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Design and Analysis of an Algorithm for Slice Handover in 5G Networks

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Abstract- This research focuses on the mobility management technique of network slicing in 5G networks. Network slicing involves dividing the physical network infrastructure into multiple virtual networks called network slices, each optimized for specific applications or use cases. Network slice handover enables seamless transfer of a user's connection between different network slices without interrupting the quality of service. The research aims to analyze and develop an algorithm for making network slice handover decisions in segmented 5G networks and evaluate its performance. The research proposes an algorithm for network slice handover delivery decisions based on an analytic model using Markov chain. The network model's architecture and the implementation of the vertical delivery decision-making algorithm are described. The performance of the algorithm is evaluated using key performance indicators (KPIs) related to quality of service at the connection level, such as the likelihood of new calls being blocked, or connections being lost. Simulations are conducted to assess how changes in metrics, such as contact arrival rate, capability, new call threshold, base bandwidth unit, and call departure rate, impact the quality-of-service measurements. The simulation results show that the developed algorithm generally provides good quality of service levels, with a lower likelihood of dropping a distribution call compared to new calls being blocked in all cases. The research contributes to the understanding and improvement of network slice handover in 5G networks by proposing an algorithm and evaluating its performance through simulations. The results demonstrate the algorithm's effectiveness in maintaining quality of service during network slice handover.

Keywords- 5G systems, Software Defined Networks, 5G- NetworK, Slice Handover, Machine learning;,Network Function Virtualization.

I.INTRODUCTION

With the advent of 5G networks, the deployment of advanced mobility management technologies has become essential to efficiently allocate network resources and meet the diverse needs of users. To enable seamless transitions across network segments and cater to the requirements of various 5G applications, new mobility management techniques have been introduced, including network slicing. Network slicing is a significant mobility management technique that divides the physical network infrastructure into multiple virtual or logical networks known as network slices. Each slice is optimized and tailored for specific applications or use cases, offering distinct network capacity, coverage, and latency characteristics (Mouawad,& Tohme 2020). Network slice handover is a critical feature in 5G networks that facilitates uninterrupted user connectivity during transitions between different network slices. It allows users to maintain their quality of service while moving between different network environments or when their service requirements change. The network slice handover process involves transferring a user's connection from the current slice to the targeted slice, ensuring seamless service continuity, and maintaining the desired level of service quality and security. This process can be initiated automatically or manually, depending on the specific application or use case (L. J. Vora ,2015).

In this context, the design and analysis of an algorithm for slice handover in 5G networks becomes paramount. Such an algorithm aims to optimize the handover decision-making process, considering factors such as user preferences, network topology, service requirements, and quality of service metrics. The algorithm needs to make informed decisions in real-time, ensuring efficient resource allocation and seamless user experience during handover (I. Afolabi, 2018).

The objective of this research is to analyze and develop an algorithm for making network slice handover delivery decisions in segmented 5G networks. The proposed algorithm considers the unique characteristics of each network slice, user demands, and network conditions to determine the optimal handover strategy. The algorithm will be designed to maintain or improve the quality of service during handover, minimize service disruptions, and optimize resource utilization (A. Perveen et al.,2019).

To evaluate the performance and applicability of the algorithm, simulations will be conducted using a network model and analytic techniques. Key performance indicators, such as call blocking probability, connection loss probability, and other quality of service metrics, will be used to assess the algorithm's effectiveness in different scenarios. The simulation results will provide insights into the algorithm's performance and its ability to deliver seamless handover experiences in 5G networks (A. Thantharate et al.,2019).

By developing and analyzing this algorithm, this research aims to contribute to the advancement of network slice handover techniques in 5G networks. The results will help improve the efficiency, reliability, and user satisfaction during handovers, ultimately enhancing the overall performance of 5G networks.

II.RESEARCH PROBLEM

The research problem addressed in this study is the optimization of handover decision making in network slice handover algorithms for 5G networks. The existing handover decision-making algorithms often rely on predefined rules based on signal strength or network load, which may not always be optimal. The objective is to develop more sophisticated algorithms that consider factors such as user preferences, network topology, and service requirements to make informed handover decisions. To achieve these objective various approaches can be explored, including machine learning-based techniques, reinforcement learning, game theory, cognitive radio, and hybrid approaches.

Machine learning algorithms can be trained using large amounts of data to predict the best target network slice for a user. Reinforcement learning algorithms can learn from past experiences to adjust the decision-making process. Game theory models can optimize handover decisions by considering interactions between network slices. Cognitive radio can dynamically select the best network slice based on available resources and user requirements. Hybrid approaches can combine multiple techniques to optimize handover decision making. The research emphasizes the need for a multidisciplinary approach that incorporates network topology, user preferences, and service requirements in the optimization process. By developing new algorithms that can make real-time handover decisions while considering the unique characteristics and key performance indicators (KPIs) of each network slice, the study aims to improve the efficiency and effectiveness of network slice handover in 5G networks.

1.Research objective

The research objective of this study is to design and analyze an algorithm for slice handover in 5G networks, with a focus on optimizing handover decision making. The main goal is to develop a sophisticated algorithm that considers various factors, such as user preferences, network topology, and service requirements, to make informed and efficient handover decisions in real-time. Specifically, the research aims to:

1. Investigate and analyze the challenges and requirements of slice handover in 5G networks, including seamless service continuity, resource allocation, mobility management, dynamic QoS adaptation, scalability, and overhead considerations.
2. Review existing handover decision-making algorithms and techniques in the context of network slicing, identifying their limitations and areas for improvement.
3. Explore and evaluate different approaches for optimizing handover decision making, such as machine learning-based algorithms, reinforcement learning, game theory models, cognitive radio techniques, and hybrid approaches.
4. Develop a novel algorithm that considers the unique characteristics and KPIs of each network slice, incorporating factors such as user preferences, network conditions, and service requirements to make optimal handover decisions.
5. Conduct extensive simulations or experiments to evaluate the performance of the proposed algorithm in terms of handover latency, resource utilization, service continuity, and overall user satisfaction.
6. Compare the performance of the proposed algorithm with existing handover decision-making approaches, highlighting its advantages and potential for improving the efficiency and effectiveness of slice handover in 5G networks. By achieving these research objectives, the study aims to contribute to the advancement of network slice handover algorithms, providing valuable insights and practical solutions for seamless and optimized handover in 5G networks.

