoroughly be distinctive. It is inferred that at lower frequencies, the arrangement of impedance structure would successfully appear to carry on in an unexpected way. Promote, we likewise concentrate the instruments of stochastic geometry that utilization in the EHF/THF groups helps in the three wonders of recurrence like in directivity of transmitting and get receiving wires, obstructing the radiation recurrence that will be on high mode and the ingestion of atoms (Niu, 2015). Presently go to the unsympathetic elements that that assistance in the spread rushes of the EHF and THF groups that help to keep up the 5G obstruction framework. Initially, the high way misfortune influences the in electromagnetic waves on these frequencies and when the measure of the receiving wire of EHF/THF is littler the expansion in misfortune happen. Signal spread further inch works with sub-atomic retention. This case show the procedure through which the proliferating sign of inside vibrating atoms changed over into active vitality in electromagnetic vitality (Akyildiz, 2014). As oxygen is plentiful in nature and it unmistakably impacts the way misfortune in the EHF band. On account of THF band vapors of waters go about as the essential part in the misfortune. Whatever is the sort of retentive the statement of energy got at a separation from transmitter it infers that it is more intricate it is additionally incorporated into the type and the power work law too. The checks likewise required for the transmission of the collector and the transmitter motion through profoundly directional radio wires so the need of energy constraint to diminish the spread misfortune. The review reveals to us that the transmitter and collector reception apparatus if is on high directivity, will bit by bit take the correspondence framework to the commotion impediment set of principles (Jormet, 2011). Along these lines, it is expressed that the correspondence is not obstruction free if well sharpened sharp-shaft is not on the correct skyline. To settle the difficulties that present in the bar framing receiving wires is the purpose behind the multifaceted nature of the high directivity challenge. Notwithstanding it is likewise tentatively explored that specifically condition the part of impedance is particular. The denser the system the propelled component of systems administration be utilized and they depend on Pico cell and transfers of customer yet when straight gadget to-gadget correspondence happen there is still impedance and spread misfortune happen notwithstanding when the directional receiving wires are in action(Jung , 2016) .

### 2.2.1 Propagation in EHF/THF Bands

The basic elements that are able to make a difference from the other bands are the presence of the sub-atomic ingestion that is calmed much congenial in the THF band. As it is researched that the 60 GHz the unlicensed band, on the highest point of it the loss of spread because of assimilation happen is on the grounds that oxygen (O2) particles and water vapor (H2O) is the second number of the retention of atoms. As the misfortunes happen in that way so the method of recurrence is specific. The composed type of them got PSD of the EHF/THF groups (Jormet , 2011).

$$S_{Rx}(f;r) = \frac{S_{TX}(f)G_{Tx}(f)G_{Rx}(f)}{L_A(f;r)L_P(f;r)}$$ Equation 1

The above equation shows that, f is the operating frequency (L. S. Rothman,2014 ), the distance that separates the transmitter and receiver is designated by the r, Stx(f) is the power spectral density of transmitted signal and LA (f; r), LP (f; r) shows the absorption loss and spreading loss respectively, while the GTx (f) and GRx (f) designated the gains in antenna in transmission and reception these can be taken as constant in specific frame of work.

Following equation describe the loss of absorption.

$$L_A(f;r) = \frac{1}{\tau(f;r)'}$$ Equation 2

In above τ (f; r) i. e is followed by the Beer-Lambert law τ (f; r) ≈e-K(f)r and is designated as the medium of transmittance which is the coefficient medium available in the database of HITRAN model in the Beer-Lambert law K(f) is the coefficient of medium that is in included in the HITRAN database(L. S. Rothman,2014 ),. This is to assume that in the free space of spherical propagation, propagation loss can be taken out (Rothman, 2014), through this (;)=(4□□□□⁄)2 in this equation c shows that electromagnetic wave speed. Along with the path loss THz band also define the noise. First of all, when radiation is out of phase it is absorbed by the equal frequency of molecules present in the medium as it is radiated. This absorption of electromagnetic waves is said to be medium emissivity and according to the communication point of view, it is to be considered as the noise source. Now in the power spectral density noise of molecular absorption is (L. S. Rothman, 2014 ):

$$s_m(f;r) = \frac{s_{Tx}(f)G_{Tx}G_{Rx}}{L_P(f;r)}[1-\tau(f;r)] \qquad \text{Equation 3}$$

As till now, there is no proper investigation about this that is this noise is as much high is it effect the reception of the signal. As through this, we address the presence and absence of noise affects. The two ways are present to address that the noise entering in conductors. Johnson-Nyquist is the way by which thermal stirring of the electron. When contributing with EHF/THF frequencies the noise form changes. It's basically the operating frequency and it round about using in power spectral density

$$S_{JN}(f) = \frac{hf}{\exp(hf/k_BT)-1} \qquad \text{Equation 4}$$

when precise the noise at power spectral density at the side of receiver and h is the Planck's constants(L. S. Rothman,2014 ).

$$S_T(f,d) = \frac{hf}{\exp(hf/k_BT)-1} + \frac{S_{Tx}(f)G_{Tx}G_{Rx}[1-\tau(f,r)]}{L_P(f,r)} \qquad \text{Equation 5}$$

### 2.2.2 RAN with higher data rates

Radio network is a fundamental wedge of portable correspondence scheme. It applies the innovation of radio network. Furthermore, it possesses the cell phones and PC that remotely interface with the center system and other client hardware gadgets. A delegate usefulness of RAN has taken upon the silicon chip.

The present innovation of RAN is HSPA and LTE have higher information rates and transporter total. In this microwave connect with whole deal systems, they have utilized this potential for quite a while and use this work. These waves additionally are ready to section the arrangement and utilized for equally transporting the movement signal the two microwaves refer to be as radio-connection holding. In the radio-interface holding, the security plot additionally used to connection this vehicle for the productive assurance. On the off chance that any of the connections fizzles, the second will accommodate high administrations. This said to be the insurance, where connect set up in that way that one is for transport and other sitting tight for their reinforcement security. This system will likewise consider eluded where serious rain is relating and shortage of channels that endure rain. Their capacity can be expanded by injecting low-recurrence with high-recurrence to lessen the rain sufferance. The recurrence that is low and will be beyond any doubt to give high need administrations at high recurrence, lessen openness will help bring down recurrence use (Jonas, 2008).

### 2.2.3 3GPP blockage of LoS

Since, an essential impact that considers is observable pathway blockage in it, this idea is portrayed in numerous past papers in the premises of microwave correspondence framework in which amongst transmitter and beneficiary the primary concern to square is structures. In any case, on account of millimeter-wave and THz they work above short separation in correlation of microwave cell frameworks so the building squares are not properly being the real issue in outside condition (Lee ,2011). For the most part on these frequencies the way of LoS amongst transmitter and collector is hindered by the client and in that range is any question their volume is bigger than the wavelength is adequately consider to be an obstruction. Display day contemplates reveal to us that in the report of beam following reenactment 60 – 80 % of vitality at the collector side that originates from the LoS elements and confer the channel nature of beneficiary side. So the procedure of LoS conceivable is additionally to be considered in the execution displaying in greatly low recurrence of correspondence framework by the clients (Jung, 2016).

### 2.2.4 Blocking model

Blocking model hubs go about as the protuberance in the way of the LoS. So the off chance is that we assume to intrude on the intercession way of LoS at specific frequencies, the beneficiary Rx hindered by different obstructions and by then impedance at the collector side is zero. To fasten this interim of the beneficiary from the interferer, the taking after condition demonstrates the likelihood of blocking (L. S. Rothman,2014 ).

$$p_B = 1 - e^{-\lambda(x - rB)rB} \qquad \text{Equation 6}$$

### 2.2.5 Highly directional antennas

As indicated by the theoretical model of impedance, the arrangement of correspondence in the THz was acquainted with take the impact of sub-atomic retention. The work is the concentration by the Nano-scale correspondence framework. This impact does not obtusely typify with the framework. In the deride structure of the continuous wave correspondence framework was acquainted with evaluate additionally in a similar theory this should be possible with SINR. In all the examination arrangement this result is for the Omni directional reception apparatus succession that has completely the comparative alike example that will be seen at the base frequencies.

### 2.2.6 Antenna Radiation Pattern Models

The structure of radio wire radiation design demonstrates the cone and cone-in addition to circle show. The underlying model of radiation radio wire is for single cone-formed pillar and their width control the directivity of the receiving wire. The second one has the side flaps of the single primary projections which are demonstrated as space all through the receiving wire. Conversely of the primary radiation, receiving wire compares with the directional radio wire that is perfect. However, the model of the second directional radio wire is like the sensible reception apparatus. To mimic the cone demonstrate radio wire pick up is required for the flaps of the receiving wire with a point of directivity. For the instance of second model increase required for the primary and side projections of the receiving wire that is useful in lift the signs of the radio wire that from where it comes and lost (Vitaly ,2015).

