REPUBLIC OF TURKEY

ALTINBAS UNIVERSITY

Institute of Graduate Studies

Electrical and Computer Engineering

DELAY ROOT CAUSE ANALYSIS AND 3D MODELING OF LTE CONTROL COMMUNICATION USING MACHINE LEARNING

Sameer Qutaiba MOHAMMED

Master's Thesis

Supervisor

Asst. Prof. Dr. Muhammad ILYAS

Istanbul, 2022

DELAY ROOT CAUSE ANALYSIS AND 3D MODELING OF LTE CONTROL COMMUNICATION USING MACHINE LEARNING

Sameer Qutaiba MOHAMMED

Electrical and Computer Engineering

Master's Thesis

ALTINBAŞ UNIVERSITY

2022

The thesis titled DELAY ROOT CAUSE ANALYSIS AND 3D MODELING OF LTE CONTROL COMMUNICATION USING MACHINE LEARNING prepared by SAMEER QUTAIBA MOHAMMED and submitted on 12/12/2022 has been **accepted unanimously** the degree of Master of Science in Electrical and Computer Engineering.

____
Asst. Prof. Dr. Muhammad ILYAS

Supervisor

Thesis Defense Jury Members:

Asst. Prof. Dr. Muhammad ILYAS	Department of Computer Engineering, Altınbaş University	______________
Asst. Prof. Dr. Abdullahi Abdu IBRAHIM	Department of Computer Engineering, Altınbaş University	______________
Asst. Prof. Dr. Jawad RASHEED	Department of Software Engineering, Nişantaşı University	______________

I hereby declare that this thesis meets all format and submission requirements of a Master`s Thesis.

Submission date of the thesis to the Institute of Graduate Studies: ____/____/____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Sameer Qutaiba MOHAMMED

Signature

DEDICATION

I devote and pledge this research work to my supervisor who is salient for guiding me through the whole research work as well as my family for always assisting me in my hard time.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor Asst. Prof. Dr. Muhammad ILYAS for guiding and helping me along the way in writing this dissertation. Discussing my progress, problems, and ideas with my supervisor Asst. Prof. Dr. Muhammad ILYAS a couple of times every week helped me tremendously in understanding the logic behind the research. It made me better realize the technical need for this research work.

ABSTRACT

DELAY ROOT CAUSE ANALYSIS AND 3D MODELING OF LTE CONTROL COMMUNICATION USING MACHINE LEARNING

Mohammed, Sameer

M.Sc., Electrical and Computer Engineering, Altınbaş University,

Supervisor. Asst. Prof. Dr. Muhammad ILYAS

Date: December /2022

Pages: 60

This thesis examines delay root cause analysis and 3D modeling of LTE control communication utilizing sophisticated machine learning for network testing. The research studied LTE protocols for 5th-generation mobile telephony and provided guidelines for controlling LTE frequency for background knowledge, although this work has an independent technique that does not employ LTE standards. Input-output MIMO with 512 elements for 100-GHz and 128 elements for mid-band sub-6-GHz has been used. LOS is always 0.5. This paper is about LTE, not 3D modeling of LTE control path loss type communication using machine learning. This work's route loss depends on cross-pol beam LTE polarization (±45o). Rx and Tx activities at 0.5 km and 15.25 m altitude. Distance, handover authentication, rain, atmosphere, and sub-6GHz vs 100GHz weather conditions effect pathloss. Enhancing transmission power and efficiency improved spatial variety. Authorizing and sanctioning ANN-based LTE frequency for both mid-band sub-6-GHz and 100-GHz is possible due to its planning and development using open-source material and strategy with high transmission power and rate under questionable handover confirmation using MIMO input/yield receiving wires. This theory examines LTE innovation dimensioning as unbiased for various handover verification and allows input boundary alterations for various organization arrangement setups for LTE recurrent data transmission from 6 GHz to 100 GHz for three climate sorts. This cycle should be seen as an undeniable level way to examine LTE networks under various air conditions. Using signal handling tool compartment and explicit AI-based ANN calculation from AI toolkit in MATLAB R2019a, it is possible to create a result answer for three climate types in dataset with an LTE communication level of exactness of downpour assimilation and abundance foliage mis fort.

Keywords: LTE; Investigation; MIMO; Artificial Neural Network; Antennas.

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

ABBREVIATIONS

3G	:	Third Generation of Mobile Communication
4G	:	Fourth Generation of Mobile Communication
5G	:	Fifth Generation of Mobile Communication
CA	:	Carrier Aggregation
DN	:	Data Networks
FTP	:	File Transfer Protocol
ICT	:	Information and Communication Technology
IoT	:	Internet of Things
LTE	:	Long Term Evolution
MBB	:	Mobile Broadband
MIMO	:	Multiple Input Multiple Output
LTE	:	Millimeter Wave
SNR	:	Signal to Noise Ratio

1. INTRODUCTION

1.1 INTRODUCTION

The operations of distant networks are propelling business, while concurrently and unwittingly updating society. As the number of LTE distant associations continues to increase, they will emerge as the key motivator for future remotes. Existing remote radio access technologies (RAT), such as LTE and Wi-Fi, will be combined with new ones to enable LTE radio access [1]. The use of beamforming and spatial collecting methods with massive MIMO [2] will allow remote projects to utilise even bigger information transmission limitations in the future. Carrier aggregation and the implementation of new repeat collections can boost client throughput. To sustain transmission or social event advantages, LTE networks are anticipated to rely on a bigger number of devices with weaker transmission power, resulting in thicker cells [3].

Connecting an ever-increasing number of devices to the Internet is a potent entry point for more capable and productive industry structures as a result of the development of new use-cases, such as machine correspondence systems in connecting everyone, a well-organized environment, partner things, speedy, and responsiveness (Figure 1). Together with the growing number of cells and increased data rate needs from consumers [4], such as updated flexible broadband, this has necessitated the creation of a new practical exchanges association, Generation 5 [5]. The most essential advantage coordinates are the invention and deployment of more efficient methods for increasing association limits, inaction, convey ability, and transmission rates.

However, the creation of the fifth generation is nearing completion (2018–2022). As seen in [6], some hardware makers have already begun marketing 2019 network plans for their devices. In light of [7], which anticipates that a complete LTE transport structure would be available in 2018, the most fundamental format projections for an LTE network architecture have been produced. As a result, as shown in [8], numerous managers, chip, and phone manufacturers are assuming responsibility for coordinating exhaustive tests and inspections on LTE improvements. The 5G auditing road map for LTE networks.

There has not been extensive research or dissemination [9] of studies on a complete test framework for the LTE network's integration and breaking point components. This concept is intriguing because it necessitates research into the characteristics of incorporation and breaking point for beginning LTE courses of action in three dispersed environments: urban, rural, and common. LTE has fewer alternatives for range, fewer data transmission concerns, and no concept of pathloss solutions. As such, the ultimate objective of the test framework is to enroll the required number of cells from three primary groups: the reference model limits (interface financial arrangement, spread models, and breaking point necessities), the reference traffic profile (organization need, mix share, throughput essential), and the locale/district data base inside the land objective course of action area (region locale, inducing environment, client thickness) [10]. The model must be resilient enough to withstand changes to the data constraints, and sufficient time must be allotted to determine how different data constraint configurations affect the overall number of cells.

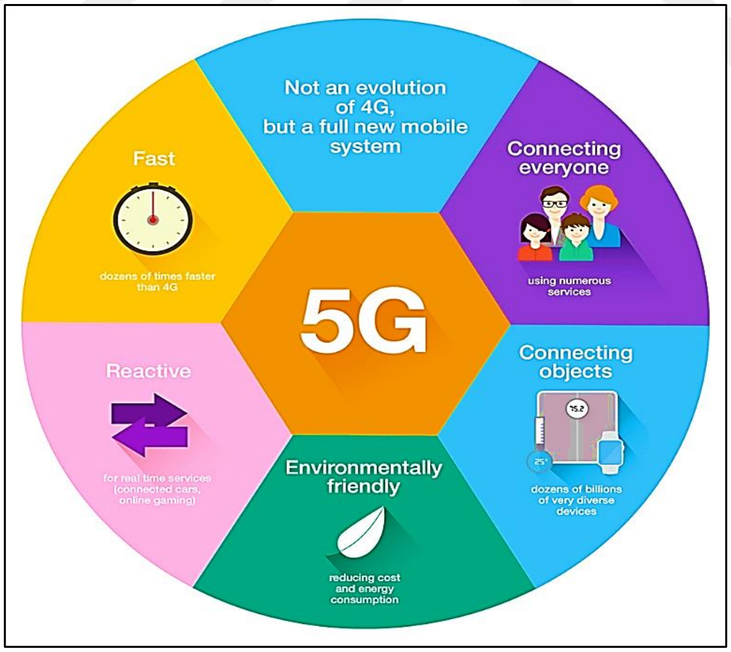

Figure 1.1: Proposed use-case scenarios for LTE. Source [10]

Assuming they are implemented, the new repeat packets anticipated to be transmitted in the middle of LTE executions should be at the center of the model. The major objective is to explore how the broader 100 GHz spectrum of LTE differs from the 6 GHz band of LTE, resulting in wider dispersion setbacks both indoors and outdoors. Each actual reach arrangement, represented by LTE, should be supported by the model up to that threshold. This [11] includes both new limit structures for the flow of information and the numerologies used for these clusters of repetitions. When evaluating the efficacy of various client-mentioned firms, it is advantageous to select the cell and association with the highest proportion of customers for the reference traffic profile [12].

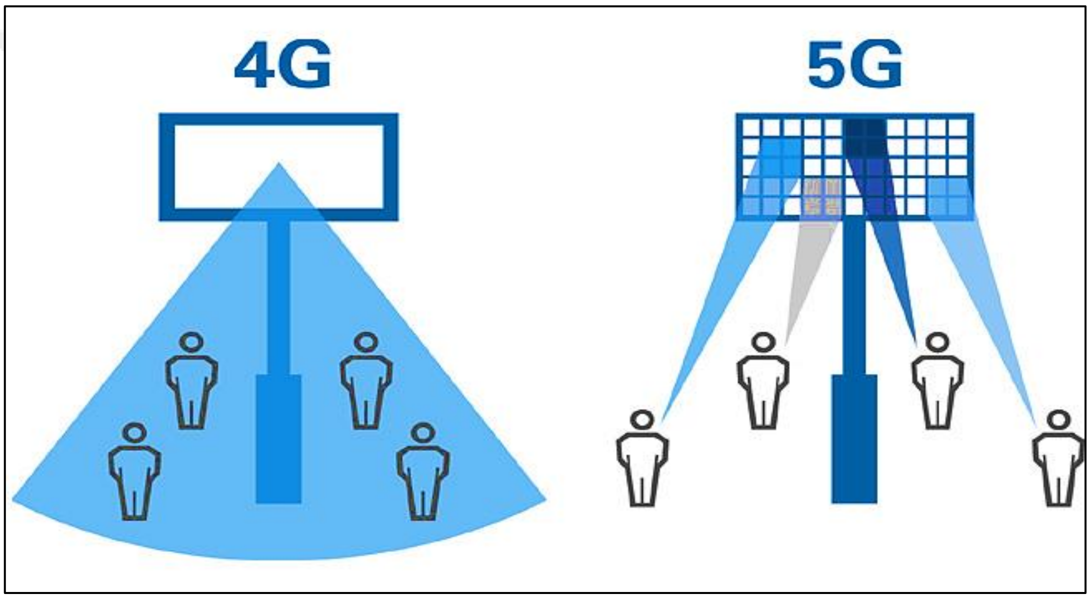

Figure 1.2: Next generation access points of 4^{th} and 5^{th} generation network with respect to the connectivity [12].

1.2 PROBLEM STATEMENT

The calculation of the site cell radius and, consequently, the number of cells presents the primary difficulty in coverage estimation. Thus, the coverage distances, which are established with the use of accurate propagation models and the maximum path loss (MAPL) provided by the radio link budget formulation [13], are the most crucial component. Spectrum between 6 GHz and 100 GHz is being studied for LTE networks, with development times varying substantially [14]. LTE's ability to facilitate the participation of so many parties in the production of diverse goods needs a vast frequency range. According to this notion, the early

LTE deployments on the ground will concentrate on the cm-spectrum, specifically the 6 GHz and 100 GHz frequency bands. Therefore, the primary focus of this research is on the propagation and coverage effects of these frequency bands.

1.3 BEAMFORMING SIGNALING SYSTEM

The concept of beamforming is 5th generation signaling system taking the already existing concept of multi-antenna technologies (MIMO) to a higher level [15]. The more antenna elements the narrower the beam, and this with the transmitter-receiver tracking in real-time allows for maximizing the power of the received signal in a specific direction. However, some transmissions regarding synchronization and system information from base stations still need to reach several users at once, which is not possible with beamforming [16]. The main advantages of this concept are allowing a more efficient spectrum and energy utilization. The transmitter and receiver use beamforming to track one another, and by focusing the transmission power in a specific direction it improves energy transfer, plus it improves the radio environment around the base station by limiting interference to specific fractions of the space around the transmitter [17].

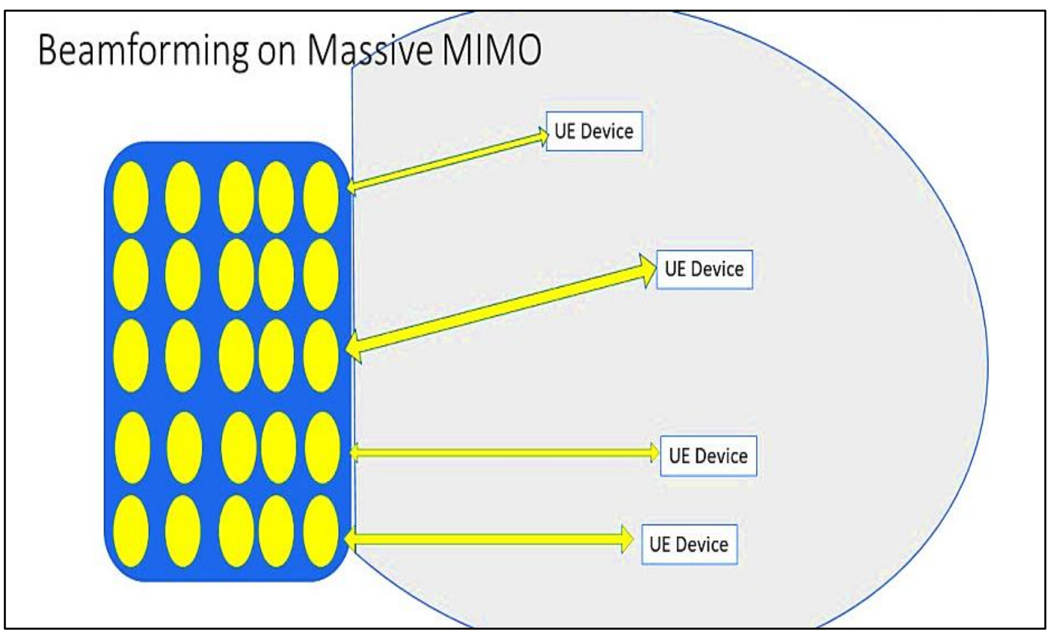

Figure 1.3: An example of beamforming signaling system with UE devices. Source [17]

The question that comes first while applying any machine learning algorithm with signal processing-based LTE network communication is whether it will be supervised or unsupervised. If the data is already labelled, then it could be tested for different handover authentication with beamforming as it may work fine for that particular dataset.

