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5G NETWORK SLICING: FEATURES, APPLICATIONS, CHALLENGES AND TECHNOLOGIES (FACT'S)

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Abstract. In 5G networks, network slicing is an essential technology that enables effective resource allocation for a wide variety of services and applications. In the review, the several approaches to network slicing, such as static, dynamic, SDN-based, NFV-based, and hybrid, as well as the benefits and drawbacks of each approach, are broken down and analysed. This analysis also highlights the use of sophisticated techniques such as reinforcement learning and machine learning to optimise the decisions made on network slicing and increase network performance. In addition, the paper discusses the safety issues that are related with network slicing and underlines the need for more research to develop new methods and frameworks that would enable network slicing in 5G networks to be carried out in an efficient and effective manner. The most important conclusions from this analysis can help direct future research on network slicing, and its techniques can assist network operators in selecting the solution that is the most appropriate for the requirements of their particular use case and applications.
Keywords. 5G, network slicing, resource allocation, virtual networks, SDN, NFV, machine learning, reinforcement learning, security, privacy, network complexity.

I. Introduction

Network slicing is one of the most important aspects of 5G networks. This feature makes it possible to establish numerous virtual networks on top of a single physical infrastructure, each of which has its own set of distinguishing qualities and service level agreements (SLAs). When it comes to enhancing the performance of network slicing in 5G networks, machine learning techniques have the potential to play a pivotal role. Using a supervised learning model is one of the potential methods that might be used to create a machine learning algorithm for the slicing of 5G networks. In this method, the algorithm is educated by being exposed to a dataset containing information on network traffic and resource usage, as well as the SLAs and performance metrics that correspond to those factors. The algorithm utilises this data to provide a prediction about the arrangement of network slices that will produce the best results for a particular combination of traffic and resource needs.
Identifying patterns in the data that pertains to network traffic and resource utilisation may also be accomplished by the application of an unsupervised learning model, such as a clustering method. After that, the algorithm is able to classify groups of traffic and resource usage patterns as belonging to the same category, and assign them to distinct network slices according to the

specific SLAs and performance requirements of each group. Regardless of the strategy that is chosen, it is essential to make certain that the algorithm for machine learning is flexible enough to adjust to shifting network conditions and patterns of traffic. This is something that can be accomplished through the utilisation of online learning strategies, which make it possible for the algorithm to continuously update its model in light of new data.

Network slicing is a fundamental technique in 5G networks that enables efficient and effective resource allocation for a wide variety of services and applications. It gives network operators the ability to partition the network into many virtual networks, each of which is tailored for a particular use case, such as virtual reality apps, smart cities, or autonomous cars. Network slicing is a strong technology that will be utilised in order to enable the extensive variety of applications that 5G networks will be able to handle.

The fifth generation (5G) of mobile networks is the next generation of mobile networks and offers speeds, capacities, and connections not seen before. It is anticipated that they will fundamentally alter the ways in which we communicate and engage with the environment around us by making possible the development of applications and services that were not feasible with earlier generations of mobile networks. 5G networks include a number of critical qualities, including low latency, high bandwidth, and huge connection, which make them suitable for supporting a wide range of use cases. These use cases include everything from Internet of Things applications to high-bandwidth applications like video streaming.

Throughout this literature study, we will investigate the previous studies that have been conducted on 5G network slicing and the methodologies that pertain to it. In this section, we will examine the benefits and drawbacks of various approaches to network slicing and summarise the most important results from the relevant research. The purpose of this study is to offer a complete assessment of the present state of research on 5G network slicing and to identify future research paths and possibilities. Specifically, the review will focus on the following:

II. Literature Review

A. 5G Network and Technology

In X. Li et al. (2016), the vision and needs for 5G networks are discussed. These criteria include the need for faster data speeds, better latency, and support for vast interconnection. It also sheds insight on the difficulties that are connected with the construction of a 5G network, such as the requirement for new spectrum allocation and the deployment of infrastructure. A. An outline of the technological needs and constraints connected with 5G networks is provided by Osseiran et al. (2014). In it, the necessity of new radio access technologies like millimeter-wave and massive MIMO for supporting increased data speeds and huge connection is discussed. It also brings to light the requirement for novel network designs, in order to accommodate a wide variety of applications and services. K. A detailed overview of the potential and difficulties connected with 5G networks is presented by Yang et al. (2019). It analyses the possible influence that 5G might have on several other businesses, including the healthcare industry, the transportation industry, and the entertainment industry. It also brings to light the difficulties that are involved with the development of 5G networks, such as the availability of spectrum, the deployment of equipment, as well as concerns over security and privacy.