III. BACKGROUND AND LITERATURE REVIEW

Since the mobile communication technology has advanced dramatically. The most prominent developments in wireless technologies are in terms of subscriber numbers and mobile technology (Gruber, 2018). Wireless technology improvements span multiple decades and are continually progressing (Salih et al., 2020). The term "Generation (G)" relates to the evolution of the system according to the pace, technologies employed, and frequency. Each generation is distinguished by capabilities, skills, and characteristics that distinguish it from the prior generation (Lalor et al., 2005). This section briefly introduces the evolution of wireless networks, outlining the main characteristics of each generation, it then expands the theory on 5G NS and slice handover.

The beginning generation of wireless technology is known as the first generation (1G). This first version of GSM was introduced in 1991, it offered basic voice and text messaging services using the Time Division Multiple Access (TDMA) technology to enable multiple users to share the same frequency channel (Sharma, 2013). The initial data transfer rate was 9.6 kbps, which was suitable for voice and basic text messaging services. The GSM Phase 1 standard also introduced the use of Subscriber Identity Modules (SIM) for user authentication and network security. The main method underlying 1G was frequency reuse, which was solely utilized for voice conversations. One of the key advantages of GSM Phase 1 was its ability to support international roaming, allowing users to use their mobile phones in different countries without having to switch to a different network (Pereira & Sousa, 2004).

The second generation of the GSM wireless is the 2G wireless technologies. This version of GSM was introduced in 1994 and brought significant improvements to call quality and added new features like caller ID, call waiting, and call forwarding. It also introduced the SMS service that allowed users to send text messages up to 160 characters long. Based on several latest digital technologies at that time, such as Time Division Multiple Access (TDMA) technologies, the 2G+ which is known as "Enhanced Data rates for GSM Evolution" (EDGE) and was introduced in 2001 and enabled data transfer rates of up to 384 kbps.

EDGE achieved this by using a more efficient modulation scheme called 8PSK (Eight Phase Shift Keying). This version of GSM also introduced the use of Multimedia Messaging Service (MMS), which allowed users to send messages containing multimedia content like pictures and videos. In addition to introducing new features like caller ID and SMS, GSM Phase 2 also brought improvements to network capacity and coverage. This was achieved by using more advanced radio frequency planning techniques and by allowing network operators to use smaller cell sizes. GSM Phase 2 also introduced the use of circuit-switched data (CSD), which allowed users to send data over the GSM network at a speed of up to 14.4 kbps. EDGE allowed mobile operators in GSM Phase 2+ to offer faster mobile internet services like email and web browsing. EDGE also paved the way for the introduction of 3G technologies like UMTS, which offered even higher data transfer rates and more advanced services like video calls and mobile TV (Vora, 2015).

3G is the third generation of wireless technology. It provided multimedia services and higher data rates, in addition to introducing the Code Division Multiple Access (CDMA) technologies. This version of GSM, also known as "Universal Mobile Telecommunications System" (UMTS), was introduced in the early 2000s and was a significant improvement over previous version. UMTS enabled data transfer rates of up to 2 Mbps, which was suitable for mobile internet browsing and video calls. It also introduced new features like video messaging and mobile TV. UMTS was a major step forward in terms of mobile data capabilities, offering data transfer rates of up to 2 Mbps and enabling services like mobile internet browsing and video calls. UMTS also introduced new network architecture and signaling protocols to support the new services and applications (Mogal, 2014).

The fourth generation of wireless technology is 4G. It integrated the 3G network with fixed internet in order to be able to provide wireless mobile internet. This version of GSM, also known as "Long-Term Evolution" (LTE), was introduced in 2008 and offered data transfer rates of up to 100 Mbps. LTE achieved this by using "Orthogonal Frequency Division Multiplexing" (OFDM) technology, which enables multiple users to share the same frequency band. LTE also introduced new features thatallows multiple frequency bands to be combined to increase data transfer rates, such as: "Voice over LTE" (VoLTE) and carrier aggregation. LTE was designed to provide even higher data transfer rates and lower latency than UMTS, making it suitable for applications like real-time video streaming and online gaming. LTE also introduced new network architecture and protocols, including the new radio access technology OFDM (Frattasi et al., 2006).

5G is the fifth generation of wireless technology. It was innovated to provide high bandwidth, low latency and continuous connection. It was introduced in 2010 and offers higher data transfer rates of 20 Gbps. 5G achieves this by using new technologies like "millimeter-wave frequencies" and Massive MIMO to enable faster and more reliable connections. 5G also introduces new features like NS to enable operators to create slices for each specific use case like IoT, critical communications, and others. 5G represents a major leap forward in terms of mobile data capabilities, offering data transfer rates of up to 20 Gbps and enabling new use cases like augmented reality and autonomous vehicles. 5G also introduces new network architecture and protocols, including New Radio (NR), which is a new radio access technology (Frattasi et al., 2006).

Galis et al. (2017) presents that one of the main challenges in NS is the handover process between slices, which requires the seamless transfer of session state and QoS parameters from one slice to another. Each network slice has its own set of resources, network functions, and QoS parameters, which can be dynamically allocated and managed to meet the requirements of each different applications and services. The 5G network architecture includes three main layers: "radio access network" (RAN), transport network, and core network. Each layer can be sliced independently, allowing network operators to create customized network slices. In this literature review, we will discuss the technical details and approaches for 5G NS handover.

Handover is a critical aspect of 5G NS, as it enables the seamless transfer of session state and QoS parameters between slices. Zhang et al. (2018) highlighted the importance of network slice handover in ensuring seamless service continuity and maintaining quality of service (QoS) for users. The authors identified several issues and challenges related to network slice handover, such as handover delay, handover decision-making, and cross-slice resource allocation. The paper also proposed several solutions to address these challenges, such as context-aware handover, predictive handover, and adaptive resource allocation. Wu et al. (2018) discussed the need for dynamic NS in 5G systems "to support heterogeneous services with varying QoS requirements".