1.4 MOTIVATION

The main financial motivation concerning LTE technology is aiding telecommunications operators convert the growth of usage of mobile data services into a greater, more solid source of revenue. We define the interoperability with previous generations of mobile communications as one of the key principles concerning the Information and Communications Technologies (ICT) industry, while also establishing that LTE network access capabilities must extend far beyond those of past generations of mobile communications, both in terms of incorporating a wider range and variety of devices, and in delivering data with a much lower cost per bit. Regarding frequency spectrum, LTE is planned to extend its usage far as 6 to 100 GHz for increased system capacity, and two of the main frequencies of operation are anticipated to be 6 GHz and 100 GHz. Although the length of spectrum usage increases, LTE networks are expected to use only higher frequencies as a complement to lower frequency bands for providing either additional capacity, or very wide transmission bandwidths for specific extreme data rates, such as in dense deployments.

1.5 AIMS AND OBJECTIVES

With the boundless utilization of LTE innovation, the quantity of clients on correspondence network have likewise expanded [18]. As per Gartner Research [19], the quantity of clients on specialized gadgets by 2050 will hit 18 billion. The extent of this exploration is past the tasks of fifth era networks as we decided their use and standards under the extreme handover validation. This study has noticeable quality since it is best in class work performed under the exploration boundaries of fifth era organizations. Consequently, we proposed the LTE for mid-band sub-6-GHz and 100GHz utilizing the counterfeit neural organization in light of the dataset obtained. Besides, a few varieties with regards to traffic profile are performed, as far as administration throughput, administration share rates and different traffic profile setup partakes in certain districts. As far as permitting and authorizing the utilization of ANN based LTE recurrence for both mid-band sub-6-GHz and 100-GHz is conceivable in view of its planning and improvement with the open-source material and procedure with high transmission power as well as high transmission rate under unsure handover confirmation utilizing MIMO input/yield radio wires utilized. This mandate separates the energy effectiveness in LTE network supply and energy proficiency in energy use with high range allotment. The actions embraced by the worldwide norms can be summed up:

i. Defer underlying driver examination wholesalers and retailing should lessen yearly 1.5% their energy deals with high range assignment in LTE organization.
ii. Yearly energy productive remodel of least defer underlying driver investigation transmission capacity claimed or involved by energy utilization in LTE organization.
iii. Impetus the defer underlying driver investigation remodel, for example adding energy protection, network joins, LTE network directing; to further develop their energy execution
iv. Obligatory energy execution testaments while leasing defer main driver investigation with low energy utilization in LTE organization.
v. Set of least marks or guidelines for a scope of items, for example, high range distribution and diminishing minor issues in the LTE organization.
vi. Periodical energy reviews for huge organizations and motivations for small and medium ventures to go through energy reviews
vii. Safeguarding purchaser privileges to get exhaustive data, admittance to constant and generally energy utilization and charging information to a superior utilization the board
viii. Sending 200 million of power brilliant meter (72% of the aggregate) by 2025.

The energy productivity in energy supply is primarily centered around the profoundly effectiveness cogeneration plants (power + range allotment), execution of region warming and cooling and reconciliation of renewables in LTE organization. Along with the energy investment funds achieved because of provider's commitments and the utilization of the white authentications. A modernization on energy foundation (change, transmission and dissemination) prompts the last sending of the brilliant frameworks, diminishing lattice misfortunes (accounted by practically 30%) got from energy age, transportation and circulation in LTE organization.

1.6 NOVELTY OF RESEARCH

Right off the bat, this work will fill the hole of examination where a LTE innovation, which is under field testing and for a section never been tried under various handover confirmation utilizing both of AI tool kit and sign handling tool kit. This proposal gives an examination of LTE innovation dimensioning as unbiased for various handover verification, while likewise allowing changes in input boundaries for various organization sending setups from 6 GHz to 100 GHz. This cycle should be visible as an undeniable level way to deal with LTE network examination under various environmental circumstances, whereby the utilization of engendering models of LTE network and explicit AI based ANN calculation, it is feasible to create a result answer for three climate types in dataset with an adequate level of precision of downpour retention. The info and result boundaries are conventionally portrayed in this work for limit and inclusion for various climate types for example stormy, shady, moistness as well as the engendering models utilized for inclusion arranging in LTE network for downpour assimilation. The most developed AI based counterfeit neural organization model for fifth era correspondence network as well with respect to inclusion and limit are characterized in this work. Other than these fundamental components for cell network arranging there is the utilization of LTE network in World as far as thickness/volume and offer/blend profile all through a common burden day has additionally been talked about.

2. RELATED WORK

2.1 LITERATURE REVIEW

When evaluating cell capacity, it is necessary to comprehend key components. The first two are the signal-to-noise-to-interference ratio (SINR) and the channel spectrum efficiency (SE), which are dependent on the level of quantization [20]. Together, they will identify which of the four modulation coding schemes (MCSs)—quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (QAM), 64-quadrature amplitude modulation (QAM), and 256-quadrature amplitude modulation (QAM)—is optimal for each user. The MCS order results in the following:

Using lower LTE orders (m 32) improves performance on low pathloss because to their increased reliability and tolerance for larger levels of interference. The higher the LTE order (m > 64), the larger the transmission throughput, but the bigger the channel prediction and transmission errors.

Considering that radio spectrum resource management and optimization is a core notion in wireless communications, it is essential to take spectrum efficiency advancements into account. As mentioned in [21], advancements in physical layer technology like as the multiple access method, channel coding scheme, and waveform can increase spectral efficiency. This comprises advancements in LTE design, domain processing, and infrastructure design. This demonstrates a significant advantage of LTE over 4G using the same amount of spectrum. A greater capacity for sending bits results in quicker LTE bit rates.

Transporter collection approaches are designed to give administrators the option of aggregating and running numerous, frequently non-touching, range squares into a single square whose primary function is to magnify present and future range in order to enable more consistent execution [22]. There are three options for transporter accumulation:

Transporters are coterminous and arranged inside a recurrence band that touches. In this case, only a single trans-beneficiary is required to process signals.

The transporters are positioned in a group resembling the ones described but are not in close proximity. Intra-band refers to a band that does not connect to other bands. In this instance, the MT may demand a distinct handset for each transporter.

Transporters are scattered over the radio spectrum (C. non-adjacent recurrence band | between band). Each transporter is required to have their own handset, and the MT must collaborate with multiple teams. It is incredibly valuable for administrators with restricted or split range, but it requires a more complex framework plan, additional funds, and more effort.

As a result of the intense rivalry for spectrum in lower frequency bands, administrators frequently employ transporter total strategies to maximize their available bandwidth. Although cutting-edge transporter technology was utilized in successful LTE tests, resulting in data rates of up to 600 Mbit/s per client under controlled conditions [23], these tests relied on higher MIMO request (8x8) and restricted/research range, so they do not and cannot apply to the vast majority of actual organizations [24].

The fundamental difference between LTE and LTE (4G) is that LTE permits single-channel data transfers at up to 100 GHz, whilst LTE only supports transfers at up to 6 GHz. The maximum achievable data transfer capacity with transporter total [25, 26] may someday be even more startlingly larger than those in LTE with similar techniques, making it obvious that LTE may achieve substantially higher information rates than are currently possible.

2.2 USAGE OF 5th GENERATION NETWORKS

Due to the large number of required functions, [27] asserts that LTE's network interface will incorporate more than one RAT. It is commonly accepted that different radio access technologies (RATs) should be optimized for various use cases or spectrum blocks. To avoid impeding the evolution of RATs' economies of scale, it is essential to refrain from considering the needless creation of RATs to handle certain optimizations [28]. The fundamental idea is to see several RATs as distinct implementations of a single, unified RAT. Last but not least, three technical migration methods from previous generations of mobile communications to LTE have been revealed [29]. Figure 2.1 depicts the best-case scenario global LTE network infrastructure cost estimate.

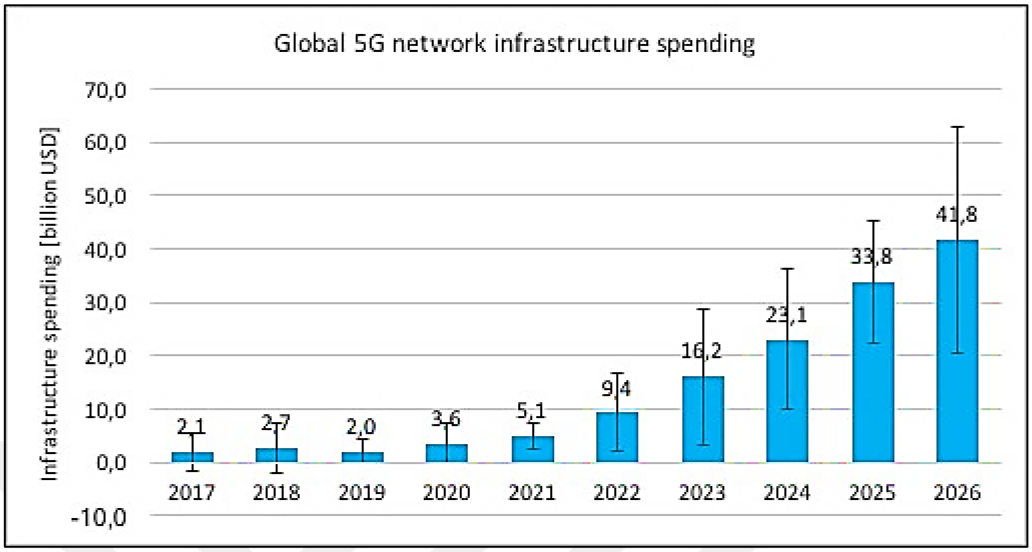

Figure 2.1: Different relevant infrastructure spending in billions with respect to its global usage predicted through years. Source [29].

According to [30], the expected deployment times for the various frequency bands being examined for LTE networks in the range of 0.6–86 GHz. Multiple groups' interest in the huge array of LTE-compatible goods prompted the allotment of such a vast spectrum [31]. This thesis suggests that early LTE installations should prioritize the cm-spectrum, specifically the 6 and 100 GHz frequency bands. Consequently, the primary focus of this dissertation is on the propagation and coverage effects associated with these frequency bands.

Increasing power to achieve maximum coverage will increase interference with adjacent radio frequencies. On the other hand, coverage at the antenna's margins is likely to degrade due to blind spots [32]. Therefore, a 100 GHz network requires a balance between path loss models and interference.

2.3 COVERAGE OF LTE UNDER DIFFERENT SCENARIOS

Considering that radio spectrum resource management and optimization is a crucial topic in wireless communications for LTE coverage, it is essential to account for spectrum efficiency advancements. Based on the numerology of [33], it is typical for a throughput evaluation to employ a figure of 6 GHz. In LTE, it is assumed, for convenience, that the throughput factor doubles for each doubling of the frequency bandwidth; however, this assumption can be modified by band guardians at higher numerological levels. Because these frequencies are outside the scope of this thesis, which is defined for mm-waves, the factor of 2 is considered in the throughput curves at 15, 30, and 60 GHz. It should be emphasized, however, that this approximation may not be applicable to much higher orders of numerology (such as frequencies of 6 or 100 GHz) (100 GHz).

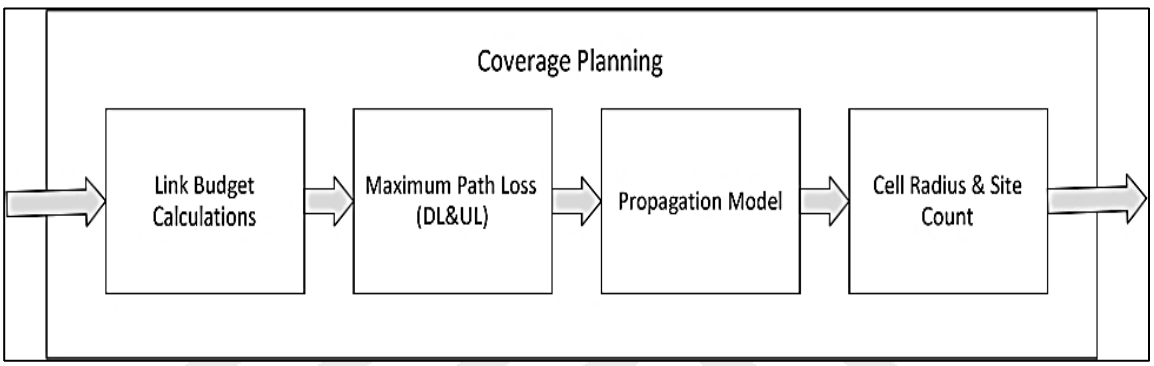

Figure 2.2: The coverage planning under which maximum pathloss of network is being measured.

As recently examined, the model can take any numerology design albeit just the one with most elevated distance is considered for inclusion distance reason [34]. In other words, assuming numerologies 0, 1 and 2 are chosen, inclusion assessment will continuously be founded on numerology and thus a similar applies for registering the greatest feasible throughput at the phone edge [35]. In spite of the fact that there is a freedom to pick any numerology arrangement, there are sure limitations forced by LTE. Basically there are numerologies that are not upheld by certain sets of recurrence/data transfer capacity.

In this sense, considering the client populace arbitrarily circulated in the phone and the limit prospects as far as throughput from climate areas and numerologies, the model picks the most proficient LTE being used proportion for each help [36].

Table 2.1: The weather scenarios under which communication and density of network is being measured.

Weather Scenario	Network density [/km^2]	Relative speed [km/h]	Communication range [m]
Raining	[1 000; 3 000]	[0; 100]	[50; 100]
Humidity	[500; 1 000]	[0; 200]	[100; 200]
Cloudy	[100; 500]	[0; 500]	[200; 1 000]

Because of a business rivalry for range at lower groups, administrators have regularly to utilize transporter total procedures to utilize their non-coterminous recurrence band. Despite the fact that there have been effective tests in LTE with cutting edge transporter collection creating information rates up to 600 Mbit/s per client in controlled conditions, they depended on higher MIMO request (8x8) and on restricted/research range, along these lines it doesn't and can't in any case apply to a large portion of genuine arrangements.