In Taleb et al. (2018), the authors discuss the security and privacy challenges that are associated with 5G networks. Some examples of these challenges include the requirement for new security measures to protect against cyberattacks and the requirement for privacy-preserving data management techniques. This also brings to light the potential that exist for the development of new technologies that improve both security and privacy, such as blockchain and homomorphic encryption. J. The article by Andrews et al. (2020) presents an overview of the progress that has been made in the development and standardisation of 5G networks, in addition to the problems that are involved with the implementation of 5G networks. It stresses the need for continuous investment in research and development to allow new and creative applications and services, and it explores the potential impact that 5G might have on many industries, such as manufacturing and education. R. The article by Bonetto et al. (2019) offers a thorough analysis of the many technical difficulties and potential benefits related with 5G networks. In it, the necessity of developing new radio access technologies like massive MIMO and millimeter-wave is discussed in order to handle increased data rates and huge connection.

The article by Z. Ahmed et al. (2020) gives an outline of the technical features of 5G networks as well as the upcoming applications of these networks. It explores the potential influence that 5G might have on many industries, including as healthcare, transportation, and entertainment, and it underlines the problems that are connected with the development of 5G networks, such as the distribution of spectrum and the deployment of infrastructure. In addition to this, it underlines the prospects for new and creative applications and services, such as driverless cars and smart homes. A. El-Sherbiny et al. (2020) explore the potential and constraints related with 5G networks for the applications of smart cities. It explores the necessity for new network designs, to enable these applications and shows the potential influence that 5G may have on a variety of smart city applications, such as smart transportation and energy management. It also brings to light the necessity of business and government working together in order to secure the effective deployment of 5G networks in smart cities. N. The article by Noman et al. (2020) offers a detailed analysis of the present status of 5G wireless networks as well as their potential future possibilities. It explores the technological problems and possibilities connected with 5G networks, such as the need for new radio access technologies, network slicing, and edge computing. Also, it addresses the necessity for new radio access technologies. It also covers the economic and social ramifications of 5G networks, including their potential influence on employment and economic growth, as well as other topics in this realm.

A summary of the developments that have taken place in 5G network technology, standards, and implementation can be found in S. R. Rao et al. (2021). It highlights the prospects for new and innovative applications and services, such as smart homes and autonomous cars, and analyses the problems that are connected with the introduction of 5G networks, such as spectrum allocation and infrastructure rollout. This finding also underscores the necessity of continuing to spend in research and development in order to allow novel apps and services to run on 5G networks. J. An in-depth analysis of the enabling technologies and research difficulties related with 5G cellular networks is provided by Liu et al. (2019). In it, the necessity of developing new radio access technologies like massive MIMO and millimeter-wave is discussed in order to handle increased data rates and huge connection. It also brings to light the requirement for novel network designs, in order to accommodate a wide variety of applications and services. In addition to this, the study presents an in-depth analysis of the research issues that are linked with 5G networks, such as protecting users' privacy and maximising energy efficiency. K. Doppler et al. (2017) lays out the goals, prerequisites, and difficulties involved with 5G mobile network technology. It emphasises the necessity of faster data rates, reduced latency, and improved dependability in order to serve new and upcoming applications, such as driverless cars and virtual reality. In addition, the study draws attention to the fact that in order for these applications to be supported, new network designs. It presents a complete examination of the technological problems that are involved with 5G networks, such as the control of interference, network optimisation, and security.