The authors proposed a NS architecture that allows dynamic allocation of network resources based on service demands and user preferences. The paper also discussed the challenges related to network slice handover and proposed a handover mechanism based on a hierarchical slicing architecture. Mahmood et al. (2018) investigated the impact of network slice selection on handover performance in 5G networks. The authors proposed a network slice selection algorithm that is considering the user preferences and QoS requirements as main criteria for the selection of the most appropriate network slice for a user session. The paper also proposed a handover mechanism based on dynamic slicing and resource allocation to ensure seamless service continuity during handovers. Network slice handover is a critical mechanism that allows users to move seamlessly between different network slices as they change their location or service requirements. The need for network slice handover arises due to several factors, such as changes in network conditions, service requirements, or user preferences. For example, if a user is streaming a video on a network slice optimized for high-bandwidth applications and moves to an area with poor coverage, the network slice handover mechanism will transfer the user's session to a different network slice optimized for better coverage or lower latency.

Iv.METHODOLOGY AND PROPOSED FRAMEWORK

As mentioned before, optimizing handover decision making requires a multidisciplinary approach that considers various factors such as network topology, user preferences, and service requirements. Accordingly, this research is focusing on developing new algorithms that can optimize handover decision making in real-time while considering the unique characteristics or KPIs of each network slice. In this research, a data-driven algorithm for slices handover in 5G slice-based network is being introduced for automated handover decision making. By using specific AI and ML techniques, the algorithm can analyze network performance data and predict when a handover is likely to be required.

This can help the network to proactively select the best network slice for the user, improving the user experience and reducing network congestion. Based on specific KPIs -that are specified and selected by the researcher-, the most appropriate slice will be selected to ensure the best network performance and QoS. Such a novel proposed algorithm can be formulated into a framework that will be verified through several parameters related to the KPIs that was selected. The work on building this algorithm will start first by defining the KPIs that indicate a proper utilization of slices' resources with the best network performance. Secondly, AI and DL techniques will be derived to analyze the circumstances of the current slice which will be called pre-handover slice or source slice. According to the analysis results, the need of handing over from this slice to another slice that is called post-handover slice (candidate or target slice) can be decided, and the required characteristics of the post-handover slice will be determined. Accordingly, the algorithm will provide the suggestion of the slice or slices that are best matching the required post-handover slice characteristics to determine which one of them to be the new host for the serviced network application.

1.System Design

The sliced network design enables the establishment of logically distinct networks that share infrastructure, letting slices supply specific use cases. The developed method is based on the formulae and representations used by Falowo in, and the handover decision algorithm is evaluated using a numerical technique, based on the Markov decision process. Our proposed scheme makes use of the network module developed and Python to calculate the outputs and depict the graphs. The Operating System was the following: Windows 10, Processor: Intel® Core™ i7-1265UL Processor, RAM: 16 GB DDR3, Storage: 500 GB SSD.

2.Network model

Network slicing is a concept that allows many self-contained networks to be built on a maximum of a single shared infrastructure. Infrastructure Providers (InPs) are the owners of shared infrastructure and handle supplying resources to tenants. Tenants receiving resources from InPs include Mobile Virtual Network Operators (MVNOs). In sliced networks, resource distribution is carried out through a tiered approach that encompasses both InPs and MVNOs. They are positioned at distinct stages of the organization and have diverse resource allocation responsibilities. InPs distribute resources to MVNOs, who then distribute the resources to different slices. A sliced network has the following three separate slices, each with its own set of needs: eMBB, mMTC, and uRLLC. The slices have resources allotted to them for their specialized use cases, but they are not responsible for taking any calls. The CAC algorithm is realized at the MVNO level, which handles taking calls from various users. When a call is accepted to the eMBB slice in one MVNO it is then handed over to the eMBB slice in another MVNO or the uRLLC slices an MVNO (Ren, Z., et., al.,2021). Assumptions of Network Model During the implementation of the network model, the following assumptions were made. In order to maximize radio resource use, the MVNO gives all slices equal priority when distributing resources. Users are prioritized at each slice based on their arrival time. Since its UEs are not mobile, the mMTC slice does not support handoff calls.

- In eMBB and uRLLC, handoff calls take precedence over new calls.
- Each user has their own set of requirements.
- In a slice, users are evenly dispersed.

The architecture of a 5G network should be designed by considering both software control and hardware infrastructure, as well as their interworking. Network slicing, a key paradigm in this regard, enables the fulfillment of diverse network requirements by using a unified physical infrastructure and shared network resources. It supplies independent instances for specific network functions to run autonomously

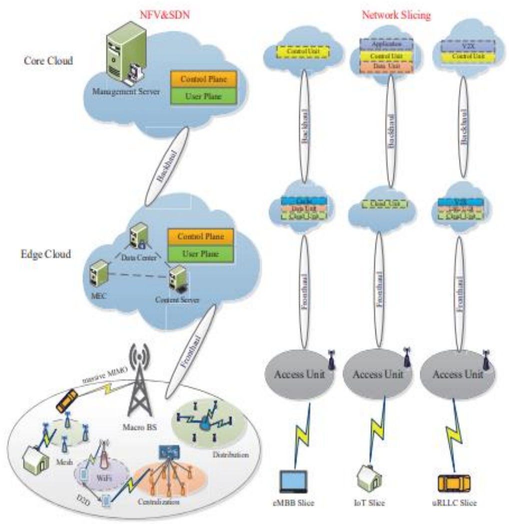


Figure 1 5G Architecture

(Alfoudi., et., al.2018).

Software-defined networking (SDN) has gained widespread acceptance as a promising technique for implementing network slicing through network function virtualization (NFV). NFV replaces traditional network elements, such as the mobility management entity (MME), policy and charging rules function (PCRF), and packet/service gateway (P/S-GW), with commercially available servers. These servers also host the functions of dedicated physical infrastructures. Each server acts as a pool of virtual machines (VM) running on commercial off-the-shelf hardware and software. By introducing resource pooling, the traditional radio access network (RAN), which includes centralized processing units like baseband units (BBU) in cloud RAN (C-RAN), can be virtualized to enable service slicing based on different quality of service (QoS) requirements (Ampririt, et al.2022).

Figure 1 illustrates the logical architecture of a 5G system based on network slicing. In the radio access plane of the 5G system, a heterogeneous network is set up to accommodate multiple radio access technologies (RATs) and ease efficient cooperation between them. Dense deployments of small cells and Wi-Fi access points are implemented to meet the growing demand for data traffic in 5G systems. Additionally, device-to-device (D2D) communications are employed to enhance system ability, improve energy and spectrum efficiency, reduce communication delays, and alleviate the backhaul burden on microcells. In network slicing-based 5G systems, D2D communications play a critical role, particularly in enhancing the quality of local services, supporting emergency communications, and enabling the Internet of Things (IoT). In Figure 1, the traditional centralized architecture of the core network (CN) has transformed into a core cloud architecture, separating the control plane from the user plane to minimize control signaling and data transmission delays.