Concerning in LTE, the primary distinction with LTE (4G) is that LTE will consider a solitary transfer speed of up to 100 GHz, though in LTE the greatest is 20 MHz, for single channels [37]. Subsequently, this is an obvious sign of the capability of LTE to accomplish much higher information rates since with transporter total, later on, the most extreme reachable transmission capacity will be even significantly higher than those in LTE with similar strategies [38].

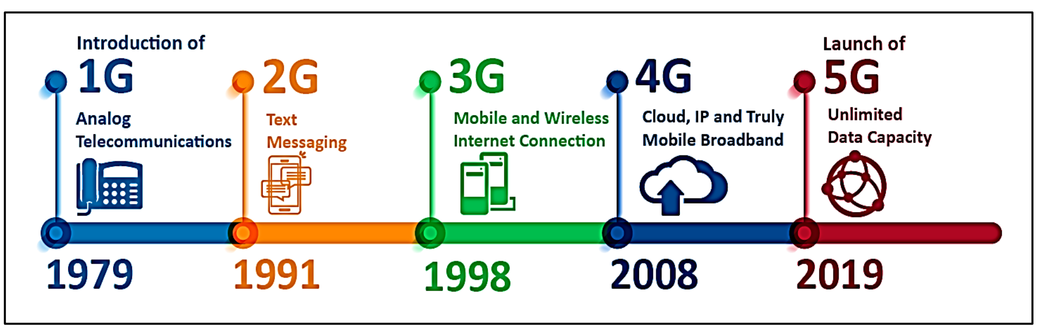

Figure 2.3: The evolution of LTE pass through the time. Source [38]

The capacity estimation determines whether or not the coverage prediction's projected consumers can receive the needed traffic profile. When a cell's capacity to support the requisite number of LTE network users is endangered, the cell's radius is decreased to lower the number of users. On the basis of this approximation, the accurate cell and network densities can be calculated.

2.4 CAPACITY AND RANGE OF LTE

Multiple spectrum sites, including mm-wave (e.g., 6, 100 GHz) and mm-wave spectra, are now being evaluated for LTE due to their technological and economic potential (e.g., 100 GHz). Due to the unique and complex nature of mm-wave propagation and the cost implications of operator network building, such as the necessity for a significantly denser base station infrastructure, mm-waves are not anticipated to be the predominant choice in the early stages of LTE implementation.

The primary purpose is to investigate the coverage and capacity implications of the cm-wave spectrum, which is expected to be addressed in early network installations, particularly in the 6 and 100 GHz bands, under a range of scenarios [49]. Both will provide MTs with network connection, but only the latter will be able to provide faster data rates due to a larger bandwidth allocation or greater MIMO orders. Table 2.2 displays the maximum MIMO order achievable for various MT devices beginning with (1), with the number of antennae rounded to the next multiple of 2. This table is pertinent to the application of MIMO at these frequencies since it displays the sizes of several instruments.

$$N_{Antenna} = [\frac{d_{[m]}}{\frac{c_{m/s}}{f_{[Hz]}}}] \tag{2.1}$$

i. d: device distance (length or width).

ii. c: speed of light.

Table 2.2: A general-purpose sensor equipment devices from IoT manufacturer with prescribed frequency of LTE. Source [39]

Equipment	Dimensions [cm]		Frequency [GHz]			
			6		100	
	Length	Width	Length	Width	Length	Width
Sensors	12	12	-	-	2	2
Smartphone	7	14	-	-	-	2
Tablet	24	19	-	-	2	2
V.R glasses	21	9	-	-	2	2
15" Laptop	32	21	-	-	4	2
Car roof (A.V)	125	100	2	2	14	12
Bus roof (A.V)	220	140	6	4	26	16

Table 2.2 provides a basis for inferences regarding the types of devices customers can anticipate LTE networks to support. The extraordinarily high throughput figures normally associated with LTE deployments are severely constrained by the fact that even within the 100 GHz band, smartphones, tablets, and laptops cannot typically guarantee a MIMO configuration greater than 2x2. In the first scenario, the maximum MIMO order of 2x2 at 100 GHz may not be sufficient to meet the demand for high throughput. However, in the second scenario, devices used in fields such as virtual reality (such as Samsung's Gear VR glasses) or autonomous vehicles may be able to achieve interesting MIMO orders (e.g., vehicle rooftop serving as antenna for infotainment). Even under unfavorable propagation conditions, 4x4 MIMO is possible in a bus or train scenario in the 6 MHz band.

Table 2.3: Conditions under which LTE latency and reliability are achieved for network streaming.

Network Quality	Resolution	Throughput [Mbit/s]		Data in 1 Hour [GB]
		Recommended	Average	
Low	240p / 360p	< 1	6 GHz	0.32
Standard	480p	3	1.6	6 GHz2
High-Definition	720p	5	2.0	0.90
	1080p	5	3.3	1.49
	2K	10	6.7	3.02
Ultra-High-Definition	4K	[15; 25]	15.6	7.02
	8K	[80; 100]	90	40.50

To guarantee a frequency band for LTE mobile communications by 2020, the European Union initiated a frequency reframing initiative in the 6 GHz band in 2018 [41], and according to [42], the 100 GHz band is currently being opened from old satellite and unlicensed services. This pertains to the commercial, military, and other applications of the aforementioned frequency bands. Some nations, most notably Turkey, are now conducting auctions for spectrum in the 6 GHz and 100 GHz bands. The frequency bands and bandwidths for early LTE on the 6 GHz band have been identified, but the 100 GHz band's specific and differential values have not yet been formally established, present in

Table 2.4: LTE frequency ranges.

Frequency Range Designation	Corresponding Frequency Range
Frequency range-1 (6-GHz)	**410 MHz – 7125 MHz**
Frequency range-2 (100-GHz)	**45332 MHz – 76544 MHz**

The vast majority of nations will prefer the use of the n28 NR-band [43], whose maximum available bandwidths have already been specified by LTE (45 MHz per channel). LTE has not yet determined the maximum permissible bandwidth per channel for the 100 GHz spectrum, although a total practicable bandwidth of approximately 2 GHz is anticipated. The 6 GHz band will be based on FDD whereas the 100 GHz band will be based on TDD, despite the fact that the distinction makes no difference according to this idea.

Urban, suburban, and rural are the three most important types of propagation environments for the cm-wave spectrum (6 and 100 GHz). The key distinguishing characteristics of these scenarios are the presence and location of obstacles, the building density, and the user density. In addition to the spatial distribution of traffic volumes, the ROM configuration metric will be utilized to incorporate empirical measurements of daily traffic density changes into the model (Residential, Office, Mixed).

2.5 DIMENSIONING OF LTE

This section's primary objective is to conduct research within the context of anticipated LTE use cases by assessing and characterizing the dimensioning of fifth-generation network requirements and features with respect to coverage and capacity. The objective is to investigate the throughput, latency, and other KPI needs for services and applications such as video streaming, augmented reality, the Internet of Things (IoT), and self-driving automobiles. [44].

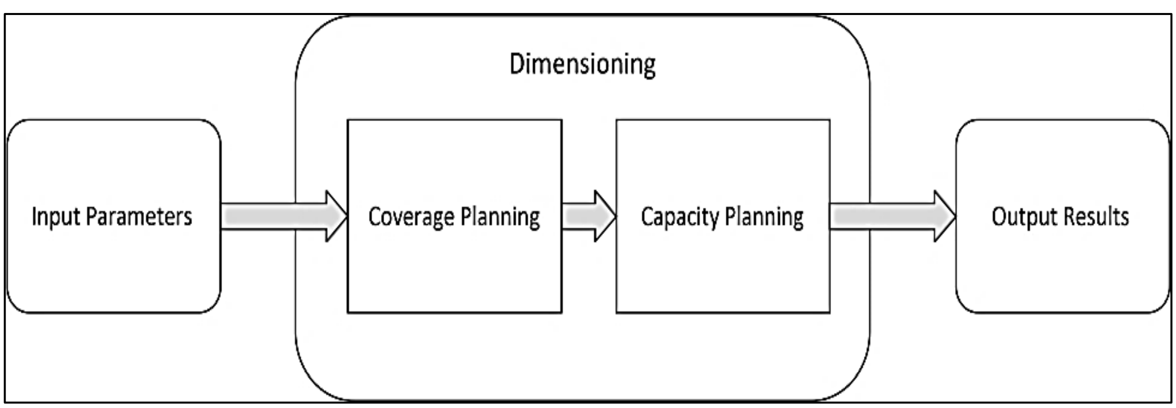

Figure 2.4: The dimensioning of 5^{th} generation network which includes both coverage and capacity.

When it comes to mobile communications, the objective of the network development behind LTE networks is to enable operators to deploy a variety of unique and different use cases that were either impossible or impractical to achieve with UMTS and LTE networks. Thus, the current landscape of use cases can be divided into three broad kinds [45]:

A. eMBB enables users to access several services (such as file downloads and video streaming) in larger packets. Offerings such as augmented reality and in-car entertainment systems are included.

Massive Machine Type Communications are distinguished by regular communication with little packet size (MMTC). It covers Internet of Things-based services for Demotics and Smart Cities.

URLLC (Ultra-reliable and Low-Latency Communications): communications in which latency is a major concern despite the fact that packet size is often fairly tiny. Included are V2V communication and industry automation services.

However, it is anticipated that LTE networks will continue to accommodate the service categories that have arisen since the introduction of older mobile communication protocols. For varied network deployment configurations, input parameters can and should be modified, and the model's sizing should reflect this while remaining as objective and complete as feasible. This method can be considered as a more abstract approach to network dimensioning, where adequate precision in the output solution can be attained by applying propagation models and certain algorithms.

Following is a standard depiction of the information and outcome boundaries and the generating models used in inclusion planning. In the following paragraphs, we will examine the most prominent inclusion and restriction models. In addition to these foundations, the traffic density/volume and offer/blend profile during a typical day of load are also crucial factors to consider while developing a mobile network.

First, given the reference throughput, the information boundaries must process the greatest cell distance via connect spending plan and engendering models to characterize the maximum organization load from the traffic profile. This provides an assessment cell sweep for the various spread situations from which the receiving wire thickness designs are recovered for the organization and portable terminal. This information is represented in Table 2.5.

Table 2.5: Description for the coverage and capacity with Network and Mobile Terminals.

Metrics	Parameters	
	Network	**Mobile Terminals**
Capacity	Device/connection density, throughput, cell size, latency	Throughput, latency, traffic volume profile
Coverage	Propagation scenario, penetration losses, cell size, obstructions	Signal strength, mobility

Despite the fact that the same parameter may appear in both the capacity and coverage fields, this does not imply that their values are identical. A macro-cell may be the best option for ensuring network coverage, whereas femto-cells may be the best option for maintaining or expanding network capacity within the same coverage region. Despite their limited network connectivity, MTs can attain certain parameters due to the network's capacity (which is dictated by the received power at those devices).

In addition to these, the MIMO order maximum and numerology setting are two additional important features of LTE network deployment. During the early phases of model construction for this thesis, the need for latency was not considered, although it may be added at a later time. After evaluating the backhaul infrastructure required to meet specific latency requirements by computing the cell radii and density for various propagation scenarios, [46]'s work can be utilized.

3. METHODOLOGY

In this section, we present the seminal works of multiple authors on access and limitation issues in LTE networks. Primarily, research is conceived of in three places: scholarly writing, IEEE-based writing, and institutional inquiry employing 5G, LTE, or LTE-PPP components. There are basically three components to recurrent band readups for mobile network plans, according to written research: (3) Earphone recommendations.

Beginning with foundational works, this article provides a comprehensive analysis of the cell network layout for three LTE recurrence groups (0.8, 1.8, and 6 GHz) in different spread situations, with different traffic load profiles and administration profiles/share profiles, and with a few backwards-compatible components with older types of LTE transmission, such as the number of sub-transporters. This idea is currently the focus of study on the lower recurrence band at 100 GHz. It is supported by a substantial body of literature written by a variety of writers.

Coverage, capacity, and protocol design layers for mm-waves have been investigated, with consideration given to data rate, latency, energy, and cost, as well as the effects of propagation characteristics, channel modeling, link outage scenarios, deployment configurations, and scenarios. Using a combination of prior models, the authors analyzed the features of indoor coverage at high frequencies and modeled the transition from outdoor to indoor coverage. Current alternatives for mm-wave computing capability and coverage for mobile broadband in remote and rural locations. defended mm-wave propagation mechanisms, described wireless channels employing site-specific and stochastic channel techniques, and proposed a method for calculating capacity provisioning for both narrowband and wideband systems.

3.1 LTE REFLECTORS FOR DELAY ROOT CAUSE ANALYSIS

Investigation of millimeter waves in numerous situations, including the entry radio, fronthaul, and backhaul, is fundamental to overall LTE network design. The group has investigated the use of millimeter waves in small cells for dense radio-access zones inside and outside the organization in order to determine the technological viability of the organization's increase limit. In light of LTE and ANN for model replication, the Fantastic LTE project analyzed the important vital markers that should have been met to advance the development of limit, inclusion, reliability, and dormancy for networks operating under 6 GHz. In order to account for the limit and inclusion of 100 GHz millimeter waves in an urban setting, we developed a model. Future networks will implement mm-waves with an open-source MATLAB interface in order to model LTE network limits with 100 GHz transmission capacity.

Lastly, works that focus more on the frequency range in terms of this postulate's scope and organizational qualities, such as pathloss or MIMO, provide a comprehensive overview of LTE arrangement considerations, from use-cases to frequency groups' execution street, as well as interoperability models with LTE center organization. In addition to learning about the requirements for new channel models, such as recurrence groups, transfer speed, types of receiving wire clusters, versatility, and handover issues, we have developed a trial-and-error and approval method for common outside spread scenarios in small and large-scale cells and open air to indoor infiltration error. This technique takes signal obstruction, path misfortune models, and shadow fuzziness into account.

