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Electronics and Communication Engineering

Minor Project Report

on

Simulate and Analyse 5G Network Slicing using Open-source Software for different Use-cases

By:

1. **Prateek Patil** USN: 01FE19BEC058
2. **Adnan Ladji** USN: 01FE19BEC252
3. **Yash Mahale** USN: 01FE19BEC265
4. **Suraj Baddi** USN: 01FE19BEC268

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Under the Guidance of

Prof. Shamshuddin K

Prof. Naveen K N

K.L.E SOCIETY'S
KLE Technological University,
HUBBALLI-580031
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SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to attest to the fact that the project titled " **Simulate and Analyse 5G Network Slicing using Open-source Software for different Use-cases**" is a bonafide work carried out by the student team of " **Prateek Patil [01FE19BEC058], Adnan Ladji [01FE19BEC252], Yash Mahale [01FE19BEC265], Suraj Baddi [01FE19BEC268]** ". The project report has been authorised since it meets the standards for the Minor project work provided by the university curriculum for BE (VI Semester) in KLE Technological University's School of Electronics and Communication Engineering for the academic year 2021-2022.

Shamshuddin K/Naveen K N	**Dr. Nalini C. Iyer**	**N. H. Ayachit**
Guide	**Head of School**	**Registrar**

External Viva:

Name of Examiners | **Signature with date**

1. Dr. S. R. Nirmala — 19/5/2022
2. Dr. Rajendra

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ABSTRACT

Due to developing markets, there has been a large growth in users or subscribers, as well as a wide array of use cases in recent years. To satisfy the growing demand, the operable spectrum for base stations should be extended to accommodate more users with high data rates. The development of the 5G network is more difficult since it must cater to multiple needs at the same time while employing a common infrastructure. The attenuation of the signal rises when the frequency is increased. After a specific threshold, the signal's power cannot be increased. As a result, the frequency range used and signal attenuation must be balanced. Milimeter Waves, Small-cell, Massive MIMO, and Beamforming are some of the technologies needed to efficiently offer 5G networks. The key foundation for 5G implementation is network slicing, which allows for diverse and possibly opposing quality of service or QoS requirements. Each slice has an SLA(Service level agreement) defined which allows monitoring of whether the required SLA is met.

Network slicing is an end-to-end approach that uses similar infrastructure to cover all current network blocks while creating numerous logical networks with varied QoS requirements. The principal network that formed the initial connection between the user and the base station is RAN slicing, which is the section between the client and the base station. We will investigate and simulate the various 5G use cases in this article, including eMBB for high data rate, uRLLC for low latency, and mMTC for more subscribers. To simulate the different parameters of the RAN Slicing, we used Slicesim, an open-source software.

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Introduction

Every ten years, the wireless infrastructure of the cellular industry undergoes a substantial change as shown in figure 1.1. Briefcase-sized phones and short text messages between small number of professionals defined the 1G era. In the years preceding up to 2G, demand for mobile services grew dramatically and has never slowed. The 3G era was defined by wallet-sized phones, SMS, and mobile internet access. Thanks to 4G, Nowadays we have smart phones, app stores, YouTube etc. Now it is time for 5G. By including new technologies like autonomous cars, augmented reality, virtual reality, and enhanced video and gaming, 5G is now completely transforming both our professional and personal lives. It's worth noting that, unlike previous generations, 5G isn't projected to overtake 4G. Many applications, such as normal mobile phone conversations and low-data transactions, will continue to be carried over a 4G network, with 5G primarily being used for large-computing and low-latency applications.

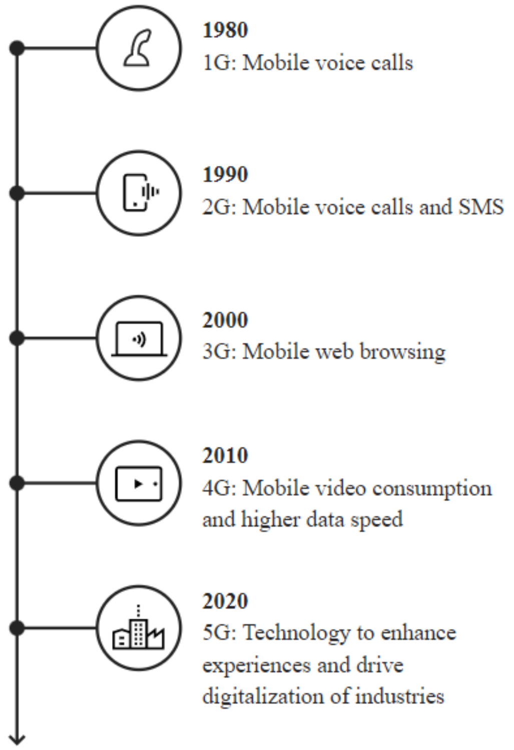

Figure 1.1: Evolution of Network over years

Given the speed and adaptability it will offer to networks, 5G will be a vital element for the Internet of Things (IoT) to take off. Because it uses the 30 GHz to 300 GHz band, 5G provides a number of advantages over 4G:

1. Increasing the speed : Peak 5G speeds of up to 10 Gigabits/sec are expected to be ten times faster than 4G.

2. Lower Latency : 5G has a latency of less than 1 millisecond, compared to 10 to 50 milliseconds for 4G.

3. Greater capacity : 5G networks will be able to support a greater number of connected devices, up to one million per square kilometre, according to some estimates.

5G comes up with the five different technologies which include Millimetre waves (mm Waves), Small cells, massive MIMO, Beam-forming, and Full duplex. Today's wireless network technology faces a hurdle that is because more customers and devices are utilizing much data than it has ever been, there is minimum bandwidth left for everyone, leading to delayed service and more interrupted connections. As a consequence, network operators are experimenting with new technology such as Millimetre waves, which are more powerful than radio waves in terms of frequency and range from 30 to 300 gigahertz, as opposed to the bands below 6 GHz that is the area which previously had been reserved for mobile phones. Millimetre waves, on the other hand have a significant drawback: they face difficulty in penetrating through buildings or objects, and they can be taken up by plants and rainfall. Therefore in 5G networks, traditional cellular towers will almost probably be complemented with a upcoming innovation called as small cells. These are the tiny base stations that can be placed every half a mile or more throughout cities and use very little power to operate. Thousands of these stations might be deployed throughout a city to establish a dense network. However, as the number of base stations grows, the infrastructure required grows as well. When transmitting millimetre waves, antennas on small cells can be significantly smaller than standard antennas. Because of the size difference, installing cells on street lamps and buildings is even easier. Apart from transmitting via millimetre waves, 5G cell will feature significantly more number of antennas than existing mobile network base stations in order to benefit from a new system known as massive MIMO.