## 2.3 State-of-the-art in research

The range of millimeter wave uses the electromagnetic band in the traverse of 30-300 GHz that compares the wavelength from a limit of 10mm to 1 mm. In this research, it has been specified that the millimeter wave recurrence typically calls for the attention to the recurrence extended in the scope of 6-300 GHz. One of the distinctive features of this frequency is that it has a short wavelength, furthermore it has an enormous data transfer capacity and strong impact with the air factor and the elements associated with it like oxygen and invades through the vast majority of the strong materials (Vitaly ,2015). This prompts the quality of the space-dispersing environment, where a large portion to divert is in the mass and prompt the course of the clamor floor. To legitimately enact the bar shaping, this massive cluster at beneficiary and transmitter side gives high directivity pick up, which repays the way loss that is exorbitant, lacking of backup influence transmission. As directional transmission is experienced, so mm Wave correspondence encounters a spatial entry that builds up a correspondence linked in between the direction and ranges those progressions as per the directional level. A perspective of the inclusion is seen at the past looks into. Generally these models find an unsystematic isotropic and practically identical use of the procedures like Poisson point and furthermore the Matter bad-to-the-bone process is considered. In a large number of the past reviews receiving wire radiation example is thought to be Omni directional and the separation capacity of the way misfortune is influence law, even all things considered it is to be viewed as that for various reaches, and dissimilar correspondence qualities are to be experience. This deride up was accounted for in the past literary works that simultaneously holds every one of the impacts of the EHF/THF ranges. New reviews stamp the impedance display in the presence of the directional reception apparatuses and furthermore by the impediment of the human bodies so the EHF traverses start to arrive. The proliferation demonstration uses the surrendered exponential shortcoming of signal that is happening by the atomic inclusion misfortune. Besides, this model assumes the deter interferer circumstance on the firm spot and shouldn't be practical for incredible condition. The SIR examination of the obstruction in presence of assimilation lost is engaging. In disdain on the off chance that it introduce show decline to recognize the impact of blocking. This report tallies the lessening coefficient of assuming retention steady and furthermore denies the impact of blocking. In fuse with this a large portion of the reviews that decide the reproduction based reviews likewise that assessing the mm-wave framework that early are present. In spite of the fact, that this is significant to the extensive variety of frequencies and furthermore, hub densities and antenna configuration confines the example.

The model of THz Communication has advanced into the impacts of atomic ingestion and contributes much in this regard. The research intends to recognize the non-scale correspondence arrangement and outlines the impact of blockage was not epitomize. The model ceaselessly speaks with THz communication framework. In any case, in these cases result demonstrates the unidirectional radio wires gives the example of impedances that have comparable structure that will see at the lower recurrence. In addition, specifics of THz waves inciting, specifically, nuclear absorption has a conspicuous quantitative effect on the mean check level and SINR values.

In this way, the effect of nuclear ingestion should not be avoided the impedance showing for more mind boggling circumstances. There are not very many reviews that watch out for the impact of multi-customer impedance at the association layer. The examination considers the radio wire directivity and nuclear digestion, yet does not combine blockage and is performed just for the picked channel get to technique. Also, the analysts develop an arrangement for mm-waves, neglecting the blockage and nuclear ingestion impacts. There have been various other directional MAC traditions, yet none of these works either assess the impedance level in a subjective association or join other fundamental multiplication impacts.

## 2.4 The proposed allocation

With the help of this research, utilizing the instruments of stochastic geometry, it was made easy for the researcher to build up a diagnostic model of obstruction and SINR for frameworks working in the EHF groups that unequivocally records the accompanying three outcomes innate which are as follows:

- Directivity of the Tx and Rx antennas,
- Additional path-loss part caused by molecular consumption, and
- Blocking of high frequency radiation.

Two radiation design models of directional radio wires are trusted to have the cone model tending to a good directional antenna, and the cone-plus-sphere in addition to demonstrate the catching of specifics on any non-perfect directional receiving wire with part projections. The mean interference and the receivers' SINR are the metrics of interest. Employing the developed model, we numerically investigate the multi-user interference in several scenarios. Each of our results show that the mean interference increases when the Tx or the Rx or both are equipped with directional antennas. In conditions of SINR, the blocking effect increases, on the other hand it is degraded by molecular absorption.

# 3. THE PERFORMANCE EVALUATION MODEL

## 3.1 Overview

In this chapter, we discuss the network scenario for the mm wave and scheduling algorithms used in communication systems. Round Robin and Best Channel Quality Indicator (BCQI) scheduling algorithm has been presented in section 3.3. The details of implementation of mm wave technology are discussed in section 3.4 and finally the performance metrics has been explained in section 3.5.

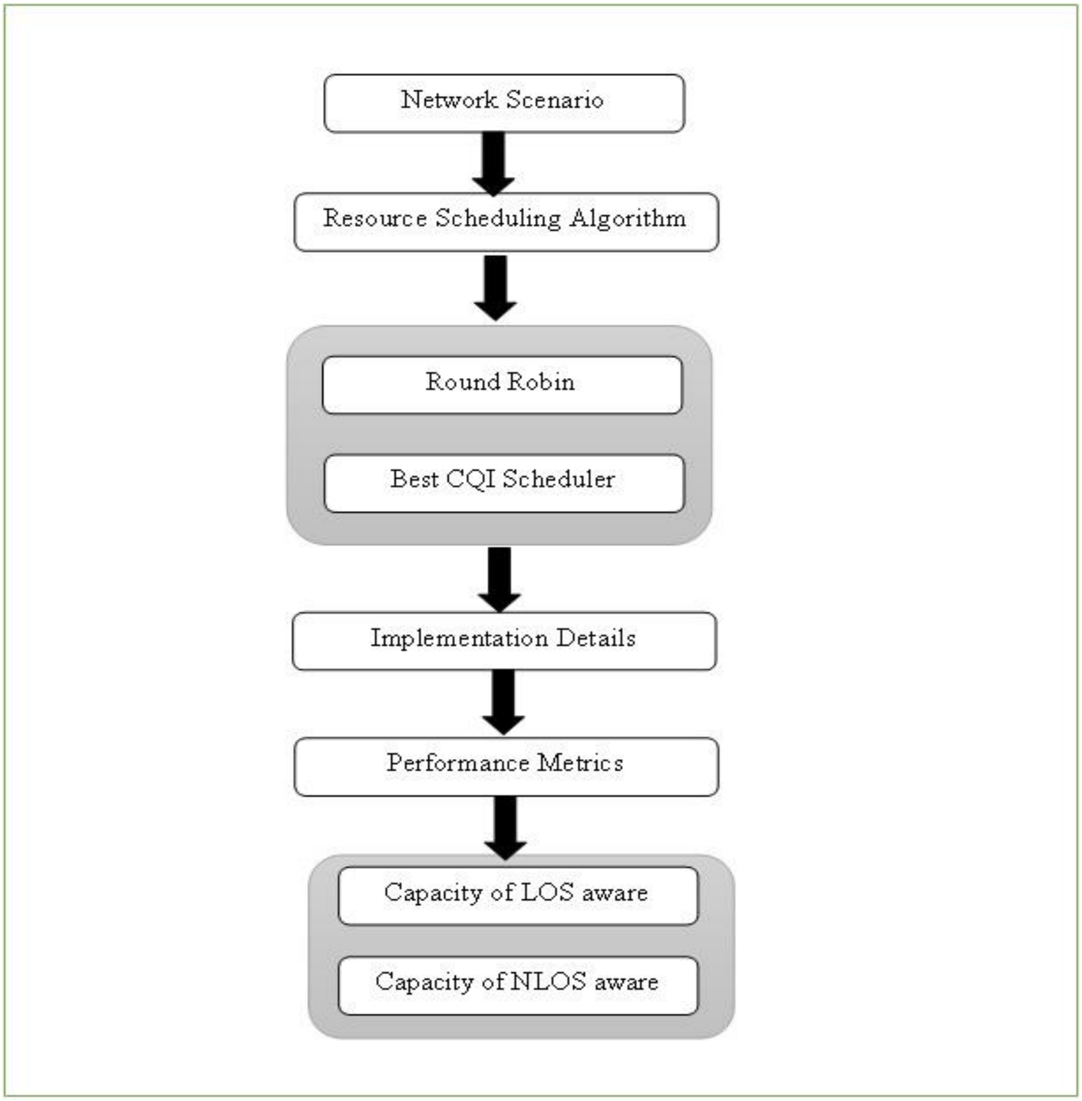


Figure 2. The performance Evaluation model

## 3.2 Network Scenario

The mm wave technology is the future technology since it has the ability to meet the current growing traffic demand. Due to exponential growth in mobile applications there is a need for high bandwidth which could not be met by the current technologies and it has become necessary to move towards higher band frequencies in quest for high bandwidth. Radio propagation waves are affected largely by physical objects and the extent of distortion caused to the overall signal greatly depends on the frequency and surroundings. The millimeter-wave communication takes place at far higher frequency than that of classical bands.