H. Chen et al. (2020) presents a thorough analysis of 5G network slicing, which is an essential component of 5G networks and a major enabler technology. It explores the idea of network slicing, which enables many virtual networks to coexist on a same physical network infrastructure, and it highlights the benefits of network slicing, such as greater service agility, increased resource utilisation, and a higher quality of service. Also, a summary of the research problems connected with network slicing, such as resource allocation and management, security, and orchestration, is presented in this study. M. A detailed analysis of the research issues and developing technologies related with 5G networks is provided by M. Alam et al. (2020). It examines the necessity of new radio access technologies, network designs, and supporting technologies, in order to provide support for a wide variety of applications and services. The paper also discusses the necessity for collaboration between industry and academic institutions in order to address the research challenges associated with 5G networks and highlights the potential impact that 5G could have on various industries such as healthcare, transportation, and the entertainment industry. N. The article by Kheirkhah et al. (2019) explores the potential and constraints related with 5G wireless networks for the applications of virtual and augmented reality. It brings to light the necessity for faster data rates, reduced latency, and improved dependability in order to offer immersive and engaging experiences in virtual and augmented reality. The paper also discusses the potential impact of 5G on various industries, such as education, entertainment, and healthcare, and highlights the need for continued research and development to enable new and innovative virtual and augmented reality applications and services on 5G networks. Additionally, the paper examines the potential impact of 5G on various industries, such as education, entertainment, and healthcare. These research papers give a complete overview of the problems and potential connected with 5G networks. Moreover, they underline the necessity for continuing research and development to allow new and creative applications and services. They also explore the possible influence that 5G networks might have on a variety of businesses and underline the necessity for industry, government, and academic institutions to collaborate in order to ensure the successful deployment of 5G networks. It is also explored in great length the research issues that are involved with 5G networks, such as protecting users' privacy and maximising energy efficiency.

	Feature	**Description**	**Pros**	**Cons**	**Methodology**

K. Doppler et al. (2017)	Higher data rates	5G networks provide higher data rates than previous generations of cellular networks, enabling new and emerging applications that require high bandwidth.	paves the way for cutting-edge technologies like augmented and virtual reality, as well as video streaming in 4K resolution.	Requires significant investment in infrastructure, including new base stations, spectrum, and backhaul.	Simulation, modeling, and experimentation.
J. Liu et al. (2019)	Lower latency	5G networks provide lower latency than previous generations of cellular networks, enabling real-time applications.	Enables new applications and services such as real-time remote surgery, autonomous vehicles, and industrial automation.	Requires significant investment in infrastructure, including new base stations and backhaul.	Simulation, modeling, and experimentation.
N. Kheirkhah et al. (2019)	Massive connectivity	Much more devices can connect to a 5G network at once than to a 4G network, thanks to huge interconnectedness.	promotes the development of cutting-edge industries including the Internet of Things, smart cities, and smart homes.	Requires significant investment in infrastructure, including new base stations and spectrum.	Simulation, modeling, and experimentation.

H. Chen et al. (2020)	Network slicing	Network slicing enables for increased service agility, better resource efficiency, and higher quality of service by allowing several virtual networks to use a single physical network's infrastructure.	Paves the way for cutting-edge service models, increased efficiency, and enhanced productivity.	Requires significant investment in infrastructure, including new network functions and orchestration mechanisms.	Modeling and simulation, experimentation, and prototyping.
J. Liu et al. (2019)	Edge computing	By moving processing to the edge of the network, closer to the end-users, edge computing paves the way for low-latency applications and relieves strain on the central network.	Enables new applications and services such as autonomous vehicles, industrial automation, and augmented reality.	Requires significant investment in infrastructure, including new edge servers and software platforms.	Simulation, modeling, and experimentation.
M. M. Alam et al. (2020)	Security	The security and privacy concerns of the many apps and services made possible by 5G networks provide a significant obstacle to their widespread adoption.	Enables new applications and services that require high levels of security and privacy.	Requires significant investment in security mechanisms and protocols.	Analysis of security threats, risk assessment, and implementation of security mechanisms.
J. Liu et al. (2019)	Energy efficiency	Energy efficiency is a key challenge associated with 5G networks, as	Enables sustainability and reduces	Requires significant investment in energy-	Simulation, modeling, and experimentation.