Nowadays 4G cell towers have a dozen antenna ports to handle all cellular traffic; however, 5G cell towers can have up to a hundred ports, allowing far more transmitters to be packed onto a single array. Massive MIMO is the name for this technique. However, if the signals overlap, Signal interference is increasingly likely as more antennae are added to handle cellular traffic. As a result, in 5G sites, beam forming is essential. Massive MIMO arrays can benefit from beamforming to make better use of the spectrum around them by selecting the most efficient route for data delivery to a single user, while also reducing disturbance for neighbouring users. Millimetre transmissions are easily blocked and fade over long distances. Instead of broadcasting in numerous directions at once, beamforming can aid by compressing a signal into a focused beam that only points in the direction of a user. Apart from these four technologies, wireless specialists are experimenting with changing the way antennas transmit and receive data to achieve the high throughput and low latency required for 5G. A 5G transceiver will be capable of sending and receiving data on the same frequency at the same time. Full duplex technology is the term for this. Full duplex technology is difficult to implement because radio waves have a tendency to flow forward and backward on the same frequency, a phenomenon called as reciprocity. Experts have developed silicon transistors that act as high-speed switches to prevent these waves from rolling backwards, allowing them to simultaneously transmit and receive signals on the same frequency.

We saw that the networks worked the same for everyone in 2G, 3G, and 4G. With 5G, it is possible to create thousands (or hundreds of thousands, there is basically no limit) virtualized and independent networks on top of the physical infrastructure, this features that distinguishes

5G from prior mobile network standards is Network Slicing, which means that an operator can, for example, build a network slice based on a customer's needs or also known as use cases. These needs be an ensuring data rate, bandwidth, fast response, level of security, or quality of service, or any combination of these. Despite the fact that the list of 5G applications appears to be endless, the majority of them fall into one of three categories as shown in figure 1.2 :

1. Enhanced Mobile Broadband (eMBB).
2. Massive Machine Type Communications (mMTC).
3. Ultra-Reliable Low Latency Communication (uRLLC).

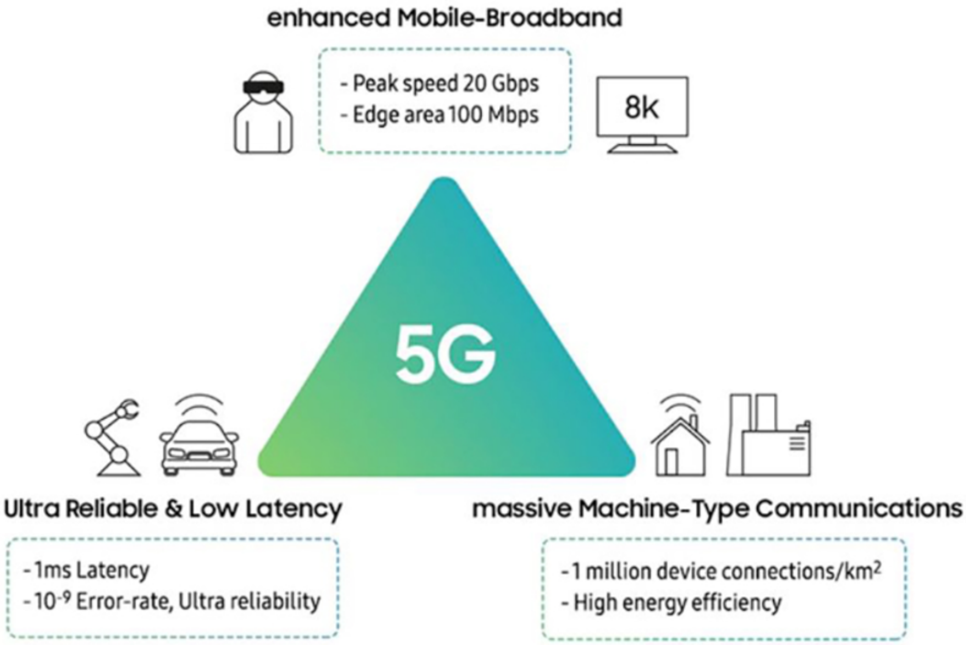

Figure 1.2: Three major use cases / 5G Triangle

1.1 Motivation

With the ever-increasing number of users and the industry as a whole, it's more important than ever to develop technology on top of existing infrastructure to fulfil a variety of needs. According to the future, each home will have several IoT devices for each duty, such as smart lights, smart security systems, smart air conditioning, and so on. These devices consume less bandwidth, but there will be more of them. In recent years, there have been more developing businesses, each with its own network specs that ISPs must support. And as the number of users accessing network resources grows, so does the demand for high data rates. The service provider must meet all of these requirements. As a result, network slicing is the most important foundation for the development of the 5G network, as it is impossible to accommodate to varied needs without it. Network slicing is a technique for creating several logical networks from a single physical network to meet a variety of market needs. Network slicing properly leverages each slice's bandwidth, ensuring that it is not wasted.

The creation of an efficient slice necessitates a greater conceptual grasp of the End-to-End network. To meet the optimum network requirements, each block in the network must be carefully studied and optimised. The ongoing demand for 5G implementation, as well as the challenges it faces, are the driving forces behind our project. Our goal is to simulate and analyse the factors involved in a slice stated in the standards, as well as to comprehend the complexities associated with its deployment.

1.2 Objectives

The following are the key objectives on which we focused:

1. To Understand the concept of 5G and Network Slicing.
2. To Explore various simulation tools available for Network Slicing.
3. To simulate 3 use-cases of 5G Network slicing.
4. To analyze the results obtained from the simulation.

1.3 Literature Survey

To start with, 4G (LTE) networks are implemented throughout the world, 5Th generation networks are based on research papers and industry level projects and networks oriented. Until 4th Generation, wireless communication networks primarily based on existence of the bandwidth availability rather focussing on the target to provide connection to bring into picture the groundwork for fast and reliable Internet access for Internet users which is kept at priority of 5g implementation, whether they are on the top of a tower. Despite the fact that the Long Term Evolution-(LTE) standard considers a good amount of variation, 5G networks are designed for machine type of communications- (MTC) to work with IOT devices. Developed to accommodate MTC like devices. The 5G networks will be a combination of technologies such as 2G, 3G, LTE, LTE A, M-2-M, and so on, instead of being a monolithic network entity, 5g mainly focuses to deliver a fast and reliable speed of data transmission, whether a person is accessing his internet from the top of the tower or sitting in the subway to bring into picture the groundwork of 5g evolution to understand the capability of the 5g applications, 5g network will be able to cover a wide range of service needs and related applications such as gaming, augmented reality Internet of Things, very low latency types of devices connected variables unlike the 4g technology, 5g is capable of handling the communication between a large number of devices as well as the variation in the traffic conditions 5g enables to provide the ability to stream for killed on any device with high data rates for networks and sensors.[1].

The latest generation of wireless technology that is 5th generation is referred to as 5G. It's the modern development of cellular technology, with the three main benefits: lower latency, faster speeds, and the possibility to connect devices in bulk at once. By the end of 2020, a l 5G wireless network is scheduled to be operational commercially. This document provides an overview of 5G wireless technology in a concise manner. It is a multipurpose wireless network capable of supporting mobile, fixed, and enterprise wireless applications. It comes with a slew of unique features that make it both powerful and in great demand in the near future. Several tests and trials must be completed before 5G can be used. The implementation of 5G on a large scale is still in its early stages. It has a bright future ahead of it and will shape the future of the mobile communication.[2].

