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5G TECHNOLOGY IMPLEMENTATION ON PROCESS PERFORMANCE IN PRODUCTION

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Master's Thesis

Supervisor

Prof. Dr. Osman Nuri UÇAN

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This thesis titled 5G TECHNOLOGY IMPLEMENTATION ON PROCESS PERFORMANCE IN PRODUCTION prepared by WASEEM KHALEEL JALIL ALADEEB and submitted on 22/12/2022 has been accepted unanimously for the degree of Master of Science in Electrical and Computer Engineering.

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I hereby declare that this thesis meets all format and submission requirements of a Master's thesis.
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Waseem Khaleel Jalil ALADEEB

Signature

DEDICATION

The foundation of my character was laid by my parents. For my closest relatives: brothers and sisters. A special debt of gratitude is due to Prof. Dr. Osman UAN for his help, intelligent comments, and careful follow-up.

ABSTRACT

5G TECHNOLOGY IMPLEMENTATION ON PROCESS PERFORMANCE IN PRODUCTION

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It is expected that 5G technology would have a substantial monetary impact on the manufacturing industry. According to certain projections, manufacturing's share of GDP might rise to $740 billion by 2030. It is expected that 5G would be able to meet the needs of networked production systems because to its fast data transfer rates, low latency, and capacity to run many devices concurrently in small radio cells. 5G has the potential to significantly accelerate the current digital transition. Despite these expected growth rates, quantifying the benefits of using 5G technology in a production setting is now challenging. Forty percent of companies report that the difficulty of gauging the financial benefits of 5G for their specific operations is the biggest challenge they face when adopting the technology. The potential for manufacturing process improvement and its monetary worth must be appraised to offer a strong basis for decision-makers to base their investment decisions on. This article provides a framework for evaluating the commercial potential of 5G technology in manufacturing and its application to improving process efficiency, outlining its salient features along the way. Fifth-generation (5G) mobile networks are the cutting edge of wireless communication. This dissertation presents an examination of recent developments in mobile communication systems. The implementation of next-generation mobile networks was met with a number of challenges at each stage. The fifth generation (5G) of mobile networks makes ultra-fast internet available to everyone, everywhere. 5G is revolutionary because of its ability to link individuals and automate systems, appliances, and inanimate things. With 5G mobile technology's varying speeds and capabilities, users and businesses alike will benefit from new opportunities for interaction. It's crucial for companies to grasp the potential of 5G networks. One of the most well-known applications of 5G wireless cellular technology is network slicing (NS), which allows operators and

communication service providers (CSPs) to build flexible and specialised logical networks. The true value of 5G network design may not be realised, however, until NS is implemented. In an era when no two companies have the same needs, telcos' capacity to make the most of their infrastructure is more important than ever. That goal is met by providing unique networking options for each client. Along with NS's economic potential, this thesis discusses the need for a slicing automation and orchestration framework. The sophisticated functional implementation of the NS code flow, as well as the goals of the present NS project, will be discussed. Important standards development organisations and industry forums are included, along with their respective activities in relation to machine learning and artificial intelligence (AI).

Keywords: 5G Technology, Networking, Csps, NS Projects; AI, ML.

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ABBREVATIONS

3GPP	: Third Generation Partnership Project
5G	: Fifth Generation Wireless Network
5GC	: Fifth Generation Core
5GPPP	: Fifth Generation Infrastructure Public Private Partnership
AI	: Artificial Intelligence
APIs	: Application Programmable Interfaces
AR	: Augmented Reality
BBU	: BaseBand Units
C-RAN	: Centralised Radio Access Network
CN	: Core Network
CSP	: Communication Service Providers
D-RAN	: Distributed Radio Access Network
D2D	: Device to Device
DBN	: Deep Belief Network
DDoS	: Distributed Denial of Service
DL	: Deep Learning
DoS	: Denial of Service
DRL	: Deep Reinforcement Learning
DSP	: Digital Service Providers
E2E	: End to End
eMBB	: Enhanced Mobile Broadband
eMTC	: Enhanced Machine Type Communication
ETSI	: European Telecommunications Standards Institute
GS-DHOA	: Glowworm Swarm-based Deer Hunting Optimization Algorithm
HSS	: Home Subscriber Server
IDS	: Intrusion Detection System

IETF : Internet Engineering Task Force

InPs : Infrastructure Providers

IoT : Internet of Things

kNN : K Nearest Neighbors

KPIs : Key Programmable Interface

LTE : Long Term Evolution

LTE-A : Long Term Evolution-Advance

MEC : Multi-Access Edge Computing

ML : Machine Learning

MME : Mobility Management Entity

mMIMO : Massive Multi Input Multi Output

mMTC : Massive Machine Type Communication

mmWAVE : Millimeter WAVE

NFV : Network Function virtualization

NFVI : NFV Infrastructure

NGMN : Next Generation Mobile Network Alliance's

NMS : Network Management System

NN : Neural Network

NS : Network Slicing

NS3 : Network Simulator 3

ONF : Open Network Foundation

OSS/BSS : Operation/Business Support System

OWFE : Optimal Weight Feature Extraction

PDN-GW : Packet Data Network Gateway

QoE : Quality of Experience

QoS : Quality of Service

RAN : Radio Access Network

RRH : Radio Remote Heads

S-GW : Serving Gateway

SDN : Software Defined Networking

SLA : Service Level Agreement

SONs : Self-Organising Networks

SSIDs : Service Set Identifiers

SVM : Support Vector Machine

TS : Technical Specifications

UCON : Usage Control Mechanism

UltraHD : Ultra High Definition

URLLC : Ultra-Reliable Low Latency Communication

V2V : Vehicle-to-Vehicle

V2X : Vehicle-to-Everything”

1. INTRODUCTION

1.1 BACK GROUND 5G NETWORK

With 5G or digital cellular networks, the service area given by carriers is broken down into smaller, more controllable pieces called cells.

Low-band spectrum means those with bandwidths under 1 GHz. Spectrum in the band most often utilized for LTE by U.S. providers is quickly depleting. However, there is a significant downside to using a low-band spectrum: its maximum data throughput will only be roughly 100Mbps.

Mid-band spectrum allows for wider coverage at a far lower latency than the low-band. However, low-band spectral structures and information remain inaccessible. The transmission rate in the mid-band may reach 1Gbps.

High-band spectrum Most people's initial thought upon hearing the term "5G" is this technology. The use of a high-band spectrum, also known as millimeter wave (mmWave), may allow for very low latency and maximum throughputs of up to 10Gbps. The problem with a high-key band is that it has limited coverage and has trouble penetrating buildings.

i. 1G: The earliest kinds of wireless telephone technology are known as 1G (or 1-G) (mobile telecommunication). Generation one debuted at the start of the 1980s. 2.4kbps is the highest possible transfer rate. Total Access Communication System (TACS), Nordic Mobile Telephone (NMT), and the Advanced Mobile Phone System (AMPS) were only some of the cellular networks utilized by subscribers (TACS**)**. In the first generation, audio conversations were aggregated and played in radio towers, which led to poor quality due to superfluous connections and increased third-party noises, as well as a lack of safety precautions. One of the most noticeable differences between 1G and 2G mobile networks is the encoders they use. While 1G networks utilize largely analog radio transmissions, 2G networks utilize digital encoders. In both systems, the radio towers (which keep tabs on the phones) are linked to the wider telecommunications infrastructure through digital signaling. While 1G calls are modulated at a higher frequency—typically 150 MHz and up—in 2G, the speech tone itself is encoded to digital signals. Due to this intrinsic advantage of digital over analog, 1G was replaced by 2G.

ii. 2G (or 2-G) stands for second-generation mobile phone technology in shorthand. Two-generation networks (2G) have three main advantages over their first-generation counterparts:

   a. Digital encoding of telephone signals allowed for a jump in mobile phone adoption rates; 2G systems were much more spectrum-efficient.

   b. The availability of data via 2G networks allowed for the creation of the short message service (SMS).

When compared to 1G, 2G is safer in terms of privacy due to the fact that all texts sent over it are digitally encrypted, as indicated above.

iii. 2.5G**:** As the backbone of the second generation of cellular networks, General Packet Radio Services are commonly required. GPRS is a feature not often seen in 2G or 1G networks. Throughputs of up to 144 kilobytes per second are achieved by combining packet switching with circuit switching. CDMA 2000, which includes GPRS and EDGE (Enhanced Data Rate for GSM Evolution), were the primary 2.5G technologies (Code Division Multiple Access).

iv. 3G: In the later half of the 2000s, the third generation made its debut. It can send data around the globe at a rate of 2 Mbps. Third-generation (3G) technology achieved its primary goal by combining high-speed mobile connection with IP-based services. Modern advancements have been made in areas apart just throughput, such as service quality. With enhanced features, including global roaming and superior audio quality, 3G quickly became a landmark generation. As their primary drawback, 3G mobile devices use greater battery life than their 2G equivalents. Plans for 3G networks are now more expensive than those for 2G networks. Third-generation (3G) wireless networks are based on a combination of newer technologies and older ones, such as “Wideband Code Division Multiple Access (WCDMA), Universal Mobile Telecommunications Systems (UMTS), and Code Division Multiple Access (CDMA) 2000. Modern protocols such as Evolution-Data Optimized (EDO) and High-Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) are also in use (EVDO)”. Third-generation (3G) cellular networks can transport data at speeds of at least 200 kilobytes per second. The generation between the third and fourth is known as "3G." Five-hundred Mbps is the range of data transmission speeds achievable by 5G networks.

v. 3.75G**:** Technology such as Fixed Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution (LTE) is anticipated to be used to provide mobile data services. Fixed WiMAX and LTE might be used to enhance the network's capabilities. In addition, it enables a large audience to get access to many high-speed services simultaneously, such as bundled Web services, P2P file sharing, and video streaming.

vi. 4G: The advent of 4G signifies a significant improvement over previous generations of wireless mobile phone technology. In order to be considered a 4G system, a network must support the International Mobile Telecommunications standards set forth by the International Telecommunication Union. In many ways, 4G LTE, the newest generation of wireless networking technology, can be thought of as the biological offspring of 3G and 2G. For future 4G networks, the Third Generation Partnership Project recently Long-Term standardized Evolution (LTE) and Mobile Worldwide Interoperability for Microwave Access (WiMAX) (3GPP). A 4G system is an excellent addition to existing communication infrastructures because of its IP-based, all-encompassing nature. It will cost customers significantly more per megabyte to have access to always-on services like voice over Internet protocol (VoIP), data transmission, and multimedia playback around the world. Applications that take advantage of a 4G network include those that send and receive multimedia content, such as video chat, HDTV, and mobile television.

vii. 5G: All the major telecom corporations in the world have joined forces in massive consortia to make 5G a reality and create global value. Despite the fact that many of these standards never reach completion, industry insiders are optimistic that the resulting system will be more interoperable (with 4G and 3G) and have some interoperability worldwide. Beam Division Multiple Access (BDMA) and Filter Bank Multi-Carrier (FBMC) Multiple Access are two examples of multiple access techniques that will allow 5G to quickly replace 4G as consumer demand continues to grow. As soon as the base station and the mobile stations are able to communicate with one another, the underlying concept BDMA approaches become clear. Due to the fact that each mobile station receives its own orthogonal beam, the primary step in this communication is dividing the antenna beam depending on the positions of the mobile stations to enable numerous openhanded accesses to the mobile stations, hence enhancing the system's efficacy. The idea of upgrading to 5G was inspired by the present trends, and the general consensus is that 5G cellular networks will be able to address the six issues that 4G has struggled to address [1].

i. Enhanced storage and transmission speeds,
ii. The round-trip delay has been reduced,
iii. Integration with a Big Thing,
iv. Cost savings Quality that doesn't fluctuate

Table 1.1: Communication Technology Comparision [2]

Generation	**1G**	**2G**	**3G**	**4G**	**5G**
Deployment	1970/1984	1980/1989	1990/2002	2000/2010	2017/2020
Data Bandwidth	2 Kbps	14-64 Kbps	2 Kbps	200 Kbps	1 Gbps
Standards	AMPS	TDMA, CDMA, GPS, GPRS	WCDMA	Single unified standard	Single unified standard
Technology	Analog cellular	Digital Cellular	CDMA/IP	Broadband LAN, WAN, and WLAN under IP network	Integration of broadband and the WWW under a single, unified IP
Multiplexing	FDMA	CDMA, TDMA	CDMA	CDMA	CDMA
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	Horizontal and Vertical"
Switching	Circuit	Circuit and panel	Packet	All Packet	All Packet
Core Network	PSTN	PSTN	Packet network	Internet	Internet

1.2 AIMS OF THE THESIS

Broad adoption of 5G communication networks, in addition to other connection alternatives, is necessary to fully realize the beneficial impact of the Fourth Industrial Revolution and related new technologies.

As a result of "5G's major functional drivers, significant improvements in service delivery, decision-making, and overall user experience will be feasible. By 2035, the global GDP will have increased by $13.2 trillion, and 22.3 million new jobs will be created along the 5G value

chain. This study employs a bottom-up technique to examine 40 use cases in order to acquire a better understanding of how the vast estimated economic production potential might be realised. You will be tasked with defining the key functional drivers of 5G, as well as the required maturity levels of these drivers, as well as the significant industrial breakthroughs and societal impact areas, during this investigation". The actions that must be done to accelerate the adoption of 5G technology and guarantee that it realises its full potential are detailed, as are the ecosystem's components, actors, and interdependencies.

1.2.1 Objectives

i. The purpose of this investigation is to determine the efficacy of the manufacturing process.
ii. Examining 5G Security Criteria
iii. This research will focus on 5G latency and slicing.

1.2.2 Research Questions

i. When it comes to 5G technology, how does production performance factor in?
ii. Can you explain how 5G handles network slicing and latency?

2. THEORETICAL BACKGROUND

2.1 5G TECHNOLOGY PROCESS PERFORMANCE IN PRODUCTION

The proliferation of IoT devices may be substantially responsible for the birth of the Fourth Industrial Revolution (IoT). Industry 4.0 is distinguished from other industrial revolutions by the enhancement of already established processes1 via the use of intelligent technology.

In this transition, connected gadgets that can collect and transmit vast volumes of data in real-time play a crucial role. Data analytics and artificial intelligence might be used to leverage this data to help drive the creation of autonomous devices [3].

Southeast Asian nations are placing their hopes on 5G technology2 (the next generation of high-speed mobile internet) to provide a more stable connection and increased capacity between devices, allowing them to fully adopt Industry 4.0 and enjoy its advantages.

Singapore is expecting to roll out commercial 5G services3 later this year as part of its efforts to construct the "backbone of the digital economy." This includes funding research and development of 5G networks. The city-telecommunications state authority plans to launch a standalone 5G network covering at least half of the city by the end of 2022.

With the new system, it will be possible to transport massive volumes of data quickly, with no lag, and without compromising security. In addition to being faster and more efficient, 5G is also far more dependable, allowing for better data transmission even in difficult environments. Also, 5G is more adaptable than Wi-Fi, so it can operate with a greater variety of sensors, wearables, and other gadgets.

As 5G rolls out, it will have a significant impact on companies that produce components for "smart factories" (a subset of Industry 4.0). New technologies and their specific applications in this field rely heavily on the low latency, high dependability, and enhanced speed made possible by 5G networks. Some examples are process automation, remote monitoring, and collaborative robots [4].

Here are seven ways in which 5G might be used in manufacturing, along with profiles of some of the companies that are already at the forefront of this technological revolution.

2.2 MANUFACTURING USE CASES OF 5G

i. Process automation

The smart factory4 is a completely digitalized and networked workplace made possible by Industry 4.0 and the Internet of Things, where machines can autonomously perform maintenance and operate operations. Automating routine, time-consuming, and sometimes hazardous jobs is a key feature of the smart factory that has the potential to improve productivity significantly. There will be fewer mishaps and mistakes as a result of human error since more individuals will be capable of doing higher-level tasks.