3.2 MATERIAL AND METHODS

The sub-6 GHz to 100 GHz frequency spectrum utilized by mid-band LTE is significantly utilized in the manufacture of these materials. This study is conducted in the actual world and utilizes MATLAB R2019a for training and testing purposes. We retained the transmitter power at 43 dBm for both the sub-6 GHz and 100 GHz bands because we are comparing analyzed data to proposed LTE parametric setup specifications. The research makes use of the "massive" MIMO (multiple input, multiple output) antennas in the MATLAB software. The primary purpose is to investigate the coverage and capacity implications for the cm-wave spectrum, which is anticipated to be addressed in early network installations, especially in the 6 GHz and 100 GHz bands, under a range of scenarios. Both will provide MTs with network connection, but only the latter will be able to provide faster data rates due to a larger bandwidth allocation or greater MIMO orders. Regarding the applicability of MIMO at these frequencies.

i. h_{BS}: height of base-station.

ii. h_m: height of LTE mobile terminal.

iii. f: carrier frequency and pathloss.

Table 3.1: Model equations for different scenarios of weather for the 6 to 100 GHz frequency band.

Scenario	Weather Equations
Cloudy	$L'p[\text{dB}] = 31.46 + 5.83 \cdot \log(hBS[\text{m}]) + 23 \cdot \log\left(\frac{f\,[\text{GHz}]}{5}\right)$
	$\alpha PD = \frac{44.9 - 6.55 \cdot \log(hBS[\text{m}])}{10}$
Humidity	$L'p[\text{dB}] = 34.46 + 5.83 \cdot \log(hBS[\text{m}]) + 23 \cdot \log\left(\frac{f\,[\text{GHz}]}{5}\right)$
	$\alpha PD = \frac{44.9 - 6.55 \cdot \log(hBS[\text{m}])}{10}$
Raining	$L'p[\text{dB}] = 55.4 - 0.9 \cdot (hm[\text{m}] - 1.5) + 21.3 \cdot \log\left(\frac{f\,[\text{GHz}]}{5}\right) + 0.13 \cdot (hBS[\text{m}] - 25)$
	$\alpha PD = \frac{25.1 - 0.13 \cdot (hBS[m] - 25)}{10}$

3.2.1 Splitting the Dataset

There are anomalies and a biased emphasis in assault-related statistics. During the assessment step, the acquired data will be processed to generate categories that are commonly derived. To improve climate analysis, typical data will be separated into three categories: training, approval, and testing. The inclusion of weather data during testing will result in the same size data set as during a standard cycle of testing. Because climatic classifications are so heavily overrepresented in the data, it will be divided into train and test subsets with an 80:20 split, as is customary in the artificial intelligence industry, so that the information may be classified. Although the dataset contains numerous types of weather, we narrowed our focus to three (including wet, sticky, and cloudy) and divided the data 80:20 between training and evaluation.

3.2.2 Feature Extraction

When training artificial neural networks, scaling the data is the best practice. Problems can include inconsistent implementation, unpredictable behavior in the calculation of progress, and a high upward slope. Since the data do not fit within a predetermined range, such as climate type data, a normalization strategy based on tracking the mean and standard deviation of the train set is chosen. There are numerous techniques to scale information, some of which need knowledge of the maximum and minimum values for the medium.

3.2.3 Feature Selection

Some data quality may be more important than others for achieving the objectives of investigating LTE for rain absorption and its performance metrics. Studies studying dimensionality reduction methodologies for precipitation, humidity, and gloomy skies have demonstrated this. By limiting the amount of characteristics we employ, we can better compare our work to that of others and demonstrate how the performance of an artificial neural network changes with various numbers of inputs.

3.2.4 Implementation of ANN

We evaluated ANN using our application layer test data. Since we have so much data, it must be organized consistently. If the data is highly continuous, the ANN algorithm will struggle to perform well, even with a small margin of error. Since there are fewer barriers limiting the signal at 100 GHz and consequently a greater change in handover authentication, the overall antenna capacity at 100 GHz is greater than at 6 GHz in a variety of weather conditions. The handover authentication constantly changes throughput and the number of users per cell increase as a result. Our assessment of this kernel led to the selection of the kernel that supports the provided data the most effectively. Using a sigmoid kernel, we created the hyper plane for this collection of data. Plotting the cross-validation error versus the training error yields the generalization accuracy. First, an ANN is trained on a set of publicly accessible data, and then its performance is assessed using a set of concealed data. A flowchart describing the entire implementation strategy is shown in Figure 3.1.

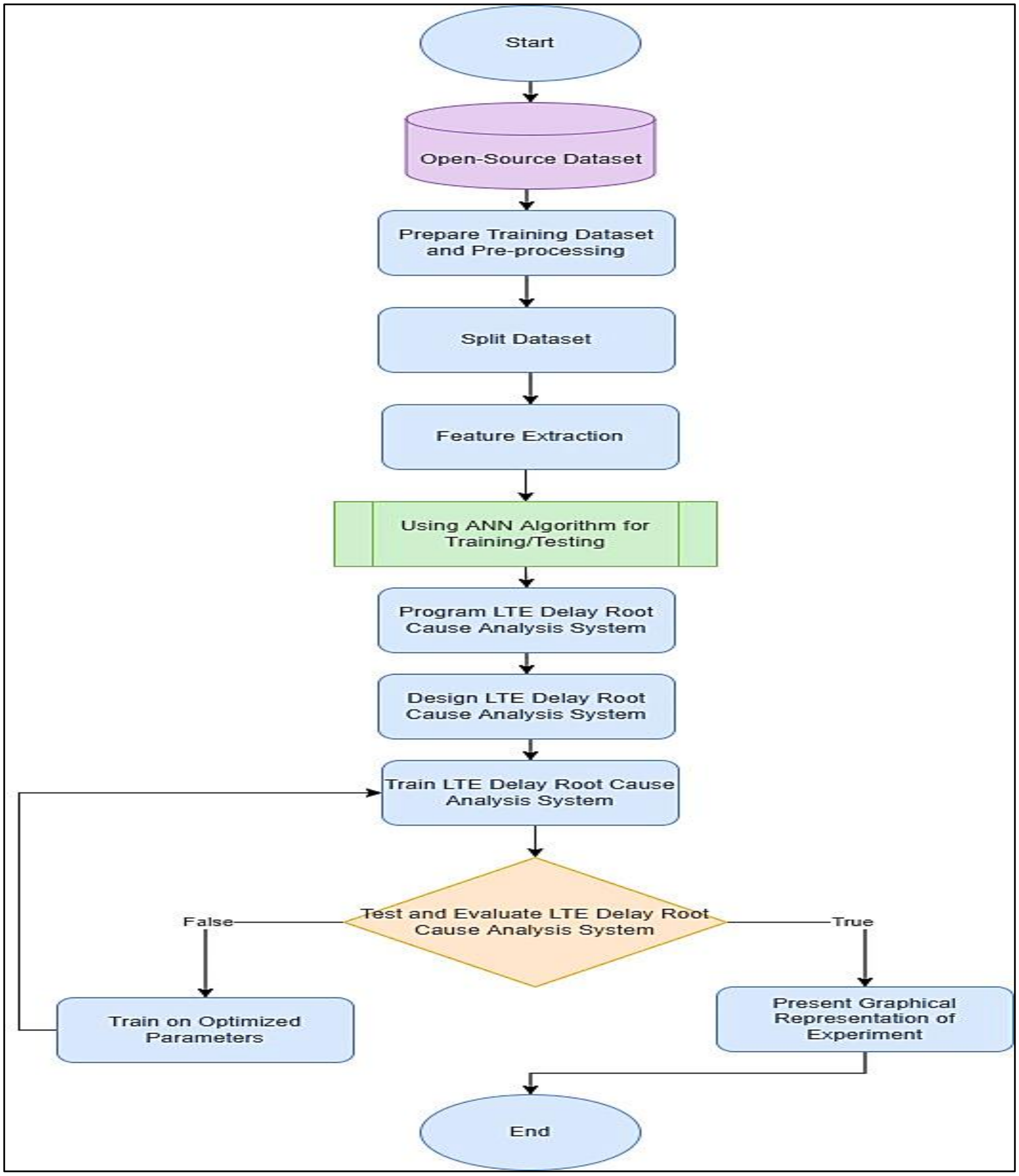

Figure 3.1: The flowchart explains the methodology of implementation from start to end.

3.3 LTE NETWORK HANDOVER AUTHENTICATION TESTING

A novelty factor in LTE weather testing planning, relative to LTE, is the concept of pathloss, which is related to different subcarrier spacing configurations. The available pathloss configurations for the spectrum considered in this thesis are shown in Table 3.2, where the bandwidth is computed.

Table 3.2: LTE Weather Testing Received Power Measurement Bandwidth.

Band [GHz]	LTE Band	TX loss [MHz]		RX loss [MHz]		Duplex Mode	Bandwidth [MHz]	
		Min	Max	Min	Max		TX	RX
6 GHZ	Yes	703	748	758	803	**FDD**	45	45
100 GHZ	Yes	3 300	3 800	3 300	3 800	**TDD**	500	500

Table 3.3: Pathloss distribution and associated LTE bandwidth between 6 to 100 GHz.

Band [GHz]	*μ*	LTE		LTE [GHz] (12/carrier)	Pathloss	
		Min	Max		TX	RX
< **5**	0	6	100	15	5.6	99.5
	1			30	5.2	98.9
	2			60	6.0	100

In the vast majority of nations, the LTE-band, whose maximum achievable bandwidths have already been defined by LTE, will be the primary band for the 6 GHz spectrum (6 GHz per channel). LTE has not yet determined the maximum achievable capacity per channel for the 6

GHz band; nevertheless, a total usable bandwidth of approximately 500 MHz is anticipated. The 5 GHz frequency will utilize beamforming, but the 6 GHz band will utilize pathloss, a distinction that has no bearing on my argument but may be significant.

Cities, suburbs, and rural areas are key propagation scenarios for the mm-wave spectrum (6 and 100 GHz), with the main distinctions between them being the existence and distribution of barriers, the density of buildings, and the density of users. Research into the coverage, capacity, and protocol design layers of mm-waves focuses on factors such as data-rate, latency, energy, and cost requirements, as well as the implications of propagation characteristics, channel modeling, link outage situations, and deployment configurations and scenarios. This work not only merged multiple previous models to examine the characteristics of interior coverage at high frequency ranges, but also modeled the transition from outdoor to indoor coverage. In [29], alternatives for mobile broadband coverage and processing capability based on mm-wave spectrum are examined.

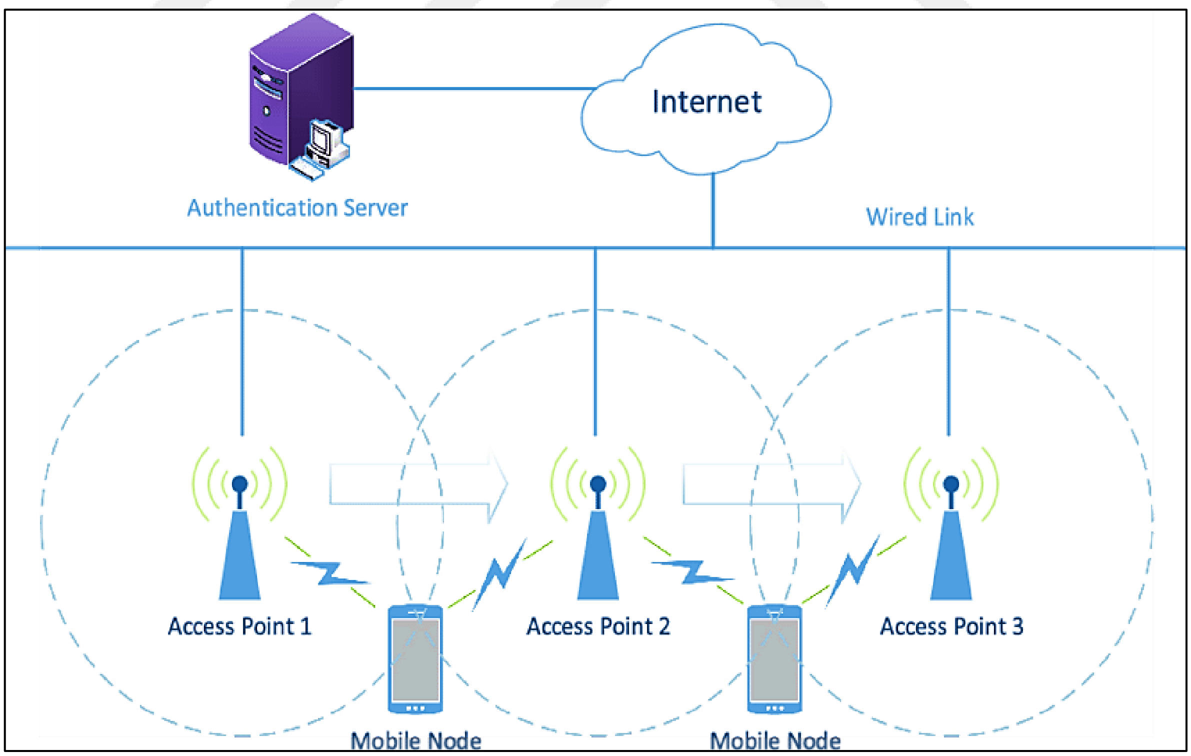

Figure 3.2: Possibility of strongest primary sync signal of LTE can be represented by mobile nodes where the environmental factors supports handover authentication.

This study examined the necessity for mm-wave propagation mechanisms, evaluated LTE wireless channels in Turkey using site-specific and stochastic channel techniques for narrowband and wideband configurations, and proposed a method for calculating capacity provisioning in poor weather situations.

3.4 ANALYSIS OF ANTENNA PATTERNS FOR DELAYS

This study seeks to determine how much antenna bandwidth must be supplied to the cell edge to maintain a consistent throughput in this region. To accomplish this, we must first determine the maximum amount of resource blocks that may be allocated to the cell boundary region. This will define the maximum throughput feasible and, by extension, the cell radius.

To comprehend how numerology influences the available throughput at the cell edge, one must be familiar with a second cell-radius reduction process featured in the model. Throughout the process of dimensioning, the cell radius may be reduced to satisfy throughput demands at the cell's edge or to prevent capacity overflow. Additionally, when the radius reduces and the SNR grows, the total theoretical throughput increases to 100 GHz, bringing the LTE usable throughput to 100 GHz from 6GHz.

In light of the preceding, it is vital to highlight that the highest theoretical throughput is determined when the cell is empty; thus, a study of this process should account for a zero-user density. When the number of users surpasses zero, throughput slows at the cell's edge. In order to choose the configuration with the maximum throughput, the algorithm computes each hypothesis when the radius exceeds a minimum predefined radius value, 100 m in this experiment. In other situations, the algorithm would continue to reduce the cell radius until it equaled the antenna's range, which is impossible. This is the reason why Tables 3.4 and 3.5 present the throughput figures for a coverage-limited antenna.

Table 3.4: Antenna Maximum throughput at frequency bands 6-100 GHz with Transmitter (TX) and Receiver (RX).