As the Internet of Things (IoT) grows in popularity, a technology that can efficiently support enormous amounts of data transfer at very high bandwidth is required. Increased capacity, enhanced data rate, and lowered latency are some of the primary objectives or needs that must be fulfilled in the near future, i.e. next-generation IoT devices. The advancement of 5G, a next-generation wireless mobile communication technology that promises to meet the demands of complex IoT infrastructures. This article focuses on the needs that 5G can meet, as well as the architecture, benefits, and drawbacks of a 5G network. The research on this form of network has been conducted in many locations around the world, according to a complete survey on 5G capable IOT devices. [3]

Fifth-generation of wireless technology (5G) is the most modern cellular technology, designed to greatly increase the speed and responsiveness of wireless networks. The volume of data supplied over wireless systems will be significantly increased with 5G. cell sites are mainly divided into different types as data transmitted by radio waves and wireless networksThe technology of Long Term Evolution provides the base for 5g that is the fourth generation of networks is used as base for 5g, while fourth generation make use of huge high powered cells towers for the transmission of signals and data for a long distance. 5g technology on the other hand, makes use of large number of small cell stations scattered over a particular region to provide the connecting to transmit the signals and data. These small cells are being deployed because the millimeter waves can travel for a shorter distance with a spectrum between 30 gigahertz to 300 gigahertz 5g which can produce high speed can travel short distance and is exposed to interference from physical towers, buildings, trees and weather changes. With the help of 5g wireless communication can get a speed of few gigabits per second which is high compared to 4g which is even faster than landline connection. The latency observed is less than a millisecond which makes it nearly idle for real time application.. As a result of the greater bandwidth and superior antenna technology available. [4].

This research study explains thoroughly the overview of beam-forming techniques which plays a very important role in MIMO systems of massive millimeter. This study Stresses on the digital processing of signals, applications and implementations related to beam-forming. The hybrid beam-forming is classified as follows

1. Hardware hybrid beamforming.

2. Resource management.

3. A variety of architectures, antennas on Transmitters and Receivers and the analog and digital signals that are generated.

4. Hybrid beam-forming in Hetrogeneous networks and small cells.

5. Analog beam-forming matrix [5].

This article looks into the slicing concept in the 5G RAN, as well as the obstacles and research issues that come with it. The goal is to determine the most viable methods for a mobile network operator to adopt the slicing idea at the RAN level in order to meet the needs of verticals. We begin by determining the various slice granularity possibilities, or how to define slices based on a combination of customer and service requirements. We next show how 5G NR capabilities may be exploited to make slice implementation easier, as well as typical slice setups from a technology and RAN architectural standpoint. The major issues of RAN slicing are then examined, with a focus on the resource allocation problem between slices that share the same frequency band. We also look into multi-tenant situations. [6].

A mobile network's effectiveness, flexibility, and resilience are only as good as its weakest link, which is made up of a number of functional characteristics and procedures. The mobile network architecture demands special attention while evaluating the evolution of 3GPP EPS since it is the design that brings together many different innovative techniques into a single mobile network. This research looks at some of the design elements that will be important in upcoming 3GPP EPS releases, as well as the progression of 3GPP EPS mobile networks in general. This article discusses the evolution more towards a "system of functions," network slicing, and software-defined mobile service control, management, and orchestration. A detailed roadmap for the advancement of 3GPP EPS and its technological aspects is also provided.[7].

This article evaluates a variety of currently available ran architecture designed for 5g network slicing which ranges from centralized cloud RAN to the distributed edge computed cloud. All the architectures are analysed on the basis of different levels and performances are calculated on the grounds of some simulation tools, the very important concept of function virtualization and the economical and technical profits using the various random access network architectures and their comparison is also discussed.[8].

Beyond 2020, new mobile network requirements will develop as a result of the advent of new service scenarios driven by user needs. Because of basic difficulties in the Evolved Packet Core (EPC), including centralised routing mechanisms, the current 4G LTE (Long Term Evolution) network is insufficient to meet emergent new requirements. In this sense, the architecture of 5G mobile networks must be changed to accommodate new use cases. We provide a network slice architecture for a 5G core network in this study, as well as functioning methods for slice selection, NAS routing, and slice reselection, in order to support several logical networks over a single physical network. [9].

Users' differing QoS requirements are expected to be met by 5G.5G networks will allow them to adapt services to consumers' individual QoS requirements. Since the arising of huge data traffic is observed, allocation of resources need to be done efficiently. All calculations and assumptions points towards network slicing to improve the diversity of 5g networks and also the flexibility of allocation of resources. Modern techniques of mobility based management are required to ensure that there is a seamless network slicing oriented 5g network systems as the network applications are diversed, efficient strategies that are developed are joint power and subsystem channel allocation scheme with sharing of spectrum with Tier Two network slicing system, which takes the responsibility of both cotier and crosstier noise, dynamically resources are allocated between different slices of each 5g network. The results are evaluated and ultimately reconstruction, network integration with other 5g network, Management of slices are explored and challenges in network slicing are studied. [10].

5g Technology is termed as multi service connection which can help to incorporate different types of applications with different performance and needs of services. This article adds addresses and focuses more to provide a survey. The first is to provide the knowledge on the newly introduced topic 5g and its supporting technologies related to 5g implementation. It starts with current trends in 5g and network slicing and existing methodologies to implement 5g. Further it provides and introduces a framework considering the current work available and pointing out holistically then the performance of the current frameworks are evaluated and issues are identified. From the researches using the newly proposed framework. [11].

Slicesim was used to simulate and visualise the notion of network slicing for drones in this article. Different configurations were investigated, and four sub-zones were created to provide a scalable zone with multiple heterogeneous networks. The visualisation was applied to both the zone and the sub-zone. and analysis, where the results reveal that 5G network slicing allows for the implementation of independent heterogeneous networks. When compared to the network, SDN performs much worse. Derived by combining all four heterogeneous variables networks. This network has more bandwidth available, a lower load on each network slice, and a bigger number of nodes. To ensure network service, a certain number of clients must be connected. Network slicing has a lot of promising outcomes and allows for a more effective approach of managing network resources, but it is still a long way off. It has its own set of challenges that prevent it from being implemented. To be compatible with 5G networks, RANs that are now in use are needed to be redesigned and updated. For resource allocation, radio scheduling mechanisms are used. The lack of any real-world counterpart is currently the most pressing concern. Interoperability will be tested using this implementation. Future projects are possible. Involve working on re-designing these networks and testing them . RANs are used to improve performance and the development of better products. Techniques that allow for more effective network resource slicing and improved network life-cycle management.[12].

1.4 Problem Statement

Simulate and Analyze 5G Network Slicing using open-source software for different use-cases.