MTU Aero Engines, a German aviation engine maker, has been looking into 5G-based industrial solutions to increase production. Blade-integrated discs (black), cutting-edge parts of jet engines, were tested in flight by pilots. These were machined from solid metal bars and needed a high degree of complexity in their creation [5].

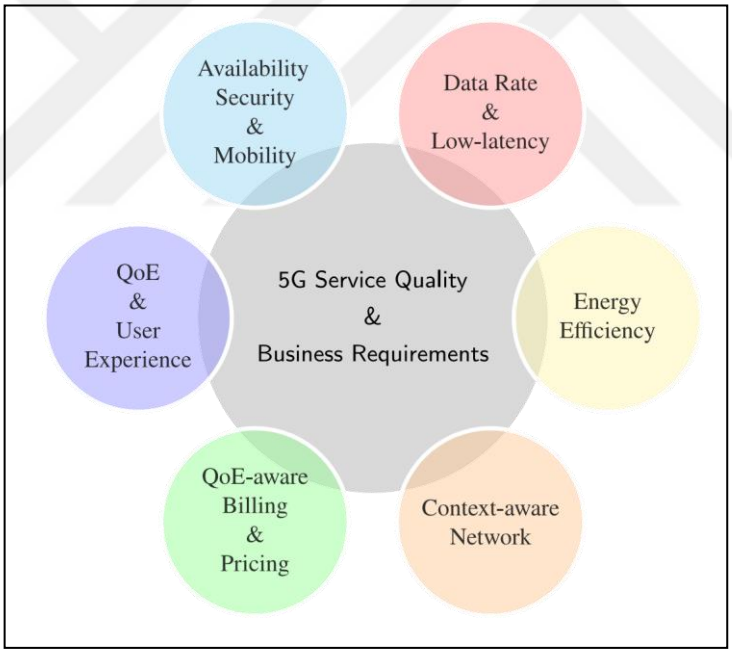

Figure 2.1: 5G services Quality [5]

Making a blisk takes around three to four months. The firm constructed an automated factory6 that could be controlled from a single network using state-of-the-art 5G manufacturing technologies (which included sensors and IoT technology). Thus, the time required to finish the process design step was reduced by 75%.

Due to its ability to facilitate the development of highly dependable systems capable of sustaining the network of information passing via different pieces of equipment and devices, 5G is a critical enabler of smart factories. Increased productivity and reduced costs are expected to contribute between $1.5 and $2.2 trillion8 to the global economy by 2023, due in large part to smart manufacturing [6].

i. Remote monitoring of production assets

Another perk of smart factories is that production assets may be monitored and managed from afar. As a result of digital technologies, managers can monitor production in real time9 without having to make frequent trips to the factory floor. This makes it easier to keep track of possessions, gather useful information in real-time, and fine-tune computer settings to boost productivity, security, and reliability.

Real-time monitoring, both within and outside the facility, might be useful for certain standard operating procedures (SOPs)[7].

During Facility Acceptance Tests, Siemens, for example, implemented the first-ever live remote monitoring system10 at their Transformers manufacturing in Mexico (FAT). The FAT verifies that the equipment Siemens has created is fit for use and up to the standards specified in the customer's contract. Customers may complete the FAT without physically visiting the facility anymore, all because of the real-time monitoring.

In a situation like this, every connection is vital. Without a quick and reliable connection between operators and clients, the FAT cannot be performed efficiently and without delay or confusion. Live, high-definition footage was broadcast from a total of twelve Siemens cameras. Operators will be able to increase remote monitoring and live broadcasting with the support of 5G's greater convenience, precision, and security, allowing them to better tackle issues as they arise.

ii. Collaborative robotics

The industrial sector makes use of a wide variety of robot types11. There are already robots on the market that can help people by transporting goods around a warehouse. Since the quantity of data needed to run a warehouse full of industrial robots exceeds what current wireless speeds can handle, most of these robots are linked through cable networks.

The usage of robots in production will be accelerated and improved by 5G since they won't be slowed down by cables. In the future years, robot use in manufacturing is projected to increase dramatically.

Ocado, located in the United Kingdom, is an online grocery store that claims to be among the biggest in the world. Over 1,100 robots12 work at their high-tech facility in Andover, England, retrieving goods from containers and delivering them to packaging stations in order to satisfy the thousands of monthly orders placed by customers. Daily commutes of up to 37 miles are made possible thanks to traffic control technology that ensures no vehicles will collide. A week's worth of purchases from customers amounts to 65,000 packages, and they can apparently pack 50 products in five minutes [8].

The real-time avoidance of accidents during such activity would need the transmission of huge amounts of data across several sensors. Automated warehouses like this will benefit greatly from the speed and capacity of a 5G network [9].

iii. Analytics to predict breakdowns and downtimes

In the manufacturing industry, unscheduled downtime is a major hindrance to achieving peak output. Research indicates that equipment failure accounts for 42% of the unscheduled downtimes experienced by industrial firms, costing them an estimated $50,013,003 annually. Manufacturers can foresee and avoid disruptions with the help of linked systems and predictive analytics. This is what the facilities of HIROTEC, a renowned manufacturer of vehicle parts, have achieved [10].

The Japanese firm connected edge analytics14 and an IoT cloud platform with its production systems in order to conduct a large number of experiments. HIROTEC was able to monitor its operations in real time, assess their efficacy, and utilize machine learning to foresee and prevent problems in mission-critical systems, thanks to these pilots. Therefore, we were able to eliminate all manual checks. Predictive analytics calls for remote monitoring and automated procedures. The dependability of data collected during pilot tests will be enhanced by 5G networks, leading to more precise weather predictions [11].

iv. Augmented reality for repairs

Thanks to 5G's low latency and reliable connectivity, augmented reality troubleshooting15 might be used to repair malfunctioning circuit boards. Swedish telecoms giant Ericsson has been experimenting with augmented reality (AR) overlays at its Tallinn, Estonia facility so that employees may repair electrical boards without needing to examine blueprints or written instructions.

The company claims that during the diagnostic procedure of a malfunctioning unit, over half of the workers' time was wasted on low-value tasks such as retrieving and attaching schematics to layout files. They use AR to pinpoint the faulty components on a circuit board. The time required to create such documentation, to alter and update it, to train staff, and to repair electronic boards is drastically cut down as a result of this [12].

v. Additive manufacturing

The manufacturing sector has been profoundly affected by 3D printing and other additive manufacturing techniques. Particularly, 3D printing16 is reshaping the administration of service parts.

Many distribution centers keep an extensive inventory of replacement parts to serve customers that insist on utilizing obsolete equipment. The majority of orders (50%) are one-time purchases of replacement components. A 3D printer may be used to create the component on demand, and analytics might be used to determine how many spares to generate. Costs associated with waste management and component stockpiling will so be reduced.

Whirlpool has begun using 3D printing in Singapore with the help of local service provider Spare Parts 3D17. An American company with a global presence, Whirlpool makes home appliances. They want to use this method to counteract the effects of technological stagnation and address localized shortages of essential components. Whirlpool places the greatest priority on the effect on customer service, namely on the availability of new replacement parts for consumers in times of need.

This might be accelerated by the arrival of 5G, which will allow operators to set up links with a number of autonomous 3D printers and then monitor their progress from a distance [13].

vi. Creation of new business models

There will be new possibilities for businesses in the industrial industry as a result of the rollout of 5G. For operators, the flexibility of mobile networks means a blank canvas on which to unleash their creativity and make use of new technologies. For instance, in today's smart factories, drones18 are employed for a wide range of tasks, including delivering materials across the factory floor and conducting aerial surveys of potential construction sites [14].

Drones' operating radius is significantly reduced if they can't connect to the internet. Airborne interference from modern LTE networks makes it difficult to monitor and operate drones. 5G networks are expected to solve these issues and allow drones to be flown in more realistic environments. Another aspect of 5G that enables operators to use the same infrastructure for various use cases is network slicing19. Since the drone-specific "slice" is isolated, it may continue to operate properly even if the rest of the network is unavailable [15].

Since 2013, Amazon has announced plans for a drone delivery system in an effort to increase package delivery speeds. Earlier this month, it was said that Prime Air service would be ready in "a few months." This remark was vague. We look forward to seeing what other innovations the 5G era ushers in since it is because of 5G that this kind of service is now technically conceivable.

2.3 5G TECHNOLOGY

The advent of 5G technology will undoubtedly alter the status quo. The data transmission rates while traveling will be quite rapid. Despite the potential financial benefits, implementing this new technology into telecommunications networks will be difficult owing to the complexity it entails. Artificial intelligence has a lot of potential because of the increasing complexity and versatility of network operations. We describe the work done by Datatonic and Vodafone Group R&D to develop ML models for traffic projections as the first step toward an AI-powered 5G network [16].

The introduction of 5G has revolutionized the telecommunications sector and beyond. With the advent of 5G technology, an unprecedented number of gadgets will be linked to networks with almost zero latency and blisteringly high data rates, regardless of their physical location. All users, human and otherwise, must be able to stay constantly connected at high speeds.

Despite 5G's enormous potential for the telecommunications industry, achieving consumers' high expectations will be a major problem. There are many potential uses for 5G that have yet to be imagined. Examples include the widespread availability of IoT devices, the use of linked vehicles, and the provision of vital medical services. 5G virtual radio and core networks are very flexible, but the predicted huge number of devices and the combination of physical and virtual network assets provide issues for their management. 5G relies heavily on artificial intelligence for the operation and optimization of such massive networks, which demands an extraterrestrial effort [17].

Many businesses are looking forward to the opportunities that 5G and the digitization of the telecom sector bring.

i. Next-generation network infrastructure,
ii. Open digital architecture
iii. Big Data & AI
iv. Cloud technology**.**

Such tenets may cause a shift in the company's long-term priorities:

Deepening customer engagement: Customer satisfaction and repeat business may be increased by delivering excellent network service and concentrating on customers' demands.

Efficient and autonomous networks: The software-based, AI-driven 5G network will cut down on operating costs by lowering the need for human network maintenance, eliminating faults before they exist, speeding up the process of recognizing and resolving abnormalities, and optimizing asset utilization.

Growing offerings in B2B and B2C: New services, business models, and income streams will emerge as a result of network virtualization and the explosion of IoT connections.

Companies like Vodafone are already putting Big Data, Analytics, and the Cloud to work in a variety of contexts. But there's still a long way to go. We'll be able to better serve our clients and run a tighter ship as a result. – Luke Ibbetson, Director of Vodafone Group R&D.

2.4 AI-POWERED TRAFFIC FORECASTING MODEL

Datatonic developed and deployed an ML solution that predicts internet traffic on a mobile network in a major European city using anonymized open-source data as part of Vodafone's efforts to build an open digital infrastructure [18].

It was intended that the thesis would prove the following points:

Discover how Google Cloud Technology may hasten the creation of ML solutions; show that it is possible to create a specialized ML model to predict traffic on a network of 10,000 sites; investigate further architectural advances and steps toward the realization of diverse use cases.

Google Cloud Platform's controlled and scalable services might potentially speed up the time it takes to complete projects. With the help of these services, data scientists can put their attention where it belongs: on strategy and models as they develop novel ML solutions.

The following services from the Google Cloud Platform were used for this endeavor. Google Cloud Storage, a scalable blob storage component, received the raw historical data and uploaded it. After the data was cleansed, Dataflow sent it over to Big Query in a large batch. Data cleansing and SQL reshaping were performed in Big Query before being fed into an ML model. When developing machine learning models in Python and TensorFlow, AI Platform Notebook offers a scalable, managed Jupyter Notebook service that facilitates simple switching between CPUs and GPUs depending on the workload. The training and prediction capabilities of the AI Platform were used in the creation of the ML models.

In the end, forecasts were saved in Big Query so that an exhaustive network analysis of the model's performance and forecasts could be carried out [19].

i. Step a: Data exploration and business insights

To start, we looked at the data closely. Using unsupervised ML methods, we may identify unique use patterns across the different network nodes. Certain areas, for instance, showed peaks in traffic immediately before and just after local business hours, when people were likely to be making their way to and from work. Other sites showed heavy foot activity during regional business hours but a precipitous drop down after hours and on weekends, designating them as commercial hubs. The same methods are used to categorize places as either residential, suburban, or commercial.

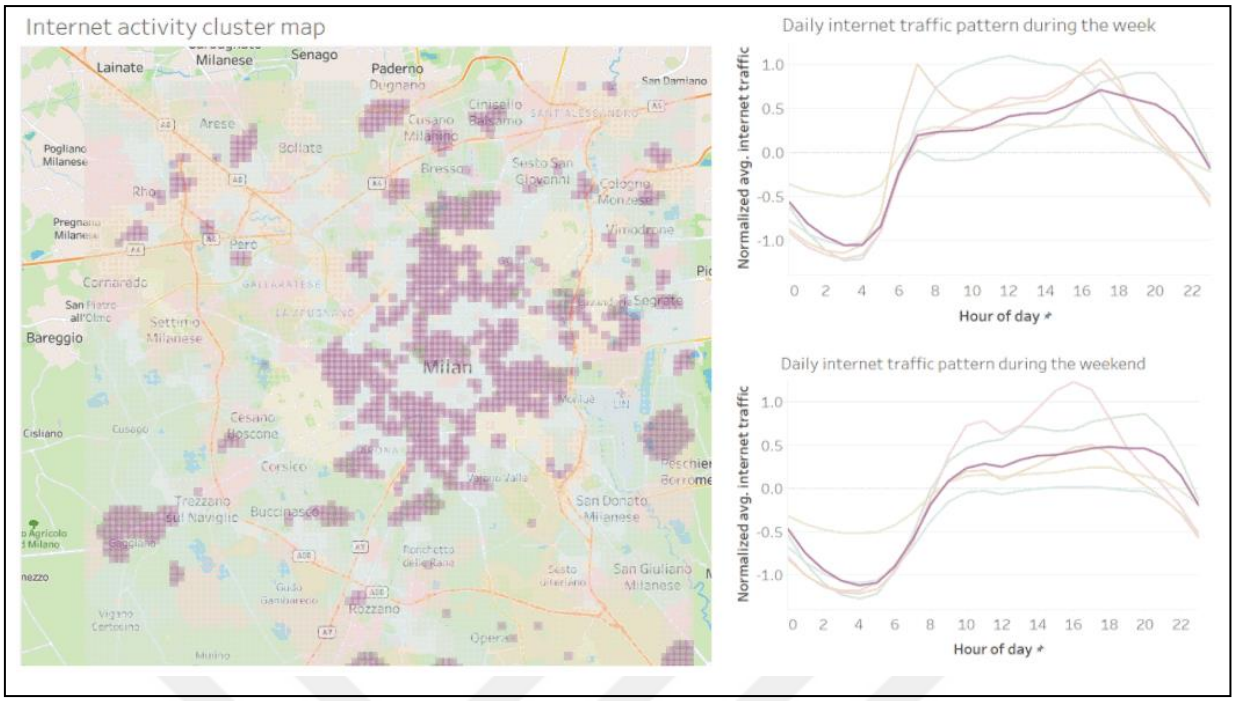

Figure 2.2: Daily Internet Uses Pattern [19]

As can be seen in Fig. 2.2, the unsupervised machine learning technique clusters locations based on the online behavior of their people, creating visually similar patterns of internet usage in various parts of the globe. In the lingo, these groups are referred to as clusters. The map's nodes are color-coded according to cluster (on the left). The right-most curves in each cluster reveal a wide range of typical web traffic patterns. Many regions of the globe exhibit visually similar patterns of internet usage, as seen in Fig.2.2. When using an unsupervised machine learning technique, locations are grouped together according to the online activities of their respective populations. In the lingo, these groups are referred to as clusters. Clusters are denoted on the map by a unique color, and the individual nodes that make up those clusters are depicted in that color as well (on the left). Common web traffic patterns are shown as a spectrum in the right-hand curves that represent clusters of similar users.

ii. Step b: Development of ML forecasting models

Once places with distinct patterns of network use have been identified, it is only natural to move on to forecasting.