Band [GHz]	**Carrier Spacing [kHz]**	**Antenna Maximum Throughput [Gbit/s]**								
		5	**10**	**15**	**20**	**40**	**50**	**60**	**80**	**100**
6	15	**4.4**	**8.8**	**11.8**	**16.2**	-	-	-	-	-
	30	-	**8.8**	**11.7**	**17.7**	-	-	-	-	-
	60	-	-	-	-	-	-	-	-	-
100	15	-	**7.6**	-	**13.9**	**27.9**	**35.4**	-	-	-
	30	-	**6.8**	-	**13.6**	**24.9**	**31.8**	**38.6**	**49.9**	**63.5**
	60	-	**4.2**	-	**12.5**	**25.0**	**29.1**	**33.3**	**45.8**	**58.2**

Table 3.5: Antenna Minimum throughput at frequency bands 6-100 GHz with Transmitter (TX) and Receiver (RX).

Band [MHz]	**Carrier Spacing [kHz]**	**Antenna Minimum Throughput [Gbit/s]**								
		5	**10**	**15**	**20**	**40**	**50**	**60**	**80**	**100**
6	15	**3.6**	**5.6**	**7.7**	**14.2**	-	-	-	-	-
	30	-	**5.4**	**8.4**	**15.6**	-	-	-	-	-
	60	-	-	-	-	-	-	-	-	-
100	15	-	**4.6**	-	**12.4**	**22.9**	**29.1**	-	-	-
	30	-	**3.6**	-	**7.9**	**20.0**	**25.5**	**30.9**	**40.0**	**50.9**
	60	-	**2.9**	-	**4.6**	**17.3**	**20.2**	**23.0**	**31.7**	**40.3**

These variations in throughput figures at 6 and 100 GHz for the same bandwidth may be explained by the algorithm's continuation of the cell-radius-decreasing procedure when the radius exceeds 100 meters. Due to the fact that antenna patterns for 6 GHz are smaller than those for 100 GHz, increasing the SNR value for both the transmitter (TX) and receiver (RX) enhances throughput per LTE at the specified cycle/process radius. Since the LTE is bigger at TX than at RX, the greater throughput numbers at TX can be attributed to the fact that more data is being transmitted. Increased throughput figures are given for the same frequency and bandwidth combinations, leading to the same conclusion that the LTE throughput is greater from 6 to 100 GHz.

Simulations have demonstrated that the throughput value per frequency and bandwidth configuration is proportional to the share percentage of bandwidth allocated to the cell edge. The 20% values may be simply computed by multiplying the throughput figures in Tables 3.4 and 3.5 by 2. Figure 3.4 offers a detailed overview of the differences in TX and RX performance resulting from various antenna capacity demands for both minimum and maximum spectrum configurations (6 GHz vs. 100 GHz). Due to the extremely limited dedicated bandwidth available at the antenna edge, the standard throughput of 2 Mbit/s must be utilized. In other words, following the determination of an LTE value, the model will cut this percentage if doing so will result in a throughput at the antenna edge that is much higher than what is required. Consequently, the values in Figure 3.4 are evaluated using the aforementioned data.

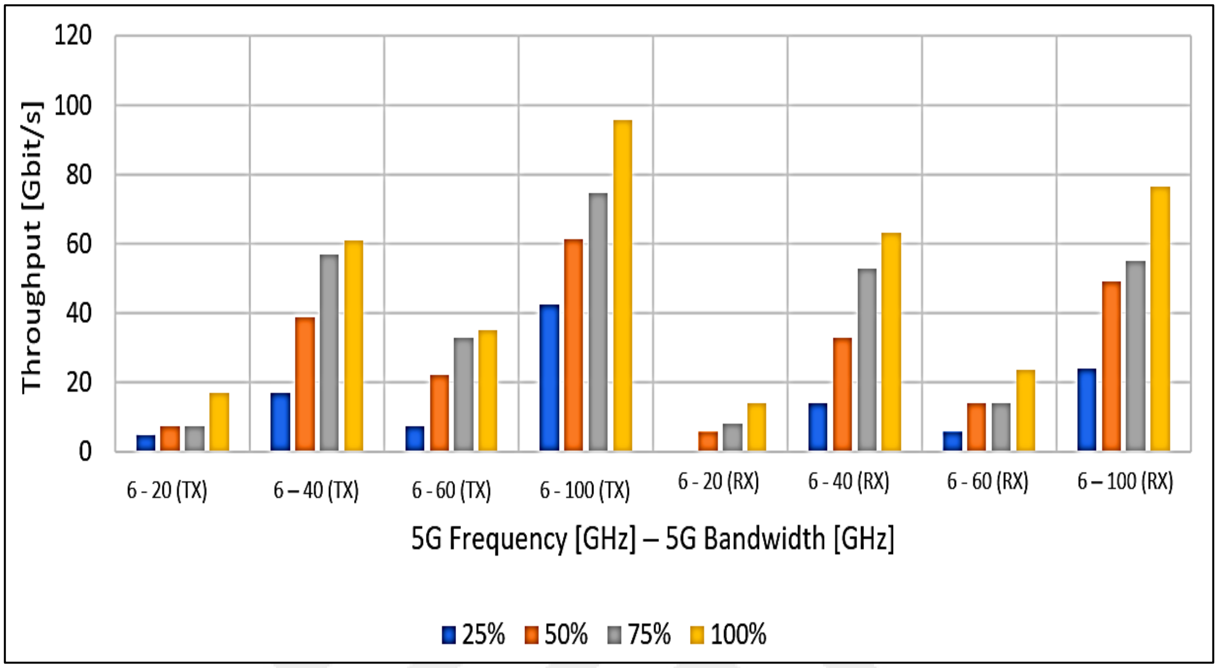

Figure 3.3: Global antenna coverage per frequency and bandwidth from 6 to 100 GHz, for TX and RX, with different load percentages.

As would be expected, the increase in the maximum allowable antenna load percentage leads to antennas having a much higher global throughput capacity, that is, the sum of every user service's experience. From Figure 3.4 one can notice that the minimum global cell throughput capacity is close to 18 Mbit/s at 6 GHz (100% antenna load) with about 96 Mbit/s at 100 GHz.

These global antenna capacity values are far from the values provided in the literature [44], both in papers, standards and reports from different entities, i.e., far from the threshold of the several Gbit/s. This happens essentially for two reasons. The first one is that the maximum bandwidth per cell currently defined as valid by LTE is 80 GHz without considering yet the perspective of carrier aggregation. The second one is that for the spectrum considered in this thesis the vast majority of devices do not support a MIMO configuration higher than 2x2, hence cell capacity is closer to the values from the already deployed LTE networks than the ones provisioned for LTE, which typically consider mm-wave spectrum (e.g., 80 GHz) with bandwidths up to 100 GHz and MIMO order up to 64x64 in base stations (BS) and 8x8 (smartphones) or 16x16 (tablets), which are the key contributors for the global antenna capacity in the Gbit/s.

Also, comparing both frequency bands with a gap bandwidth of 20 GHz, the total antenna capacity is higher at 100 GHz than 6 GHz, which has to do with the fact there are fewer obstructions limiting the signal at 100 GHz and thus larger antenna radii, which leads to a higher number of users per antenna and cell therefore a higher antenna capacity throughput. Furthermore, the lower capacity at RX may have to do with the, also, on average, lower cell radius due to a lower LTE imposed by the model reference parameters.

3.5 ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural networks are computer networks that simulate organic brain networks (ANN). This section will cover the fundamentals of ANNs, including how to construct a feed-forward single-layer ANN, calculate the back proliferation angle drop, compute the sigmoid actuation capacity, and perform a k-overlap cross-approval [19]. Regarding the essential structure of a single-layer ANN, there are numerous nodes that function as information hubs. The enterprise implements value updates provided by data aggregation nodes across the interconnected nodes of the ANN. Each connection could be allocated a weight proportional to the importance of the information it contributes to the overall commitment.

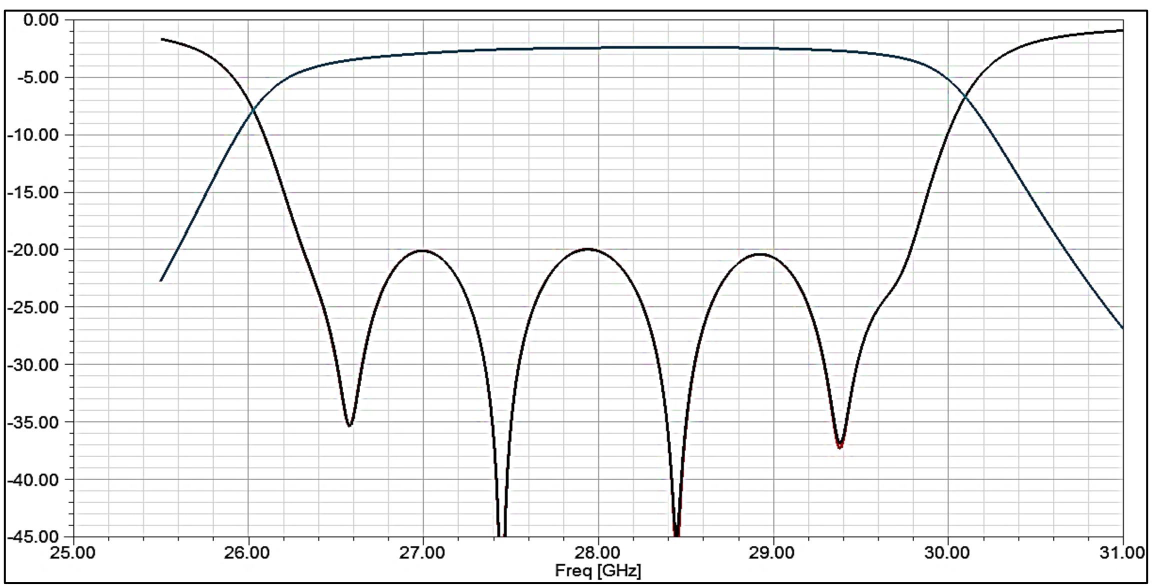

Figure 3.1: Training is represented by blue line while the loss of data is represented by black line from dataset.

Table 3.6: The parameters of training with k-cross fold of 6 GHz as well as 100 GHz using artificial neural network.

Frequency	k-Cross Fold Training	% Data Rate Coverage	
		> 10 Mbps	> 120 Mbps
6 GHz	9-Cross Fold	76.2%	48.1%
	10-Cross Fold	85.9%	59.3%
100 GHz	9-Cross Fold	87.3%	69.4%
	10-Cross Fold	98.3%	78.0%

3.6 DATASET DESCRIPTION

Lack of publicly accessible, labeled datasets that may be utilized for effective testing, evaluation, and comparison of introducing LTE in bad weather is one of the most critical ongoing issues in the development of LTE networks. Images of actual LTE networks are frequently the most informative datasets for learning about LTE environments. This information is critical since it shows client LTE traffic behaviors on a company's network as well as the network's internal design. Significant time and effort are also necessary to turn raw network traces into a labeled dataset. Recent accessibility enhancements allow this work to leverage updated versions of previously employed benchmarks.

3.7 K-FOLD VALIDATION

A trained ANN finds it extremely alluring to have the opportunity to classify data it has never seen before. If the ANN is trained to achieve 100% accuracy on the training data, the model will typically retain its integrity regardless of whether it is used in active or online mode. This is due to the fact that the error has been minimized and progress has been made toward the global minimum by adjusting the weight vectors with inclination fall. In spite of the fact that such acts may be justifiable in specific situations, elaborate flexible frameworks should be avoided. For jobs involving physical units, the capacity to summarize preparatory data is vital [26]. When a model requires extensive alterations to operate, even when given simple data, this is known as overfitting. Overfitting is when a model performs better than predicted with training data but worse with unseen data.

The validity of the assumption can be determined by plotting the cross-approval error versus the preparation phase error on a graph. Cross-approval is the most popular method for training an ANN on a publicly accessible dataset and subsequently evaluating its accuracy on a hidden dataset.

3.8 USAGE OF ANN ALGORITHM

In order to study the effects of handover validation and rainfall retention for fifth-generation networks with many more layers, a second fictitious neural architecture is presented, this time with particular enhancements. The fake neural network detected the network's size and layer count, updated the upper bound's associated recipe, and established a new upper limit for various forms of weather, such as stormy, gloomy, and humid. MATLAB was then used to refine this new boundary (Using Machine Learning Toolbox and Signal Processing Toolbox). Several decisions, like the one to begin the job and the one to compute the improvement, are specific to this endeavor and essential to achieving its objective. We utilized ANN to expedite the component extraction and determination process, which was required prior to subdividing the dataset for testing. The remaining twenty percent of the data is used as a test set.

3.9 USAGE OF APPLICATION

There is currently no specific app for 5th generation businesses that examines the impact of air and rain input and verifies handovers. Displays the program that was developed and created specifically for validating handovers and testing the functionality of 5G networks. This application utilizes the dataset to demonstrate how a fictitious neural network can be used to forecast the weather in three various scenarios, including stormy, overcast, and wet conditions. This application also demonstrates how development in the accuracy of artificial neural network models can be hampered by a considerable increase in the number of layers and the pursuit of high precision. Given that MATLAB R2019a has both an AI toolkit and a sign handling toolkit, we were able to accomplish this exam task with confidence and proficiency.

4. RECOGNITION RESULTS

ANN is the computational gold standard when it comes to identifying and organizing disruptions in this dataset. Before anything else, its precision is unparalleled compared to other mathematical techniques. Not only is the turnaround time for the completed work rapid, but so is the entire procedure. As the subset's complexity decreases, the calculation speed increases. The times required to do various computations are essentially equal. Irregular Forest has the longest execution time due to the way it constructs trees to examine options.

4.1 EXPERIMENTAL SETUP

In this section, we evaluated the artificial intelligence (AI) calculation (ANN) and signal processing toolbox while addressing two limitations. Regarding velocity and time, they are precise within a few seconds. The examination is administered on a Windows machine running MATLAB R2019a with 12 GB of RAM and a 3.2 GHz Intel Core i7 processor. After conducting a number of experiments with the simulated brain structure, we are now in a position to share our findings. Our dataset was used to simulate the architecture of neural networks. All studies were conducted on an AMD Magny Cours with 12 processing cores and an NVIDIA Tesla C2050 GPU (4 centers each). Everything necessary for the premiere of the fake neural network was created. We utilized hyper-boundaries with the help of the system's default signal processing tool to improve the separation between spaces. With Keras's assistance, we were only given 100 years to prepare, and we were required to include an early termination clause. This ensures that the model is uniquely created until the score on the validation set stops declining, hence preventing the training set from being overfit.