1.5 Application in Societal Context

Our project's major purpose was to learn more about 5G architecture, as well as 5G applications and use cases where Network Slicing is used. After that, we can make the most significant contribution to society by simulating Network Slicing on a more appropriate tool, where we can analyse the changes that occur by tuning the parameters and understanding the importance of each use case, as well as explaining how 5G will benefit society in three major areas.

1.6 Organization of the Report

We provide the brief description about introduction, motivation for opting this topic in the Chapter 1 : the main objectives concerned for this project, literature survey, problem statement which is selected by the need of current requirement, Applications in Societal Context, which gives a brief description of usage of this topic in society. Chapter 2 : It mainly describes about the Network architecture which defines the whole End-to-End Architecture of the 5G system, the split of the architecture into RAN, Core and Transport. Chapter 3 : This chapter details of the tools that were explored. Chapter 4 : This Chapter is discussion on the results obtained from the simulation. Chapter 5 : This is the project's conclusion, including a discussion of the project's future scope, such as what tools and techniques can be applied in other areas and how they might be used more effectively.

Chapter 2

End to End Architecture

2.1 5G New Radio - RAN :

Today's 5G is the product of several years of RAN progress. Low-band (below 1 GHz), mid-band (1 GHz to 8 GHz), and high-band (beyond 8 GHz) frequency bands are used in the newest 5G wireless communication architecture (24 GHz to 40 GHz). Each band will have its own set of speed, performance, capacity, and latency requirements. With this available frequency spectrum, it can accommodate millions of devices. It supports enhanced features in the area of Dynamic spectrum sharing, Carrier Aggregation, MIMO and Beamforming enhancements and management of user equipment power saving.

5G New Radio - RAN Architecture :

The following are the general ideas that guide the establishment of NG-RAN architecture:

1. Signalling and data transmission networks are logically separated.
2. It Controls all aspects of a Radio Resource Control connection's mobility.
3. It is similar to the RAN split architecture, which refers to the division of a base station (gNB) into two parts: a distributed unit (DU) and a control unit (CU) (CU).
4. Depending on the deployment, CU and DU's may be physically separated.
5. The radio resource control (RRC) and packet data convergence (PDC) protocols are included in the standard deployment of CU, whereas DU contains multiple access control (MAC) and Radio Link Control (RLC) protocols, as well as the physical layer.

2.2 5G CORE :

5G Core connects end users to the network and gives them access to its services in a reliable and secure manner. The core domain is responsible for a wide range of mobile network operations, including connection and mobility management, access controls, subscriber data management, and policy administration, among others. 5G Core network services are entirely software-based and cloud-native, providing for greater implementation expandability regardless of the underlying cloud infrastructure.

5G Core Architecture :

The 5G core infrastructure includes the following elements:

1. Function of the user plane (UPF) It transmits IP data flow between the UE and the external networks (user plane).
2. For the UE connection, Access and Mobility Management (AMF) functions as a single point of entry.
3. The AMF uses the Authentication Server Function (AUSF) to validate the UE and gain access to 5G core services.
4. A policy governance framework for governing network activity, including making policy choices and getting subscription information, is provided by the Session Management Function (SMF), Policy Control Function (PCF), Unified Data Management (UDM), and Application Function (AF).
5. Internet, operator, and third-party services are all provided by the data network (DN).

2.3 Network Slicing

Network slicing is to design and maintain a network that exceeds the minimum the needs of a diverse applications. It is a logically divided, self-contained, autonomous, and protected network segment that targets distinct services such as speed, latency, and reliability needs. The essential network functionalities can be easily designed, swiftly deployed, and dynamically managed throughout the life cycle using configurable and scalable 5G networks and powerful Service Level Agreement (SLA) and AI based orchestration. Network slicing, which logically isolates network resources, might be used to protect against security assaults. Therefore, within each slice, security and robustness measures can be configured independently. Network slicing, which logically isolates network resources, might be used to protect against security assaults. Therefore, within each slice, security and robustness measures can be configured independently.

2.4 Types of Slicing :

Despite the fact that the list of 5G applications appears to be endless, the majority of them fall into one of three categories :

2.4.1 Massive Machine Type Communications (mMTC)

This is used to connect higher density of devices in certain area and will be able to transform the IoT industry. Improves wireless connectivity performance over a wide range of applications. Its mainly meant for smart city plans and better infrastructure of city using IoT devices. With a high number of sensors, smart cities monitor utilities such as water, gas, and electricity, as well as waste management.

2.4.2 Ultra-Reliable Low Latency Communication (uRLLC)

URLLC is used to connect mission-critical applications where low latency service is prominent factor. This might be utilised in self-driving automobiles or industrial navigation system. Drone-based deliveries uses 5G URLLC to assess traffic density in real time, self-driving vehicles use it to synchronise systems.

2.4.3 Enhanced Mobile Broadband (eMBB)

This service region is essentially an upgrade and enhancement of the present cellular data service area. For large bandwidth utilisation, it offers rates of up to 10 Gbps for applications such as HD video streaming or VR/AR gaming, allowing for speedier downloads and better user experiences.