The free space path loss depends on the square of the distance and carrier frequency. It increases with the increase in distance and frequency. Hence a signal at a frequency of 60 GHz has an attenuation of almost 36 dB higher than that of signal at a frequency of 1 GHz. Millimeter wave communication are mainly focused on Line of Sight (LOS) scenarios but the presence of reflections with significant power motivates the investigation of mm-wave under Non Line Of Sight (NLOS) conditions. Mm-wave small-cells are used to improve the indoor coverage of traditional cellular technology. The focus of the mm-wave small-cells is on coverage; therefore small-cell planning and beam forming optimization must be carried out in order to provide coverage to places where devices are expected to stay, using LOS and NLOS transmissions. Low interference among small-cells is expected, cooperative transmissions or advanced antenna systems could be used to cover the area reducing the number of deployed small-cells. The separated control plane facilitates user mobility within the room, small-cells can be placed in fixed points with presence of users, while traditional cellular technology can be used as fallback during mobility. The scenario has limited mobility, no stringent timing or very smart algorithm should be provided.

This scenario consists in an area of multiple open spaces and rooms covered with traditional cellular technologies (LTE, LTE-A) small cells or WiFi, and a large number of mm-wave nano-cells providing full coverage of the space (Figure 3). The typical situations described by this scenario are malls, shopping centers, sport facilities, airports, stations, undergrounds, etc. Mm-wave small-cells are used to increase the capacity and limit interference strategies. Cooperative small cell transmissions and coordination with traditional cellular base station could help in covering difficult areas. Small-cell placement optimization is required to provide high-capacity to the whole area, cooperative beam forming and interference coordination optimization must be used as well. Small-cells are characterized by very high rates and high interference, we have typically LOS transmissions. The separated control plane facilitates user mobility within the whole area.

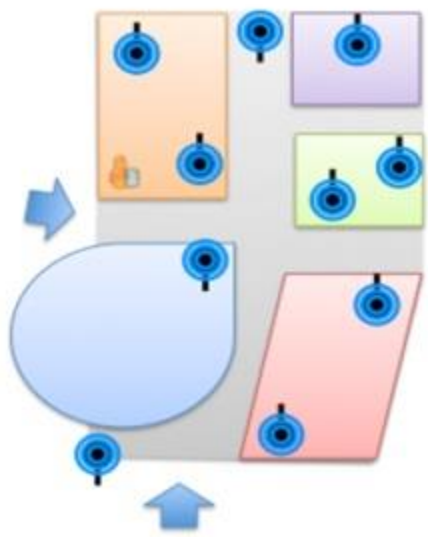

Figure 3. Public Indoor Scenario [21].

This scenario consists in a mobile network of traditional LTE/LTE-A base stations which are in charge of providing full coverage through macro/micro cells. Additionally, a number of mmwaves isolated hot-spots are placed within the urban area such as parking lots or far away from the center in emergency refuge on a motorway. Those mm-waves hot-spots cover just tens of meters with a very high transmission rate.

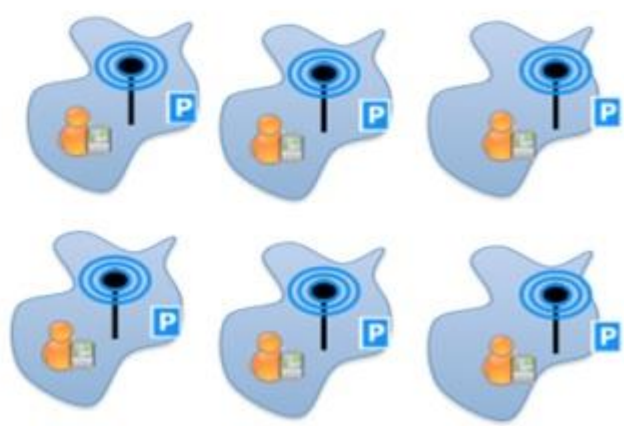

Figure 4. High Rate Hot Spot Scenario [21].

mm-wave small-cells can be used to provide coverage in locations where the coverage of the traditional cellular network is not available by providing a point of presence or they can be used to provide very high capacity in localized spaces within the coverage of the traditional cellular network. Since very short distance is required as well as no obstacles are permitted between the hot-spot and mobile users, a smart positioning of the mm-waves hot-spots in optimal places which can be easily reached by the majority of users passing over there. No mobility issues in the mmwave hot-spot are expected to occur. The separated control plane and the rich context-information can guide mobile user to find these hot-spots and reducing channel acquisition time.

## 3.3 Resource Scheduling Algorithms

Scheduling is performed during one Transmission Time Interval (TTI) which consists of two time slots. Within each TTI two resource blocks (RBs) are assigned to user. In every TTI each user measures it received signal strength from the serving base station and then computes signal to noise interference ratio. The primary objective of the resource scheduling algorithms is to maximize throughput and to provide fairness.

### 3.3.1 Round Robin Algorithm

Round Robin (RR) is one of the fundamental and widely used scheduling algorithms. Its running process is very simple and easy to implement. The RR algorithm [21] assigns equal portions of packet transmission time to each user in a circular order. RR algorithm achieves the best fairness performance if the users have similar channel conditions and similar sized packet arriving at their buffers. It is on a first come first served basis. Although RR gives every UE an equal opportunity to obtain RBs, the overall throughput is much lower than in other schedules because this scheduler does not consider the channel conditions. In LTE, different UEs have different services with different QoS requirements and it is very difficult to allow every SN to take up the same RBs for the same possibility because it will decrease the resource efficiency [22]

### 3.3.2 Best CQI Scheduling Algorithm

Best Channel Quality Indicator algorithm checks how good/bad the channel quality is based on the received signal strength. There are 15 different CQI values ranging from 1 to 15 and depending on the reports of User Equipment (UE) it transmits the data with larger transport block size and vice-versa. The SNR-CQI Mapping Model is shown in Figure 3.2.

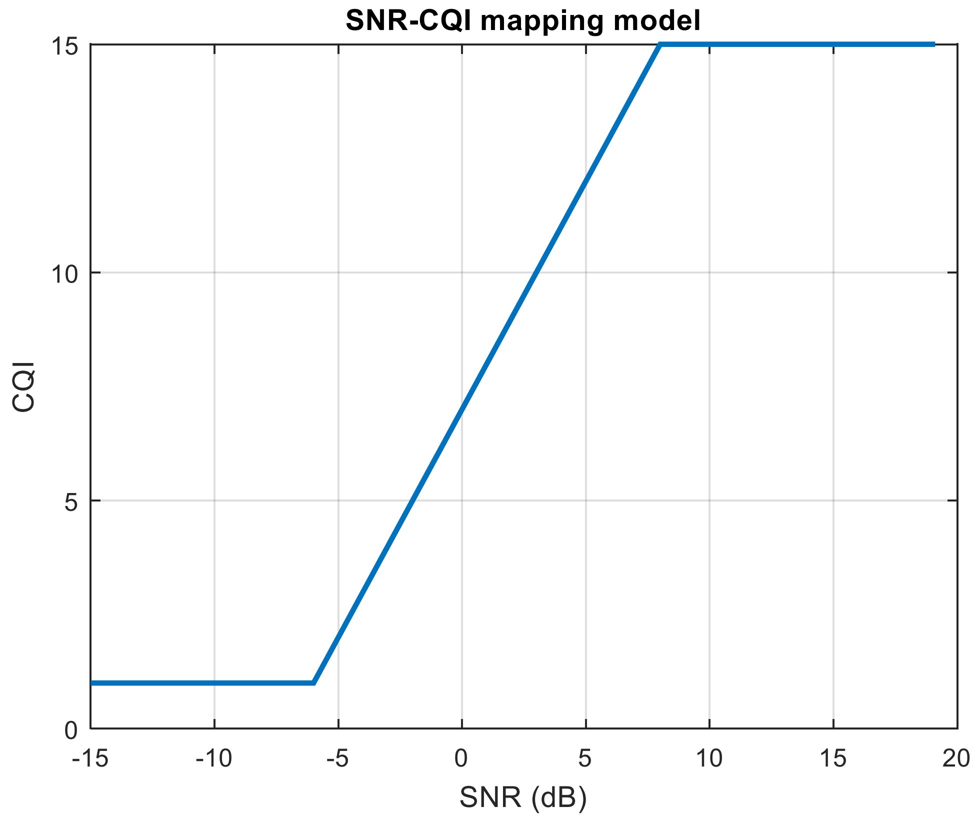


Figure 5. SNR vs CQI mapping model

Best CQI scheduling method optimizes the SN throughput by assigning the RBs to the SN with the best radio link conditions, meaning that the SNs with low CQI value have the lower chance to be served [23]. This CQI information contains the value of the signal-to-noise and interference ratio (SINR) measured by the SN. A higher value of CQI indicates a better channel condition. The best CQI is selected for scheduling based on the CQI received. BCQI scheduling scheme can increase cell throughput at the expense of worst fairness. In this scheduling mechanism, SNs located far from the base station are unlikely to be scheduled.