		they require significant energy consumption to support higher data rates and massive connectivity.	carbon footprint.	efficient hardware and software, as well as energy-efficient network design and management.	
N. Kheirkhah et al. (2019)	Virtual and augmented reality	5G networks provide new opportunities for virtual and augmented reality applications, enabling immersive and interactive experiences.	Enables new applications and services such as immersive gaming, education, and training.	Requires significant investment in infrastructure, including high-bandwidth and low-latency networks.	Simulation, modeling, and experimentation.
M. M. Alam et al. (2020)	Collaboration	Collaboration between industry, government, and academia is essential to ensure the successful deployment of 5G networks and enable new and innovative applications and services.	Enables knowledge sharing, resource pooling, and risk sharing.	Requires coordination and cooperation among multiple stakeholders with different interests and priorities.	Literature review, case studies, and surveys.

Table.1 key features, challenges, and opportunities associated with 5G networks

B. 5G Network Slicing and Techniques

Network slicing is an important technique in 5G networks because it allows the construction of many virtual networks on top of a common physical infrastructure. These virtual networks, or slices, may be tailored to satisfy the unique needs of various applications and services, such as low latency, high bandwidth, and high dependability.

Several research papers have focused on the design and implementation of network slicing in 5G networks. For example, a paper by Zhang et al. (2021) proposed a novel network slicing framework that enables fine-grained control over network resources, including bandwidth, latency, and reliability. The proposed framework uses SDN and NFV to provide a flexible and scalable platform for network slicing.

Another paper by Chiang et al. (2021) proposed a reinforcement learning-based approach for dynamic network slicing in 5G networks. The proposed approach uses a deep reinforcement learning algorithm to optimize network slicing decisions based on real-time network conditions and application requirements. The results showed that the proposed approach outperformed existing static network slicing techniques in terms of network performance and resource utilization.

In addition to network slicing techniques, several research papers have focused on the challenges associated with network slicing in 5G networks. For example, a paper by Ma et al. (2020) identified several key challenges in network slicing, including resource allocation, slice isolation, and slice orchestration. The paper proposed a comprehensive framework for network slicing that addresses these challenges and enables efficient and effective network slicing in 5G networks.

Another paper by Li et al. (2021) focused on the security challenges associated with network slicing in 5G networks. The paper proposed a secure and efficient network slicing architecture that integrates various security mechanisms, including authentication, encryption, and access control. The results showed that the proposed architecture provides robust security for network slicing in 5G networks.

Overall, these research papers demonstrate the importance of network slicing in 5G networks and highlight the need for advanced techniques and frameworks to enable efficient and effective network slicing. The proposed techniques and frameworks can help overcome the challenges associated with network slicing and enable the creation of customized virtual networks that meet the specific requirements of different applications and services.

Furthermore, there have been several studies on the practical implementation of network slicing in 5G networks. For example, a paper by Chen et al. (2021) proposed a software-defined network (SDN) based approach for dynamic network slicing in 5G networks. The proposed approach uses a central controller to manage network slices and dynamically allocate resources based on application requirements. The results showed that the proposed approach can improve network performance and reduce resource wastage compared to existing static network slicing techniques.

Another paper by Yang et al. (2021) proposed a federated learning-based approach for network slicing in 5G networks. The proposed approach uses machine learning algorithms to optimize network slicing decisions based on real-time network conditions and user preferences. The results showed that the proposed approach can improve network performance and user satisfaction compared to existing static network slicing techniques.

In addition to these studies, there have also been several studies on the economic aspects of network slicing in 5G networks. For example, a paper by Liu et al. (2021) proposed an auction-based mechanism for resource allocation in network slicing. The proposed mechanism enables service providers to bid for network resources based on the requirements of their applications, and the resources are allocated to the highest bidder. The results showed that the proposed mechanism can improve resource utilization and reduce costs for service providers.

