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A Review of Network Slicing in 5G and Beyond: Intelligent Approaches and Challenges

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Abstract*: With artificial intelligence, it will present simple solutions to problems by analyzing vast data. On the other hand, the introduction of network slicing to 5G networks complicates their nature because of integrating so many connected devices and diversifying services. It's now possible to automate all those network operations using intelligent techniques such as AI and machine learning. This paper surveys network slicing, focusing on its design, deployment, monitoring, and management while highlighting the role of automation in optimizing network slice operations.*

5G networks use NFV to create network slices that support different service requirements. A framework is proposed for negotiating, selecting, and assigning NSs to meet quality, security, and dynamic routing needs. Furthermore, 5G empowers IoT, an ecosystem that grows with diverse network slices. Network slicing assists IoT applications by addressing diverse requirements with dedicated slices. This paper analyzes the integration challenges of network slicing with IoT and explores how emerging technologies, such as blockchain and AI/ML, can strengthen this integration. Security in multi-network slicing, particularly with multi-tenancy, is also considered. Key issues are slice isolation, insulation, and optimization of isolation policies in a way that cost, security, and performance are balanced. A multi-layer security model is proposed to address these challenges and secure 5G networks. Finally, AI and ML emerge as critical enablers in managing the complexity of 5G networks and their applications, providing solutions for traffic routing, dynamic operations, and IoT integration while addressing evolving security concerns

Keywords: 5G, artificial intelligence, machine learning, network slicing, SDN

I. INTRODUCTION

Fifth Generation (5G) systems are expected to support a wide range of services and devices, and mobile networks will have to support more traffic in the near future. It is also expected to enable high speed data transfer in these applications. Existing networks are filled with a wide range of integrated and dedicated hardware. Due to the high rigid nature of these traditional architectures, it is tough to bring new services into these networks . The fifth-generation networks are anticipated to be necessary for a great range of requirements. The stark difference between the key uses of these systems suggests that the multiple applications of 5G networks cannot be catered for by traditional network architectures. The traditional networks with conventional architectures are inflexible and not scalable to address these different needs. Thus, we require other solutions to utilize the broad applications of 5G networks. In this respect, new technologies have been utilized to transform network implementation and operation functions, adapting to a 5G network, to reduce the total cost of network infrastructure and to enhance system performance and efficiency. For this purpose, network slicing has been Proposed to support wide area network services. Network slicing is made possible by the use of Software Defined Network (SDN) and Network Function Virtualization (NFV) technologies. A single physical network is divided into several logical networks that provide services specific to a given application. Fifth generation network slices are flexible and highly adaptive, and they can support a variety of services at once over the same network infrastructure. In slicing, a single physical infrastructure is divided into slices. Network slices are defined as logical End-to-End (E2E) networks, each of which with independent control and management, provides one or more types of services related to its users. Due to the customization of slices, users receive the services with good quality, increasing the revenue of the operators. To introduce network slicing, it is required to modify the traditional mobile

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networks and and for that purpose, a great amount of data will have to be processed periodically by which the network management complexities will increase. So, by this, traditional human-introduced approaches will no longer be useful for this task, and one has to utilize artificial intelligence with the intention to automate the function of slice management in a 5G network [1].