It's a good idea to have a starting point before really doing anything. Having this reference point will simplify the analysis of advanced ML models. We choose to employ a persistence model, sometimes known as a naive forecast. The value at the most recent time step is used to

predict the value at the next time step in the persistence model. The persistence model is often used as a baseline in time series forecasting due to its ease of use, speed of inference, and usefulness as a first approximation [20].

It is not easy to conduct a comprehensive comparison of the model performances for our use case because of the geographical and temporal factors included in the unique data. The errors for each model were calculated using the predictions from a test set that reflected one week of unobserved data throughout the whole network. We decided to summarise a model's accuracy by only two metrics: its mean absolute error (MAE) and its mean squared error (MSE), both averaged over a week and over 10,000 locations (MSE) [21].

In the beginning, a MultiLayer Perceptron neural network was built. Scientists working with the data are responsible for creating the characteristics that will be used to extract the desired insights from the data and then feeding them into the model. Seasonality (monthly, weekly, and daily patterns) is a common occurrence in time series, and including this information as a feature would improve the model's accuracy. Consequently, we created embeddings for the characteristics of date (weekday) and time (hour of the day). Finally, by reusing the collected information on the dependent variable (internet use), We created lag characteristics that are three hours, one day, and seven days out from the forecast period. Finally, we settled on a category characteristic to use as a representation for each node in the network. The input characteristics, such as the network's location and the time of day, are used by the trained model to create predictions regarding internet usage.

Secondly, we analyzed a dense net neural network model [22]. The approach here is to see the network as a "picture" and try to predict the values at each node in the network one hour from now. Internet use patterns are the only data fed into this strategy. To find previously unseen relationships in the data, data scientists need just run the model; they need not create features to feed the model, which might provide bias or fresh insights.

Both methods performed similarly, and they both far outperformed traditional methods of time series forecasting (we observed a 25 percent decrease in mean absolute error compared to the naive persistence model). In addition, they get outcomes that are competitive with those of SARIMA, a popular statistical approach to time series forecasting. In contrast to SARIMA, which requires a separate model for each site (that is, 10,000 models in total), our method can scale to a large number of locations at once [23].

iii. Step c: Leverage ML model insights to take actions

In order to address issues with the performance of our model, it is crucial to realize that the forecast of network internet traffic provided by our model is not the final goal but rather a necessary first step towards deploying 5G technology. It's crucial to detail the kinds of applications that these forecasts will enable, as well as the effects and benefits they'll bring to those domains. Simply put, the financial effect of traffic forecasts is minimal to non-existent for businesses. Decisions you make in light of these projections will have a significant impact on the significance and value of your business.

The telecommunications industry anticipates outcomes in several areas, including closed-loop network automation. It's no easy undertaking to gather network telemetry data, provide reliable projections, and automate choices about how to fine-tune a network. Guenter Klas, director of R&D at Vodafone Group and head of the Artificial Intelligence Research Cluster, said that once this is deployed, it will be "like magic."

Thanks to Datatonic, we accomplished our objectives considerably more rapidly and accurately than we had expected.

Aiming to reduce operating expenses and energy consumption for a complicated network, the traffic forecasting system makes use of artificial intelligence to assist efficient resource provisioning on a vast scale. In this specific application, the model's prediction will be used to advise on whether or not network resources (such as required bandwidth) should be up- or downscaled in order to strike a good balance between satisfying customers' needs for instantaneous access to their services and preserving valuable operational resources by not over providing network capacity [24].

The initial emphasis of this solution is on helping humans make choices, but it will ultimately be used to guide a second layer that can automate decisions about how much to scale up or down resources based on forecasting predictions. These advancements will allow for closed-loop, zero-touch network functioning, in which people only watch solutions without actively modifying them.

2.5 CHALLENGES

Before the 5G vision can be fully realized, many revolutionary problems related to the transition from 4G to 5G must be overcome. While technological progress makes 5G conceivable, it comes with certain limitations of its own. The use of this technology to provide services in a wide variety of settings is not without its share of difficulties. Some industries are skeptical about 5G because of its high estimated cost and its incompatibility with current generations of technology. Similar to how 2G phones can't connect to 3G or 4G networks, 3G and 4G phones can't connect to 5G networks. This requires purchasing a newer model of smartphone, which is likely to be more expensive than the monthly 4G/LTE service subscription alone.

Altering the fundamentals of cellular construction is the only long-term solution to these issues. The Mfentocells, low latency, scalability of the network, extremely long battery life, and eco-friendly communications are only some of the performance criteria for the 5G system. It's difficult to keep quality high while reducing expenses.

When seen from this angle, 5G has a long way to go before it can reliably achieve the following KPIs regarding performance.

Improve throughput by a factor of 10 for each user if you want them to enjoy really immersive experiences. This might call for the introduction of other broadcasting options [25].

Latency: provide regular Internet services, interactive and immersive experiences, and latency as low as 1ms (as needed).

Energy efficiency: Even though ICT only contributes to about 4.5 percent of worldwide energy consumption, wireless/mobile broadband infrastructures consume more than half of all energy utilized by telecommunication operator networks. Future 5G networks will require extremely low power consumption to fulfill the criteria.

Service creation time: Even though the worldwide ICT sector only accounts for about 4.5 percent of all energy used, the energy consumption of wireless/mobile broadband infrastructures is significantly higher. In order to accomplish their goals and adhere to environmental regulations, the 5G networks of the future will need to be extremely power-efficient.

Battery lifetime: provide low-throughput systems like sensors at least a tenfold gain in battery life.

Coverage: Customers have learned to expect the same level of service everywhere, so 5G service must be permanently expanded everywhere (on cruise ships, passenger airplanes, high-speed trains, and in vacation villas). One of the most exciting potential uses of satellite-wide area coverage is Internet of Things (IoT) connectivity over vast distances, which might include sensor and machine-to-machine (M2M) connections.

We go through fundamental performance issues as well as system-level worries caused by the ever-changing environment in which 5G is anticipated to work [26].

a. The difficulty with privacy-by-design is figuring out how to allow people to have really private discussions when they need to while simultaneously complying to legal obligations for data management and ownership and gaining assistance from the firms in charge of delivering the underlying infrastructure.
b. Quality of Service challenge: ensure that users are able to engage in really private communication when needed, in conformity with legislative constraints on data management and ownership, and with the backing of infrastructure providers who deliver the whole service.
c. Simplicity challenge: Provide the best network services possible to 5G users with little effort on their part (e.g., for inter-RAT switching).
d. Density challenge: “New difficulties have arisen for mobility management infrastructure as the number and types of nearby connected devices have exploded.
e. Regardless of who controls the underlying infrastructure, the multi-tenancy problem streamlines data flow between the wireless domain and the backhaul. This enables a wider range of networks (not only IP-based ones) to coexist.
f. Diversity challenge: As the number and diversity of connected devices, as well as the types of traffic they generate, continue to grow, it is critical that 5G be capable of handling all of these users and their demands.
g. Harnessing challenge: As the quantity and diversity of connected devices, as well as the traffic they generate, grows, it is critical that 5G be capable of accommodating all of these users and their expectations.

h. Harvesting challenge: new approaches of capturing environmental energy to complement battery power for portable electronics.
i. Mobility challenge: allows for unrestricted, problem-free travel between all linked systems
j. Location and context information challenge: provide a sub-meter location and context capabilities using a mix of cellular and satellite positioning technologies, hence facilitating the Internet of Things.
k. Open environment challenge: provide the internal business interfaces required for multi-tenancy and the adaptability required by operator models.
l. Manageability: Reduce the amount of time spent on manual tasks by increasing the network's manageability. The term "quality of experience" is used to describe a customer's level of satisfaction with a certain product or service (QoE). If the product or service meets or exceeds the user's expectations and the user has a pleasant experience, the customer is satisfied. Article 13 White Paper for Public Review and Comment: August 2014
m. Hardening challenge: Without the deployment of a communication infrastructure employing a combination of carrier techniques like cellular and satellite that is fundamentally immune to attacks from malicious actors and to natural calamities, the smart-grid/smart-city paradigm can never be realized.
n. Resource management challenge: Any resource (bandwidth, computation, memory, storage, and so on) must be allocated, reallocated, and released to any device and service (terminal, automobile, robot, drone, and so on) using access-agnostic control, policy, and charging methodologies and protocols (e.g., Network, Security, Data, Knowledge, Machine, and Thing as a Service).
o. Flexibility challenge: The first challenge is to provide highly adaptive control methods and protocols for the end-to-end transmission of functions, protocol entities, and related states using programmable network technologies such as SDN and NFV.
p. Identity challenge: The identity problem is figuring out how to handle identities for everything that can communicate with anything else, whether it's a computer, a car, a robot, a drone, or anything else, no matter where it is or what it uses.
q. Flexible pricing challenge: The difficulty of implementing flexible pricing stems from the need to provide consistent pricing models throughout the many sectors that will make use of the emerging 5G network. A privately owned small cell's open access to an operator's infrastructure is an example of how the underlying technology and business model may change to accommodate new use cases.

r. Evolution challenges: The difficulty of evolution is to allow for progress while making the transition from earlier systems as painless as possible" [27].

2.6 5G IMPACT ON SOCIETY

The benefits of the Fourth Industrial Revolution and new technologies directly related to it will be reaped in their totality with the widespread installation of 5G communication networks and other connectivity choices.

"The fundamental goal of fifth-generation wireless networks will be to increase the quality of the user experience, as well as decision-making processes and service delivery. By 2035, the global value chain for 5G will have grown by 22.3 million people, contributing an additional $13.2 trillion to the global economy. This paper takes a bottom-up approach, analysing 40 use cases to identify key industrial breakthroughs and social impact areas, as well as the main functional drivers of 5G and the maturity levels required for these drivers. The goal of this report is to figure out how to realise this enormous predicted economic output potential. The ecosystem's components, players, and dependencies are outlined, along with the measures needed to speed up 5G's implementation and fully fulfill its potential" [28].

2.7 NETWORK SLICING ISSUES

The concept of "chaining" in the context of intelligent service operations (also known as service function chaining). It is possible to perform many different network service functions by using intelligent service function chaining, either locally on a single node or remotely across a distributed network of nodes and virtual computers. Each node's connectivity to the rest of the network is restricted by its bandwidth and resources. For optimal performance and minimal lag, the SFC should deploy the lowest-powered, least-powerful processing nodes possible (service function chaining). By integrating routing with either a reinforcement learning-based SFC approach or a deep learning-based SFC scheme, SFC (service function chaining) becomes a practical option (service function chaining) [29].

i. Due to the requirement to take mobility into consideration, network slicing is one of the most challenging issues to solve when it comes to allocating resources in smart applications. 5G networks present a unique set of challenges due to their extraordinary density and the handovers required for different access networks. Instead of installing augmented reality-based programs, however, these problems are addressed by a system of

mobility-aware slicing. Some challenges remain, but customer-specific on-demand slicing approaches are essential if autonomous vehicles are to operate securely on roadways. The researcher proposed a Lagrangian dual-decomposition-based solution applying game-theoretic techniques to the issue of resource allocation in network slicing applications.[30]

ii. Network slicing attacks are more successful against networks with varying degrees of internal security, according to the field known variously as network forensics, network slicing, and network analysis. To improve existing forensic methods for the IoT and cloud computing (CC), new forensic methodologies, especially for network slicing, need to be developed. These cutting-edge forensic tools aren't just helpful in the event of a catastrophic attack; they may also be used to trace the origin of assaults and identify their perpetrators, even in less public places. This is why state-of-the-art forensics techniques for identifying threats like network slicing will be developed and put into use [31].

The importance of dynamic spectrum slicing in network slicing will grow as consumer demands increase. It's possible that the spectrum will be underused or overused in a fixed spectrum-slicing scenario. So as to avoid these challenges, dynamic spectrum slicing is used. It was proposed that a policy-based dynamic spectrum slicing technique be used so that the network could respond more quickly to changing traffic patterns. The use of Markov modeling to disperse user traffic was also proposed as a way to improve the slicing algorithm's overall performance.

Adaptive security mechanisms are an evolving variety of security measures that may adapt to new threats and countermeasures.

For systems that need to run across many levels of infrastructure at once, network slicing creates complicated and critical security challenges. All three of these approaches—multidomain, interslice, and interslice—raise substantial difficulties that must be overcome. Using a network that doesn't use advanced machine learning methods is risky business.

We use a static slice to discover all the components of an app or architecture that rely on it. As such, it is an effective instrument for study and investigation. In this strategy, static slicing is used to aid in the discovery of valuable phrases. Statements of interest are discovered and placed in accordance with the slicing criteria that have been set. There is a chance that debugging, dependency analysis, and other duties could benefit from a more in-depth examination of the code and product structure.

One possible application of dynamic slicing is learning only the relevant claims on the fly based on the slicing criterion values. This is one of the conceivable uses for dynamic slicing. “When dealing with sophisticated programmes that use array and pointer variables, static slicing is commonly used, however dynamic slicing should be avoided whenever possible since it incurs an unjustifiably high cost in terms of execution time and should be avoided whenever possible”. A dynamic slice is a subset of a program that contains statements, components, and connections that may significantly alter the value of an unrelated variable at any point in the architecture or code. In recent years, dynamic slicing's potential has been highlighted in applications that attempt to enhance the software's quality, stability, safety, and effectiveness, in addition to its use for user-level debugging [32].

The necessity to provide relevant remarks first is connected to the intention of making an early cut in a certain direction. That depends on the presence of action verbs like "affecting" and "influenced by" in the sentence in question. It's helpful since it shows how the calculations for slicing work graphically. Nonetheless, the procedure for identifying forward and reverse slices is the same in both cases. The system's treatment of the transition between the two flows is the single distinguishing feature [33].

Finding important statements in a program or design that will have a major impact on subsequent statements may be accomplished with the help of the forward-slicing computation flow method. All control and predicate statements that could be affected by the questioned variable are grouped together into a single forward-slice. One way to simplify debugging and understanding a program or architecture is by the use of a technique called "forward slicing." This method isolates and displays just the relevant parts of the code that depend on a single variable, statement, component, or link. It's also used for displaying code that hasn't been cleaned up for readability and doesn't depend on any one specific variable, statement, connection, etc.

3. RESEARCH METHODOLOGY

3.1 5G NETWORK ARCHITECTURE AND PROTOCOL STACK

The primary focus of the thesis will be on the protocols and infrastructure of a 5G network. A "5G network's architecture is made up of several components, including radio access networks (RANs), aggregators, an Internet Protocol (IP) network, a Nanocore, and cloud computing, among others. This potential 5G network design shows how numerous radio access networks (RANs) can communicate with one another utilising flat IP via a single Nanocore. [34] A wide range of wireless protocols can be supported by radio access networks (RANs). GSM, GPRS/EDGE, UMTS, LTE, LTE-advanced, WiMax, and Wi-Fi are some examples of these technologies.

Devices may be identified by their symbolic names under a flat IP architecture, as opposed to the hierarchical IP design employed by default IP addresses. This design significantly decreases both costs and delays by limiting the number of network nodes involved in the data flow.

An aggregator is a device whose job is to gather data from a radio access network and send it to a gateway. Position of the Base Station Controller or Radio Network Controller. In addition to nanotechnology, cloud computing and an all-IP architecture make up what is known as the "nanocore." In cloud computing, a group of servers in different locations via the Internet stores and processes data and programs for its users. The user may get the data without worrying about downloading any software on their machine [35].

There are four distinct stages in the 5G protocol stack. Listed below is a comparison of the Transmission Control Protocol/Internet Protocol (TCP/IP) stack with the Open Systems Interconnection (OSI).

OWA Layer: The Open Systems Interconnection (OSI) physical and data link layers serve as a blueprint for the open wireless architecture. Several current and prospective future wireless communication protocols might be supported by the proposed OWA thanks to its open interface baseband processing modules.