The core cloud encompasses essential control plane functions like mobility management, virtualized resource management, and interference management. On the other hand, the edge cloud hosts servers and other functionalities of the radio access network (RAN), serving as a centralized pool of virtualized resources. The edge cloud primarily handles data forwarding and control plane tasks such as baseband processing.

User-plane functions previously found in the packet/service gateway (P/S-GW) have also shifted to the edge cloud, enabling low-latency services and reducing backhaul burdens. Additionally, mobile edge computing platforms, along with data sending and content storage servers, are deployed in the edge cloud to collaboratively execute real-time and efficient storage, computing, and transmission of massive data. Virtual machines (VMs) are distributed across the core cloud and edge cloud to execute virtualized network functionalities. Through the use of software-defined networking (SDN), the VMs distributed in the core cloud and edge cloud can be interconnected, setting up mappings between the two. SDN controllers play a centralized role in controlling network slicing. Following the virtualization and software-defined redesign of the system architecture described above, network slicing can be implemented (Zhang et al.,2017). The figure supplies an example of network slicing operating on a set of generic physical infrastructures. An end-to-end network slice refers to a specific combination of network functions and resource allocation modules that are isolated from other network slices [5]. For instance, the enhanced mobile broadband (eMBB) slice requires ample bandwidth to support high-data-rate services like high-definition video streaming and augmented reality.

The eMBB slice needs caching functions, data units, and cloud units to aid control functions in delivering eMBB slicing services. The ultra-reliable and low-latency communication (uRLLC) slice emphasizes reliability, low latency, and security to provide services that are highly sensitive to latency, such as autonomous driving and vehicle-to-everything (V2X) communications. In the uRLLC slice, all dedicated functions should be instantiated at the edge cloud. The Internet of Things (IoT) slice caters to a large number of static or dynamic machine-type devices (e.g., sensors and monitors), with vertical applications positioned at the upper layer to support the diverse external services required by different commercial tenants (Apriority et al.,2022).

In network slicing management, various components interact with each other through controllers or interfaces. The key components involved in managing network slicing in the context of 5G networks are as follows:

1. Virtualized Network Function Manager (VNFM): This part handles mapping physical network functions to virtual machines (VMs). It ensures that the required network functions are instantiated and distributed to the proper VMs.
2. Software-Defined Networking (SDN) Controller: The SDN controller runs and controls the virtual network by connecting the data layer and vertical applications through interface protocols. It coordinates with the VNFM to manage the virtual network and enable dynamic control and configuration of network slices.
3. Virtualized Infrastructure Manager (VIM): VIM serves as the central component of the virtualized infrastructure. It checks the resource use status and distributes virtualized resources to VMs based on their requirements.
4. Network Management and Orchestration Unit: This unit plays a crucial role in network slicing management. It is responsible for creating, activating, or cutting network slices according to customized service requirements. It ensures that the network slices are provisioned and managed efficiently.

The introduction of network slicing in the 5G network architecture brings about significant changes in traditional network planning and deployment approaches. Network slicing allows for the customization of services based on specific application requirements and user needs. Instead of mapping each application to a dedicated pipeline in the physical network, 5G networks can supply end-to-end tailored services by using network slicing (Thantharate., et al.,2019).

By using network slicing, 5G networks can dynamically distribute network resources and adapt to changing demands, thus enhancing service flexibility and efficiency. This approach enables the provisioning of diverse services with varying performance requirements, ensuring the best user experience in the 5G network environment.

3.Call Admission Control (CAC) Model

Call Admission Control (CAC) is a network management technique that is used to regulate the number of calls that can be active on a network at any given time. This is done to ensure that there is enough bandwidth and other resources available to supply a good quality of service (QoS) for all users (Dimitriou, 2020). CAC is typically implemented at the gateway or router that connects the network to the outside world. When a new call request arrives, the CAC system will check to see if there are enough resources available to support the call. If there are, the call will be admitted. If there are not, the call will be rejected. There are a number of different CAC algorithms that can be used. Some common algorithms include:

- Bandwidth-based CAC: This algorithm distributes a certain amount of bandwidth to each call. When a new call request arrives, the CAC system checks to see if there is enough bandwidth available to support the call. If there is, the call is admitted. If there is not, the call is rejected.
- CPU load-based CAC: This algorithm checks the CPU load of the network devices. When a new call

request arrives, the CAC system checks to see if the CPU load is below a certain threshold. If it is, the call is admitted. If it is not, the call is rejected.

- Queueing-based CAC: This algorithm keeps a queue of call requests. When a new call request arrives, it is added to the queue. The CAC system then processes the calls in the queue in order, admitting calls as resources become available.

The best CAC algorithm to use will depend on the specific requirements of the network. For example, a network that supports real-time traffic, such as voice and video calls, would need a CAC algorithm that can guarantee a certain level of QoS (Guo, & Jain, 2017).

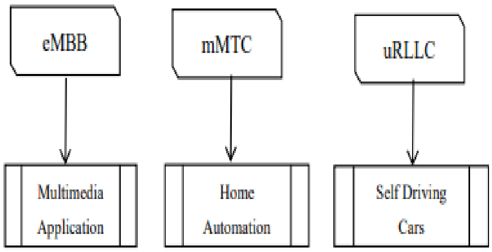


Figure 2 CAC Model

Example CAC Model

The following is a simplified example of a CAC model:

- The network has a total bandwidth of 100 Mbps.
- Each voice call requires 10 Mbps of bandwidth.
- The CAC system will only admit a new voice call if there is at least 10 Mbps of bandwidth available.

If a new voice call arrives when there is less than 10 Mbps of bandwidth available, the call will be rejected.

This is a very simple CAC model, but it illustrates the basic principles of CAC. More complex CAC models can be used to consider other factors, such as the CPU load of the network devices, the QoS requirements of different types of calls, and the mobility patterns of users (Alma'aitah, 2022).