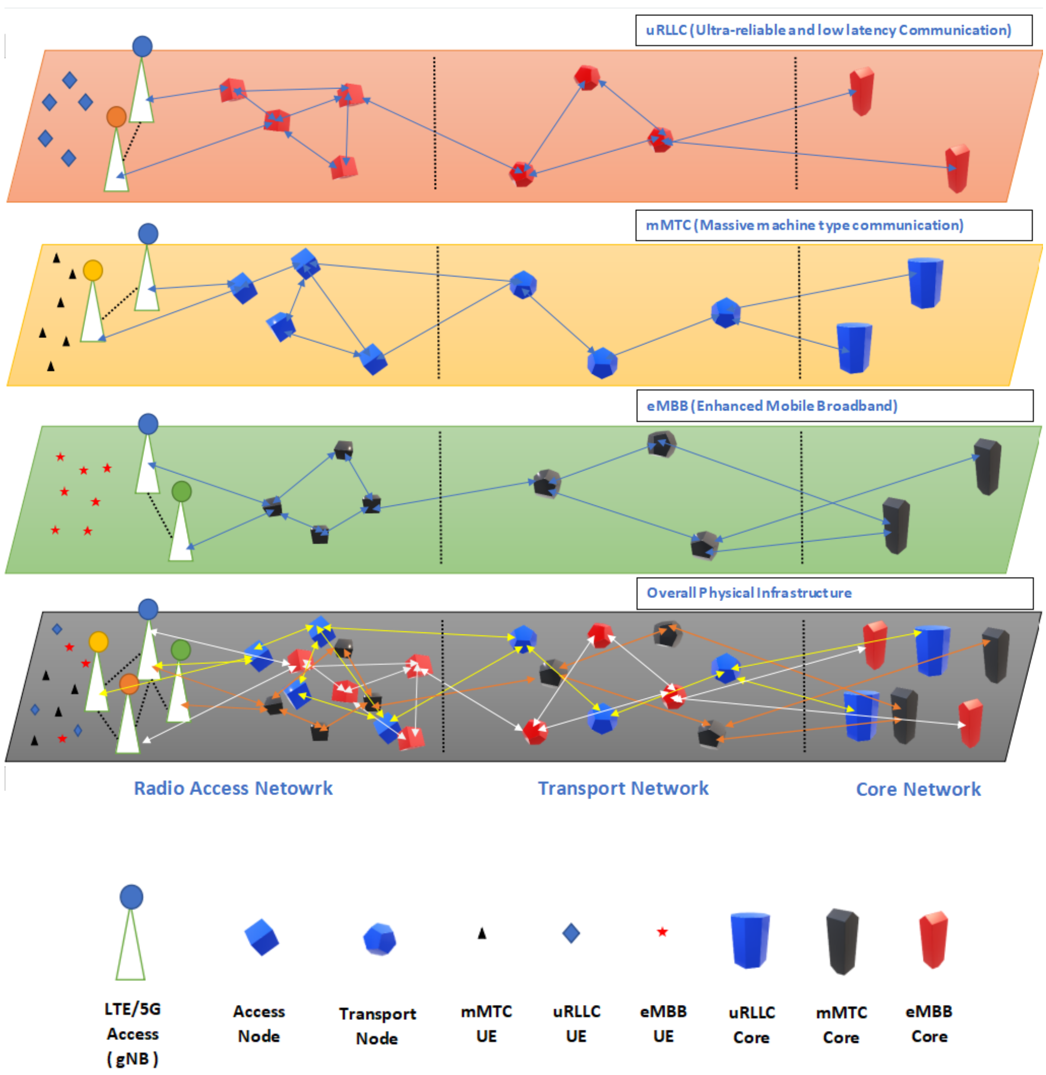

Figure 2.1: End to End Architecture

2.5 5G CORE Slicing :

Network slicing is supported by standardised enablers and various deployment choices in 5G Core. The Network Function (NF) instances that will serve the user during attach and session requests are assigned using Single-NSSAI and DNN. Dedicated NF instances provide total independence and, as a result, complete separation from other services and their users. The service provider deploys one or more E2E network slices depending on the demands. For QoS differentiation, multiple slices have same or multiple packet handling. They can also use the same or other S-NSSAIs for various PDU sessions.

5G core NFs are distributed to satisfy unique Service level agreement (SLA) demands based on criteria such as higher bandwidth, lower latency and security. The key NF is the dedicated User Plane Funtion (UPF) that enables an ideal deployment site to accommodate minimal user data traffic latency. The SMF, which is determined by the AMF and offers session management isolation, is the next NF to be dedicated. In some circumstances, data management NFs such as UDM, AUSF, PCF, and UDR, as well as other NFs, can be used to achieve ultimate isolation.

2.6 5G RAN Slicing :

5G RAN slicing enhances E2E slicing capability for dynamic resource management and orchestration, bringing a slew of new capabilities to the RAN. To enhance the RAN slice setup and operation, look at resource usage and service performance. RAN slicing is possible by details like abstraction framework or the Slice ID. This May lead to scenario where A RAN slice can be composed of many different services, each of which is handled differently by the RAN. As a result, in parallel to service level information, the QoS framework should take into consideration some slice level information The ability to assign multiple priorities to subscribers, various applications, data flows, or to guarantee a certain degree of performance for a data flow is known as Quality of Service. Service providers can differentiate their networks by implementing quality of service (QoS). QoS implementation includes link adaptation and scheduler setup, dynamic radio resource partitioning (DRRP), and admission control. Admission control ensures that the scheduler has enough resources to ensure the Quality of Service (QoS) of all authorised users when the scheduler is under heavy load. DRRP allows resources to be dynamically shared between different slices without having to reserve them statically.

The RAN selects AMF/CU-UP depending on slice ID, as well as providing dynamic resource allocation with priority requirement. We can consider the following features to be the RAN Slicing key differentiators :

1. Slice-Aware AMF/CU-UP Selection : UE and AMF request for the S-NSSAI which is provided by the RAN and based on the service level agreement selection functions will be provided, that supports the AMF and CU-UP.

2. Priority Control : A gNB cannot change the priority of UEs' scheduling with various service requirements. The priority control function allows the network slices radio scheduling priority to be controlled by the operator.

2.7 Establishing connection with a Slice :

The process of creating a secure slice connection consists of multiple phases in which various network functions play a vital role as shown in the below figure 2.2.

1. gNB and AMFs, during the NG Setup Request and response share their supported NSSAI Lists.

2. The required NSSAI and the PDU session to be formed, are optionally provided by UE. Selection of the provisional RAN slice and AMF occurs based on this data. This Completes the RRC Setup request and response.

3. The NAS Registration Request is forwarded by gNB to the specified AMF instance, which verifies the Asked NSSAI using Subscribed NSSAI. The S-NSSAI has standard network-specific values which is used in accessing the network by the UE. It consists of a Slice differentiator (which is an optional data to differentiate multiple Slices) and a Slice/Service Type referring to the behaviour of that network slice based on services, quality and other features.

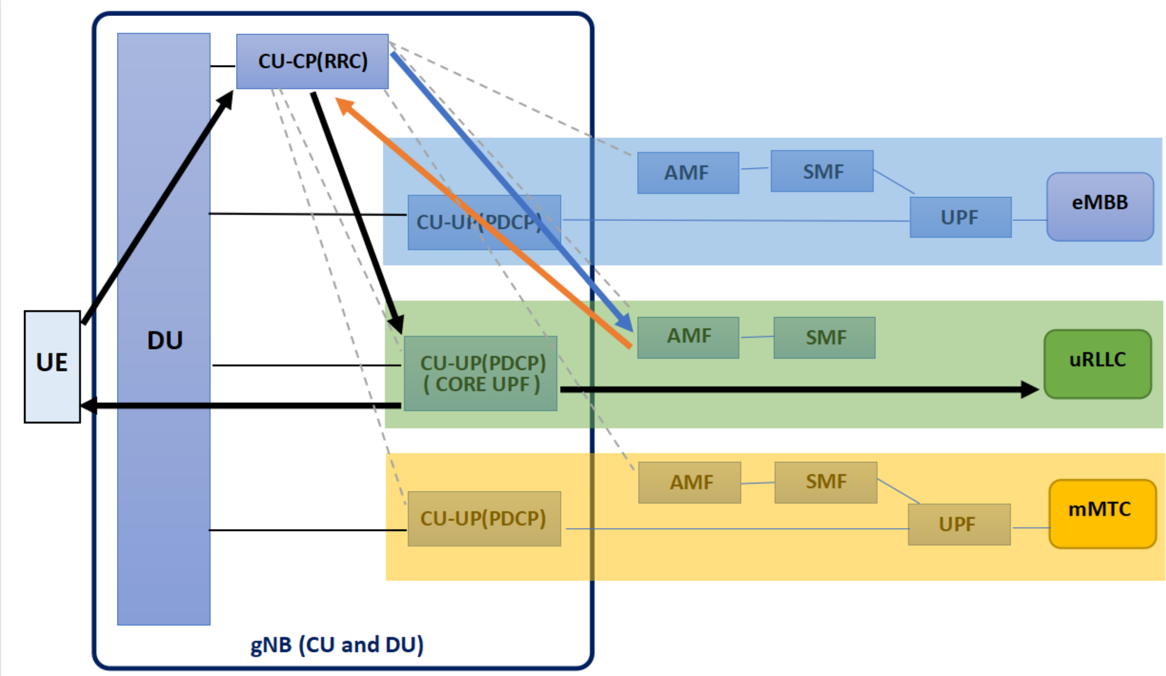

Figure 2.2: Establishing connection with a Slice

Chapter 3

Tools and Implementation

This chapter talks about the softwares that were explored and provides more details about the software that was finalised for the 5G network slicing.