Network Layer The network layer consists of an upper and lower portion. The objective is to transfer data between two IP-enabled devices or systems. The network layer is perhaps the

most important layer in the OSI model due to the fact that it has the most information about the addresses of other networks. The network layer is also concerned with the quality of service (QoS), which it determines and then communicates to the Transport layer based on data from the local server domain. The purpose of the Network layer is to simulate communication channels between nodes without requiring them to physically join. This component of the network architecture handles requests coming from the Transport layer and passes them on to the Data link layer [36]. In light of the growing importance of both data transmission speed and connection stability. The goal of developing 5G is to fix the problems with 4G networks by enabling the terminal endpoint to use several wireless technologies and to combine data streams from a variety of sources. Because customers may be in transit at any given time, it's important to plan accordingly to maintain a constant level of service quality. With 5G, users may expect a bandwidth increase of over 400 times above 4G. Software-defined radio, encryption, and flexibility will be used together with ultra-wideband and smart antennas" (Fig. 3.1).

Figure 3.1: 5G Technologies [36]

OTP Layer: The functions of the OSI stack's session and transport levels are combined into the OTP layer. When compared to a wired network, the transport layer of a wireless or cellular network is configured differently. Data loss in wireless networks is the result of a high bit error fraction at the wireless interface. As a result, updates and revisions to TCP are made available for use across cellular and wireless networks so that any corrupted or lost TCP packets may be sent again over these connections. The networking system's transport layer should be freely downloadable by the 5G mobile stations. These mobile phones must be able to download and

install (for example) TCP, RTP, RTCP, etc., or other new protocols to ensure the correct operation of the wireless technology at the various base stations [37].

Application Layer: The information is adapted so that it may be used effectively. It may be used for both encrypting and decrypting information. The best wireless channel for a certain service might likewise be identified in this manner. This layer's primary function is to display technology for the end user. At the application layer, data transfer is complete, and a graphical representation of the data is given to the user (GUI). If introduced as a new kind of service, users may find it much more convenient if integrated with 5G.

3.2 BASIC ARCHITECTURE OF 5G

The network nodes and terminals in 5G are state-of-the-art in order to function in the new environment. Similar to how fast, innovative technologies can be adopted by businesses, so too can service providers rapidly implement value-added services. However, cognitive radio technology paves the way for future enhancements with a variety of useful features, such as the ability for devices to pinpoint their location and other environmental parameters.

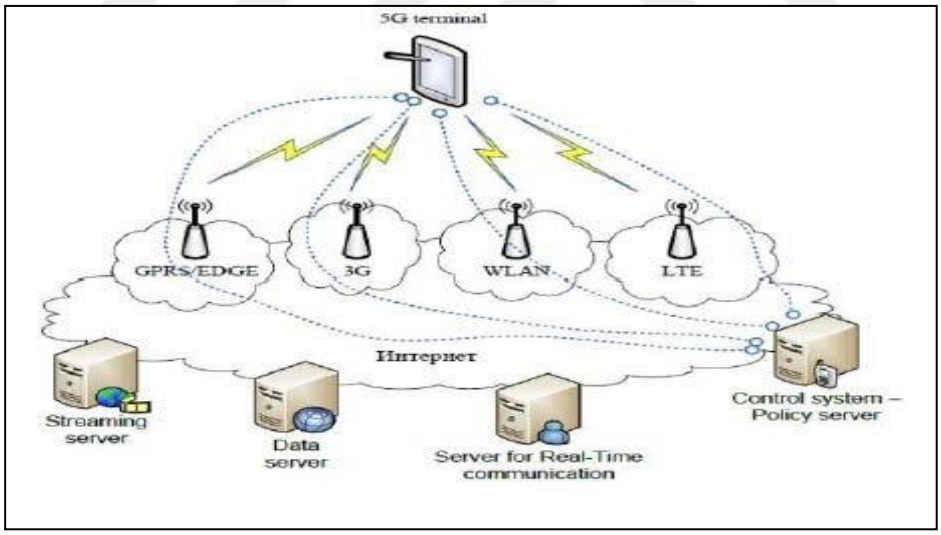

Figure 3.2: 5G Basic Architecture [37]

The following graphic illustrates how the 5G system architecture is an IP-only design tailor-made for mobile and wireless networks. The primary user terminal is the system's nerve center; auxiliary radio access technologies operate autonomously. Regarding the external internet environment, radio technologies are handled the same as any other IP connection. IP's only function is to provide enough control information for IP packet routing about sessions between

client applications and servers dispersed over the Internet. Furthermore, packet routing has to be customized to the user's needs before it can be made available.

The 5G architecture is comprised of the "core," "cellular," "wireless," and "mobile" layers. The following paragraph will focus on network design since this is the most crucial component.

3.3 NETWORK ARCHITECTURE OF 5G

A 5G network design was proposed by five separate researchers [38]; these researchers were Agyapong, Iwamura, Staehle, Kiess, and Benjebbour. We'll start with a brief overview of the network's structure before diving into its most important parts.

The network's architecture is composed of two distinct layers: the lower-level L1/L2 radio network (RN), which is in charge of lower-level services, and the higher-level network cloud (NC), which is in charge of all higher-level services. In a network that is built on the cloud, SDN and NFV make it possible to rapidly deploy and scale network capabilities. The protocol stack can be made more straightforward by fusing the functions of the Application Server and the Network Appliance Server. The RN can do this thanks to a C/U-plane split design and the utilisation of distinct frequency bands for coverage and capacity.

More than one device can be connected at the same time, groups can travel together, and mobile hotspots can exist in a variety of locations. New waveforms for connectionless and contention-based access have been created to allow for the asynchronous joining of numerous MTC devices. Data-driven network management for more effective resource allocation

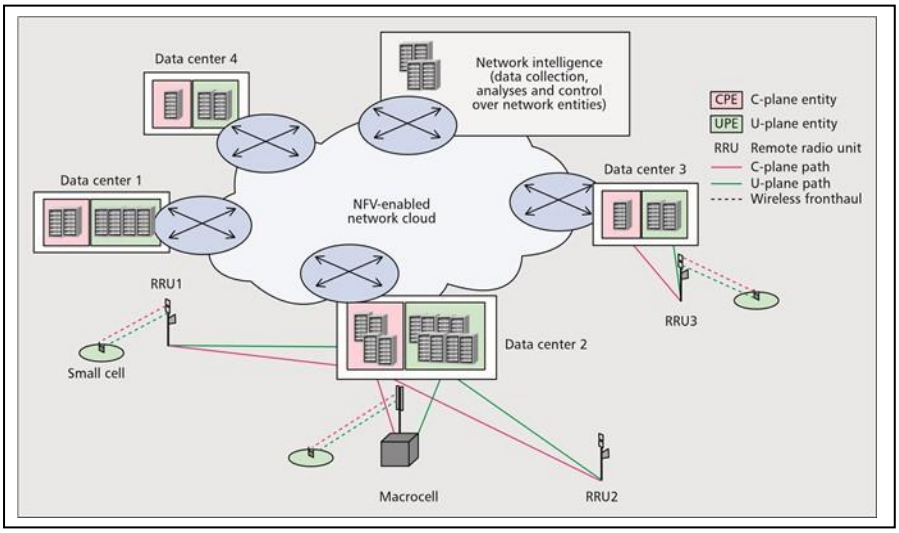

Figure 3.3: Network Architecture of 5G [39]

The radio infrastructure and network cloud are at the heart of the system. When it comes to base stations and RRUs in a radio network, there are numerous variations to choose from; nonetheless, they all perform the same L1/L2 function. In a network cloud architecture, separate organisations are responsible for managing the higher-layer capabilities of the user plane (UPE) and the client plane (CPE).

There are various cloud deployment models available. For “latency-critical services, for example, user equipment (UE) and remote radio units (RRUs) that are close to base stations and RRUs may be beneficial. To manage latency-sensitive applications, for example, it may be necessary to connect RRU3 to a smaller and closer data centre rather than a larger data centre located further away”. When RRU1 is not responsible for delivering time-sensitive services, it can be linked to a far-flung data center (data center 2) instead of a smaller, more central one. Depending on the service's requirements, the operator may establish a large or small data center.

Such a design simplifies network administration and deployment, increasing productivity and flexibility. Lower construction and operational costs for dense deployments are possible if base stations have fewer capabilities [40]. In a similar vein, both the complexity and energy usage of base stations would drop. Overprovisioning and underutilization of resources can be cut down with the help of the network cloud.

“Cloud-based networking services can be simply set up and expanded thanks to software-defined networking and network function virtualization. CPE and UPE functions in the network cloud can be quickly deployed with the help of software-defined networking (SDN) and network function virtualization”. If one data center suddenly experiences a large influx of users, you can borrow more capacity from a neighboring data center (as a result of a natural disaster). A data center can also swiftly spin up additional instances of software as needed to accommodate new applications, allowing for flexible resource allocation.

When working with a cloud, you can scale the resources available to your apps up or down as needed. Unused cloud resources can be made available to other users during periods of low demand, and more resources can be rented via IaaS models during times of high demand. It is possible that many additional "as a service" models based on the sale of individual network capabilities will succeed in the long run (XaaS). Network operators, over-the-top (OTT) service providers, and significant enterprises may be able to rent out all or part of their infrastructure

to third parties using a "mobile network as a service" or "radio network as a service" model. This is often referred to as "radio network as a service." The other approach is to build "UPE/CPE/NI as a service" models, in which only the essential aspects of a mobile network are made available to consumers. Finally, the entire platform may be licenced to third parties, such as OTT providers, to aid in the delivery of services and apps to end consumers with exceptionally low latency. The cloud's adaptability not only allows for the implementation of XaaS business models, but it also makes network building and maintenance much simpler, more efficient, and less expensive. This is made possible by the integration of SDN and NFV technology.

3.4 5G LAYERS

A Resource Layer Connected to the Infrastructure: “The infrastructure resource layer of a fixed-mobile convergent network consists of access nodes, cloud nodes (which can be either processing or storage resources), 5G devices, networking nodes, and associated links. This layer also contains the associated links. If virtualization ideas are used, it is feasible that the higher tiers and the orchestration group will have access to the resources”.

Business Enablement Layer: An example of a library that contributes to the modular design of a convergent network is a collection of software modules that perform a certain function and may be downloaded to any computer in the network. The entity doing the orchestration uses API calls to get access to the required components and functions.

Business Application Layer: operator, sector, industry, or app/service provider that relies on 5G networks.

An orchestration entity crucial to this architecture articulates these three levels. In addition to the standard automation features of OSS and SON, it enables the operation of a fully virtualized network. If you need help turning business or use cases into usable services or "slices," you may count on this group. It analyses a use case and decides how many slices of the network are required, which modular network functions should be connected, and what performance parameters should be adjusted, and then transforms this information into the available infrastructure resources. It regulates the availability and strength of these services on a global scale. It may also be able to provide APIs and XaaS principles in certain business models to allow third parties (such as MVNOs and verticals) to develop and maintain their own network

slices. When analytics are driven by data, they may be applied throughout the entire service delivery process to boost quality [41].

Network Slicing: When the C- and U-plane are controlled in a predetermined manner, a network slice, also known as a "5G slice," enables the provision of a specific type of connection's communication service. Here, a 5G slice is constructed from a group of 5G network capabilities, with each capability tied to the appropriate RAT parameters for the desired application. From the specific radio configurations and RATs used by individual 5G devices to the software modules running on cloud nodes to the specialized transport network configurations allowing for the dynamic deployment of services—all of these and more might be included in a 5G slice. Some slices may be missing functionality that has become increasingly important for mobile networks, and not all slices are created equal.

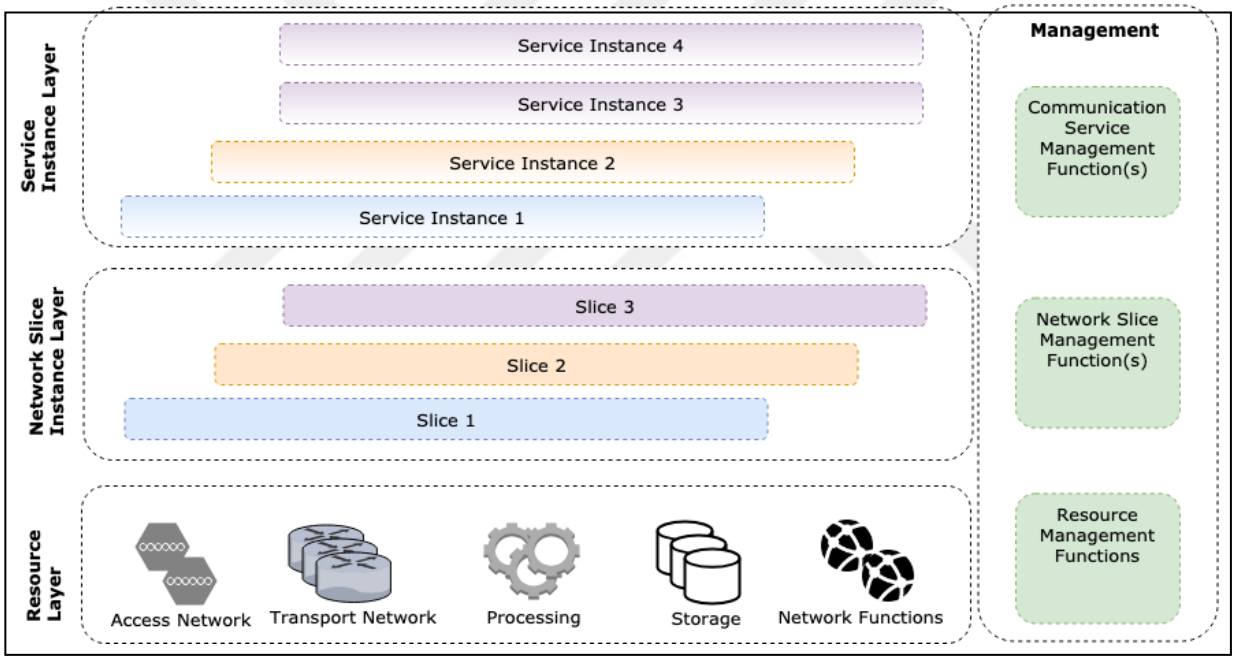

Figure 3.4: Network Slicing [42]

This study looks into the potential effects of 5G technology on the business world by combining quantitative and qualitative data and conducting the research using a mixed-methods approach (Creswell, 2014). The study looked at eight distinct demos that were part of the 5GEM initiative, which aimed to show off various applications of 5G technology in manufacturing. The eight protesters' main concerns:

i. designing a plan for the radio system,
ii. designing the infrastructure and infrastructure on the cloud for the 5G testbed,
iii. connection for permanently placed machines,
iv. connectivity to wireless devices and people,
v. extensive deployment of 5G technology in a single plant,
vi. statistical analysis of information obtained by the 5G testbed
vii. industrial control hut, and
viii. carrier installations of 5G technology

D2D Communication: It's a form of innovation that enables devices to communicate with gadgets without depending on intermediate nodes like wireless routers. Bluetooth and Wi-Fi-Direct are the most well-known D2D technologies, and both operate in the unlicensed ISM (industrial, scientific, and medical) bands. [43]

Millimetre Wave Technology: The massive bandwidth made available by 5G technology means it has the ability to achieve throughputs of gigabits per second. Providing a low-latency, high-data-rate, scalable link to a large user base may benefit from the abundant spectrum resource made available by unlicensed millimeter wave frequency bands. These bands operate between 30 and 300 GHz.