1.6.1. Benefits of CAC

There are a number of benefits to using CAC, including:

- Improved QoS: CAC can help to improve the QoS of calls by ensuring that there are enough resources available to support all active calls.
- Reduced congestion: CAC can help to reduce congestion on the network by preventing too many calls from being active at the same time.
- Increased reliability: CAC can help to increase the reliability of the network by preventing calls from being dropped due to congestion.
- Improved security: CAC can help to improve the security of the network by preventing unauthorized users from accessing the network.

1.6.7. Slice handover in 5G networks:

Slice handover in 5G networks is the process of transferring user equipment (UE) from one network slice to another without disrupting its service. This is essential for supporting a wide range of services and applications with different requirements, such as augmented reality (AR), virtual reality (VR), and self-driving cars (Perveen., et al.,2019).

Slice handover is a complex process that involves multiple network entities, including the UE, the access network (AN), and the core network (CN). The following steps are typically involved in a slice handover:

1. Handover decision: The UE and the AN decide when to trigger a slice handover. This can be done based on factors such as the UE's location, the quality of service (QoS) of the current slice, and the availability of resources in other slices.
2. Handover preparation: The UE and the AN prepare for the handover. This includes finding a suitable target slice and distributing resources to the UE in the target slice.
3. Handover execution: The UE and the AN execute the slice handover. This involves transferring the UE's state from the current slice to the target slice.
4. Handover completion: Once the slice handover has been completed, the UE can continue to receive service in the target slice.

1.6.8. Key Technology

1.6.9. Networking scaling

Networking scaling refers to the process of increasing the ability and performance of a computer network to accommodate growing demands. As businesses and organizations expand their operations, their networking infrastructure must be able to handle the increased traffic, data volume, and user demands. Scaling a network involves various considerations, including bandwidth, network devices, architecture, and protocols. Here are some common approaches to networking scaling (Campolo, et al.,2018):

1. Bandwidth Upgrade: Increasing the available bandwidth is often the first step in scaling a network. This can involve upgrading network links, such as replacing copper cables with fiber optic

cables, or increasing internet connection speed from the service provider.

2. Load Balancing: Load balancing distributes network traffic across multiple servers, devices, or network links to perfect performance and prevent bottlenecks. It ensures that no single part is overwhelmed with traffic, improving overall network scalability.
3. Redundancy and High Availability: Implementing redundancy ensures that critical network components have backup systems in case of failures. Redundant links, switches, routers, and servers help keep network availability and minimize downtime.
4. Virtualization: Network virtualization allows the creation of virtual networks on top of physical infrastructure. It offers flexibility and scalability by separating the network functions from the underlying hardware, enabling efficient resource allocation and easier management.
5. Network Segmentation: Dividing a large network into smaller segments or subnets can improve performance and security. Network segmentation enables better control over traffic flow, reduces broadcast domains, and helps isolate potential issues.
6. Scalable Network Architecture: Designing a scalable network architecture involves considering factors like hierarchical design, modular components, and scalable protocols. A well-designed architecture ensures that adding new devices or expanding the network doesn't disrupt the entire infrastructure.
7. Quality of Service (QoS): QoS mechanisms prioritize specific types of network traffic, ensuring that critical applications or services receive the necessary bandwidth and low latency. QoS helps perfect network performance and ensures a consistent user experience.
8. Network Monitoring and Management: Implementing robust network monitoring and management tools allows administrators to proactively find and address potential scaling issues. Real-time monitoring, performance analysis, and proactive maintenance help ensure network scalability.
9. Cloud Computing and Software-Defined Networking (SDN): Using cloud services and SDN can enhance network scalability. Cloud-based solutions supply on-demand resources, while SDN enables centralized network management and automation, simplifying scaling processes.
10. Scalable Protocols: Choosing scalable protocols, such as Border Gateway Protocol (BGP) for routing or Internet Protocol version 6 (IPv6) for addressing, can support the growth of a network and accommodate a larger number of devices and users.

It's important to note that networking scaling requires careful planning, considering the specific requirements and goals of the organization. It often involves a combination of hardware upgrades, software optimization, and architectural changes to ensure a scalable and efficient network infrastructure.

1.6.10. Software-defined networking (SDN)

Software-defined networking (SDN) is an approach to network management that enables dynamic, programmatically efficient network configuration to improve network performance and monitoring, in a manner more akin to cloud computing than to traditional network management. SDN is meant to address the static architecture of traditional networks and may be employed to centralize network intelligence in one network part by disassociating the forwarding process of network packets (data plane) from the routing process (control plane) (Naja, R., & Tohme, S. 2020).

In a traditional network, each switch has its own control plane and data plane. The control plane handles deciding how to route traffic through the network, while the data plane handles sending traffic according to the instructions of the control plane. In an SDN network, the control plane is centralized on a separate controller. This allows network administrators to manage the entire network from a single location. It also makes it easier to implement new features and policies.

SDN offers a number of benefits over traditional networking, including:

- Increased flexibility: SDN allows network administrators to change the configuration of the network quickly and easily. This is especially important for cloud computing and other dynamic environments.
- Improved performance: SDN can improve network performance by perfecting traffic flow and reducing latency.
- Reduced costs: SDN can help to reduce network costs by simplifying network management and reducing the need for expensive hardware.

SDN is still a relatively new technology, but it is quickly gaining popularity. A number of major vendors, including Cisco, VMware, and HP, offer SDN solutions. How SDN can be used to improve network performance and management

- Load balancing: SDN can be used to distribute traffic evenly across multiple servers, improving performance and reliability.
- Traffic isolation: SDN can be used to isolate different types of traffic from each other, improving security and performance.
- QoS: SDN can be used to prioritize different types of traffic, ensuring that critical traffic is always delivered on time.
- Network automation: SDN can be used to automate many network tasks, such as provisioning and configuration. This can save time and money for network administrators.

1.6.11. Network function virtualization (NFV)

Network function virtualization (NFV) is a network architecture concept that uses IT virtualization technologies to virtualize entire classes of network node functions into building blocks that may connect, or chain together, to create and deliver communication services. NFV relies upon traditional server-virtualization techniques such as those used in enterprise IT (Abdulqadder, I. H., & Zhou, S. 2022).

NFV offers a number of benefits over traditional networking, including:

- Reduced costs: NFV can help to reduce network costs by simplifying network management and reducing the need for expensive hardware.
- Increased flexibility: NFV allows network operators to deploy new services and features quickly and easily.
- Improved scalability: NFV makes it easy to scale the network up or down as needed.
- Enhanced resource use: NFV can help to improve resource use by allowing multiple network functions to run on a single server.