3.1 Softwares Explored and Requirements

In his project, we have explored 4 tools to perform network slicing using the parameters mentioned in the 5G-PPP standards.

3.1.1 NS-3 – Network Simulator

Is a tool that creates scripts and sets up the simulation environment using the Python/C++ programming language. A 5G NR module that uses the new radio to replicate 5G network slicing is required to simulate 5G network slicing. This module experienced multiple flaws during development, therefore our team had to abandon it.

3.1.2 srsRAN – Software Radio Systems RAN

Is a command line interface tool that can be installed on the Linux operating system. Using easy built-in commands for each specialised component, this tool establishes the major components of the 5G network, such as RAN, UE, and so on. This tool is simple to use and set up the RAN and core network, however the network parameters cannot be changed as needed. To put it another way, it was discovered to be less adaptable.

3.1.3 MATLAB and Simulink

To mimic the 5G network, Simulink models can be constructed and customised. The new radio frequency is supported by a built-in module. Only the physical layer of the protocol stack is supported by this module. The biggest disadvantage of utilising this tool is that it cannot simulate numerous base stations in a single simulation run time, and there is no actual way to slice the radio frequency of 5G in a base station.

3.1.4 Slicesim

This is a GitHub-hosted open-source simulation tool that was created specifically to simulate 5G network slicing using Python scripts. This programme creates better simulation environments and uses graphs to view all of the parameters. This is a straightforward yet effective tool for seeing network characteristics and learning more about slicing. This gives you more options when it comes to fine-tuning the parameters of a slice.

3.2 Implementation of Network Slicing

3.2.1 Slicesim

A Python script-based open-source simulation programme for simulating 5G network slicing. When it comes to fine-tuning the settings of a slice, this software provides you additional possibilities.

Some of the features of Slicesim are :

1. Flexibility in the deployment of the number of Base stations and clients.
2. User-friendly interface, as it uses python scripts for the creation of slices.
3. Generation of graphs for better visualization of the output.
4. RAN Slice simulation using standard parameters of base station and clients.

Working of the tool :

1. The working directory consists of a dedicated folder named “Slicesim” which holds all the .py python files necessary for the simulation.
2. To run the simulation, first configure the slices such as eMBB, mMTC, and uRLLC by specifying the bandwidth, delay, and QoS class in the YAML file.
3. Similarly configure the base stations and the mobility patterns expected in the simulation.
4. Once the YAML file is fully configured without any errors, Run python -m slicesim settings.yaml in the terminal.
5. This will run the python scripts and generate
   (a) Output.png – consists of all the graphs of the simulation.
   (b) Output.txt – This is a log file consisting of the simulation log for the entire run time.

Chapter 4

Results and Discussions

The 5G slicing was implemented and analysed for various scenarios, such as increasing the number of clients, changing mobility patterns, and creating more slices, by modifying various parameters. The following section discusses the results of tweaking the parameters.

4.1 Simulation Environment

Let's have a look at several simulation environments that were examined during the simulation's execution for a better understanding.

1. The total area for the simulation was 1980m x 1980m and it was run for 100 seconds.
2. Several simulation environments were considered with different configurations for Base stations, Clients, and Mobility patterns.
3. Each slice has a QoS defined based on the min/max bandwidth, Latency, and throughput.
4. Different base station capacity with different coverage areas was configured to mimic the real-time conditions.
5. The creation of slices was static and not dynamic. The creation of Dynamic slices is the future scope of this project.
6. The distribution for the clients was chosen to be a normal distribution.
7. The simulation consisted of 20 base stations with varying client sizes.

4.2 Results Analysis of 5G Slicing

As mentioned previously the analysis were done by increasing the number of clients and changing the mobility patterns. The graph of Simulation time v/s the parameters is plotted in figures.

4.2.1 Simulation Results for Increasing Clients:

For 1000 clients – (image of 1k client's simulation):