Table 3.1: Requirements and Enabling Solutions For 5G Cellular Technology [43]

S. No	5G expectation	Proposals
A	Increased throughput and data rate (about 1000 times higher than 4G, data rate around 10 Gb/s)	Multi-tiered systems, spectrum reuse, and the usage of unconventional frequencies (such as those used in millimeter-wave communication) dense urban areas, and wireless networks huge MIMO, direct-to-device (D2D) connection, and centrally-controlled radio access networks
B	short delays (between 2 and 5 ms)	C-RAN and D2D networks, full-duplex communication, mobile cloud computing, and big data Communication

Table 3.1: Requirements and Enabling Solutions For 5G Cellular Technology [43] 'Table Contied'

C	Savings in energy use (or "energy efficiency") 1000 times for each bit)	Green communication, energy harvesting, direct-to-device (D2D) communications, ultra-dense environments
D	Management of networks and programs that may run themselves	Internet of Things, Cognitive Networks, and Self-Organization
E	Superior scalability (support for up to 50 billion devices)	Massive multiple-input multiple-output (MIMO), mobile cloud computing, and wireless software-defined networking
F	Extremely close connections between objects	Direct-to-device communications improve cell edge users' network connections.
G	A/A/R/C Security Standardization	Internet of Things, Software-Defined Networking, and Big Data
H	Complex uses (like "smart city")	C-RAN, M2M communication, and network virtualization

Massive MIMO: "Massive MIMO, also known as multiple-input multiple-output (MIMO), is a critical component of 5G network architecture. Massive MIMO employs a huge number of antennas at base stations, as contrast to the 4G system's multi-user MIMO (MU-MIMO), which employs a small number of antenna components incorporated into user terminals and base stations. This is done to boost the system's throughput and capacity".

Popular search engine Google has previously admitted that mobile device use has surpassed desktop. A few years ago, the most RAM that a smartphone could have was a few megabytes; now, some smartphone configurations may rival those of the most powerful desktop PCs. It is clear that the functionality of cell phones is severely constrained without access to the internet. The more devices there are that need to connect to the internet, the more crucial fast connectivity becomes.

Most companies foresee the future needs and desires of their customers and work to develop goods and services that may make people's lives simpler. That's why people started thinking

about what 5G might be like a full decade before 4G was even widely available. As expected, 4G has been used as a stepping stone for the 5G rollout. This article expands on previous discussions on 5G's potential rollout throughout the country.

The term "5G" simply refers to the next generation of the IEEE 802.11ac-based standard when addressing cutting-edge mobile wireless technology. 5G aims to expand capacity by allowing more mobile broadband users in the same physical location to consume the same amount of data in the same period of time, in contrast to the promise of increased Internet speed made by 4G LTE. This would allow a large percentage of the population to use their mobile devices to stream high-quality video for long periods of time every day, even when they are not in range of a Wi-Fi network. The purpose of 5G research and development is to improve network security and accessibility for a large user base while reducing the price, power requirements, and lag time of machine-to-machine data transmission (also known as the Internet of things).

3.5 5G NETWORK SLICING

The basic concepts and terminology of 5G network slicing are explained in [44]. Differentiated services may be possible with 5G's network segmentation. From a more realistic perspective, you may consider factors like portability, safety, and command as means of differentiation. Performance, latency, throughput, error rate, reliability, and availability vary across the various options [23]. Each use case is given a streamlined list of service requirements. It is simpler and more productive to fulfill smaller sets of requirements than larger ones [45]. “Each network slice instance is an end-to-end logical network that offers services tailored to certain use cases, such as voice communication, video streaming, e-health, and vehicle-to-vehicle communication, in order to deliver the necessary networking characteristics. On top of a logical network's storage, network, processing, and access nodes sit a collection of network function instances. Network slices subnet instances are yet another type of private virtual network. In this document, network slice instance and subnet instance will be used synonymously to represent the fact that a network slice instance might be made up of several subnet instances. In 5G, there are two distinct but interdependent network domains: the core network and the radio access network. Chaining together multiple slices is known as sub-slice chaining”. If the necessary slices are constructed and partitioned correctly, they can be handled and controlled independently [46]. We may safely ignore all three performances, reliability, and management concerns at once [47]. 5G network slicing enables the creation of virtual networks with specific characteristics such as Quality of Service (QoS), security, and

performance requirements. Each slice can be customized to support different types of traffic and applications, such as low-latency, high-bandwidth applications like virtual reality and autonomous vehicles, or low-bandwidth, low-power applications like IoT devices.

Additionally, 5G network slicing allows for the efficient use of network resources by allocating resources to different slices based on their specific needs. This can lead to improved performance for specific applications and services, and also enables new business models such as allowing third parties to rent slices of a network for their own use.

Network slicing also brings network flexibility, scalability and security. It enables network providers to create multiple isolated slices, each with their own security protocols and policies, which can protect against cyber threats and breaches. Additionally, 5G network slicing enables operators to create and manage virtual networks in a dynamic way, allowing them to quickly adapt to changing traffic patterns and service demands.

i. Architecture

Three distinct levels, each with its own administrative powers, could make up the overall network-slicing architecture.

a. Resource Layer: In response to requests from the application layer, the service layer provides the underlying network layer with the resources and functions necessary to provide the requested service. Both may exist in mind, on a computer, or in the actual world. Data storage facilities, data processing centers, and communication nodes are all examples of resources. Instances of network slices may have rendered a service, such as routing and switching, slice selection, or authentication.
b. Network Slice Instance Layer: The slice provides the required network capabilities for service instances. The core layer is sectioned off. A single slice may support several service instances that share its underlying network resources or another slice. It is unclear if it is possible to run two independent slices on the same physical architecture and, by implication, whether they would or would not share resources and network activities.
c. Service Instance Layer: This top layer is made up of the service instances that are consuming the slices and making them accessible to customers. When used here, the word "service" refers to an instance of a service [48].

4. RESULT AND ANALYSIS

Markets that are particularly latency-sensitive include those dealing with robotics, interactive online tools and computers, and the Internet of Things (IoT). As a result, the next-generation network is pushing the limits of what is achievable in terms of data rate, latency, efficiency, and so on. Furthermore, the quantity of energy used by devices and networks, the volume of traffic, the convenience of access, and the speed of connections are all taken into account. These groundbreaking technologies necessitate more advanced technology than the currently existing 4G networks can provide.

Certain network modifications are required in order to achieve the desired low latency. Because of the substantial amount of latency created by the backhaul linking the radio access network (RAN) and the core network, the mobile edge computing trend that is currently common in network architecture, including software defining the network (SDN), is projected to continue (CN). Media execution cache (MEC)/caching, a characteristic of network virtualization, might be utilized to decrease latency dramatically. Thanks to the technology tools utilized by businesses, this event has the potential to provide financial benefits. Latency reduction also requires the study of innovative physical air interfaces based on small packets, a diversity of waveforms, short-time-interval delivery, and state-of-the-art coding and modulation methods. MIMO and other approaches for optimizing the allocation of radio resources offer data transmission top billing; carrier aggregation in millimeter waves has to be considered, and 5G networks need to establish stable and successful convergence with present LTE services before they can launch. When all the pieces are in place, the 5G technologies can run smoothly and efficiently for users. That's why new radio technology and a revamped architecture are needed to facilitate the smooth operation of the 5G broadband communication network, which should itself be an evolution of LTE.

4.1 QoS PARAMETERS

The design of next-generation networks must give careful thought to service quality in a number of different contexts. There is a critical requirement to provide data to all of these high-density services. As an illustration of the need for QoS guarantees for data-intensive applications in next-generation wireless networks. For the most part, these QoS parameters [49] are used in wireless networks:

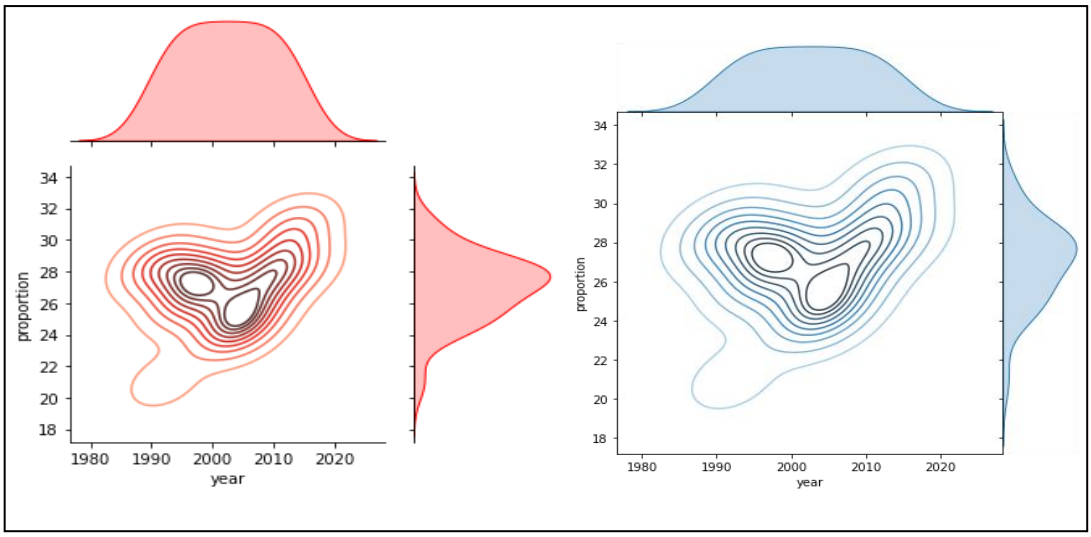

Figure 4.1: Quality of Service Parameters in terms of year and proportion

4.2 BANDWIDTH

When it comes to accommodating the needs of the next generation of cutting-edge apps, bandwidth is one of the most crucial QoS aspects. Channel capacity determines the maximum amount of data that may be sent in a given time period (or the Radio Access Network).

Bits per second are used to express the speed.

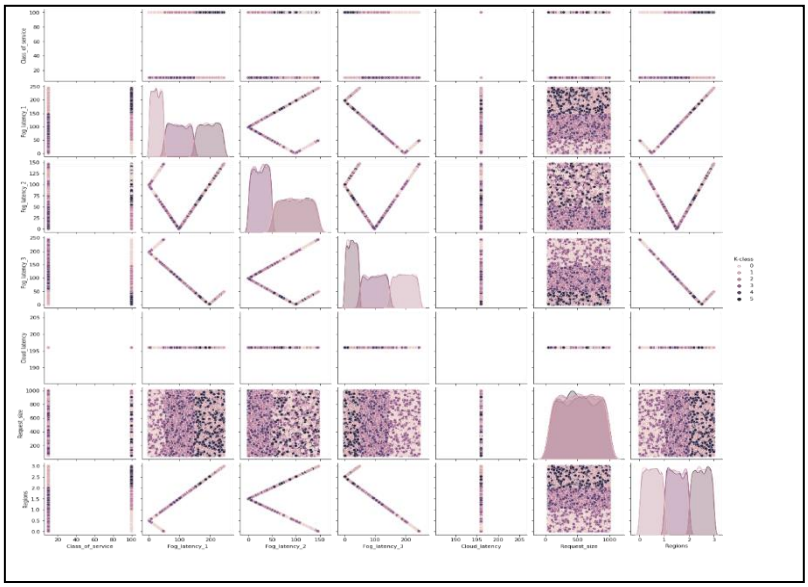

Figure 4.2: Fog and Cloud Latency Evaluation

4.3 THROUGHPUT

It is impossible to exaggerate the significance of throughput to the efficiency of the network. An increase in throughput is quantified by a rise in the ratio of successfully transmitted bits to the total number of bits in a message. A variety of parameters, including hardware, bandwidth, signal-to-noise ratio (SNR), and others, influence how much value can be extracted from a given throughput. [20] Throughput may be used as a proxy for the actual data transfer rate. In practically every scenario, more throughput is crucial.

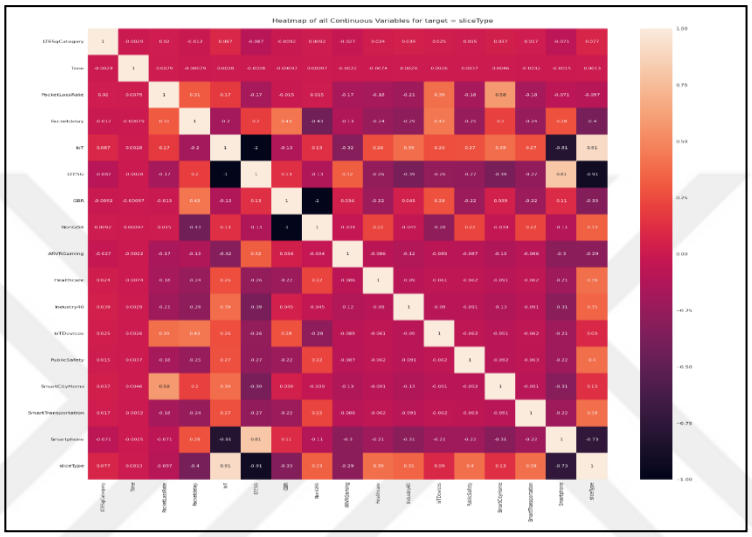

Figure 4.3: Heatmap of all the continuous variables

4.4 JITTER

Everyone anticipates delay-free, uninterrupted packet transfer, but jitter is one connection characteristic that might disrupt this ideal. Often abbreviated as "packet delay variation" (PDV), this is the variance in the time it takes for a packet to be transmitted. Especially for future high-quality audio and video streaming, it is essential that this factor is within acceptable bounds. Jitter is a critical indication of service quality that is measured as part of QoS performance measurements.

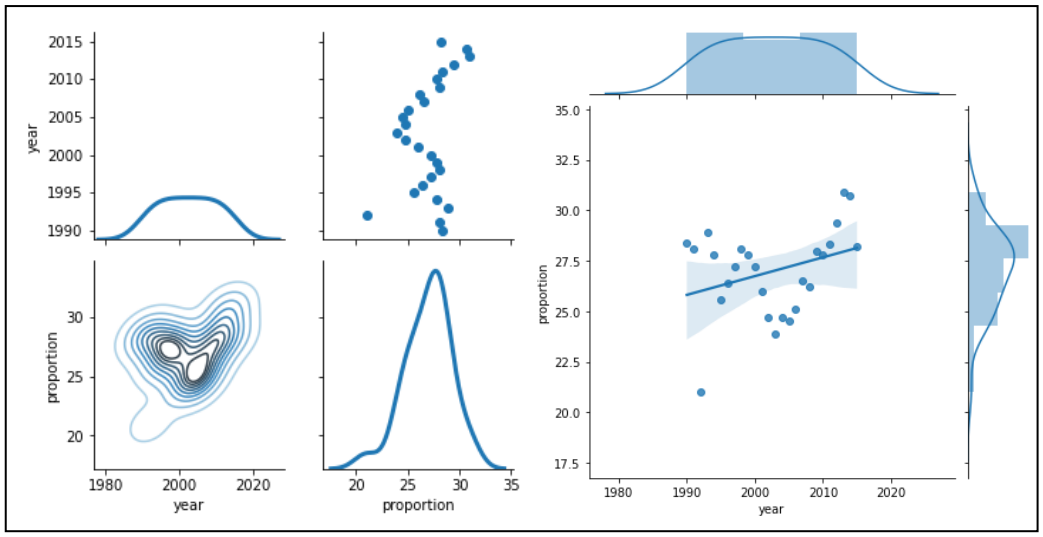

Figure 4.4: Jitter in Terms of Proportion and Year

4.5 BIT ERROR RATE

The error rate is a measure of how many times your data transfer contains corrupted information. The term "bit error ratio" is used to describe this metric sometimes. You may sum it up thus, according to us: The percentage of erroneous bits in a transmission is known as the bit error rate. The future requirements of data applications need an extremely low bit error rate (BER) [59].