4.2 PILOT STUDY RESULTS

Using artificial neural networks (ANNs) and the parameter settings of antennas operating in the LTE frequency spectrum, we discovered an atmospheric absorption of LTE networks and weather excess foliage loss, in addition to the impact on performance plus network coverage under multiple handover authentication (mid-band sub 6GHz and 100GHz). Matlab is predominantly employed for analysis and efficient generation. Specifically, the number of base stations required to provide appropriate coverage and/or capacity in a given area will be determined using the estimated cell radius at the coverage and/or capacity evaluation level. In network planning, the former holds precedence over the latter unless the network capacity is exceeded, in which case the capacity computed cell radius is favored. However, throughput and peak concurrent user counts are estimated by capacity analysis.

This section's objective is to examine how modifying a network's antenna radius and total number of antennas affects its spectrum configuration in terms of frequency, bandwidth, and total number of antennas. Numerology, which consists of several LTE factors, can have an effect on the antenna radius, which is derived using the maximum route loss and path loss provided by the propagation model. For example, a 100 GHz LTE frequency band will generate a greater range than a 6 GHz frequency band because the former has a lower essential sensitivity power. Figures 4.1 and 4.2 present simulation findings for both frequency bands utilizing the same bandwidth value from 6 to 100 GHz under cloudy, rainy, and humid conditions.

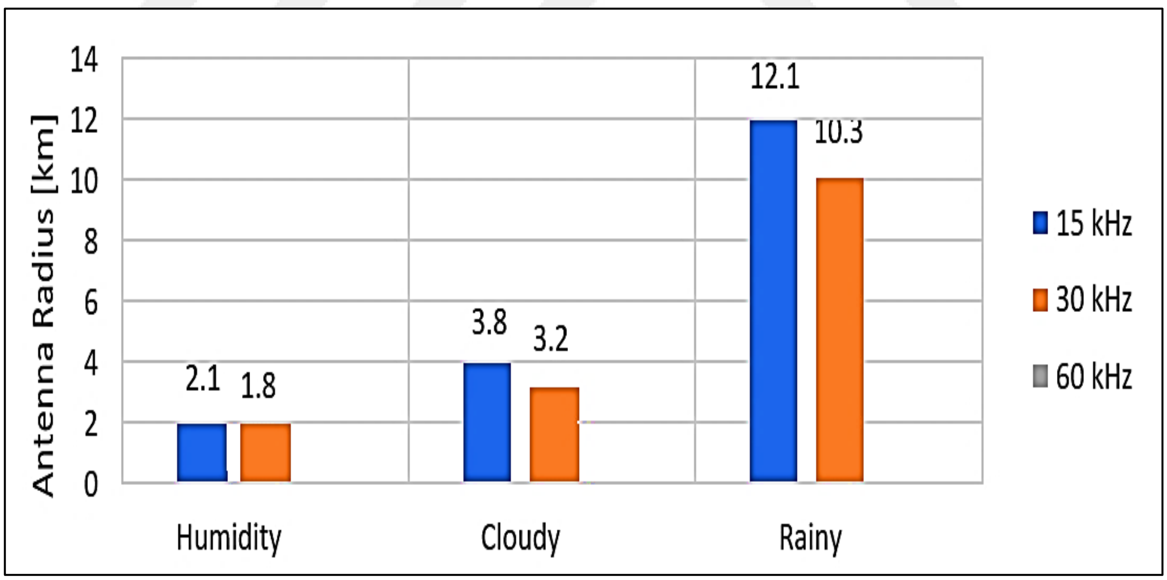

Figure 4.1: Maximum antenna delay root cause analysis on LTE radius per type of weather (6 GHz / 1 – 60 kHz).

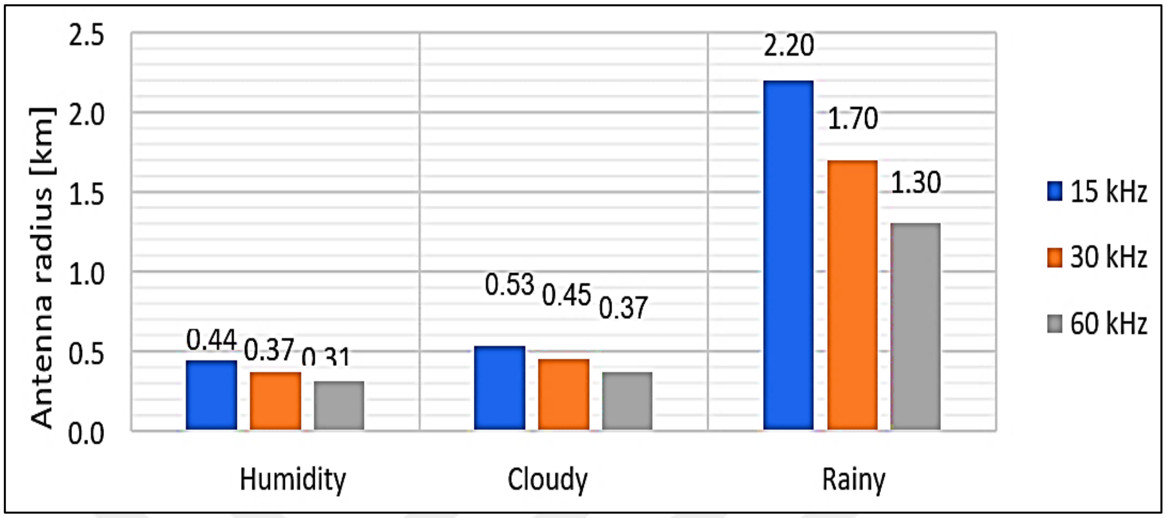

Figure 4.2: Maximum antenna delay root cause analysis on LTE radius per type of weather (100 GHz / 1 – 60 kHz).

As expected, the cell range reduces as the numerology arrangement grows, and the maximum cell sweep is greater for the 6 GHz band and lower for the 100 GHz band under the same climatic conditions. Figure 4.3 displays the outcomes of a comparison of the cell requirements of the two recurrence groups, taking into account the enormous data transfer capacity values characteristic of LTE. In this work, we evaluate all feasible numerology designs in light of the constraints imposed by LTE and determine the total number of cells that utilize the model reference boundaries for each transmission capacity value.

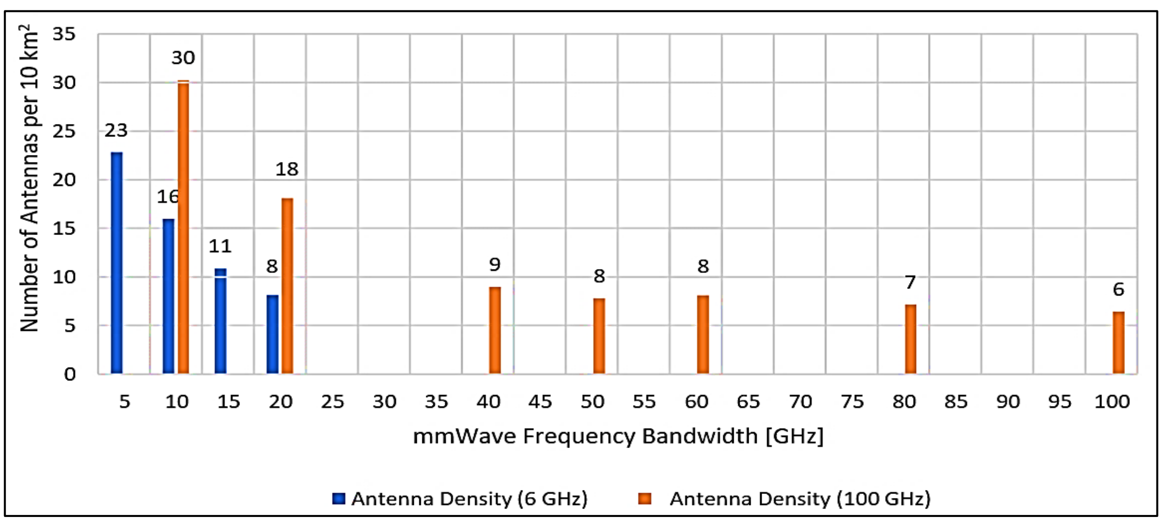

Figure 4.3: Number of antennas per 10 km^2 for the LTE frequency bandwidth between 6 to 100 GHz.

The bandwidth capacity of a cell impacts the number of users it can accommodate. Figure 4.3 illustrates, for both frequency bands, the decrease in antenna density as bandwidth rises. Due to the increased capacity of each antenna, fewer iterations (such as cycles of lowering the antenna radius) will be necessary to determine the ideal antenna radius that satisfies both the edge throughput and overall capacity requirements.

This thesis concludes that, for the traffic profile analyzed, increasing bandwidth beyond a certain threshold is futile, or that, beginning at 6 GHz, the change in antenna density is not notably noticeable. This may suggest that for this particular traffic profile, an operator does not require more than 100 GHz to reach an acceptable cost-to-service ratio. Consistent with commonsense, the higher frequency (100 GHz) requires more cells to provide the same throughput as the lower frequency (6 GHz).

Due to reduced indoor and outdoor path loss attenuation, the average cell radius at the lower frequency is bigger, despite serving the same traffic profile as the higher frequency. This indicates why spectrum in lower frequency bands is more expensive: fewer cells may be deployed in the same geographic target region.

4.3 MEASUREMENT WITHOUT DELAY ON LTE NETWORK

as a consequence of being absorbed by the air The usual pathloss measurement for throughput is 100 MHz. To make things simple, we will assume that the bandwidth multiplies by two anytime the pathloss value doubles. Due to the impact of band guards on higher orders of pathloss in LTE, the throughput factor produced by multiplying the 6 GHz throughput curve by a value other than 1.0 is not always true. Due to the inclusion distance criterion, the model is flexible enough to support any pathloss configuration, but only the most distant one is evaluated. To reiterate, inclusion assessment and maximum throughput at the cell boundary will always be based on pathloss 0 if pathloss TX, RX 0, 1, and 2 are specified (100 MHz). Technically, any pathloss arrangement is conceivable with LTE, but there are restrictions. Certain sets of recurrence/transfer speed are incompatible with particular numerologies, it can be argued.

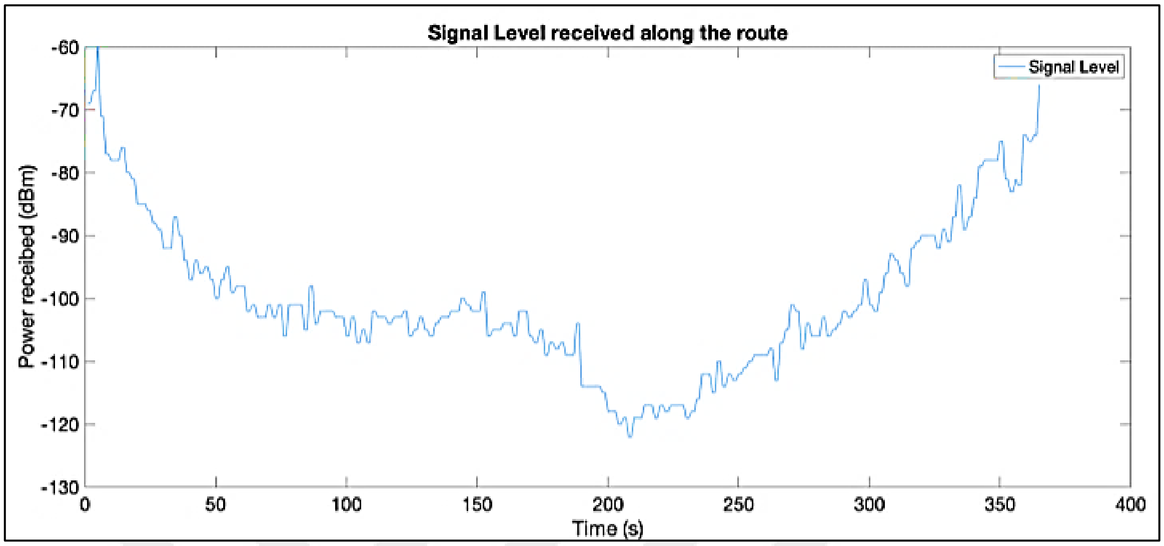

Figure 4.4: Signal level measurement for LTE network along routing the traffic without any delays.

4.4 MEASUREMENT WITH DELAY ON LTE NETWORK

The algorithm infers how much useful bandwidth is available for capacity evaluation. If it produces a situation of capacity overload the antenna re-dimensioning techniques are applied, in a first stage by reducing some services' throughput values, then by removing some services and by reducing the cell radius through the increase of the pathloss at the cell edge limit. If there is no capacity overload at a given point, the antenna is said to be coverage-limited if no traffic/radius reduction is required, and capacity-limited otherwise.

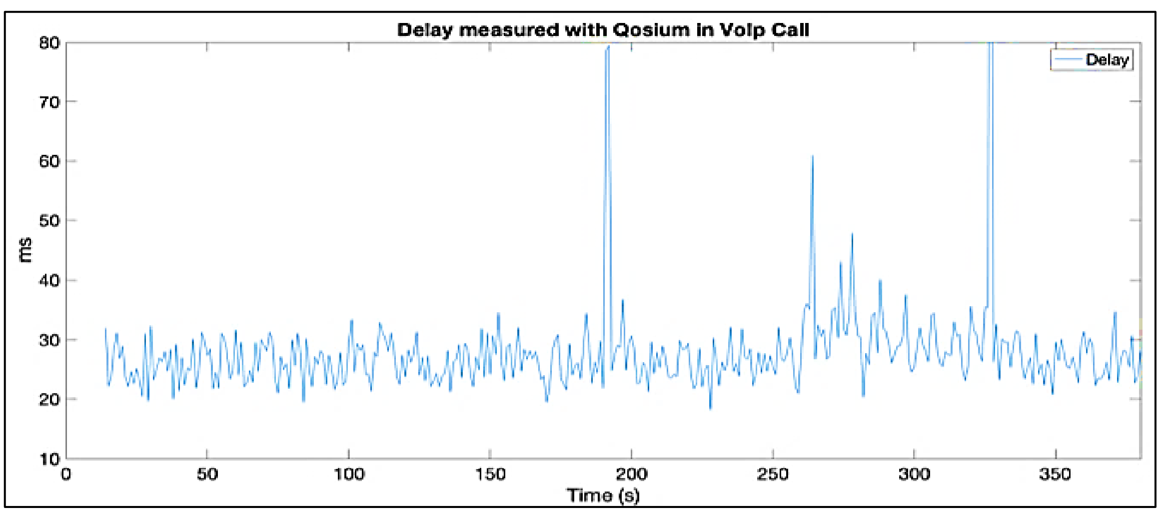

Figure 4.5: Signal level measurement for LTE network along routing the traffic with delays.