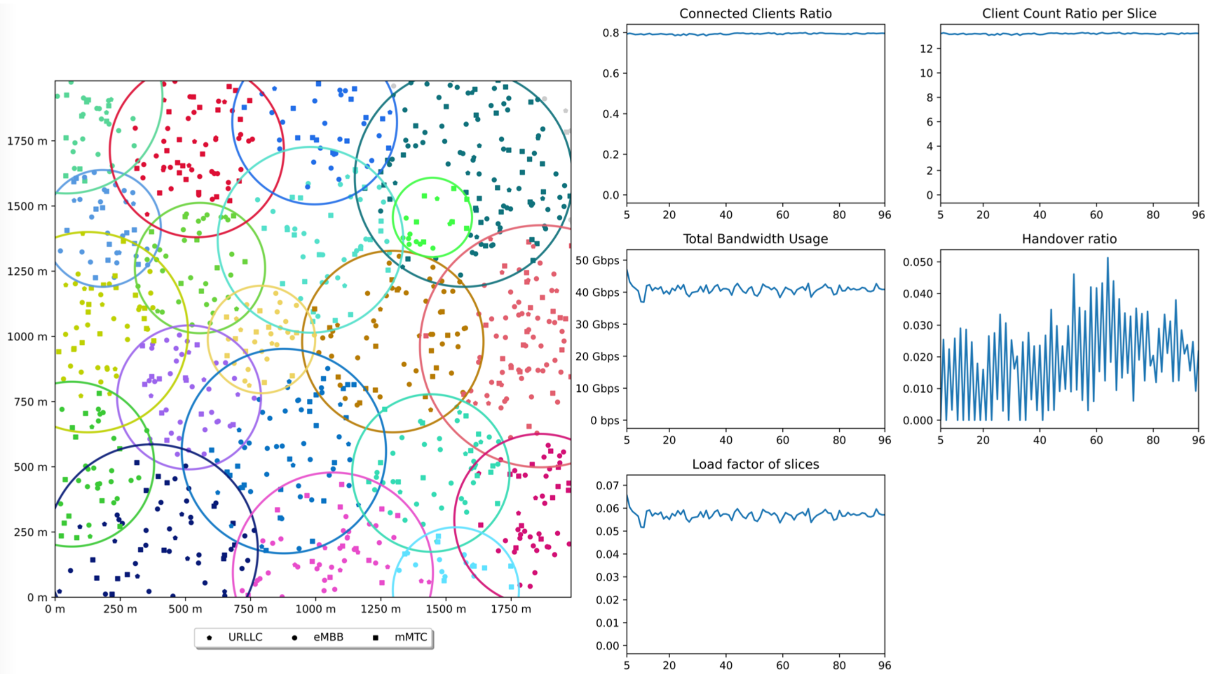

Figure 4.1: Plot for 1000 clients

Results

1. Total clients = 1000
2. Total connected clients = 830
3. Connected Clients ratio = 1000 / 830 = 0.83
4. Total bandwidth usage = 43.794 Gbps
5. Total bandwidth capacity of base stations combined = 715 Gbps
6. Bandwidth usage ratio in slices = 43.794 / 715 = 0.06
7. Client count ratio / base station / slice = (830 / 20) / 3 = 13.9
8. Handover Ratio = 0.0227

For 5000 clients – (image of 5k client's simulation):

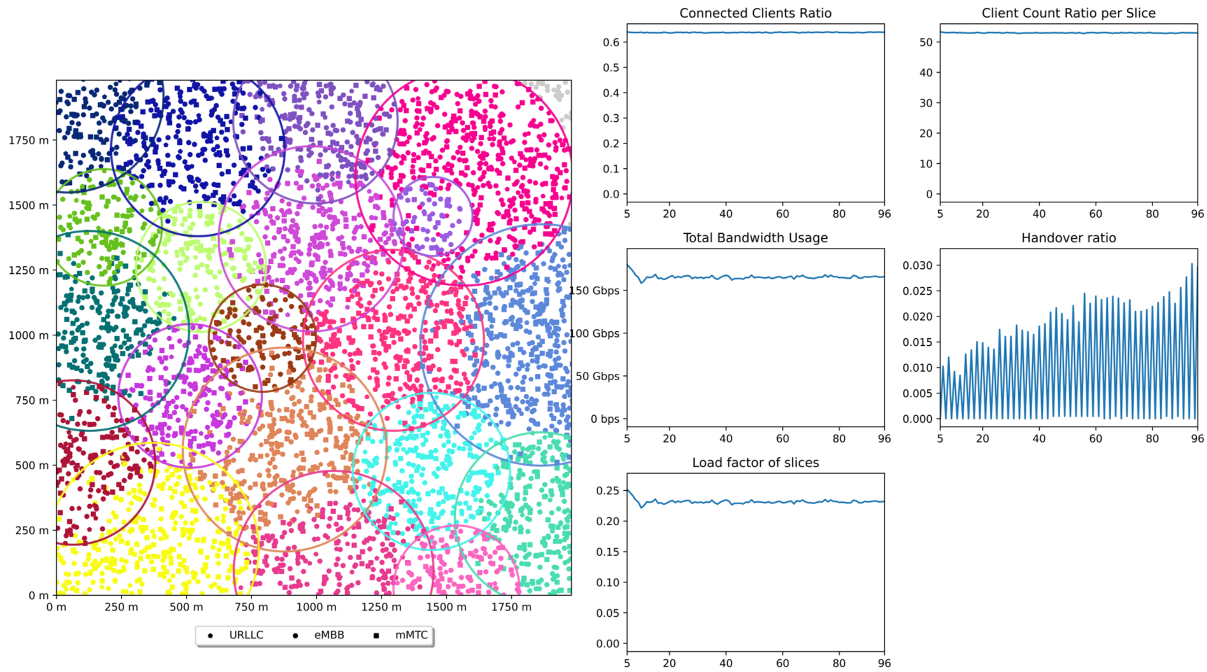

Figure 4.2: Plot for 5000 clients

Results

1. Total clients = 5000
2. Total connected clients = 3200
3. Connected Clients ratio = 5000 / 3200 = 0.64
4. Total bandwidth usage = 173.69 Gbps
5. Total bandwidth capacity of base stations combined = 715 Gbps
6. Bandwidth usage ratio in slices = 173.69 / 715 = 0.24
7. Client count ratio / base station / slice = (3200 / 20) / 3 = 53.4
8. Handover Ratio = 0.0081

Comparison for Increasing number of clients

Table 4.1: Table of Comparision of values for Increasing Number of Clients

For Increasing Number of Clients		
Parameters	1000 Clients	5000 Clients
1. Total connected clients	830	3200
2. Connected Clients ratio	0.83	0.64
3. Total bandwidth usage	43.794 Gbps	173.69 Gbps
4. Bandwidth usage ratio in slices	0.06	0.24
5. Client count ratio per slice	13.9	53.4
6. Handover Ratio	0.0227	0.0081

We did simulations with various client counts to compare characteristics such as connected client ratio, total bandwidth consumption, slice load factor, client count ratio per slice, and handover ratio. We noticed that when the number of customers increased, the average number of connected clients decreased but the average bandwidth utilisation and load factor increased.