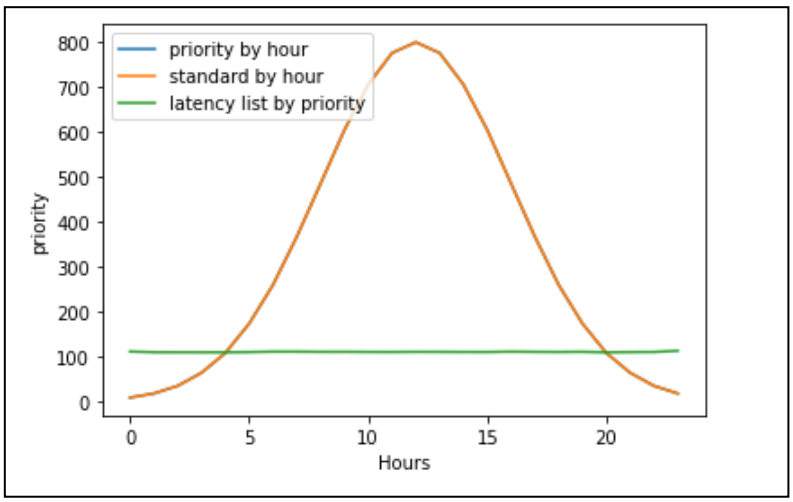

Figure 4.5: Bit Error Rate And The Evaluation Of Priority In An Hour

4.6 PACKET DELIVERY RATIO (PDR)

It's exactly what it sounds like: the ratio of delivered packets to all packets sent across a network. PDR is what determines how efficient the next-gen network will be. Somewhere among the clouds or the sky is the only possible location.

4.7 ROUTE DISCOVERY TIME

How long it takes to find a path from one location to another is measured in terms of route discovery time. Since nodes in a mobile ad hoc network may move around freely, the network topology is always changing. The routing algorithm finds the best possible route before any data is sent. It is important to minimize the time spent determining the best path between two points in order to connect dispersed nodes effectively. Next-generation applications need the use of smart routing algorithms to provide the shortest possible route-finding times.

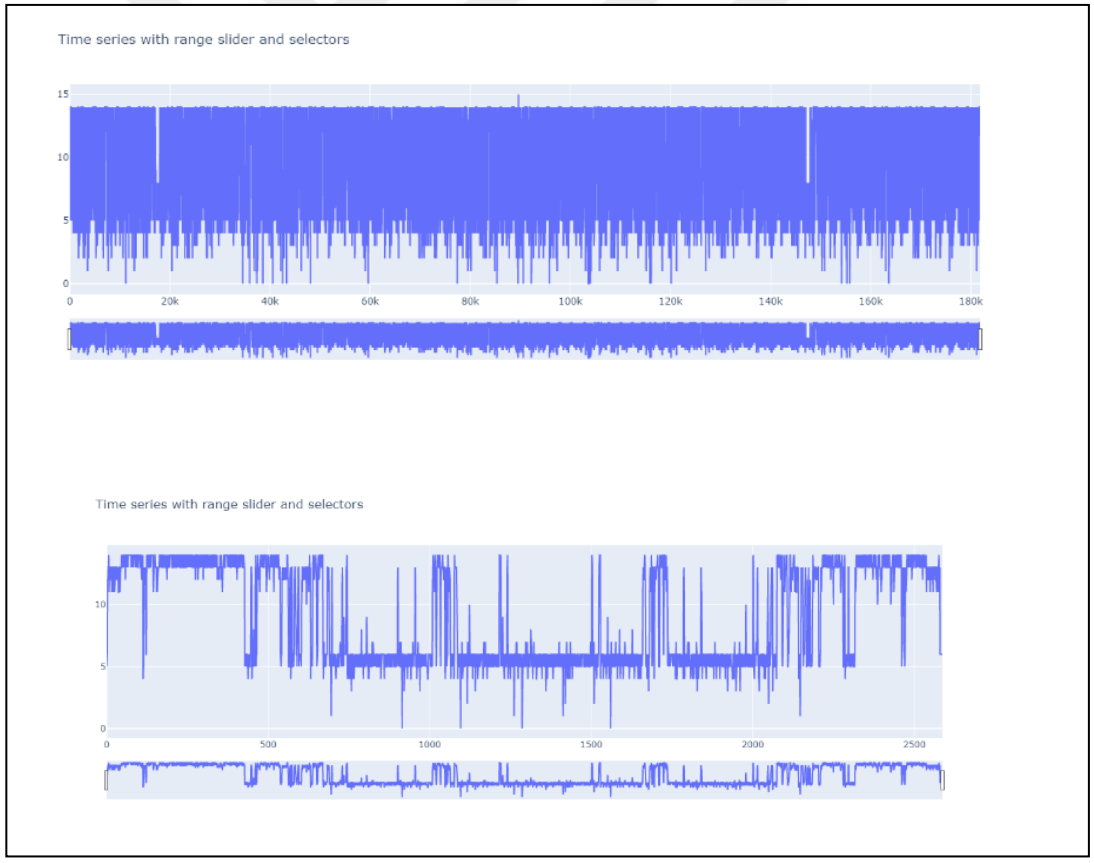

Figure 4.6: Time Series with range slider and selector

4.8 LATENCY

In the context of online communication, "latency" describes the amount of time spent waiting when utilizing a certain network. The difference between minimal delay and severe delay should not be overlooked. “The time it takes for a communication to travel from its source to its destination is known as end-to-end delay (EED) [20]

The following equation expresses the link between delay and its four causes: [19]

$$\text{Latency} = \text{P.T} + \text{T. T} + \text{Q.T} + \text{P.D.} \quad (4.1)$$

where

P.T. : Propagation Time

T.T. : Transmission Time

Q.T. : Queuing Time

P.D. : Processing Delay

An effective network requires minimal latency. For the 5G era, we will focus on latency in our study thesis”.

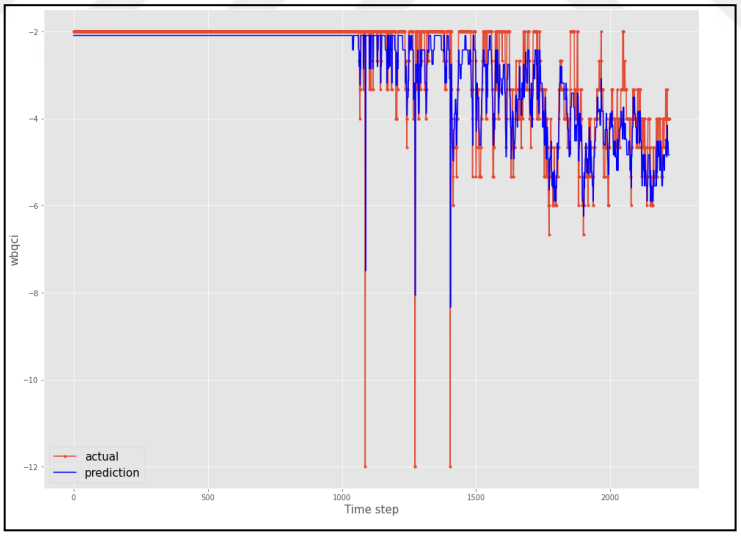

Figure 4.7: Latency In Terms Of A Time Step Function

There are certain levels of latency and dependability for specific Tactile Internet services. The time it takes for a packet of data to travel from its source to its destination, including any processing time, is known as the Data Transfer Time.

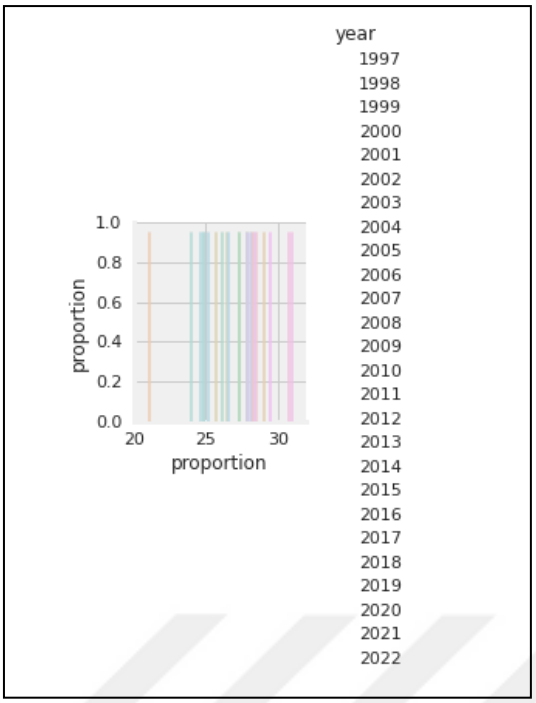

Figure 4.8: Latency and reliability in terms of proportion and year

To comply with strict latency standards, certain adjustments are made to significantly reduce wireless transmission. LTE transmission time intervals are now 1 millisecond; however, this is expected to fall to between 0.1 and 0.25 milliseconds in the near future. The waveform must be able to support brief packets in addition to managing low latency. OFDM, or optical frequency division multiplexing, is a popular approach in today's broadband communication networks. This is primarily owing to its capacity to maintain stability across multiple-path channels. Tactile Internet applications in 5G networks require extremely small packets in order to achieve millisecond latency transmissions. “To accommodate this, major changes would be required in the cellular PHY, including numerology, reference symbol design, channel estimation, and channel coding. OFDM-based systems can achieve a latency of one millisecond by adjusting the numerology (i.e., symbol duration, sub-carrier spacing, etc.), length of a sub-frame, allowing for high degrees of diversity, conducting quick channel estimate, and fast channel decoding (e.g., with convolutional codes). Evidence suggests that by adjusting the OFDM numerology, a system based on OFDM can attain extremely low latency”. One study even managed to achieve a delay of 1 ms using a variant of OFDM numerology.

In order to achieve a latency of 1 ms and support the coexistence of vertical applications, a flexible frame structure is used. To accommodate fluctuating service requirements, the Time To Intent (TTI) might be dynamically modified.

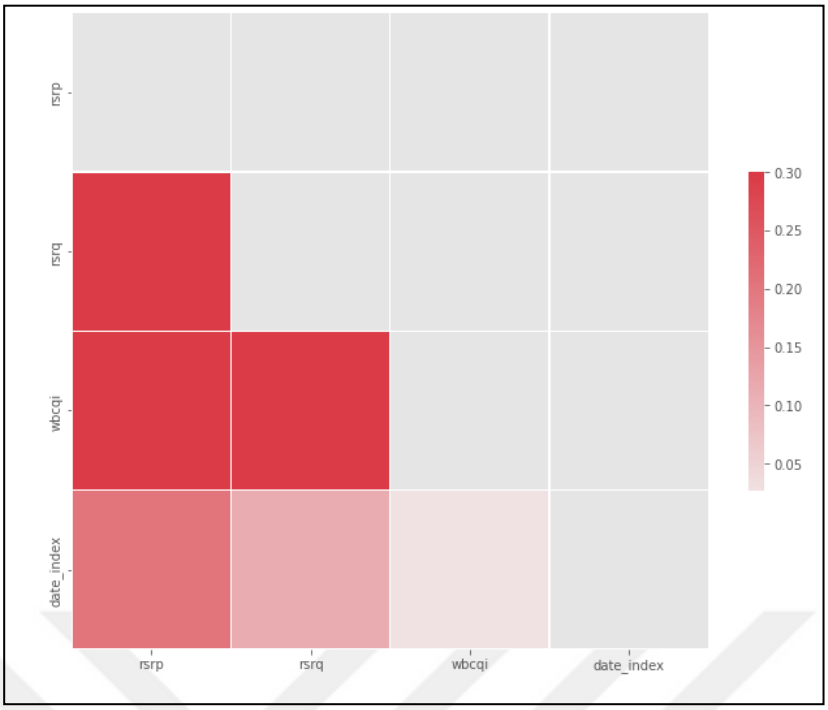

Figure 4.9: RSRP, RSRQ, WBCQI, Date index calculation in 5G technology

4.9 TECHNICAL PERFORMANCE REQUIREMENTS FOR 5G

Technical performance standards are specified in Report ITU-R M.2410 [25]. These standards were developed in response to critical capabilities and the IMT-2020 goal. Table 4.1 summarises the technical performance standards that the reader can get. The technical performance standards have been fully documented. 3GPP did additional study on deployment scenarios and related needs associated with the three use scenarios in order to bring the ITU-5G R vision closer to reality. This investigation is detailed in 3GPP TR 38.913, which may be found here. 3GPP's aspiration to provide more capabilities than was needed by ITU is reflected in the fact that its standards are often more stringent than those set by the organization. An in-depth analysis of the 3GPP specifications is beyond the realm of this work. Inquisitive individuals are urged to investigate [24].

Table 4.1: URLLC Technical Performance Requirement.

Performance Requirement	**DL**	**UL**	**Comparison to IMT Advanced requirement**
User plane latency	1 ms	1 ms	>10x Reduction compared to IMT advanced
Control plane latency	20 ms	20 ms	>5x Reduction compared to IMT advanced
Mobility interruption time	0	0	Much reduced
Reliability	99.9999% within 1 ms	99.9999% within 1 ms	-

4.10 SOURCES OF LATENCY IN A CELLULAR NETWORK

For instance, there are two broad classes of cellular network (LTE) delay:

i. User Plane (U-Plane) Latency
ii. Control Plane (C-Plane) Latency

The amount of time it takes a packet to complete a full circuit from one end of an E-UTRAN edge to the other end of a user equipment (UE) tied to the same E-UTRAN node is referred to as user plane latency. The length of time it takes for a piece of user equipment (UE) to transition from a dormant to an active state is referred to as control plane latency. When a user equipment is idle, it has no interactions with the radio resource control system (RRC). Following a successful RRC handoff, the user equipment (UE) transitions from a dormant state to a dedicated mode that is fully functional. Because application performance is very sensitive to U-plane latency, low-latency communication is critical for the UE while it is in the U-plane. [22]

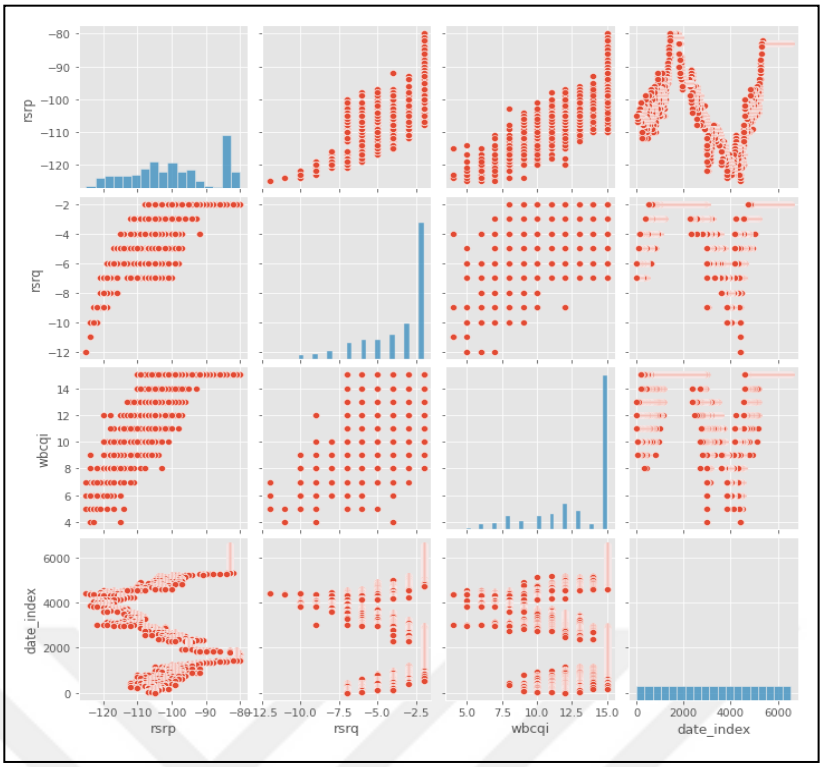

Figure 4.10: User Plane Latency

The time it takes to transfer a packet across a cellular network might be cut in half by network integration between the radio access network (RAN), the backhaul network, the core network, and the data center/Internet. To understand this, please refer to Figure II-2.