NFV is still a relatively new technology, but it is quickly gaining popularity. A number of major vendors, including Cisco, VMware, and HP, offer NFV solutions (Bish., et al.,2023).

How NFV can be used to improve network efficiency and agility:

- Virtualized security system: A virtualized security system can be deployed on a standard server, cutting the need for a dedicated security system appliance.
- Virtualized router: A virtualized router can be deployed on a standard server, cutting the need for a dedicated router appliance.
- Virtualized load balancer: A virtualized load balancer can be deployed on a standard server, cutting the need for a dedicated load balancer appliance.

NFV can also be used to create new and innovative network services. For example, NFV could be used to create a network service that supplies on-demand bandwidth to businesses.

1.7. Result and Finding

The algorithm's performance was assessed using call blocking and call dropping probabilities in different network scenarios based on network characteristics. The algorithm underwent testing using these settings, and the outcomes were visualized through graphs generated using Python's matplotlib module. The call blocking and call dropping probabilities for each network slice were analyzed to compare the effectiveness of the two implemented techniques. Table 1 presents the call blocking and call dropping probabilities for different 5G network slices.

Table 1 Call Blocking / Dropping

Slices	Call Blocking/Dropping Probability	
	Inter Slice	Intra Slice
eMBB_BP	0.0457	0.1379
eMBB_DP	0.0034	0.0699
uRLLC_BP	0.2351	0.1185
uRLLC_DP	0.1186	0.0615
mMTC_BP	0.0016	0.034

1.7.1. Capacity Impact on eMBB Call Blocking/Dropping Probability

The impact of ability on the call blocking and call dropping probabilities for enhanced Mobile Broadband (eMBB) can be analyzed. As the ability of the network increases or decreases, it can have an effect on the likelihood of call blocking and call dropping events. To evaluate this impact, various capacity scenarios can be considered, such as increasing the number of users or reducing the available bandwidth. By simulating these scenarios and measuring the resulting call blocking and call dropping probabilities, it is possible to understand how ability influences the performance of the network.

The analysis can be conducted by implementing algorithms or models that simulate the behavior of the e MBB network under different ability conditions. These algorithms can consider factors such as user traffic, available resources, and quality of service requirements. By comparing the call blocking and call dropping probabilities across different ability scenarios, it becomes possible to find the relationship between ability and the performance of the eMBB network. This analysis can supply insights into the network's ability to handle increasing user demands and optimize resource allocation to minimize call blocking and call dropping events. Graphical representations, such as plots or charts, can be created using Python's matplotlib module to visualize the impact of ability on eMBB call blocking and call dropping probabilities. These visualizations can help in understanding the trends and patterns associated with different ability levels and their effects on network performance**.**

Figure 2 illustrates the relationship between capacity and call blocking/dropping probabilities in both intra-slice and inter-slice handover scenarios. Inter-slice handover proved superior Quality of Service (QoS) performance, showing significantly lower call blocking and dropping probabilities compared to intra-slice handover.

The inter-slice handover showed the lowest occurrence of call blocking and dropping events, with a minimum of 36% lower probability compared to intra-slice handover. Moreover, the inter-slice handover showed a remarkable improvement, with probabilities at least 89% lower than those saw in intra-slice handover scenarios. This highlights the effectiveness of inter-slice handover in keeping high QoS levels. The results show that inter-slice handover outperformed intra-slice handover in terms of call blocking and dropping probabilities, highlighting its ability to supply superior QoS, particularly under conditions of high-capacity demand.

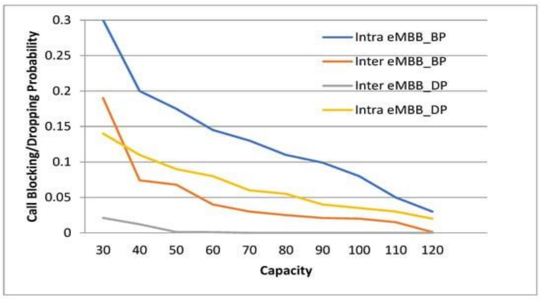


Figure 3Call Blocking/Dropping Probability of eMBB Intra and Inter Slice.

During inter-slice handover, it is possible for calls intended for the enhanced Mobile Broadband (eMBB) slice to be allowed in the ultra-Reliable Low Latency Communications (uRLLC) slice. This means that when a call cannot be accommodated in the eMBB slice, it can be seamlessly transferred to the uRLLC slice before reaching the point of being blocked or dropped. As a result, inter-slice handover reduces the number of calls that are blocked or dropped compared to intra-slice handover scenarios. This capability enables a more efficient use of network resources and ensures a higher level of service availability, as calls are redirected to an alternative slice rather than being rejected outright.

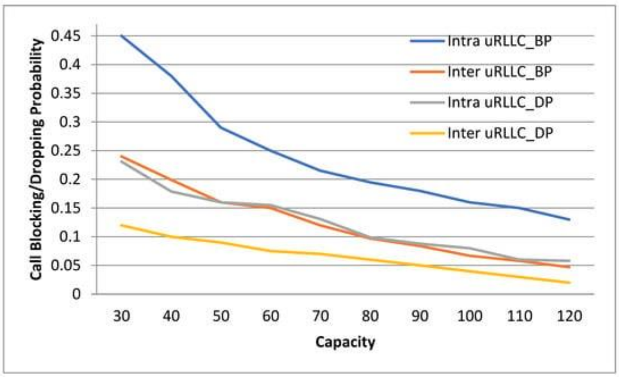
1.7.2. Capacity Impact on m MTC Call Blocking Probability

The impact of ability on the call blocking probability for massive Machine Type Communications (mMTC) can be assessed. As the ability of the network varies, it can influence the likelihood of call blocking events in the mMTC slice. To analyze this impact, different ability scenarios can be considered, such as increasing the number of connected IoT devices or adjusting the available resources for mMTC communication. By simulating these scenarios and measuring the resulting call blocking probabilities, it becomes possible to understand how ability affects the performance of the mMTC network.

The analysis can be conducted using algorithms or models that simulate the behavior of the mMTC network under different ability conditions. These algorithms can consider factors such as the number of devices, traffic patterns, available resources, and quality of service requirements.