## 3.4 Implementation Details

The users are generated using Poisson distribution during the simulation period. Each user is allowed to enter and exit the system. Poisson distribution is the model for an event occurring within a given time interval. The Probability of the Poisson distribution is given by

$$p(x,\lambda) = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad \text{For } x = 0, 1, 2\ldots\ldots$$

where, $\lambda$ is the average number of events in a given interval of time. The figure below shows the Poisson distribution probability for average of events 10.

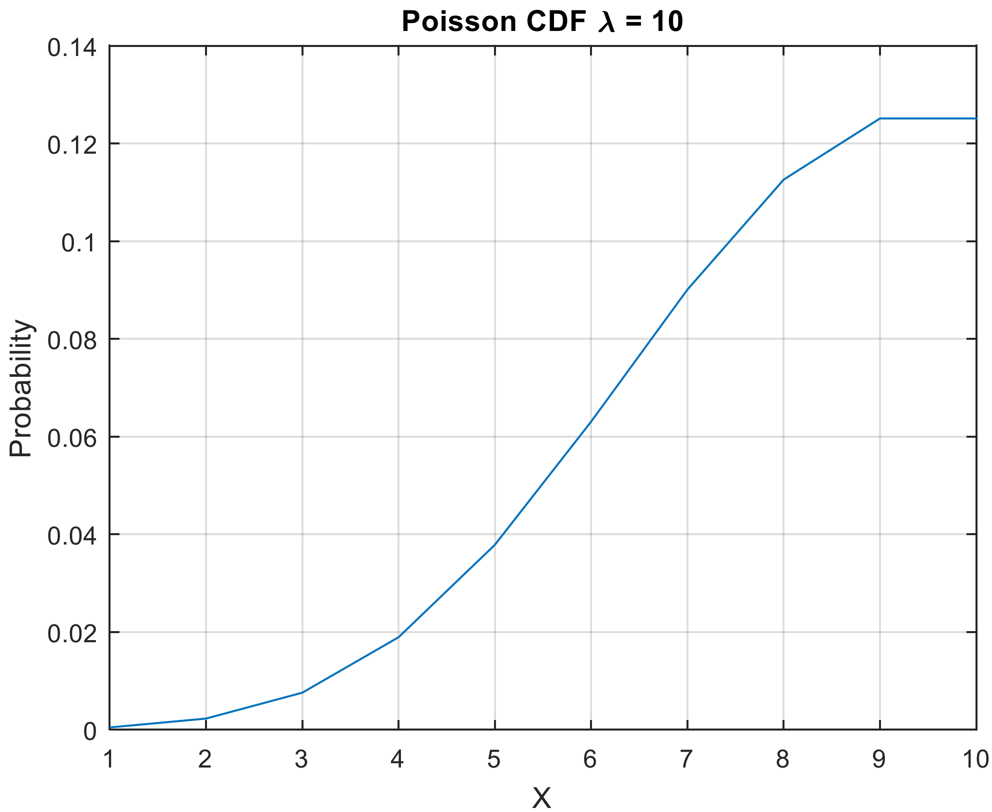


Figure 6. Poisson probability

**Algorithm I (Main Algorithm)**

1. Set variables L (length), Breadth (B), Bandwidth (BW), resource block (RB).
2. Set arrival rate/Lambda = [1 : 10], arrival time
3. Input Simulation time
4. **FOR** I = 1 to length(Lambda)
    a. Set node_entering_time = 0.
    b. LOSCapacity = 0, Capacity of LOS.
    c. NLOSCapacity = 0 Capacity for NLOS.
    d. Start Timer.
    e. **WHILE** (timer < Simulation Time)
        i. **IF** timer > node_entering_time
            1. Generate an arrival time of user using a Poisson distribution
            2. Generate users using Poisson distribution
            3. Calculate Total Users
            4. Find start and destination location for each node

5. Update location of each node within an area
6. Find interfering users
7. Find path loss for both LOS and NLOS users
8. Call the BCQI Algorithm
9. Transmit the signal using OFDM Modulation
10. Find the total Capacity for both LOS aware and NLOS aware users.

**ii. END**

**f. END**

5. **END**

**Algorithm II (Best CQI Scheduling Algorithm)**

6. Set Bandwidth for LOS
7. Set Bandwidth for NLOS
8. Compute the SINR for all the users
9. Arrange the SINR in descending order for all users
10. Assign resource block for all the users.
11. Compute the Capacity for LOS aware users
12. Computer Capacity for NLOS aware users.