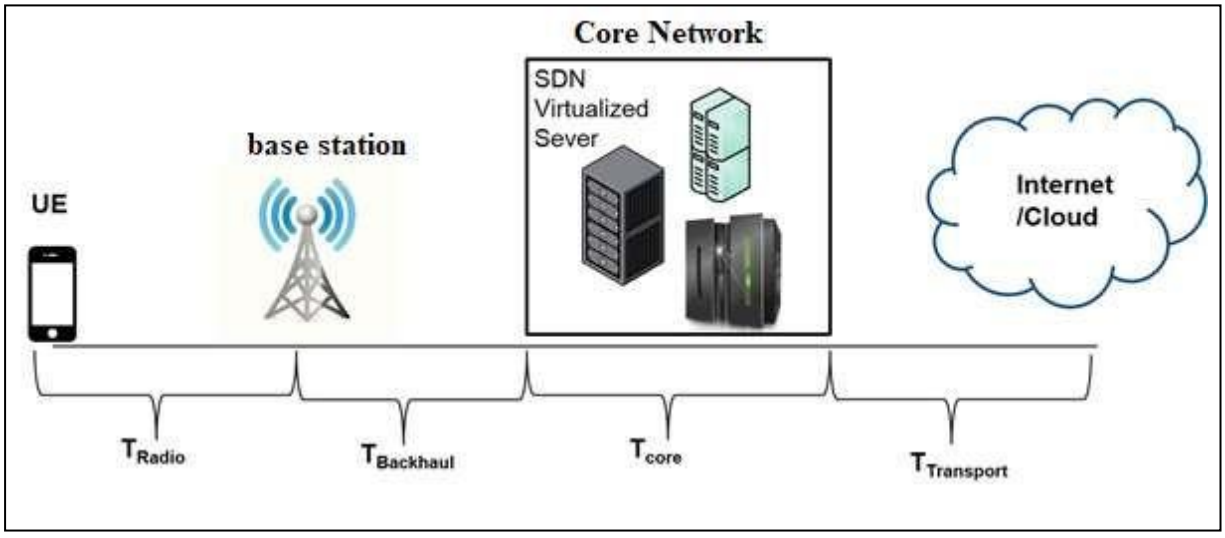

Figure 4.11: Latency in E2E delay of packet transmission.

Figure analysis suggests that the total one-way transmission time [22] of the current cellular system may be stated as

$$T = T_{radio} + T_{backhaul} + T_{core} + T_{transport} \quad (4.2)$$

where Tradio is the amount of time, a packet spends in transit between an eNB/gNB and a UE, the vast majority of which is devoted to the physical layer of the connection. In this scenario, the eNBs/gNBs, UEs, and surroundings all play a part. The total time to send includes the time it takes to transmit, the time it takes the eNB/UE to process the transmission, the time it takes to retransmit, and the time it takes for the signal to propagate. Time is used by the eNB while it performs operations such as channel encoding, rate matching, scrambling, CRC attachment, precoding, modulation mapper, layer mapping, resource element mapping, and OFDM signal synthesis.

$\boldsymbol{T_{backhaul}}$ is crucial for the growth of infrastructure linking eNB/ gNB to EPC/CN. Linking the eNB/gNB to the main network often involves copper cables, microwave or optical fibers, or other comparable technologies. In many cases, the latency associated with microwaves is less than that of optical fibers. However, microwave [22] performance may be limited by spectral restrictions.

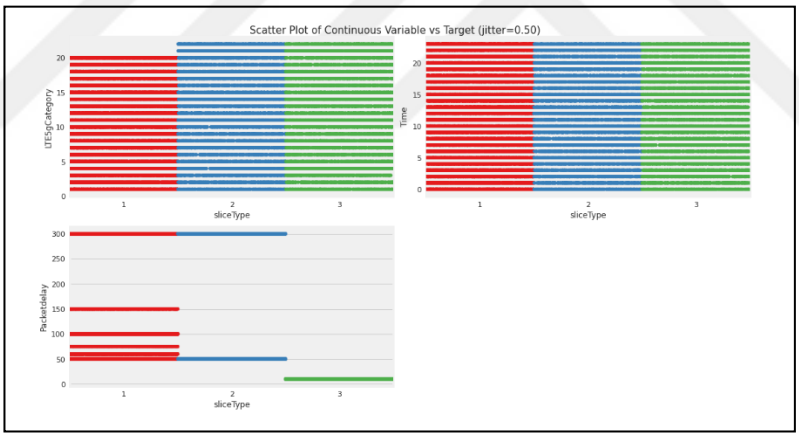

Figure 4.12: Scatter plot of continuous variables vs. jitter

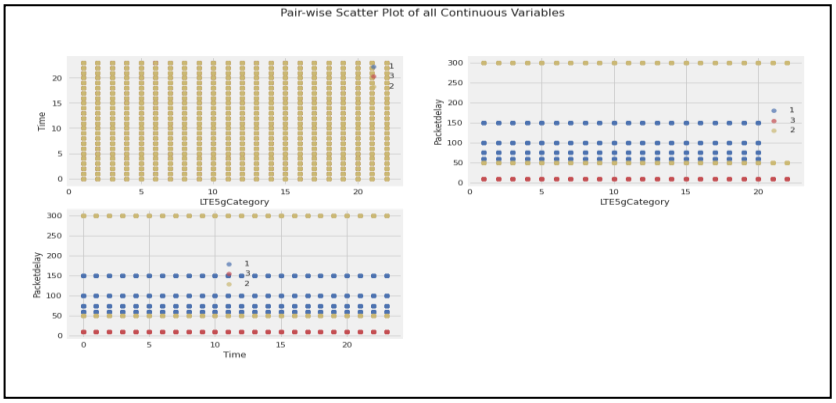

Figure 4.13: Pair-wise scatter plot of all continuous variables

$\boldsymbol{T_{core}}$ is the amount of time the core network spends processing. “Mobility Management Entity (MME), Serving GPRS Support Node (SGSN), and Software-Defined Networking (SDN)/Network Functions Virtualization (NFV) all contribute to this. Core network processing techniques include NAS security, EPS bearer control, mobility anchoring, UE IP address allocation, idle state mobility management, and packet filtering”.

$\boldsymbol{T_{transport}}$ time between the network's core and the Internet/cloud is measured. A number of variables, including bandwidth, protocol, and distance from the server to the network's core, might impact this delay.

So, we may approximatively calculate the E2E delay, TE2E, as 2 x T. Time of first transmission, first channel estimation, first encoding, first decoding, and all retransmissions are all part of the Tradio (due to packet loss). To be more specific, the Tradio for a fixed user may be represented as:

$$T_{radio} = T_Q + T_{FA} + T_{tx} + T_{bsp} + T_{mpt} \qquad (4.3)$$

Where:

Tq is the length of time one must wait in line, which increases linearly with the number of persons competing for a certain amount of service (as in multiplexing).

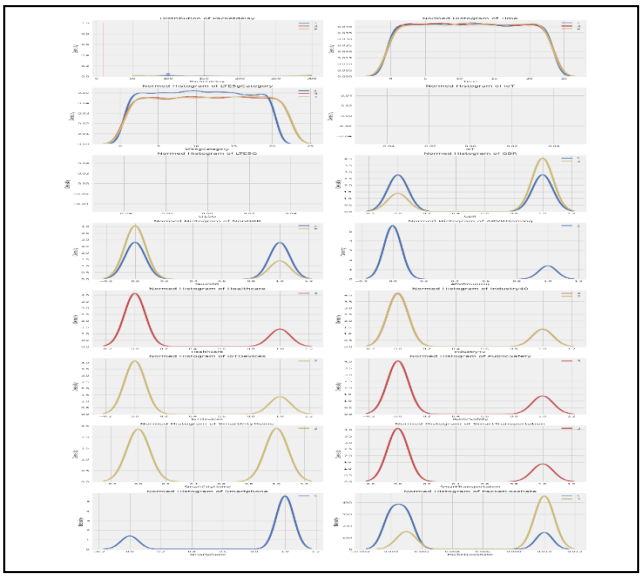

Figure 4.14: Normed Histogram for 5G Technology

T_{FA} The frame alignment lag may range from 0 to 1ms, depending on the design and duplexing preferences of the system (FDD mode, TDD mode)

T_{tx} transmission processing time and payload transmission using at least one TTI; the status of the radio channel; the size of the payload; the available resources; transmission errors; and retransmissions;

T_{bsp} the amount of time it takes for a signal to be processed by the base station,

T_{mpt} The slow performance of the user interface. It has been shown that the capabilities of both the base station and the user equipment (UE) have an impact on the delay experienced by the UE.

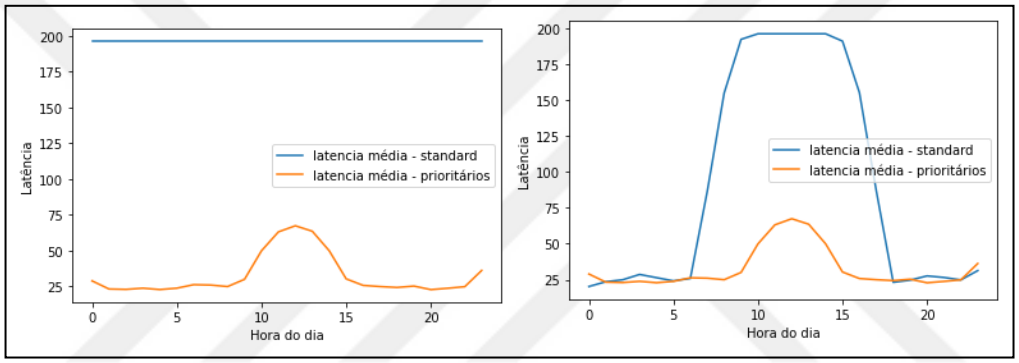

Figure 4.15: Standard and Prioritized graphs of the bandwidth of 5G technology

4.11 URLLC PHYSICAL LAYER IN 5G NR

Due to the need to concurrently consider latency, dependability, and throughput, 5G NR's physical layer architecture must be quite different from that of 4G LTE systems (packet, slot, and frame). Particularly delay-responsive packet structure and a flexible frame structure for fast decoding. As an added bonus, once the URLLC service is enabled, the packets are sent immediately. In order to do this, we must use a scheduling system that speeds up the transmission of URLLC packets. A solution that dramatically reduces the re-transmission time is necessary because HARQ re-transmission falls short of the latency requirement unless the TTI of a packet is extremely low.

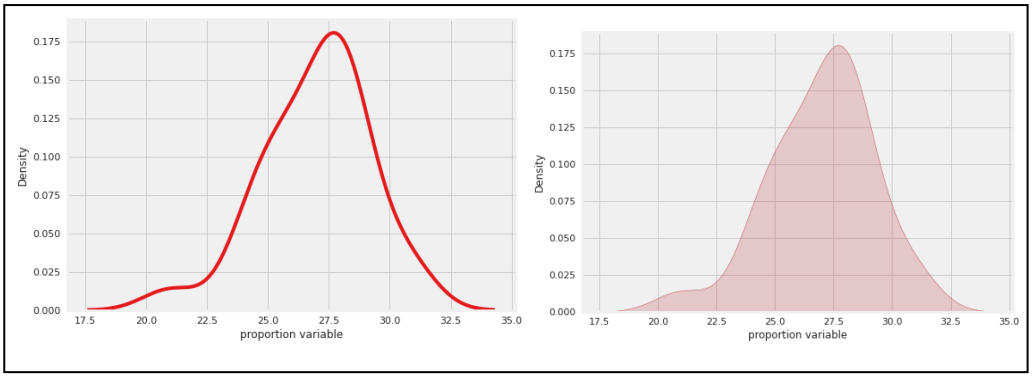

Figure 4.16: Proportion Variable and the density variable in the physical layer

Solutions at the physical layer of URLLC networks, such as the packet and frame structure to reduce latency, multiplexing systems to overlay the URLLC service into enhanced mobile broadband and MTC services, and approaches to resolving existing problems. We can observe that the latency improvement is on par with the reliability boost. Latency, however, was unanimously agreed upon by attendees at the 3GPP NR standardization meeting. [24]

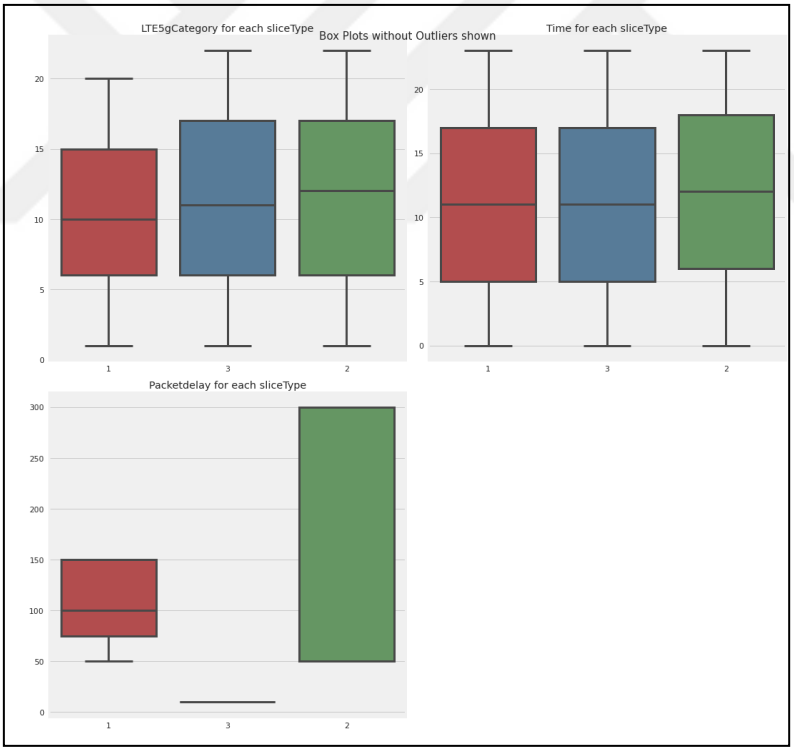

Figure 4.17: LTE 5G category, time, and packet delay for each slice type

4.12 PACKET STRUCTURE

The primary challenge in developing URLLC packets is cutting down on time it takes to process and send them. Keep in mind that Tproc is comprised of the following phases: packet

reception, channel enumeration, control (scheduling) information extraction, data packet decoding, and error checking. As a non-square packet spread in the axis of frequency is employed as a starting point in 5G NR systems, the structure is designed to reduce transmission lag as much as possible. In addition, channel acquisition, data detection, and control channel decoding should be pipelined together to reduce latency Tproc. This requires collecting all three parts of a packet (data portion, pilot, control).

As part of 5G NR, the data channel and the control channel are both enhanced with the use of the low-density parity check (LDPC) code and the Polar code, respectively. Various methods have been developed over time to reduce the computational complexity (and thus the processing delay) of these codes while simultaneously increasing their decoding performance. Polar code consecutive cancellation list decoding and the nonbinary LDPC decoder is two examples of such methods [29].

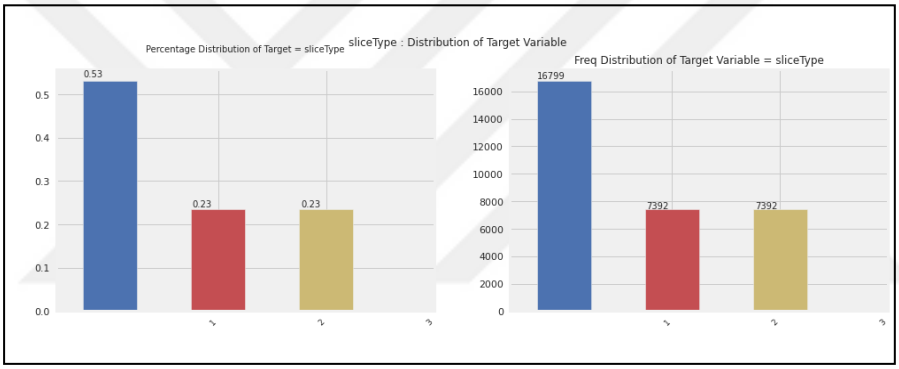

Figure 4.18: Percentage distribution and frequency distribution for slice-type target variables

4.13 LATENCY-SENSITIVE SCHEDULING AND FRAME STRUCTURE

The creation of a universal frame format capable of supporting many different types of frequencies and services is a key objective of 5G NR. Mechanisms that allow for more fluid frame scheduling have been suggested for this same reason.