By comparing the call blocking probabilities across different ability scenarios, insights can be gained about the relationship between ability and the ability of the mMTC network to accommodate incoming communication requests. This analysis can help in perfecting resource allocation and designing efficient strategies to minimize call blocking events in mMTC.
Visual representations, such as graphs or charts, can be created using Python's matplotlib module to visualize the impact of ability on mMTC call blocking probabilities. These visualizations can supply a clear understanding of how varying ability levels affect the performance of the mMTC network and aid in making informed decisions for ability planning and resource management. Figure 3 presents a chart

proving the blocking probability in both inter-slice and intra-slice handover scenarios. The chart shows that inter-slice handover consistently showed a significantly lower blocking probability compared to intra-slice handover, with a minimum reduction of 88 percent.



In inter-slice handover, calls intended for the massive Machine Type Communications (mMTC) slice could also be allowed in the enhanced Mobile Broadband (eMBB) and ultra-Reliable Low Latency Communications (uRLLC) slices. This means that when a call could not be accommodated in the mMTC slice due to capacity constraints, it was redirected to one of the other slices that had sufficient capacity to handle the call before it reached the point of being blocked. As a result, inter-slice handover resulted in a lower number of blocked calls compared to intra-slice handover, where calls were unable to be passed to other slices.

This capability of inter-slice handover to dynamically distribute resources across slices enhances the overall performance of the network and reduces instances of call blocking. By efficiently using available ability in multiple slices, inter-slice handover perfects the handling of incoming calls and ensures a higher level of service availability for mMTC communication.

1.7.3. Capacity Impact on uRLLC Call Blocking/Dropping Probability

Contrary to the findings presented in Section 4.1 and Section 4.2, the analysis in Figure 4 shows that the call blocking and dropping probabilities for intra-slice handover were actually lower by at least 45 percent than those saw in inter-slice handover scenarios. Additionally, the call dropping probability for intra-slice handover was found to be 42 percent lower than that of inter-slice handover. The discrepancy in results can be attributed to the specific characteristics of the network and the conditions under which the analysis was conducted. In the case of inter-slice handover, while calls from extra slices were accommodated in the ultra-Reliable Low Latency Communications (uRLLC) slice, the slice did not have sufficient dedicated bandwidth to handle uRLLC calls. As a result, a higher number of calls were blocked and missed during the inter-slice handover.

These observations highlight the importance of considering the specific requirements and resource allocation for each slice during handover scenarios. The bandwidth allocation and capacity planning for each slice play a crucial role in keeping the desired Quality of Service (QoS) levels. Intra-slice handover, which focuses on keeping continuity within a single slice, proved lower call blocking and dropping probabilities compared to inter-slice handover due to its dedicated allocation of resources.

These results emphasize the need for careful consideration of resource allocation and bandwidth management during inter-slice handover to ensure that the QoS requirements of each slice, particularly the uRLLC slice, are adequately met.

Figure 4 Call Blocking Probability of mMTC Intra and Inter Slice

VIII.DISCUSSION AND ANALYSIS

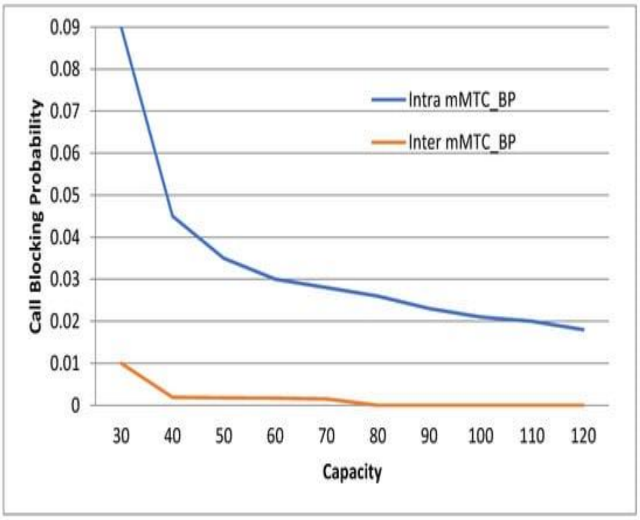


Figure 5 Call Blocking/Dropping Probability of uRLLC Intra and Inter Slice

The proposed 5G network slice handover algorithm is designed to ensure that users can move seamlessly between different network slices without interruption or degradation in service. By selecting the most appropriate target network slice and coordinating the handover process between source and target network slices, this algorithm helps to optimize network performance and improve the user experience to ensure uninterrupted communication for users as they move from one network slice to another.The outline of the proposed framework of the algorithm would be as follows:

1. User equipment (UE) initiates the handover process by sending a request to the source network slice.
2. The source network slice analyzes the request and determines if the UE needs to be handed over to a different network slice.
3. If a handover is required, the source network slice selects the most appropriate target network slice based on factors such as network availability, quality of service (QoS), and user preferences.
4. The source network slice then sends a handover request message to the target network slice, which includes information about the UE and the ongoing communication session.
5. The target network slice receives the handover request and performs its own analysis to determine if the UE can be accommodated on its network.
6. If the target network slice is able to accommodate the UE, it sends a handover response message back to the source network slice indicating its readiness to accept the handover.
7. Once the source network slice receives the handover response message, it begins the handover process by sending a message to the UE instructing it to switch to the target network slice.
8. The UE then switches its connection from the source network slice to the target network slice and resumes communication.
9. The source network slice and target network slice exchange messages to update their respective network states and ensure that communication is properly transferred.

The concept of network slicing offers a compelling approach to building multiple self-contained networks on a shared infrastructure. Infrastructure Providers (InPs) handle supplying resources to tenants, which include Mobile Virtual Network Operators (MVNOs). The distribution of resources occurs through a tiered approach, involving both InPs and MVNOs, each positioned at distinct stages of the organization with diverse resource allocation responsibilities. In this network model, three separate slices exist: eMBB, mMTC, and uRLLC, each catering to specialized use cases and having their own resource allotment. The responsibility of taking calls lies with the MVNO, where the Call Admission Control (CAC) algorithm is implemented. When a call is accepted in one MVNO's eMBB slice, it can be handed over to another MVNO's eMBB slice or the uRLLC slices. Several assumptions were made during the implementation of this network model. All slices are given equal priority for resource distribution by the MVNO to maximize radio resource use. Users within each slice are prioritized based on their arrival time, and the mMTC slice does not support handoff calls due to the non-mobility of its User Equipment (UE).