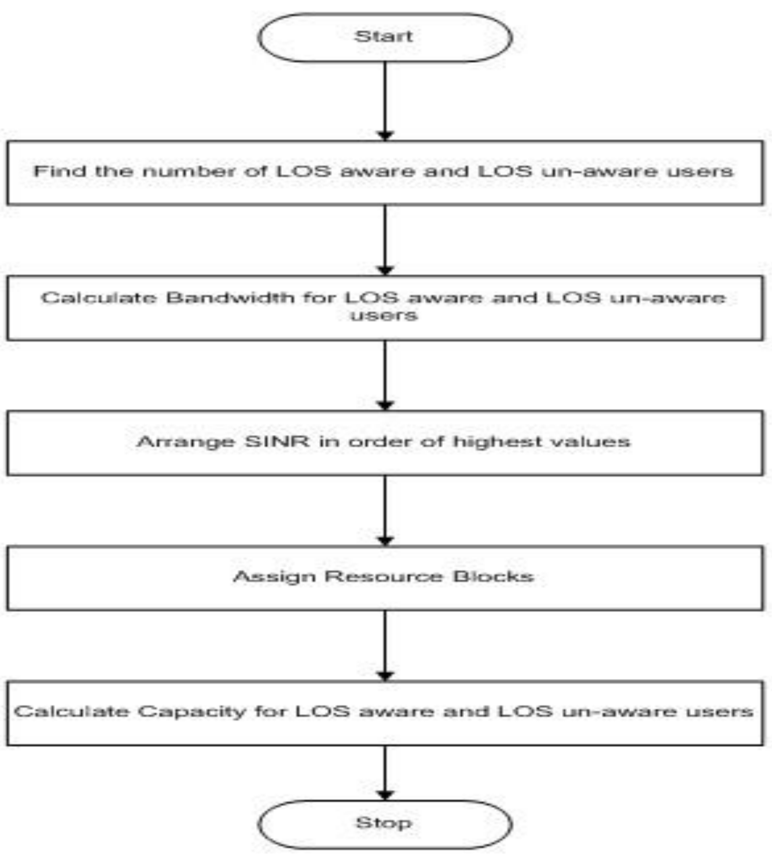


Figure 7. Flowchart for BCQI Algorithm

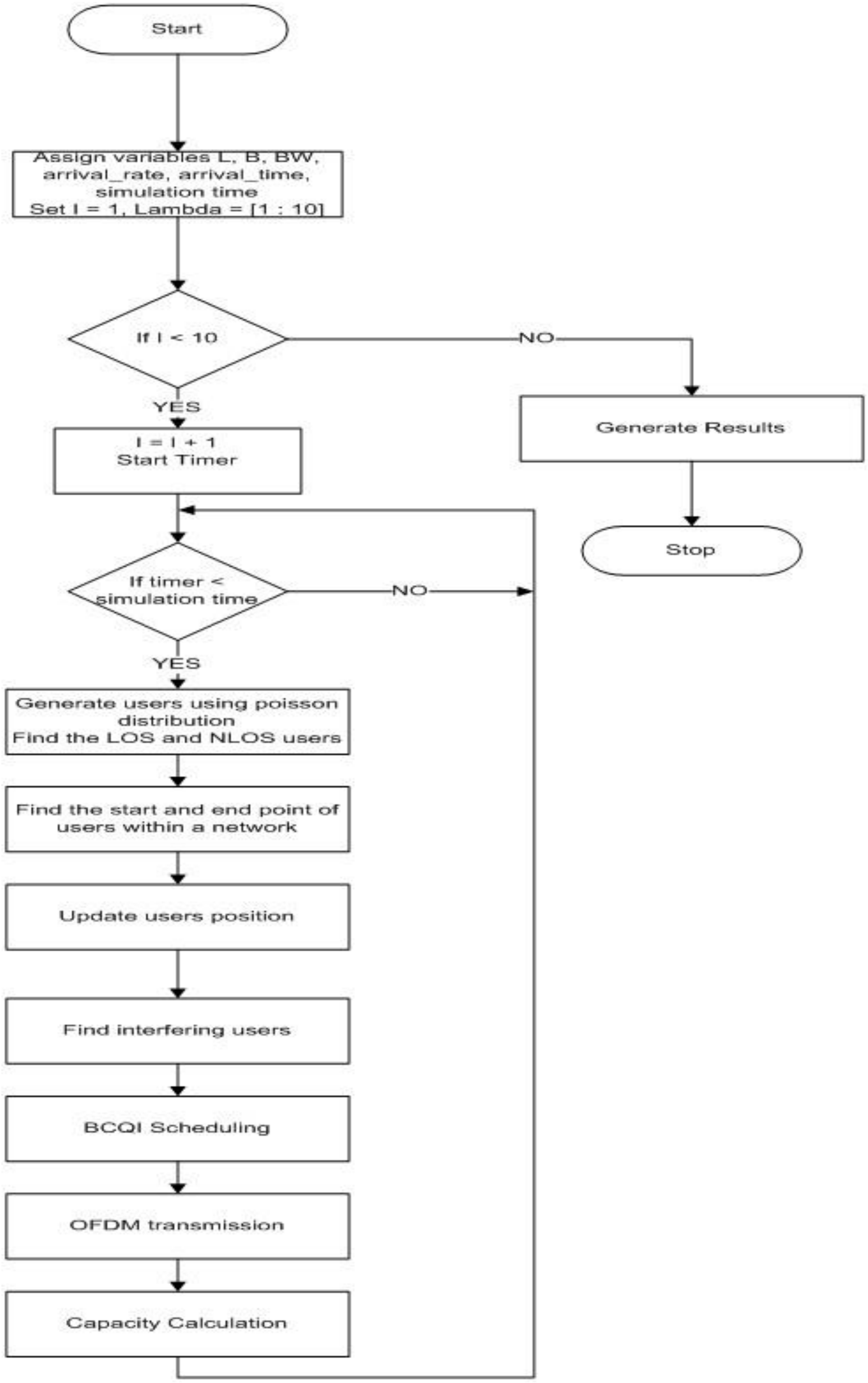


Figure 8. Flowchart for main algorithm

## 3.5 Performance Metrics

The performance evaluation of the millimeter wave technology has been done based on capacity of the LOS aware users and Capacity of NLOS users. The channel capacity is dependent on the Signal to Interference noise ratio of the system and the performance is highly degraded in case of NLOS scenario. The path loss of each user was estimated as

$$PL = P_T - G_T - G_R - L_p - L_M \qquad 3.1$$

Where PL is the path loss, $P_T$ is the transmit power of the base station, $G_T$ is the transmit antenna gain, $G_R$ is the antenna gain of receiver, $L_P$ is the free space path loss and $L_M$ represents the miscellaneous path loss.

The free space path loss is given by

$$L_p = 16\pi^2 (R/\lambda)^n \qquad 3.3$$

Where R is the range, $\lambda$ is the wavelength of the carrier signal and n is the Path Loss exponent. For LOS conditions the path loss exponent can be taken as n = 2.5 and n = 1.7 for urban area cases. When the number of user increases the direct link for the users are blocked and the hence the path loss exponent also increases to 3.5 – 6. Hence because of the large path loss exponent the path loss increases and has to be compensated by 1) increasing the transmit power levels 2) high antenna gain and 3) low noise and receiver sensitivity. The transmit power cannot be increased beyond certain level since large transmit power increases the interference level. To achieve high capacity high antenna gain can be employed, hence massive MIMO systems are the perfect choice for mm wave communications.

Path loss exponent n is greater for non LOS environments and hence reliable communication is only possible for shorter ranges at low end of mm wave spectrum. While sufficient gain appears to be available for a wide range of mm wave frequencies in small cell applications, the number of users that can be serviced in this environment remains to be determined. In addition, the fact that mm wave signals do not penetrate brick and concrete means that mm wave cells may have to be located strictly indoors or strictly outdoors, a factor that could limit their application.

The path loss for Non- Line of Sight is given by the equation

$$PL(d)(dB) = \alpha + \beta 10 \log(d) + \xi, \xi \sim \mathrm{N}(0, \sigma^2) \qquad 3.4$$

Where d is the distance in meters, $\alpha$ and $\beta$ [4] are the least square fits of floating intercept and slope over measured distance and $\sigma^2$ is the lognormal shadowing variance.

The signal to interference noise ratio is now calculated by

$$SINR[dB] = P_R[dB] - N_T[dB] \quad 3.5$$

Where $P_R$ is the received signal strength by the user from the base station and $N_T$ is the interference from interfering base stations. Hence the capacity of each user is now evaluated using the equation

$$C = BW \log_2(1 + SINR) \quad 3.6$$

### 3.5.1 Capacity for LOS Aware

The capacity of LOS Aware users is calculated by taking those users which are at Line of Sight with the base station. For LOS users we have considered free space path loss model. The received signal strength of each user is calculated for an entire simulation period and then average to get the total capacity.

### 3.5.2 Capacity for LOS un-aware

For calculating the capacity of LOS un-aware users we consider both LOS and NLOS users. When the users cross each other the SINR gets dropped significantly which cause in the decrease of capacity for LOS un-aware users. The path loss calculation for NLOS users is given in equation 3.2

# 4. SIMULATION RESULTS AND ANALYSIS

## 4.1 Introduction

This chapter discuss about the results and the implementation of the millimeter wave in MATLAB 2015a. The users are placed within a geographic area using Poisson distribution. The variable for mm wave was assigned according to defined by ITU standard and the base station with a frequency of 28 GHz [21] is placed at the center assumed to have an Omni-directional antenna. The coverage radius of the antenna was fixed and a circle was drawn. The nodes enter and exit the circle regularly in the process of the simulation and the capacity was calculated for both LOS and NLOS users [23]. The parameters taken for simulation are mentioned below.

| **Simulation Parameters** | **Values** |
|---|---|
| Area | [2 km x 2 km] |
| Radius | 1 km |
| Base Station Power | 20 dBm |
| Frequency | 28 GHz |
| Bandwidth | 1 GHz |
| Resource Block | 50 |
| Distribution | Poisson |
| Arrival Rate | [1 : 10] |
| Arrival time | 15 secs |
| Modulation | OFDM |
| No. of Receive Antenna | 2 |
| No. of Transmit Antenna | 2 |
| Fading Channel | Rayleigh |
| Scheduling Algorithm | BCQI |
| Simulation Time | User Defined |
| Performance Metrics | Capacity |
| Speed | 4 km/hr |

Table 3. Simulation Parameters

## 4.2 User Placement

To evaluate the capacity for mm wave technology, we have considered two types of users. Users which are directly at the LOS with base station and users that are not directly at LOS with base station. The placement of users in considered following a Poisson distribution. The arrival rate of users is varied from 1 to 10 with time and is allowed to move within a coverage area. The base station is considered to be placed at the center and the users move randomly within the area. The users enter into the system from any point within a circle and then move towards the random destination. With time the number of users also increases. The position of the users are updated using the formula given below

$$X_{new} = X_{old} + d\cos\theta \qquad 4.1$$

$$Y_{new} = Y_{old} + d\sin\theta \qquad 4.2$$

$$d = vt \qquad 4.3$$

From distance formula, distance = velocity x time.

| | |
|---|---|
| $X_{new} = X_{old} + vt\cos\theta$ | 4.4 |
| $Y_{new} = Y_{old} + vt\sin\theta$ | 4.5 |

($X_{new}$, $Y_{new}$) denotes the updated x-coordinate and y-coordinate of the users, ($X_{old}$, $Y_{old}$) represents the old position of a user. V is the speed of a user in km/hr and $\theta$ is the angle between the source and destination.

In our simulation the arrival time modeled as Poisson distribution which means the time at which the users arrive. So each time a user's arrive in a network the number of users increases. For a NLOS user the angle difference between the users should be less than 0.5 degree. The capacity of NLOS of users falls drastically due to less received signal strength (RSS) [23] value.

## 4.3 Implementation

Figure 8 shows the implementation model of mm wave technology in which an area of 2km x 2km is considered and the Delta sign [23] at the center represents the base station. The square symbol with red color denotes the users. We have assumed a user enter into the system area from a point and leaving the area from other point within a coverage radius. The user is moving at a speed of 4km/h. The received signal strength at any point of time is calculated based on the user distance from the base station. The communication can best happen for Line of Sight [21]. Whenever the moving user will cross another user, it will drop the signal significantly.