Reference	Pros	Cons	Methodology
Zhang et al. (2021)	- Enables fine-grained control over network resources	- No specific cons mentioned	Proposed a novel network slicing framework
Chiang et al. (2021)	- Uses reinforcement learning to optimize network slicing decisions based on real-time network conditions and application requirements - Outperforms existing static network slicing techniques	- Limited to reinforcement learning-based approach	Proposed a reinforcement learning-based approach for dynamic network slicing
Ma et al. (2020)	- Identifies key challenges in network slicing and proposes a comprehensive framework that addresses these challenges - Enables efficient and effective network slicing in 5G networks	- No specific cons mentioned	Identified challenges in network slicing and proposed a comprehensive framework
Li et al. (2021)	- Addresses the security challenges associated with network slicing in 5G networks - Provides robust security for network slicing	- No specific cons mentioned	Proposed a secure and efficient network slicing architecture
Chen et al. (2021)	- Uses SDN to dynamically allocate network resources based on application requirements - Improves network performance and reduces resource wastage	- Limited to SDN-based approach	Proposed an SDN-based approach for dynamic network slicing
Yang et al. (2021)	- Uses machine learning algorithms to optimize network slicing decisions based on real-time network conditions and user preferences - Improves network performance and user satisfaction	- Limited to federated learning-based approach	Proposed a federated learning-based approach for network slicing

Liu et al. (2021)	- Enables service providers to bid for network resources based on the requirements of their applications - Improves resource utilization and reduces costs for service providers	- Limited to auction-based mechanism	Proposed an auction-based mechanism for resource allocation in network slicing

Table.2 5G network slicing and techniques

III. Existing Methodology

Technique	Methodology	Pros	Cons	Results	Use Case
Static slicing	Pre-defined allocation of resources for each slice	Simple, predictable, low overhead	Limited flexibility, inefficient resource utilization	Suitable for low-variability applications	IoT networks, industrial automation
Dynamic slicing	Real-time allocation of resources based on demand	Highly flexible, efficient resource utilization	Complex, high overhead, difficult to manage	Suitable for high-variability applications	Video streaming, online gaming
SDN-based slicing	Uses SDN to manage network slices	Centralized management, high flexibility	Limited scalability, complex implementation	Suitable for small-scale networks	Enterprise networks, campus networks
NFV-based slicing	Uses NFV to create and manage network slices	High scalability, cost-effective	Limited flexibility, complex implementation	Suitable for large-scale networks	Mobile operator networks, cloud data centers
Hybrid slicing	Combination of static, dynamic, SDN, and NFV techniques	Provides a balance of flexibility and efficiency	Complex, requires sophisticated management	Suitable for a wide range of use cases	Smart cities, healthcare

Table.3 comparing the existing techniques for 5G network slicing

IV. Key Findings

From the literature review and analysis of existing methodologies for 5G network slicing, some key findings are:

a. Network slicing is a promising technology for enabling efficient and effective resource allocation in 5G networks.

b. Network slicing can be used to support a wide range of applications with varying requirements.

c. Different methodologies for network slicing, including static, dynamic, SDN-based, NFV-based, and hybrid, have been proposed to address the challenges associated with network slicing.

d. Each methodology has its pros and cons, and the choice of methodology depends on the specific use case and application requirements.

e. Advanced techniques, such as reinforcement learning and machine learning, can be used to optimize network slicing decisions and improve network performance.

f. Security is a critical concern in network slicing, and robust security mechanisms must be implemented to ensure the privacy and integrity of network slices.

g. While network slicing offers numerous benefits, it also increases network complexity and requires sophisticated resource allocation algorithms.

h. Further research is needed to address the challenges associated with network slicing and to develop new techniques and frameworks to enable efficient and effective network slicing in 5G networks.

V. Challenges:

There are several challenges associated with the deployment and implementation of 5G networks, as reported in various research papers. Some of the key challenges are:

a. Spectrum Availability: One of the biggest challenges of 5G networks is the availability of spectrum. 5G networks require higher frequency bands, which are limited in availability and may require new spectrum allocation. This may result in regulatory and political challenges, as well as increased costs for operators.

b. Infrastructure Deployment: The deployment of 5G infrastructure is a major challenge, as it requires significant investment in new infrastructure, such as small cells and fiber optic cables. The deployment of infrastructure can be hindered by various factors, such as the lack of suitable sites for antennas and towers and the high costs associated with the deployment.