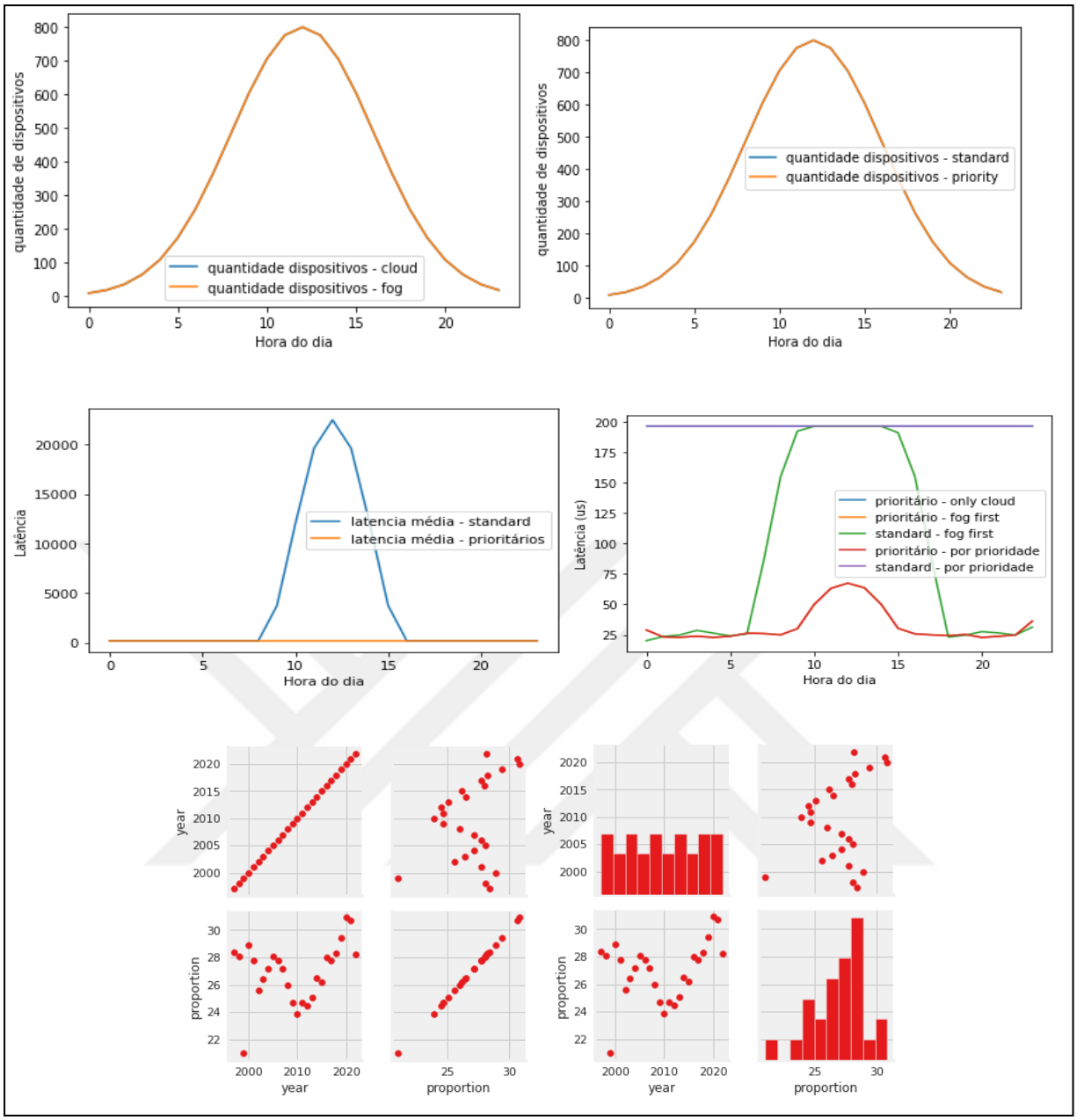

Figure 4.19: Cloud and fog for each slice type evaluation

5. DISCUSSION

5.1 OPEN SECURITY CAPABILITIES AND PROVIDE SECURITY AS A SERVICE

Managing identities, authenticating users, preventing and responding to distributed denial-of-service attacks, and protecting the secrecy and integrity of service traffic are just some of the many security management tasks that are increasingly expected of businesses of all sizes and in all sectors. However, not every company in a given sector will have the resources to develop security management in-house for reasons including cost, complexity, etc. It might be helpful to hire a security agency for these individuals. Telecom networks have done excellent work in their security capabilities, and customers have learned to trust them after years of dependable service (i.e., authentication, identification, and key management). Many networks see a significant commercial opportunity in offering network security as a service to certain industries. As an example, networks might check the credentials of users trying to access a service and then report their findings to the appropriate industries. Provider networks have the option of hosting their security service in the cloud or developing a dedicated virtual network segment for the industry that is paying for it. Certain industries may now begin incorporating security procedures into their operations.

Create Segments of Your Virtual Network: To facilitate finer-grained resource management and scheduling, a virtual network must be partitioned into discrete "slices," or groups of network nodes that are not connected to one another. Concerns about data breaches caused by hackers acting outside the healthcare slice are one reason why patients in the healthcare slice would want only their doctors to have access to their medical information. Equally, applicable isolation measures may be employed with respect to virtual network slices that provide the same application service. While both Businesses A and B may be supported by the same kind of virtual network slices, Business A may nevertheless choose to restrict the use of its resources by Business B. Users will only feel comfortable storing sensitive information in the cloud if they are given assurances that their data will be isolated and protected inside their virtual network slices, much as in a traditional private network.

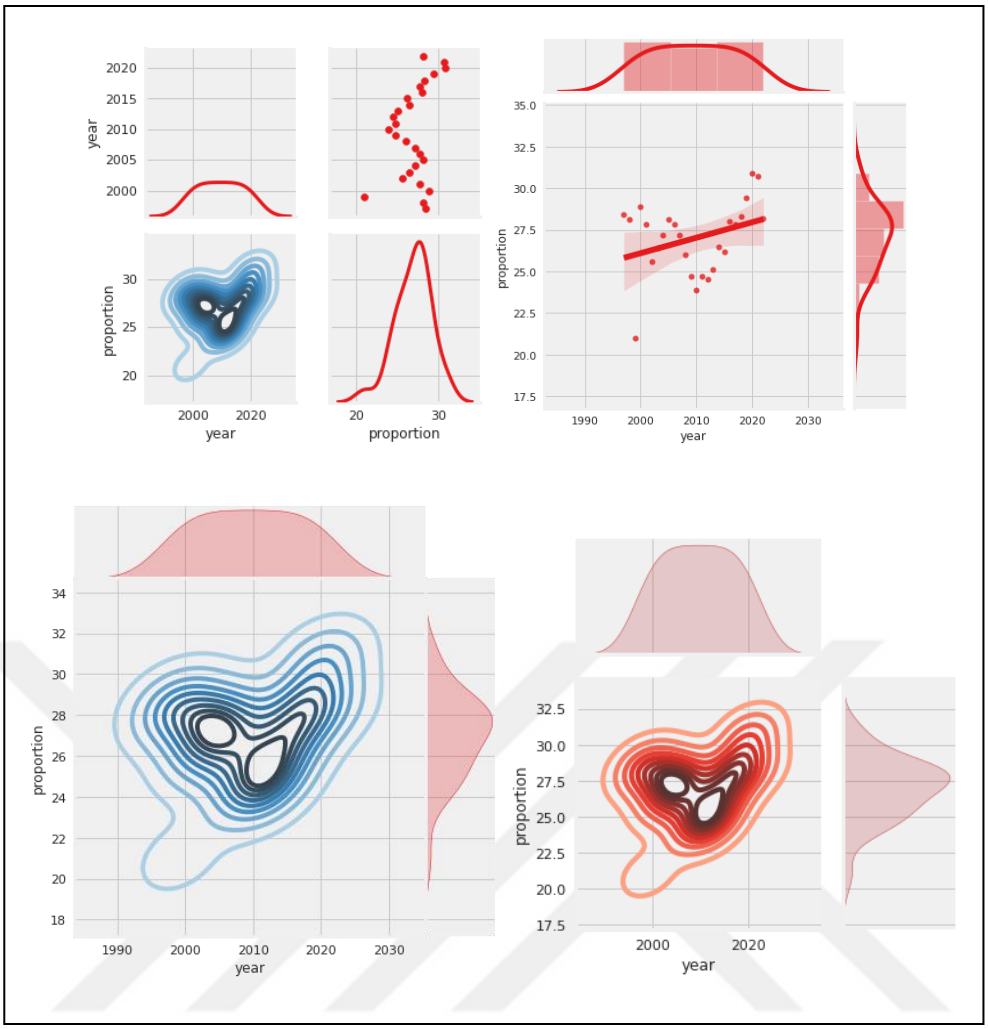

Figure 5.1: Isolated virtual network slices for each proportion and year

Security Assessment: To support a wide range of vertical market use cases, such as healthcare, IoV, and IoT, 5G will necessitate an open platform. The platform's components can be further segmented into groups based on their intended functions. It's likely that in the future, software and hardware manufacturers will work together to create better goods. This not only saves money, but also reduces the time required to perform a service. To support the development of an open software and hardware ecosystem, network function units (NFUs) from different suppliers must be compatible with one another via standardised interfaces. To maintain comprehensive platform security, all NFUs may need to validate each other's safeguards. A tried-and-true method is to have service providers sign a trust agreement before comparing their security measures. In spite of the success of open-source software and hardware, the proliferation of these technologies is stymied by the high cost of the testing paradigm. Therefore, it seems to be time for a standardized assessment method and toolset so that all NFU producers can adhere to the same standards. In order to evaluate NFU security, certain quantitative criteria must be developed. Two such factors are the minimum required password

length and the minimum required password complexity. The process through which these security indicators are defined and assessed is crucial. If well-accepted security standards are utilized, even independent testing organizations may be able to provide reliable assessments of network function units. Successfully evaluated network nodes may be awarded a certificate and electronic signature for automated verification upon integration, which aids in monitoring security risks and ensuring prompt response in the case of an incident.

Low-Delay Mobility Security: New delay-sensitive applications, such as automotive networks and telesurgery, necessitate secure, low-latency communication. The 5G network may need to provide quality service with a latency of less than 1 ms to reduce the likelihood of catastrophic events and human error. Additionally, the 5G network's ultra-dense deployment technologies enable normal mobility management procedures even while in transit. To reduce the delay, mobility management's logical entities and processes must be improved. By rethinking and upgrading the mobility security architecture, a lightweight and compatible mobility management system that can fulfill the stricter delay requirements of the 5G network may be developed.

User Privacy Protection: Due to the fact that 5G networks will be used by several industries. The result is that the 5G network will carry a great deal of information that may be considered highly confidential, such as personal details about users. Any damage caused by a data breach might be catastrophic. The evolution of data mining methods has allowed for the retrieval of sensitive information previously unavailable to the public. So, it's crucial that the 5G network safeguard the privacy of its users and the many industries that will be tapping into the network.

Usage management of privacy information in the 5G network: In order to provide users with specialized network services, the 5G infrastructure takes into account the users' individual preferences and adapts itself automatically (such as slice modification or selection). Even if a user has their privacy settings on, their information may still be used for sensing service types. This includes information on the user's health and location. To alleviate customer privacy concerns, the 5G network must provide a clear norm for service sense. Once utilized, the method must detail what will become of the private data.

More rigorous privacy protection scheme in 5G network: Users' private information may be subject to varying degrees of protection when several access methods are used in a heterogeneous network. In addition, 5G works with several network topologies. User

information may travel across many access networks, and NFUs offered by different vendors. This means that private user information may be floating across the Internet. Data mining methods might potentially be used to uncover sensitive user information. In light of this, it is essential to thoroughly assess the risks associated with making sensitive data public on the 5G network.

6. CONCLUSION & FUTURE WORK

To usher in the 5G era, governments, vendors, operators, and academic institutions worldwide are pooling resources and using innovative approaches. Throughout these negotiations, we need to remain working together toward a common goal of finalizing the 5G specification. Important considerations for 5G right now include the following: We've shown that there are now two different ideas about what 5G is, and these divergences of opinion will determine its release date. From the first angle, 5G will enter the commercial market as soon as enough influential people in the business declare it will, but there is no way to measure when this happens. The second approach is more precise since it defines a series of technical criteria that a service must achieve in order to be termed 5G.

The specified criteria for 5G are a synthesis of both perspectives, which means there are discrepancies within the set. For instance, if there were a mandate to reduce power consumption when deploying a new RAN, it would be difficult to implement beamforming since it uses so much more energy than the existing RAN. That's why it's impossible to predict when 5G will arrive until we find out what it really is. Proof that a replacement RAN improves mobile networks should be sufficient to win support. Key to the 5G standard is the latency of less than one millisecond, which is required by physical constraints. If this barrier proves insurmountable and 5G's standards for sub-1ms latency are loosened, as we have demonstrated, the necessity for a new RAN might be called into doubt. Perhaps the question of whether or not a new air interface can be developed that significantly enhances mobile networks should be prioritized above the race to an arbitrary deadline of 2020.

It raises the issue of the industry's future prospects. If a new air interface is not created, the industry is likely to pursue an evolutionary approach to 5G, expanding upon existing technologies like LTE and Wi-Fi while adding new capabilities and designs. Investing too much time in 5G could delay the development of more pressing technologies. Future mobile networks will incorporate technologies like network function virtualization/software-defined networking (HetNets), low power low latency (LPLT), and multiple LTE-Advanced (LTE-A) carriers. Each of these technologies has the potential to bring substantial benefits to operators in the near future, and LTE now accounts for only around 5% of all mobile connections, so there is lots of room for expansion. As much as 69% of all connections in wealthy nations, including South Korea, Japan, and the United States, are made via LTE. This figure is closer

to 2% in developing nations. As a result, operators have a considerable window of opportunity to recoup their investment in LTE networks. Furthermore, network operators have made significant progress on improving the data throughput of their existing networks by introducing multiple-carrier LTE-A technologies; as a result, further development of LTE technology is feasible. Despite the fact that LTE is now having monetization and connectivity issues, these improvements will allow operators to launch a considerable number of the 5G-related services well before 5G becomes a commercial reality.

The industry would be well to take advantage of the government's intense focus on the 5G problem and the substantial resources it has made available for study and development in the area. The industry must seize this opportunity by investing in initiatives that benefit both operators and customers. To prevent a splintered international vision of 5G, this work should be conducted inside a standard framework.

With the introduction of 5G, businesses may improve their strategy for investing in new infrastructure. Our experience with previous generations of mobile technology has taught us that 5G will be useful in ways that we cannot and will not foresee at this time. When compared to the predicted impact, "next big thing" services trailed behind, whereas "smaller" services (like SMS) had a huge one (e.g., video calling). The arrival of 5G has the potential to significantly alter the mobile ecosystem as a whole. To be more specific, this is an opportunity for authorities to improve the environment in a way that sustains investment in innovative technology. Some applications that worked effectively on 3G and 4G may not be as successful on 5G. If operators start actively thinking about 5G business cases as soon as feasible, they will have a greater say in shaping the new paradigm. The GSMA and its members will continue to drive the development of 5G. The GSMA, as the mobile industry's trade body, is excited to collaborate with others and take the lead in developing the 5G ecosystem in whatever form it takes.

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