Handoff calls receive priority over new calls in the eMBB and uRLLC slices, and users within a slice are evenly dispersed. To effectively design a 5G network architecture, both software control and hardware infrastructure must be considered, along with their interworking. Network slicing plays a key role in fulfilling diverse network requirements using a unified physical infrastructure and shared network resources. Software-defined networking (SDN) coupled with network function virtualization (NFV) has become a widely accepted technique for implementing network slicing. NFV replaces traditional network elements with commercially available servers, hosting virtual machines (VMs) that run the functions of dedicated physical infrastructures.

This virtualization allows for service slicing based on different quality of service (QoS) requirements. The logical architecture of a 5G system based on network slicing is illustrated in Figure 1. The radio access plane consists of a heterogeneous network accommodating multiple radio access technologies (RATs) and easing efficient cooperation between them. Small cells, Wi-Fi access points, and device-to-device (D2D) communications are deployed to meet the increasing demand for data traffic in 5G systems. D2D communications play a critical role in enhancing local services, supporting emergency communications, and enabling IoT. The core network architecture has shifted from a centralized model to a core cloud architecture, separating the control plane from the user plane to reduce signaling and data transmission delays.

The core cloud handles control plane functions like mobility management, virtualized resource management, and interference management. The edge cloud, on the other hand, hosts radio access network (RAN) functionalities and acts as a centralized pool of virtualized resources, performing data sending and baseband processing tasks. User-plane functions and mobile edge computing platforms are also deployed in the edge cloud to enable low-latency services and efficient storage, computing, and transmission of data. Virtual machines (VMs) are distributed across the core cloud and edge cloud to execute virtualized network functionalities, and SDN controllers play a centralized role in controlling network slicing. Through virtualization and software-defined networking, network slicing can be effectively implemented, allowing for the fulfillment of diverse network requirements while maximizing resource use and supplying tailored services for different use cases. The combination of network slicing, SDN, and NFV in the design of 5G architectures presents numerous opportunities for delivering enhanced services, improving efficiency, and accommodating a wide range of applications and user requirements.

The contrasting findings about intra-slice and inter-slice handover call blocking and dropping probabilities present an interesting topic for discussion. The results reported in Section 4.1 and Section 4.2 show that intra-slice handover had significantly lower probabilities compared to inter-slice handover. However, the observations in Figure 4 contradict these findings, showing that intra-slice handover actually had higher performance in terms of call blocking and dropping probabilities. This discrepancy underscores the complexity and variability of network characteristics and conditions that can influence handover performance.

It suggests that the effectiveness of intra-slice and inter-slice handover mechanisms may depend on specific factors such as resource allocation, bandwidth availability, and quality of service requirements. One possible explanation for the contradictory findings is the impact of resource management during inter-slice handover. While inter-slice handover allows calls to be accommodated in alternate slices, the specific allocation of resources, particularly in the ultra-Reliable Low Latency Communications (uRLLC) slice, may not have been sufficient to meet the demand. This limitation could have resulted in more calls being blocked and missed during inter-slice handover, leading to higher call blocking and dropping probabilities compared to intra-slice handover. This discrepancy raises important considerations for network operators and designers. It highlights the need for careful resource planning and allocation during handover scenarios, especially in multi-slice environments. Adequate bandwidth and resource provisioning for each slice, particularly for slices with stringent quality of service requirements like uRLLC, becomes crucial to avoid performance degradation and call losses during handover. Further research and analysis are warranted to explore the underlying factors contributing to these contrasting results and to identify strategies for optimizing handover performance in different network scenarios. This discussion emphasizes the importance of considering the specific characteristics and requirements of each slice, as well as the allocation of resources, in order to ensure seamless and efficient handover operations while keeping the desired quality of service for different communication types.

1.8. Limitations and Future Work

This research has been concentrating on the development of an algorithm for making handover choices in sliced 5G networks. The method is assessed using a network model comprised of three network slices. The call blocking and dropping probabilities are used to evaluate the algorithm's performance. Because sliced 5G networks are complicated, this research does not go into detail on the network's physical architecture or how resources are assigned to the slices. Due to the very limited time allocated for this research, several call admission control techniques cannot be implemented owing to their complexity. The aim of this research project was to design an algorithm for making handover decisions in sliced 5G wireless networks and evaluate its performance using an analytical model.

IX.CONCLUSION

In conclusion, network slicing offers a powerful approach to building self-contained networks on a shared infrastructure, enabling the fulfillment of diverse network requirements while maximizing resource use. Infrastructure Providers (InPs) supply resources to tenants, including Mobile Virtual Network Operators (MVNOs), who further distribute the resources to different slices. This tiered approach allows for efficient resource allocation and management. The network model assumes equal priority for all slices during resource distribution, prioritization of users based on arrival time, and non-support of handoff calls in the mMTC slice. Handoff calls take precedence over new calls in the eMBB and uRLLC slices. These assumptions contribute to perfecting resource use and meeting specific user requirements within each slice. The architecture of a 5G system based on network slicing incorporates both software control and hardware infrastructure. Software-defined networking (SDN) and network function virtualization (NFV) play crucial roles in implementing network slicing by replacing traditional network elements with virtualized functions running on commercially available servers. This virtualization enables service slicing based on different quality of service (QoS) requirements and eases the efficient allocation of resources. The logical architecture of a network slicing-based 5G system integrates a heterogeneous radio access plane, core cloud, and edge cloud. It uses small cells, Wi-Fi access points, and device-to-device (D2D) communications to enhance system ability and support local services, emergency communications, and IoT applications. The separation of the control plane and user plane in the core cloud reduces latency and perfects control signaling.

The edge cloud acts as a centralized pool of virtualized resources, handling data forwarding, baseband processing, and mobile edge computing tasks. Through the deployment of virtual machines (VMs) and SDN controllers, network slicing can be effectively implemented, allowing for the customization of services and the efficient management of network resources. This approach opens up opportunities for enhanced services, improved efficiency, and tailored solutions for different use cases and user requirements. network slicing, coupled with SDN and NFV, supplies a flexible and scalable solution for meeting the diverse demands of 5G networks. By using a shared infrastructure and independent network instances, it enables efficient resource allocation, optimized performance, and the provision of specialized services for various applications, ultimately driving the advancement of next-generation communication networks.

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