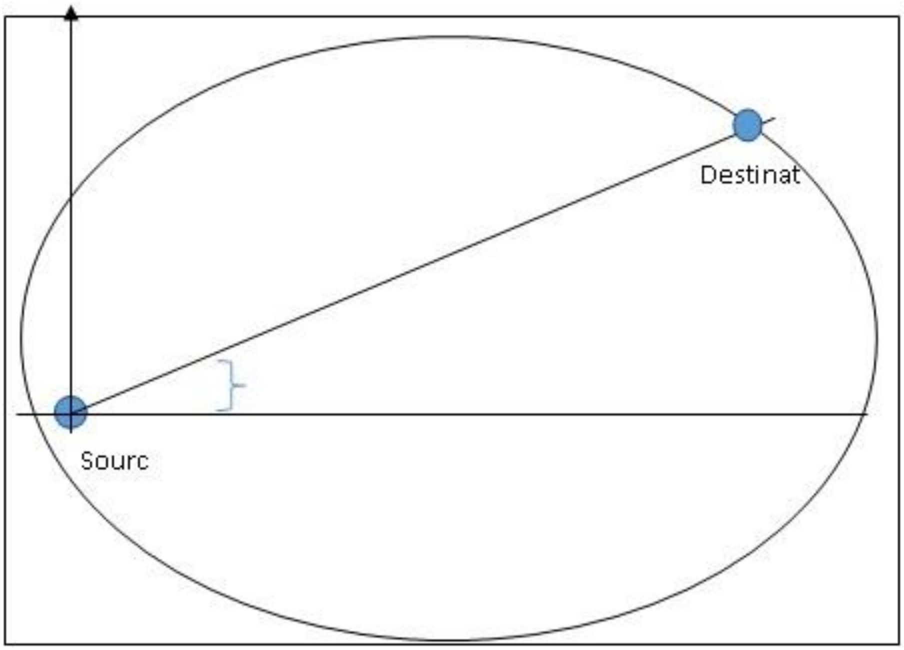


Figure 9. Angle Calculation.

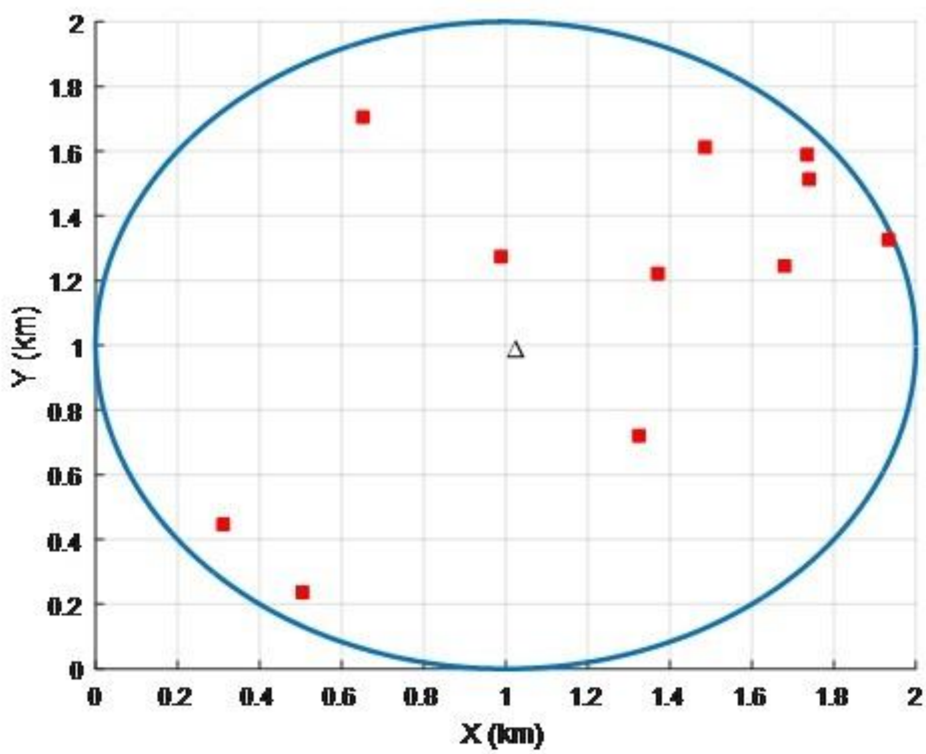


Figure 10. System Model

## 4.4 Results Analysis

The performance metrics used to measure the performance of mm wave is Capacity. Once we determine the path loss for Tx-Rx pair, we can compute the average Signal to Interference Noise Ratio (SINR) at each receiver. The SINR is used to determine the bandwidth allocated to each user and the data rate per unit time. The capacity of the cellular system is determined by the SNR. The bandwidth allocated for each user is calculated at run time. We dynamically calculate the number of LOS and NLOS users at each arrival time and hence the bandwidth allocated for LOS aware users is given by

$$BW_{LOS-aware} = \frac{BW_{total}}{N_{LOS}} \tag{4.6}$$

Similarly the bandwidth allocated for LOS unaware users is given by

$$BW_{LOS-unaware} = \frac{BW_{total}}{N_{NLOS} + N_{LOS}} \tag{4.7}$$

Where $BW_{LOS\text{-}aware}$ denotes the Bandwidth occupied by each LOS aware users, $BW_{LOS\text{-}unaware}$ represents the bandwidth occupied by each LOS unaware users and $BW_{total}$ represents the total bandwidth of the system. $N_{LOS}$ is the number of LOS users and $N_{NLOS}$ is the number of NLOS users.

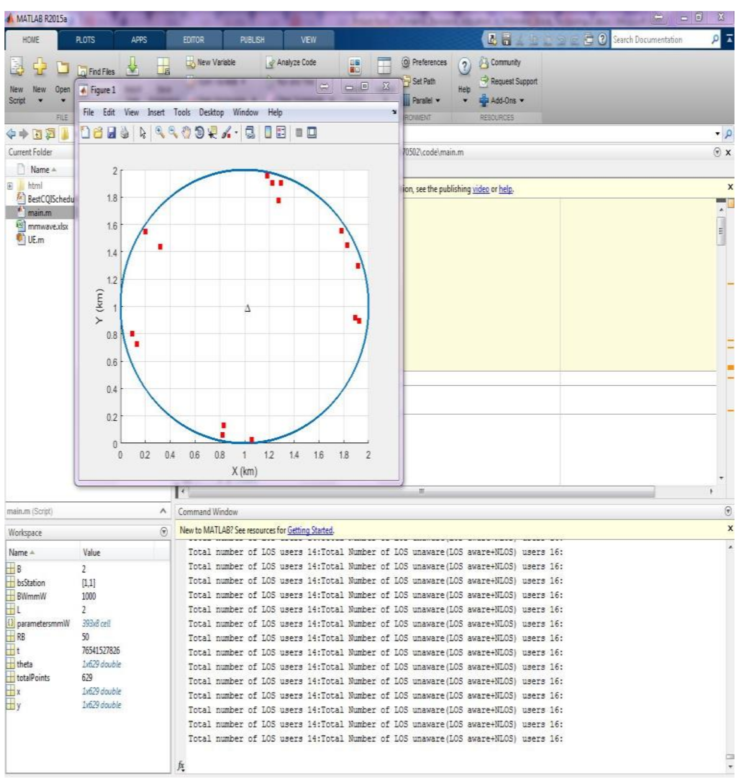


Figure 11. Simulation

| **Arrival Rate** | **LOS aware Capacity (Mbps)** | **LOS unware (Mbps)** |
|---|---|---|
| 1 | 219.0209 | 82.88969 |
| 2 | 293.1799 | 92.70717 |
| 3 | 317.6747 | 100.3822 |
| 4 | 482.3815 | 173.5869 |
| 5 | 524.3749 | 175.0367 |
| 6 | 614.4676 | 203.4858 |
| 7 | 796.1991 | 246.9575 |
| 8 | 930.7871 | 289.9573 |
| 9 | 1000 | 500 |
| 10 | 1000 | 500 |