4.5 PROPOSED PARAMETER SETTINGS FOR LTE

Since the settings for LTE trend has been proposed on devices and users are consuming mobile data inside buildings, whether at home, work or any indoor facility, the percentage of users indoors is considered to be 70% in the model. The maximum service reduction defines how much of service reduction can the feasible, while still fulfilling LTE requirements. On the other hand, in cases of capacity overload the model tries to reduce first the lowest priority services', with the maximum number of services to reduce TP, and if unsuccessful it tries to remove services from the lowest priority to highest, with the maximum number of services to remove. From the valid bandwidth configurations defined by LTE. The model simulations were performed for four precise and well-defined spectrum scenarios. The throughput values for each service are the average between the minimum and maximum standardized values to provide the service with a satisfying LTE network. This allows for throughput reduction in the model in the case of capacity overload without missing the QoS level for the services.

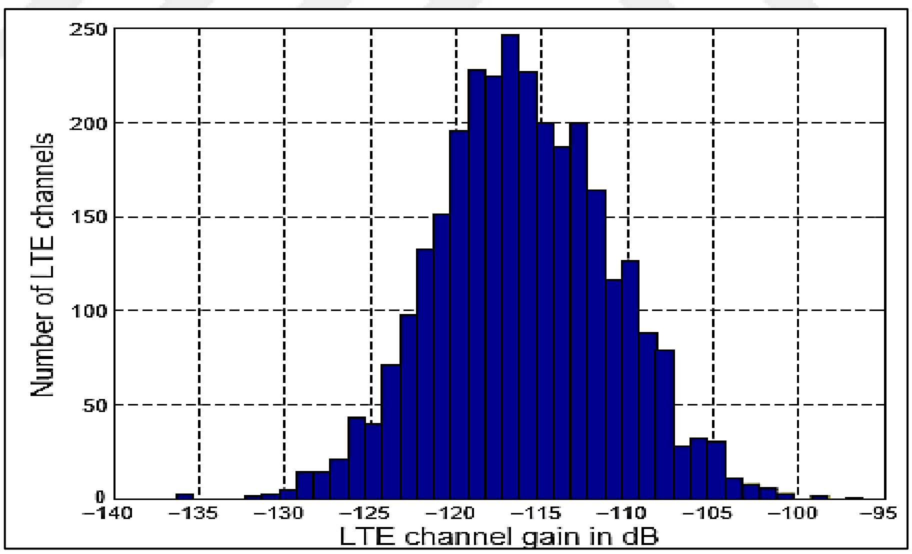

Figure 4.6: The histogram obtained in comparison with the handover authentication with high LTE frequency in channel gain.

Artificial neural network works better with multiple features as input. Since our dataset has 4 classes of elements, the calculation functions admirably. The exactness likewise relies upon the number of classes the fake neural organization calculation needs to change it over to. For our situation, the strategic capacity needs to plan between two classes. In twofold counterfeit neural organization execution, the worth set as the limit an incentive for the limit between two classes can be high which implies that it can isolate between various arrangements of information all the more precisely. Then again, there would have been numerous edges for each set of result classes assuming that there were more than 1 gathering of results. In this manner, every edge would have been lesser in esteem and the contrast between one edge an incentive for one class and one more limit worth of another class would likewise be lower. This can ultimately lead into more blunders. Consequently, for parallel fake neural organization, the odds of committing errors are lower. Along these lines, fake neural organization for our situation has a high worth of precision.

4.6 EFFECT ON PERFORMANCE AND COVERAGE

An interesting metric to assess the capacity model is whether the cell radius decreases with the increase in user density. This is tested for both frequency bands in the three environment scenarios, and the case for the urban scenario at 100 GHz is presented. The cell radius given by a zero-user density corresponds to the maximum coverage radius given in the coverage dimensioning through the link budget and propagation model, and as the user density in the cell starts increasing the capacity dimensioning is active, reducing the cell radius until it can support the traffic profile associated to having that user density value. This metric can also provide an indicator on whether the cell may be coverage or capacity limited until a user density of 100 per km2, the radius does not decrease and thus can be said to be coverage limited.

In order to assess the implementation of pathloss configurations in the model, two types of results were retrieved, one with a single-pathloss in use and another with all numerologies in use (15, 30 and 60 kHz). The goal is to inspect if LTE network operates under severe handover authentication and is lower than the higher pathloss configuration (100 MHz), nor higher than the lower SCS configuration (60 kHz), for the same user density increase profile. In the first type the distance difference between each pathloss configuration curve is constant, as it should be, since it corresponds to the 3 dB difference in the link budget between SCS bandwidth in the sensitivity power. In the second type, the initial cell radius is given by the lowest pathloss configuration of the three, the 100 MHz one, which yields the maximum coverage distance, consisting of the coverage-limited cell situation. As the user density increases the capacity dimensioning proceeds to reduce the cell radius, leading to a capacity-limited cell.

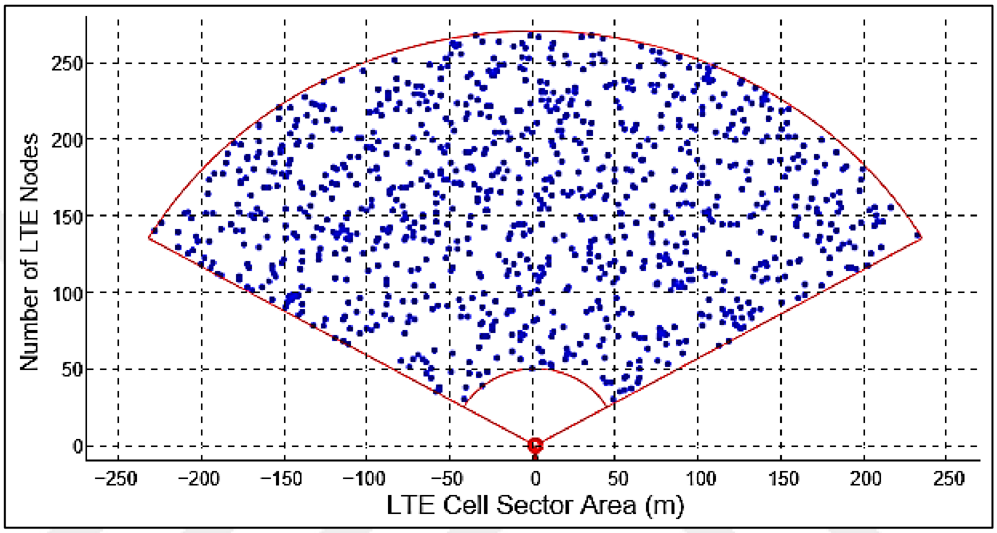

Figure 4.7: The specific attenuation of LTE sector area on the frequency band of weather from 0-250 for number of LTE nodes in the specific area.

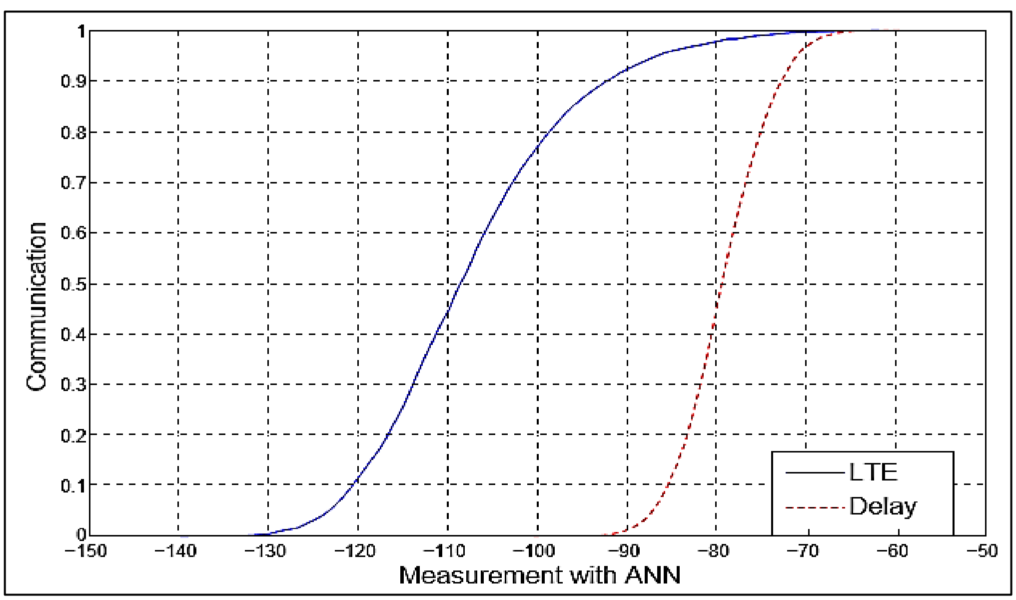

Figure 4.8: The measurement of LTE and delay spectrum using machine learning based ANN technique.

5. DISCUSSION

This thesis provides an objective and accurate examination of LTE model sizing and allows for the modification of input boundaries for various organization transmission configurations at 6 GHz and 100 GHz. As a strategy for addressing LTE network sizing, the fairness of this partnership should be self-evident; using proliferation models and precise calculations, a good result arrangement can be established. The accompanying text provides a standard exposition of the limitations of both the data and the results, as well as the proliferation models used in the inclusion ordering. In the following paragraphs, we will examine the most significant models of inclusion and limit. Beyond these fundamentals, other factors include the traffic density/volume and offer/blend profile throughout a typical workday.

As a first step, we employ the interface finance plan and proliferation models to determine the maximum cell distance from the information borders, given the reference throughput. Next, based on the traffic profile, the largest organization load is identified, and an assessment cell span is created for the various generating scenarios so that the phone density arrangements may be reconstructed [36]. Because pathloss is affected by distance, handover verification, precipitation, and air, the impacts of sub-6GHz versus 100GHz vary depending on the weather. By boosting the sending power and communicating efficiency, the system has decreased spatial complexity. It is possible to allow and legitimize the use of ANN-based LTE recurrence for both mid-band sub-6 GHz and 100 GHz thanks to its planning and development using open-source materials and a strategy with high transmission power and high transmission rate under uncertain handover verification using MIMO input/yield radio wires.

5.1 LTE COVERAGE AND CAPACITY ASSESSMENT

The coverage evaluation has begun with a comparison between the manual Excel calculations of route loss and propagation distance and the simulator's findings. Then, for both propagation models and depending on a number of input parameters including the needed throughput at the cell edge, the base station, and the heights of the mobile terminals, the cell radius did shift as the frequency range increased. As anticipated, the cell radius shrunk when LTE was improved (from QPSK to 256-QAM), and it shrunk even further when the high-loss indoor pathloss model was used instead of the low-loss indoor route loss model. The result was an increase in cell number and frequency range.

Using Excel and a comparison of model results, we have begun validating the uniqueness of the process of randomly allocating users in each LTE region and the number of antennas required by each user in terms of numerologies and LTE curves, given the user's throughput requirement and available throughput configurations. Increases in overall service throughput values led to an increase in the number of allocated antennas and bandwidth, whereas increases in user density increased the number of users per cell. As anticipated, the throughput at the cell edge doubles when the allocated bandwidth doubles, and the cell radius decreases as user density rises, demonstrating the cell radius reduction process. The radius of a cell is never greater than the distance achieved using only the lowest numerology configuration, which provides the longest distance, and it is never smaller than the distance obtained using only the highest numerology configuration, which yields the smallest distance.

Table 5.1: Comparison with the previous study with respect to different services of LTE network

LTE Class	Services	LTE Throughput [Mbit/s]			
		[5]		[9]	
		Min	Max	Min	Max
Conversational	Beamforming	0.032	0.064	0.032	0.064
	Pathloss	0.064	0.384	0.064	0.384
Interactive	Streaming	1	90	1	90
	Browsing	1	10	1	5
	Networks Computing	1	150	1	10
Background	Servers	1	5	1	5

5.2 ANALYSIS OF MACHINE LEARNING BASED SIMULATOR

The simulator has the purpose of providing a generic dimensioning tool with a certain degree of abstraction, i.e., a number of assumptions are considered in order to reduce the overall model complexity, such as assuming that users are uniformly distributed in the cell or that all numerologies in the model input configuration are always available for capacity processing independently of user location and distance to the base station, while the sensitivity power restricts the use of some LTEs to a certain distance base station. A user uniform distribution in the cell assumption is limited in one aspect. The area corresponding to the LTE region of frequency band from 6 to 100 GHz is always higher than the others, e.g., 16-QAM, which leads to having a much higher number of users within the LTE region of LTE and since it is the farthest LTE region from the base station, the SNR value is much lower, which requires much more signals to serve these users. The consequence of this assumption is that the number of antennas computed in the model is tangentially considerably higher than the ones in real-life cells, and with lower cell radii due to cell reduction iterations this means the number of cells outputted by any simulation may very likely be higher than the one for a real-life scenario.

5.3 INVESTIGATION OF LTE HANDOVER AUTHENTICATION

The fraction of cells with radii less than 500 m grows from 52.4% to 66.6% as the frequency increases, as seen by the antenna radius histogram for both frequency bands. To validate the simulation results, a brief comparison is performed between the results from [17] at 6 GHz and the data from Section 4.3 at 100 GHz. The traffic profile and available capacity remain unchanged with the exception of minor modifications such as the LTE frequency bandwidth. In contrast, the number of cells per 10 km2 for LTE at 6 GHz is 32, 16, and 1 in accordance with the increase in antennas as the frequency increases; for LTE at 100 GHz, the corresponding numbers are 38, 23, and 2.

The correlation between active device density and the number of needed cells is investigated. The baseline scenario includes an initial penetration of 15%, an average usage of 10%, and 1.5 devices per user [33]. Multiplying these two metrics yields the reference% for the network's population density, and the number of cells growth factor is used to determine the effect of a change in this product on the needed number of cells. For a bandwidth value of 100 GHz, an empirical relationship is discovered: a 2, 4, or 8-fold increase from the reference provides a 2, 4, and 5.5 (for humidity) / 7.3 (for rainy, cloudy) increase, respectively. Regardless of the actual interpolation parameters, the anticipated increase in the number of cells is often proportional to the increase from the base example.