4.2.2 Simulation Results for Mobility patterns:

<u>**For 1000 clients – (image of 1k client's simulation):**</u>

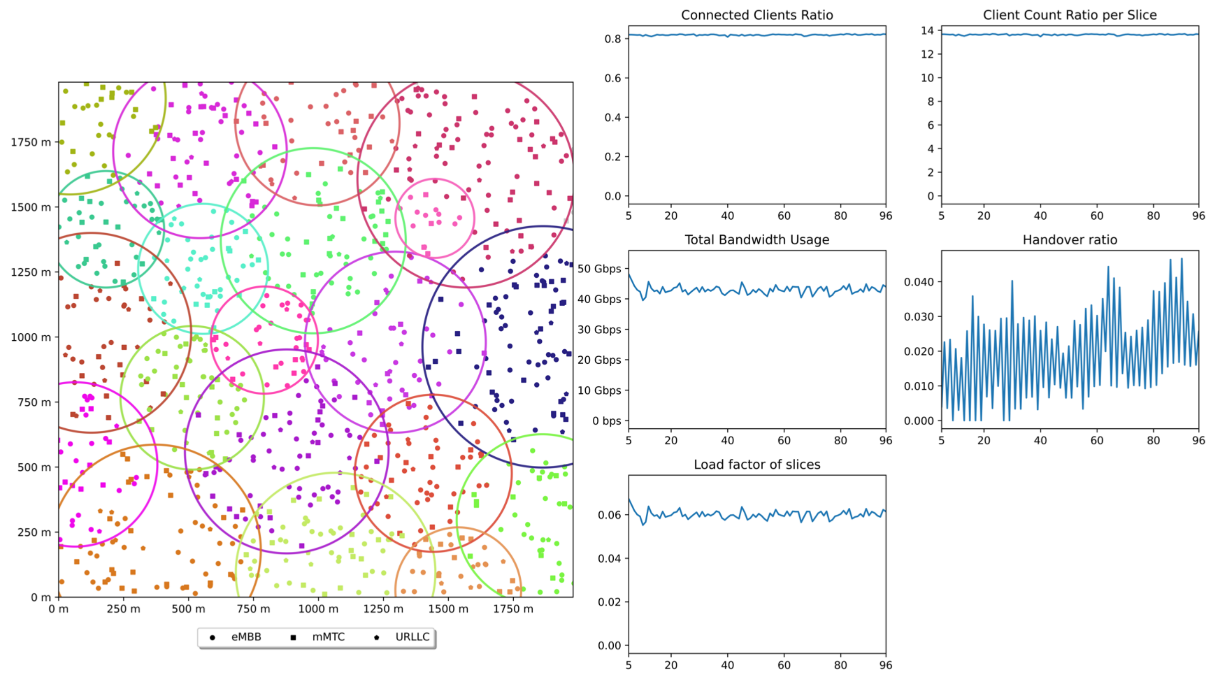

Figure 4.3: Plot for 1000 clients

Results

1. Total clients = 1000
2. Total connected clients = 820
3. Connected Clients ratio = 1000 / 830 = 0.82
4. Total bandwidth usage = 43.218 Gbps
5. Total bandwidth capacity of base stations combined = 715 Gbps
6. Bandwidth usage ratio in slices = 43.218 / 715 = 0.06
7. Client count ratio / base station / slice = (820 / 20) / 3 = 13.6
8. Handover Ratio = 0.0219

For 5000 clients – (image of 5k client's simulation):

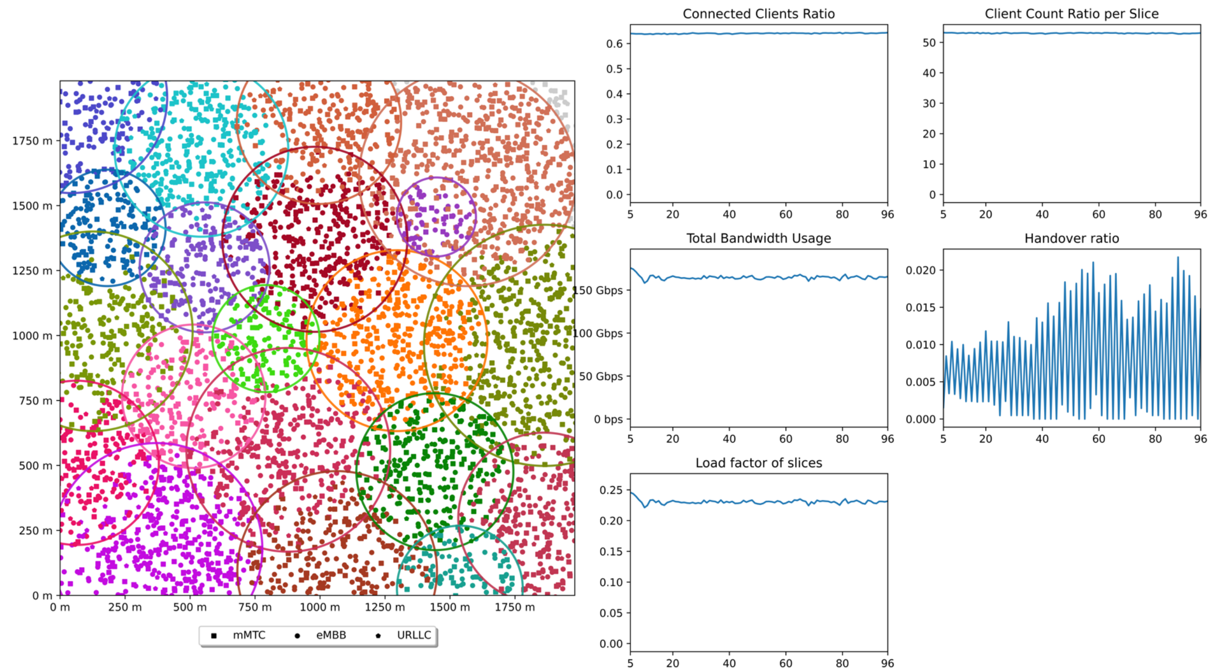

Figure 4.4: Plot for 5000 clients

Results

1. Total clients = 5000
2. Total connected clients = 3250
3. Connected Clients ratio = 5000 / 3250 = 0.65
4. Total bandwidth usage = 164.389 Gbps
5. Total bandwidth capacity of base stations combined = 715 Gbps
6. Bandwidth usage ratio in slices = 164.389 / 715 = 0.23
7. Client count ratio / base station / slice = (3250 / 20) / 3 = 54.166
8. Handover Ratio = 0.0079

Comparison of the values by Increasing Mobility Patterns

Table 4.2: Table of Comparision for Increasing Mobility Patterns

For Increasing Mobility Patterns		
Parameters	1000 Clients	5000 Clients
1. Total connected clients	820	3250
2. Connected Clients ratio	0.82	0.65
3. Total bandwidth usage	43.218 Gbps	164.389 Gbps
4. Bandwidth usage ratio in slices	0.06	0.24
5. Client count ratio per slice	13.6	54.166
6. Handover Ratio	0.0219	0.0079

We performed simulations with all clients considered to be mobile/moving to compare characteristics such connected client ratio, total bandwidth use, slice load factor, client count ratio per slice, and handover ratio. The average number of connected clients, average bandwidth utilisation, load factor all tend to rise as the number of customers grows but and average Handover ratio decreases.

Chapter 5

Conclusions and Future Scope

This chapter summarises the project's findings as well as the accomplishments made as a result of it. The acquired results are reviewed in detail, as well as future work that may be done to increase the quality of the summary.

5.1 Conclusion

We ran simulations with different numbers of clients and different mobility patterns to examine how crucial parameters like connected client ratio, total bandwidth utilization, load factor of slices, client count ratio per slice, and handover ratio varied. With the help of the simulation's output graph, these modifications were useful in offering some insights for the RAN establishment and the challenges in slicing. When we expanded the number of customers, we saw that the pressure on the infrastructure grew, as did bandwidth utilisation, resulting in fewer clients being connected to the base station. And as the number of mobile clients grew, more mobile clients switched between base stations, lowering the handover ratio.

5.2 Future Scope

In this project, we have simulated RAN slicing where the base station's radio spectrum is divided to provide service to different use-cases. There are 3 main use cases currently mentioned in the standard to cater to a different set of users. RAN slicing is the main establishment between the use and the base station. It is the main part of the End-to-End slice as it creates the initial connection between the user and the base station and allocates the required bandwidth for each user based on the slice requested by the connected user. Therefore, we were Explore the best simulation tool with which we simulated the 3 use-cases of slicing and analyzed the parameters. The future scope of this paper is to implement the End-to-End slicing using software-defined networks for orchestration and management of the slices. To optimize the slice and to develop better algorithms for dynamic slice creation and the further optimization of the resources.

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