Table 4.  User Capacity for LOS aware and LOS unaware

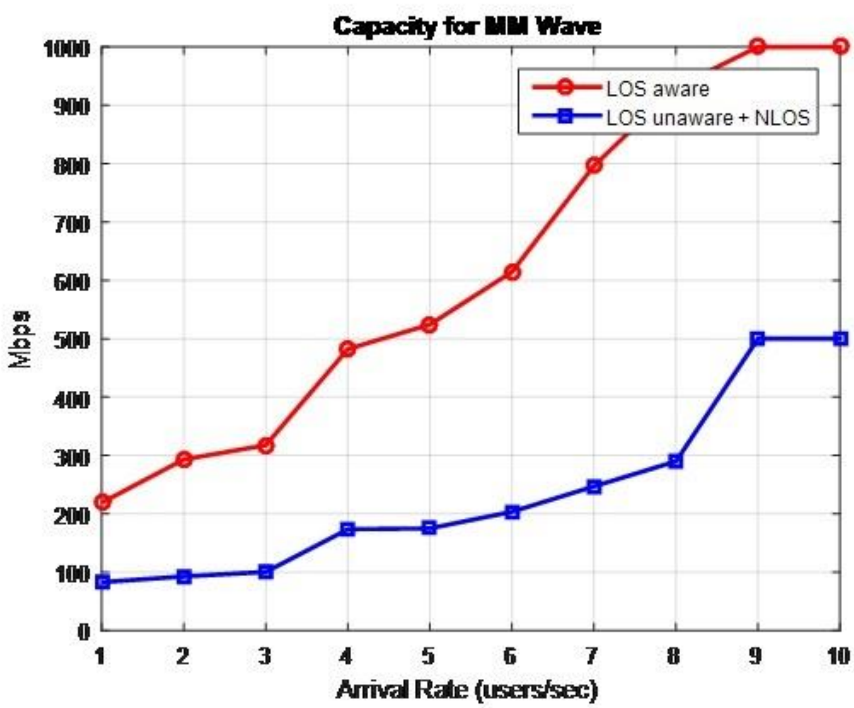


Figure 12.  Capacity of LOS aware and LOS unaware

Figure 12 shows that the capacity of the LOS aware is higher than that of LOS unaware. Since the capacity of LOS unaware decreases [22] drastically due to path loss effects.

## 4.5 Capacity Calculation

As the node moves closer to the base station the received signal strength of the user increases exponentially and it decreases when it moves away from the base station. The signal to interference noise ratio is required to calculate the capacity of user. From equation 4.6 and 4.7 we get the bandwidth allocated for each user. To calculate the capacity of LOS aware users, we consider all the LOS users, at the beginning of the simulation there are high number of LOS users and as the simulation time increases the number of LOS users decreases. Taking all the LOS users we add all the capacity of users and find the average capacity. From the table it shows that the value of capacity for LOS users is higher than that of LOS unaware users. For LOS unaware the number of user’s increases which decrease the allocated bandwidth for each user and also the crossing of user significantly degrade the performance which reduces the capacity for LOS unaware users.

## 4.6 Code

```
%% main file

clc;
clearvars;
global parametersmmW t BWmmW
%% System Parameter Declaration
L = 2;                                           %length in km
B = 2;                                           %breadth in km
RB = 50;                                         %total number of resource block for 5G.
BWmmW = 1e3;                                     %BW for 5G in 1 Ghz. 1000 MHz
    bsStation = [L/2 B/2];                       %base station position
    %%
    theta = 0 : 0.01 : 2 * pi;
    x = L/2 + L/2 * cos(theta);
    y = L/2 + L/2 * sin(theta);
    totalPoints = length(x);
    simulationTime = input('Enter Simulation Time in Hours:');
```

```
simulationTime = simulationTime * 3600;
fmm = 28; %frequency in GHz
arrival_rate = 15; %arrival mean time in minutes.
Lambda = [1 : 10]; %intensity or arrivate rate of users in a network
NLOS_CAPACITY = zeros(1, length(Lambda)); %Capacity for NLOS.
LOS_CAPACITY = zeros(1, length(Lambda)); %Capacity variable for LOS.
for len = 1 : length(Lambda)
close all; %close all the figures
%% variable declaration
xUpdate = []; %initialize xcoordinate
yUpdate = []; %initialize ycoordinate
a = 0;
totalUsers = 0;
simTime = 0;
node_entering_time = 0; %nitialize a variable
LOSCapacity = 0;
NLOSCapacity = 0;
t = tic;
cnt = 0;
%% plot figure
figure;
hold on;
plot(x, y, 'LineWidth', 2);
text(bsStation(1), bsStation(2), '\Delta', 'FontSize', 10)
grid on
xlabel('X (km)');
ylabel('Y (km)');
%%
parametersmmW = {'Time(secs)', 'User ID', 'Speed(m/sec)', 'X(km)', 'Y(km)', 'SINR(dB)', 'type', 'Throughput(Kbps)'};
if exist('node' ,'var')
    clearvars node
end

while (simTime < simulationTime)
    %% using poisson distribution to enter the users inside the system.
    total = [];
    if toc(t) > node_entering_time
        node_entering_time = node_entering_time + poissrnd(arrival_rate); %time for nodes to enter.
        % taking into account poisson distribution.
```

```
        3.      nousers = poissrnd(Lambda(len));
         %number of users entering into the system.
        4.      total = [a + 1 : a + nousers];
         %id of each user
        5.      totalUsers = totalUsers + nousers;
         %total User
        6.      for i = 1 : nousers
        7.      val = randi([1 totalPoints], 1);
         %getting start location
        8.      destinationvalue = randi([1 totalPoints], 1);
         %getting desintaion location
        9.      node(total(i)) = UE(total(i), x(val), y(val),
         x(destinationvalue), y(destinationvalue));
        10.     end
        11.     a = totalUsers;
        12.     fprintf('Remaining Time = %f secs of %f
         secs\n', toc(t), simulationTime);%
d. end
e. % total bandwidth divided by the number of users.
f. BWuser = BWmmW/totalUsers;
   %Bandwidth for each user.
g. if exist('node', 'var')
        1.      for k = 1 : size(node, 2)
        2.      if strcmp(node(k).State, 'Enter')
            1. %% mobility of each user.
            2. mobilityModel(node(k));
            3. xUpdate(k) = node(k).xposition;
            4. yUpdate(k) = node(k).yposition;
            5. h(k) = plot(xUpdate(k), yUpdate(k), 'sr',
               'MarkerSize', 6, 'MarkerFaceColor', 'r');
            6. %% finding the interfering users. The users
               which are in the LOS of the BS.
            7. interfering_users = [];
               %initializing interfering users.
            8. for nN = 1 : size(node, 2)
                  a. if k ~= nN
                  b. if abs(node(nN).degree - node(k).degree)
                     < 0.3
                       i. interfering_users =
                          [interfering_users nN];
                          %finding interfering users.
                  c. end
                  d. end
            9. end
            10.     % check if interfering users exists or
               not.
            11.     if ~isempty(interfering_users)
                  a. %path loss for Non Line of Sight
                  b. pathLoss_NLineOfSight(node(k));
                  c. sinr = SINRCALC(node(k));
                  d. node(k).path = 'NLOS';
            12.     else
```

```
%calculate path loss for line of sight
users.
pathLoss_LineOfSight(node(k));
sinr = SINRCALC(node(k));
node(k).path = 'LOS';
end

end
end
%calculating Capacity for LOS and NLOS.
cnt = cnt + 1;
[LOSCapacity(cnt), NLOSCapacity(cnt)] =
BestCQIScheduling(node, RB, BWuser);
end
pause(0.1)
if exist('h', 'var')
delete(h)
end
simTime = toc(t);
end
% LOS aware capacity.
LOS_CAPACITY(len) = mean(LOSCapacity);
if isnan(LOS_CAPACITY(len))
LOS_CAPACITY(len) = BWmmW;
end
%NLOS aware capacity.
NLOS_CAPACITY(len) = mean(NLOSCapacity);
if isnan(NLOS_CAPACITY(len)) || isinf(LOS_CAPACITY(len))
NLOS_CAPACITY(len) = BWmmW;
end
end

xlswrite('mmwave.xlsx', parametersmmW);
LOS_CAPACITY = sort(LOS_CAPACITY);
NLOS_CAPACITY = sort(NLOS_CAPACITY);
figure;
plot(Lambda, LOS_CAPACITY, '-or', 'LineWidth', 2)
hold on;
plot(Lambda, NLOS_CAPACITY, '-sb', 'LineWidth', 2)
xlabel('Arrival Rate (users/sec)');
ylabel('Mbps');
title('Capacity for MM Wave');
legend('LOS aware', 'LOS unaware + NLOS')
grid on;
```