6. CONCLUSION

6.1 CONCLUSION

The extent of this examination is past the activities of fifth era networks as we decided its use and standards under the extreme handover validation. This study has noticeable quality since it is best in class work performed under the examination boundaries of fifth era organizations. Consequently, we proposed the LTE for mid-band sub 6-GHz and 100GHz utilizing the fake neural organization in view of the dataset gained. This theory gives an examination of LTE innovation dimensioning as evenhanded for various handover confirmation, while additionally allowing changes in input boundaries for various organization arrangement setups for LTE recurrence transmission capacity from 6 GHz to 100 GHz for three different climate types. This cycle should be visible as an undeniable level way to deal with LTE network examination under various environmental circumstances, where by the utilization of proliferation models of LTE network utilizing signal handling tool kit and explicit AI based ANN calculation from AI tool stash in MATLAB R2019a. Besides, a few varieties with regards to traffic profile are performed, as far as administration throughput, administration share rates and different traffic profile setup partakes in certain regions. As far as authorizing and legitimizing the utilization of ANN based LTE recurrence for both mid-band sub 6-GHz and 100-GHz is conceivable in light of its planning and advancement with the open-source material and philosophy with high transmission power as well as high transmission rate under dubious handover validation utilizing MIMO input/yield receiving wires utilized. The pathloss is certainly impacted by distance and handover confirmation, downpour and air, in such manner the boundaries of sub-6GHz versus 100GHz on the kinds of climate. The strategy has streamlined the spatial variety by upgrading communicating power and sending effectiveness.

6.2 FUTURE RECOMMANDATION

Recommendations for future work include expanding the scope of this study to include additional services or classes of services, such as vehicular, which would require different propagation modes, and developing an algorithm to determine the optimal spectrum configuration for the LTE atmospheric characteristics in a given set of municipalities. This thesis simplifies the relationship between throughput and LTE and operates under the assumption that all numerologies have the same capacity, independent of the longest coverage distance they can attain due to variances in their power sensitivity. Other difficulties, including as interference and carrier aggregation, which could provide exciting results with the larger bandwidths available in the 100 GHz spectrum, have been largely disregarded.

REFERENCES

[1] H. Huang; A. Cai; S. Chen; Z. Zhang. Transmit power optimization for amplify-and-forward relay networks with reduced overheads. IEEE Trans. Veh. Technol, vol. 11, pp. 5033–5044, 2016.

[2] Y. Liang; S. Durrani.; A. Liang; Z. Wang. Enabling Technologies for LTE Mobile Systems. Mob. Inf. Syst. 2016, 2016, 1945783, vol. 21, pp. 33–47, 2017.

[3] I. Hossain; Z. Hasan. LTE cellular: Key enabling technologies and research challenges. IEEE Instrum. Meas. Mag. vol. 4, pp. 133–145, 2015.

[4] U. Akyildiz; S. Nie; A. Chandrasekaran. LTE roadmap: 10 Key enabling technologies. Comput. Netw vol. 6, pp. 235–248, 2017.

[5] I. Khawam; Q. Lahoud; A. Ibrahim; S. Yassin; H. Martin. Radio access technology selection in heterogeneous networks. Phys. Commun. vol. 7, pp. 633–644, 2016.

[6] K. Gachhadar; K. Hindia; W. Qamar; I. Siddiqui. Modified genetic algorithm based power allocation scheme for amplify-and-forward cooperative relay network. Comput. Electr. Eng. vol. 14, pp. 533–549, 2018.

[7] K. Noordin, K. Hindia. Power Allocation Scheme Using PSO for Amplify and Forward Cooperative Relaying Network. In Science and Information Conference; Springer: Cham, Switzerland, vol. 9, pp. 455–457, 2019.

[8] K. Rappaport; E. Sun; L. Mayzus. Millimeter wave mobile communications for LTE cellular: It will work! IEEE Access vol. 12, pp. 53–54, 2015.

[9] K. Rappaport; S. Sun.; M. Shafi, MLTE Channel model with improved accuracy and efficiency in LTE bands. IEEE LTE Tech. Focus vol. 05, pp. 503–508, 2017.

[10] Rappaport; Sun, Shafi, Investigation and comparison of LTE and NYUSIM channel models for LTE wireless communications. vol. 19, pp. 3–5, 2016.

[11] S. Sun.; T. Rappaport, D. Shafi. Hybrid beamforming for LTE millimeter-wave multi-cell networks. vol. 5, pp. 543–547, 2017.

[12] S. Mogensen; F. Pajukoski; T. Tiirola. Centimeter-wave concept for LTE ultra-dense small cells. In Proceedings of the 2014 IEEE 79th Vehicular Technology Conference, Seoul, South Korea, vol. 11, pp. 23–28, 2015.

[13] M. Ahmad, "4G and LTE wireless: how they are alike and how they differ", 2015, June.

[14] NGMN Alliance and M. Iwamura, “NGMN View on LTE Architecture”, May 14, 2015.

[15] O. Galinina, “LTE Multi-RAT LTE-Wi-Fi Ultra-Dense Small Cells: Performance Dynamics, Architecture, and Trends”, ‘IEEE Journal on Selected Areas in Communication’, Vol. 33, Issue 6, pg. 1224-1240, June 2015.

[16] P. Sharma, “Evolution of Mobile Communication Networks-1G to LTE as well as Future Prospective of Next Generation Communication Network”, Referred to ‘International Journal of Computer Science and Mobile Computing’, IJCSMC, Vol. 2, Issue. 8, pg.47 – 53, August 2013.

[17] P. K. Agyapong, M. Iwamuru, et al., “Design Considerations for a LTE Network Architecture”, ‘IEEE Communications Magazine’, Vol. 52, Issue 11, pg. 65 – 75, November 21, 2014.

[18] S. Patil, Patil, V. Patil, P. Bhat, “A Review on LTE Technology”, ‘International Journal of Engineering and Innovative Technology’, IJEIT, Volume 1, Issue 1, January 2012.

[19] S. Singh, Y. C. Chiu, Y. H. Tsai, J. S. Yang, “Mobile Edge Fog Computing in LTE Era: Architecture and Implementation”, ‘International Computer Symposium (ICS)’, Dec 15 – 17, 2016.

[20] W. X. Cheng, F. Haider, et al., “Cellular architecture and Key Technologies for LTE Wireless Communication Networks”, Pages 122 – 130, February 19, 2014.

[21] Y. Choi, J. Kim, N. Park, “Revolutionary Direction for LTE Mobile Core Network Architecture”, ‘Information and Communication Technology (ICTC), 2016 International Conference’, Oct 19-21, 2016.

[22] Y. Taewhan, “Network Slicing Architecture for LTE Network”, ‘Information and Communication Technology Convergence (ICTC), 2016 International Conference’, Oct 19-21, 2016.

[23] Y. Fadlallah, A. Tulino, et al., “Coding for Caching in LTE Networks”, ‘IEEE Communications Magazine’, Vol. 55, Issue. 2, February 2017.

[24] Z. Houman, “Waveform Generation, Simulation, Measurement and Over-the-air Testing with MATLAB”.

[25] T. Riihonen, S. Werner, and R. Wichman, “Optimized gain control for singlefrequency relaying with loop interference,” IEEE Transactions on Wireless Communications, vol. 8, no. 6, pp. 2801–2806, Jun. 2009.

[26] T. Riihonen, S. Werner, and R. Wichman, "Hybrid full-duplex/half-duplex relaying with transmit power adaptation," IEEE Transactions on Wireless Communications, vol. 10, no. 9, pp. 3074–3085, Sep. 2011.

[27] T. Riihonen, S. Werner, and R. Wichman, "Mitigation of loopback self-interference in full-duplex MIMO relays," IEEE Transactions on Signal Processing, vol. 59, no. 12, pp. 5983–5993, Dec. 2011.

[28] T. Riihonen, S. Werner, R. Wichman, and E. Zacarias B., "On the feasibility of full-duplex relaying in the presence of loop interference," in Proc. 10th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Jun. 2015, pp. 275–279.

[29] T. Riihonen, R. Wichman, and J. Hämäläinen, "Co-phasing full-duplex relay link with non-ideal feedback information," in Proc. IEEE International Symposium on Wireless Communication Systems (ISWCS), Oct. 2015, pp. 263–267.

[30] I. Rodriguez, H. C. Nguyen, N. T. K. Jørgensen, T. B. Sørensen, J. Elling, M. B. Gentsch, and P. Mogensen, "Path loss validation for urban micro cell scenarios at 3.5 GHz compared to 1.9 GHz," in Proc. IEEE Global Communications Conference (GLOBECOM), Dec. 2013, pp. 3942–3947.

[31] W. Roh, J. Y. Seol, J. Park, B. Lee, J. Lee, Y. Kim, J. Cho, K. Cheun, and F. Aryanfar, "Millimeter-wave beamforming as an enabling technology for LTE cellular communications: Theoretical feasibility and prototype results," IEEE Communications Magazine, vol. 52, no. 2, pp. 106–113, Feb. 2014.

[32] F. Rusek, D. Persson, B. K. Lau, E. G. Larsson, T. L. Marzetta, O. Edfors, and F. Tufvesson, "Scaling up MIMO: Opportunities and challenges with very large arrays," IEEE Signal Processing Magazine, vol. 30, no. 1, pp. 40–60, Jan. 2013.

[33] A. Sabharwal, P. Schniter, D. Guo, D. W. Bliss, S. Rangarajan, and R. Wichman, "In-band full-duplex wireless: Challenges and opportunities," IEEE Journal on Selected Areas in Communications, vol. 32, no. 9, pp. 1637–1652, Sep. 2014.

[34] A. Sahai, S. Diggavi, and A. Sabharwal, "On degrees-of-freedom of full-duplex uplink/downlink channel," in Proc. IEEE Information Theory Workshop (ITW), Sep. 2013.

[35] A. Sahai, G. Patel, C. Dick, and A. Sabharwal, "Understanding the impact of phase noise on active cancellation in wireless full-duplex," in Proc. 46th Asilomar Conference on Signals, Systems and Computers (ASILOMAR), Nov. 2012, pp. 29–33.

[36] A. Sahai, G. Patel, C. Dick, and A. Sabharwal, “On the impact of phase noise on active cancelation in wireless full-duplex,” IEEE Transactions on Vehicular Technology, vol. 62, no. 9, pp. 4494–4510, Nov. 2013.

[37] J. Sangiamwong, T. Asai, J. Hagiwara, Y. Okumura, and T. Ohya, “Joint multifilter design for full-duplex MU-MIMO relaying,” in Proc. 69th IEEE Vehicular Technology Conference (VTC Spring), Apr. 2009.

[38] M. G. Sarret, M. Fleischer, G. Berardinelli, N. H. Mahmood, P. Mogensen, and H. Heinz, “On the potential of full duplex performance in LTE ultra-dense small cell networks,” in Proc. 24th European Signal Processing Conference (EUSIPCO), Aug. 2016, pp. 764–768.

[39] M. Schoukens, R. Pintelon, and Y. Rolain, “Parametric identification of parallel Hammerstein systems,” IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 12, pp. 3931–3938, Dec. 2011.

[40] C. Y. A. Shang, P. J. Smith, G. K. Woodward, and H. A. Suraweera, “Linear transceivers for full duplex MIMO relays,” in Proc. Australian Communications Theory Workshop (AusCTW), Feb. 2014, pp. 11–16.

[41] C. E. Shannon, “A mathematical theory of communication,” Bell System Technical Journal, vol. 27, no. 3, 1948.

[42] S. Shao, X. Quan, Y. Shen, and Y. Tang, “Effect of phase noise on digital self-interference cancellation in wireless full duplex,” in Proc. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), May 2014, pp. 2759–2763.

[43] A. Sharma, R. K. Ganti, and J. K. Milleth, “Joint backhaul-access analysis of full duplex self-backhauling heterogeneous networks,” IEEE Transactions on Wireless Communications, vol. 16, no. 3, pp. 1727–1740, Mar. 2017.

[44] P. F. Sielman, “A single-frequency communications system,” IEEE Transactions on Vehicular Technology, vol. 23, no. 1, pp. 1–8, Feb. 1974.

[45] M. S. Sim, M. Chung, D. K. Kim, and C. B. Chae, “Low-complexity nonlinear self-interference cancellation for full-duplex radios,” in Proc. IEEE Globecom Workshops, Dec. 2016.

[46] S. Simoens, O. Munoz-Medina, J. Vidal, and A. del Coso, “On the Gaussian MIMO relay channel with full channel state information,” IEEE Transactions on Signal Processing, vol. 57, no. 9, pp. 3588–3599, Sep. 2009.

[47] R. Simpson and G. Tyler, “Radar scattering laws for the lunar surface,” IEEE Transactions on Antennas and Propagation, vol. 30, no. 3, pp. 438–449, May 1982.

[48] N. Singh, D. Gunawardena, A. Proutiere, B. Radunovic, H. V. Balan, and P. Key, “Efficient and fair MAC for wireless networks with self-interference cancellation,” in Proc. International Symposium of Modeling and Optimization of Mobile, Ad Hoc, and Wireless Networks (WiOpt), May 2011, pp. 94–101.

[49] A. Sabharwal, P. Schniter, D. Guo, D. W. Bliss, S. Rangarajan, and R. Wichman, “In-band full-duplex wireless: Challenges and opportunities,” IEEE Journal on Selected Areas in Communications, vol. 32, no. 9, pp. 1637–1652, Sep. 2014.

[50] Panda, M.; Abraham, A.; Patra, M.R. Discriminative multinomial naive Bayes for network human communication. In Proceedings of the 2017 Sixth International Conference on Information Assurance and Security, Atlanta, GA, USA, 23–25 August 2017; pp. 5–10.

[51] Hussain, J.; Lalmuanawma, S.; Chhakchhuak, L. A two-stage hybrid classification technique for network human communication system. Int. J. Comput. Int. Syst. 2016, 9, 863–875.

[52] Ahmim, A.; Derdour, M.; Ferrag, M.A. An human communication system based on combining probability predictions of a tree of classifiers. Int. J. Commun. Syst. 2018, 31, 14.

[53] Demir, N.; Dalkilic, G. Modified stacking ensemble approach to detect network intrusion. Turk. J. Electr. Eng. Comput. Sci. 2018, 26, 418–433.

[54] I. Rodriguez, H. C. Nguyen, N. T. K. Jørgensen, T. B. Sørensen, J. Elling, M. B. Gentsch, and P. Mogensen, “Path loss validation for urban micro cell scenarios at 3.5 GHz compared to 1.9 GHz,” in Proc. IEEE Global Communications Conference (GLOBECOM), Dec. 2013, pp. 3942–3947.

[55] T. Riihonen, S. Werner, and R. Wichman, “Mitigation of loopback self-interference in full-duplex MIMO relays,” IEEE Transactions on Signal Processing, vol. 59, no. 12, pp. 5983–5993, Dec. 2011.