c. Security and Privacy: The increased connectivity and data exchange in 5G networks create new security and privacy concerns. The high-speed and low-latency nature of 5G networks make them more vulnerable to cyber-attacks, such as Distributed Denial of Service (DDoS) attacks. This requires new security measures, such as the implementation of end-to-end encryption, secure booting, and secure device provisioning.

d. Interoperability: The integration of different network technologies, such as 5G and Wi-Fi, presents a challenge for interoperability. This is particularly important for seamless handovers between different networks and the management of different types of devices and applications.

e. Energy Efficiency: The deployment of 5G networks requires a significant amount of energy, which is a challenge for sustainability and cost-effectiveness. The increased number of devices and the use of small cells require efficient power management and energy harvesting techniques.

Overall, these challenges highlight the need for a coordinated effort among stakeholders, including governments, regulators, operators, and vendors, to ensure the successful deployment and implementation of 5G networks.

VI. Features:

Research papers have identified several key features of 5G networks, which differentiate them from previous generations of wireless networks. Some of the most significant features are:

a. High Data Rates: 5G networks offer significantly higher data transfer rates than previous generations. According to research, 5G networks can deliver peak data rates of up to 20 Gbps, which is approximately 20 times faster than 4G networks. This allows for faster downloads, streaming, and other data-intensive applications.

b. Low Latency: 5G networks are designed to have very low latency, which is the time it takes for data to travel between devices. Research has shown that 5G networks can achieve latencies as low as 1 millisecond, compared to 4G networks which typically have latencies of 30-50 milliseconds. This low latency is critical for real-time applications, such as autonomous vehicles and remote surgery.

c. Massive Connectivity: 5G networks can support a much larger number of devices than previous generations. According to research, 5G networks can support up to 1 million devices per square kilometer, compared to 4G networks which can only support up to 100,000 devices per square kilometer. This increased capacity is necessary to support the growing number of IoT devices and smart city applications.

d. Network Slicing: 5G networks support network slicing, which allows for the creation of multiple virtual networks on a shared physical infrastructure. Each virtual network can have its own unique characteristics and service level agreements (SLAs). This allows for more efficient use of network resources and better customization of services for different applications and users.

e. Edge Computing: 5G networks support edge computing, which allows for processing and storage of data closer to the devices that generate it. This reduces latency and improves performance for real-time applications, such as virtual and augmented reality.

Overall, these features of 5G networks have the potential to enable new and innovative applications and services, such as autonomous vehicles, smart cities, and virtual reality.

VII. Applications

5G network slicing has various applications in different industries, some of which are:

a. Healthcare: 5G network slicing can be used to create virtual networks for medical devices and systems. For example, remote surgery, medical imaging, and patient monitoring can be performed using a dedicated virtual network with low latency and high reliability.

b. Smart Cities: 5G network slicing can enable the development of smart city applications. Virtual networks can be created to prioritize critical services and applications in times of emergencies.

c. Autonomous Vehicles: 5G network slicing can be used to create a dedicated virtual network for autonomous vehicles. This technology can support real-time communication and coordination between vehicles, infrastructure, and other connected devices.

d. Entertainment and Gaming: 5G network slicing can enable the development of immersive and interactive entertainment and gaming experiences. Virtual networks can be created to prioritize bandwidth and low latency for high-quality streaming and real-time gaming.

e. Industrial Automation: 5G network slicing can support industrial automation applications such as robotics and remote monitoring.

VIII. Conclusion:

5G network slicing is a promising approach that allows network operators to create multiple virtual networks with different performance characteristics on a shared physical infrastructure. This technology offers a wide range of benefits such as increased flexibility, network efficiency, and improved user experience. Various techniques and methodologies have been proposed in the literature to address the challenges associated with 5G network slicing, including deep learning, game theory, reinforcement learning, and heuristic algorithms. These approaches have shown promising results in optimizing network resources and improving network performance. However, there are still some challenges that need to be addressed to fully realize the potential of 5G network slicing. These include security and privacy concerns, complexity, and scalability issues. More research is needed to develop efficient and effective techniques for these challenges. Overall, 5G network slicing has the potential to revolutionize the way we use and experience network services. With the continued development of this technology, we can expect to see more innovative applications and use cases in the future.

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