**71. User Equipment Class**

```
classdef UE < handle

properties
xposition
```

```
    b. yposition
    c. xdestination
    d. ydestination
    e. State
    f. ID
    g. Throughput
    h. degree
    i. PL
    j. SINR
    k. BS
    l. path
74.    end
75.    properties (Constant)
    a. speed = 4000/3600;
    b. L = 2;
    c. B = 2;
    d. NF = -140;                       % Noise Power dBm
    e. f = 28e9;                        %frequency in GHz.
    f. TxP = 20;                        %transmit power in dBm
76.    end

77.    methods
    a. function OBJ = UE(id, x, y, x1, y1)
        1.    OBJ.xposition = x;
        2.    OBJ.yposition = y;
        3.    OBJ.xdestination = x1;
        4.    OBJ.ydestination = y1;
        5.    OBJ.ID = id;
        6.    OBJ.State = 'Enter';
        7.    OBJ.BS = [OBJ.L/2 OBJ.B/2];
    b. end

    c. function mobilityModel(OBJ)
78.    %              if strcmp(OBJ.State, 'Enter')
        1.    angle = atan(abs((OBJ.ydestination -
         OBJ.yposition)/(OBJ.xdestination - OBJ.xposition)));
        2.    OBJ.degree = rad2deg(angle);
        3.    if OBJ.xposition > OBJ.xdestination
            1. a1 = -1 * cosd(OBJ.degree);
        4.    else
            1. a1 = 1 * cosd(OBJ.degree);
        5.    end

        6.    if OBJ.yposition > OBJ.ydestination
            1. a2 = -1 * sind(OBJ.degree);
        7.    else
            1. a2 = 1 * sind(OBJ.degree);
        8.    end
        9.    OBJ.xposition = OBJ.xposition + OBJ.speed * a1
         * 0.001;
```

```
            OBJ.yposition = OBJ.yposition + OBJ.speed * a2 * 0.001;

            di = sqrt((OBJ.BS(2) - OBJ.yposition)^2 + (OBJ.BS(1) - OBJ.xposition)^2);
            if di > OBJ.L/2
                OBJ.State = 'Exit';
            end
        end
%       end

function pathLoss_LineOfSight(OBJ)
    alpha = 61.4;
    beta = 2;
    sigma = 5.8;
    d = sqrt((OBJ.xposition - OBJ.BS(1))^2 + (OBJ.yposition - OBJ.BS(2))^2);
    OBJ.PL =  alpha + 10 * beta * log10(d * 1000) + normrnd(0, sigma);%20 * log10(d) + 20 * log10(f) + 92.45;
end

function pathLoss_NLineOfSight(OBJ)
    d = sqrt((OBJ.xposition - OBJ.BS(1))^2 + (OBJ.yposition - OBJ.BS(2))^2);
    alpha = 72;
    beta = 2.92;
    sigma = 8.7;
    OBJ.PL =  alpha + 10 * beta * log10(d * 1000) + normrnd(0, sigma);
end

function x = SINRCALC(OBJ)
    rxPower = (OBJ.TxP - 30) - OBJ.PL;
    OBJ.SINR = rxPower - OBJ.NF;
    x = OBJ.SINR;
end

function modulationScheme(OBJ)
    mod = comm.OFDMModulator('NumGuardBandCarriers',[4;3],...
    'PilotInputPort',true, ...
    'PilotCarrierIndices',[12 11; 26 27; 40 39; 54 55], ...
    'NumSymbols',2, ...
    'InsertDCNull',true);
    modDim = info(mod);
    dataIn = complex(randn(modDim.DataInputSize),randn(modDim.DataInputSize));
```

```
                8.     pilotIn =
                complex(rand(modDim.PilotInputSize),rand(modDim.Pilo
                tInputSize));
                9.     modData = step(mod,dataIn,pilotIn);
                10.    demod = comm.OFDMDemodulator(mod);
                11.    [dataOut, pilotOut] = step(demod,modData);
                12.    [num, ~] = BER(dataIn, dataOut);
                13.    OBJ.Throughput = num;
        h. end

80.     end
81.     end
```

**82. Best CQI Scheduling Algorithm**

```
83.     function [losCap, nlosCap] = BestCQIScheduling(ue, nT, BW)
84.     %% only the nodes with best SNR are provided channel
85.     global parametersmmW t BWmmW
86.     [~, nr] = size(ue);
87.     id = [];
88.     sinr = [];
89.     cnt1 = 1;
90.     cnt2 = 1;
91.     for i = 1 : nr
92.     if strcmp(ue(i).State, 'Enter')
        a. sinr = [sinr ue(i).SINR];
        b. id = [id i];
        c. if strcmp(ue(i).path, 'LOS')
                1.     %counting number of LOS users.
                2.     cnt1 = cnt1 + 1;
        d. else
                1.     %counting number of NLOS users.
                2.     cnt2 = cnt2 + 1;
        e. end
93.     end
94.     end
95.     [~, index] = sort(sinr, 'descend');
96.     index = id(index);
97.     BWLOS = BW/cnt2;
   %Bandwidth for LOS aware users.
98.     fprintf('Total number of LOS users %d\n', cnt1)
99.     fprintf('Total Number of LOS unaware users %d\n', (cnt1 +
   cnt2));
100.    BWNLOS = BW/(cnt1 + cnt2);
   %Bandwidth for LOS unaware users. adding both LOS + NLOS
101.    losCap = 0;
102.    nlosCap = 0;
103.    cap1 = 0;
104.    for l = 1 : nT
105.    if l <= length(index)
        a. i = index(l);
```

```
        b. if strcmp(ue(i).State, 'Enter')
                1.      if strcmp(ue(i).path, 'LOS')
                2.      % Capacity Calculation for LOS aware users.
                3.      cap = real(BWLOS * log2(1 + ue(i).SINR));
                 %LOS aware.
                4.      cap1 = real(BWNLOS * log2(1 + ue(i).SINR));
                 %LOS unaware.
                5.      if ~isinf(cap) || ~isnan(cap)
                    1. losCap = losCap + cap;
                    2. if losCap > BWmmW
                        a. losCap = BWmmW;
                    3. end
                6.      end

                7.      if ~isinf(cap1) || ~isnan(cap1)
                    1. nlosCap = nlosCap + cap1;
                    2. if nlosCap > BWmmW
                        a. nlosCap = BWmmW;
                    3. end
                8.      end
                9.      parametersmmW = [parametersmmW; {toc(t) i
                 ue(i).speed ue(i).xposition ...
                10.     ue(i).yposition ue(i).SINR 'LOS' losCap}];
                11.     else
                12.     % Capacity Calculation for NLOS unaware users.
                13.     cap = real(BWNLOS * log2(1 + ue(i).SINR));
                14.     if ~isinf(cap) || ~isnan(cap)
                    1. nlosCap = nlosCap + cap;
                       %adding both LOS aware and unaware.
                    2. if nlosCap > BWmmW
                        a. nlosCap = BWmmW;
                    3. end
                15.     end

                16.     parametersmmW = [parametersmmW; {toc(t) i
                 ue(i).speed ue(i).xposition ...
                17.     ue(i).yposition ue(i).SINR 'NLOS' nlosCap}];
                18.     end
        c. end
106.    else
        a. break;
107.    end
108.    end
```

# 5. CONCLUSION

According to the need of cellular spectrum all around the world a very limited amount of research has been done on the mm wave communications of the mobile. The measurement of wide propagation campaigning at 28 and 38 GHz has been performed in order to gain an insight on the AOA, RMS, AOD, their path loss, delay spread, rejection characteristics, building penetration for the future design of mm-wave cellular system. The given work has presented the collected data in the urban environment at 38 GHz and 28 GHz. The given work has presented the data that was collected in the urban environments at the 38GHz frequency in Austin around the University of Texas and at 28 GHz in New York University. The outage obtained from the studies that are conducted at 28GHz and 38GHz has shown that the 200 meter cell radius by a base station can make a steady coverage.  In Austin the path loss was smaller than in New York due to the fact of dense urban environment whereas the reflection coefficient in New York for the materials that were outdoor was significantly higher e.g. it was 0.896 and 0.740 for tinted and clear non tinted glass respectively in comparison with the materials that were in door. In the similar way penetration losses for the outdoor materials in the New York materials were larger because the signals cannot penetrate through the materials that are outdoor. Outdoor networks are isolated from the indoor networks suggesting that access points, data showers and repeaters are needed to be installed for the hand offs at the entrances of any residential and commercial buildings. The observation of delay spread value and measured path losses from the heavy urban environment of New York and lighter environment of Austin a substantial differences in the propagation parameters were found. In New York City the multipath delay spread was found much larger as compare to the Austin due to the highly reactive nature of the dense urban environment. One of the key factors for the design of urban cellular was the small scale fading that was tested during the procedure and showed a minor change in the impulse response and received power when 400 Mcps signals and highly directional antennas were used. The collected data over the course of such campaigns related to the measurement has allowed the development of the model of statistical channel that are extremely valuable for the development of 5g communication system on the mm wave bands in the coming duration. (Petro , 2016) ,(Vasilakos , 2015).

This is conclude that interference grow when transmitter and receiver  provision with directional antennas . Therefore that hang-up with useful signals that efficacious recoups the improvement in communication system in which majority case limit the noise. So these effects further create improvement in SINR but in the case of molecular absorption that depraved it considerably.

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