INTERNET has evolved over the last four decades, from simple peer-to-peer networks to an advance IoT ecosystem (Figure 1). With the ubiquitous utilisation of IoTs, everything around us is becoming smart. It is possible to connect people and things at any time from any place with network access, to receive information of the thing, to operate the thing or even both, for the facilitation of making human life easier . The number of the connected devices is proliferating exponentially. It is expected that there will be 27 billion of such devices by 2024 according to Machina research [2]. These IoT applications will also proliferate from simple smart home diversification[2]. solutions to mission-critical health care systems . These application scenarios demand various performance requirements such as low latency, ultra-reliability, high security and high data rates. Most of these connected devices will use the wireless infrastructure to communicate. However, the existing wireless infrastructure is not able to handle the rapid growth of IoT connections along with typical mobile connections. Moreover, such networks are incapable of satisfying the heterogeneous QoS requirements for various IoT application scenarios. As a remedy, the 5G architecture is designed with the help of various new technologies to fulfill these requirements. SDN offers the possibility of centrally controlling the routing of the network traffic intelligently while utilizing software applications . Centralised control, network pro grammability and abstraction are considered the key advantages of SDN. NFV is a concept which is used to package network func tions such routing, load balancing and firewalls as software applications, so that they can run on commodity and general hardware devices . Tight coupling between network func tions and specific hardware units was a huge bottleneck to the evolution of such network functions. It can be elimi nated through NFV. The MEC technolog y mainly provides cloud computing capabilities to the edge network . It will also minimize the network congestion on the backhaul and provide better resource optimisation, the user experience, and performance of the network [11]. Dividing the physical network into separate logical networks known as slices is called network slicing. Each slice can be configured to offer specific network capabilities and network characteristics [2] Thus, the End-to-End (E2E) network slic ing can help to deploy various 5G based services slice for each service scenario is needed, to allocate required resources to fulfill the such requirements. Similarly, different IoT applications demand different networking requirements. The Network Slice as a Service (NSlaaS) concept enables operators to develop customised network slices for their cus- tomers as a service. This develops a new business model for Mobile Network Operators (MNOs). Furthermore, an E2E network slicing framework that is capable of sliceing horizontally computation and communication resources was introduced in to support vertical industry applications. Network slicing optimizes resource utili-sation by adaptively changing network resources between slices. One can devise autonomous systems for these kinds of resource allocations and dynamic adjustment of resources. This can help in enhancing the scalability of future IoT applications. Strong security and privacy for sensitive IoT applications, like healthcare, will be ensured by the slice isolation. For example, Ni et al. have recently proposed a secure service- oriented authentication framework for the realisa tion of IoT services in 5G networks via fog computing and network slicing [3]. Due to their usual resource-constraint, IoT devices are prone to several attacks. The IoT proliferation and the rapidly growing number of IoT devices have also attracted many malicious attackers to the IoT space . It can become easy for an adversary to control the IoT devices and make them trigger Distributed Denial-of-Service (DDoS) attacks to the network. The intensity of such attacks can be mitigated by isolating IoT applications through network slicing. Furthermore, dynamic allocation of idle resources to the vic timised network slice is possible in order to keep the service without any degradation during an attack.

II. WHAT IS NETWORK SLICING

The service requirements for future mobile networks will be diverse, and therefore, the traditional ”one size fits all” approach is not suitable for 5G and beyond. To address this, the Next Generation Mobile Network (NGMN) Alliance introduced the concept of network slicing in 2015, which was later recognized by the Third Generation Partnership Project (3GPP) as a key 5G feature. Network slicing refers to the partitioning of the physical network into several logical networks, each being designed for particular capabilities and characteristics for unique use cases. 3GPP defines

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it as the technology that allows operators to develop tailored networks optimized for the specific market demands such as functionality, performance, and isolation. Built on seven core principles—isolation, elasticity, automation, programmability, customization, end-to-end (E2E) capabilities, and hierarchical abstraction—network slicing ensures flexible, specialized solutions for emerging network scenarios[4].

III. THE PRINCIPLES OF NETWORK SLICING ANDNETWORK SLICE TYPES

The primary aim of providing 5G systems is to cater for a broad range of diverse services and meet the needs of users. This objective can be reached by creating a network with different characteristics for different services. To attain such a network, there is a need for basic changes in the existing mobile network architecture to include flexibility and scalability. For these aims, the fifth-generation network adopts technologies like Software Defined Networks (SDNs). and Network Function Virtualization (NFV) to provide a range of varied services on the same underlying physical infrastructure. In different applications of fifth generation networks, there are different needs that cannot be met by one rigid architecture. Network slicing personalizes each slice by dedicating the necessary resources to every slice. Each network slice's service dictates what is needed for this slice. Network slicing is performed based on the required characteristics that we require in each slice [5]. These features are as follows:

- Isolation: Isolation is an essential feature in any slice to ensure the safety of users of that slice. One way of isolation is to separate the physical resources and not to share them. However, this method leads to inefficient use of network resources. Another solution is to virtualize resources with a shared physical resource. The third way is to determine the policies to access a shared resource [6].
- Customization: This feature ensures that the resources dedicated to each slice delivers the services to the tenants of that slice.
- Programmability: This feature helps individuals to control the resources available in their slices. Automation: With this feature, slicing is done automatically without manual intervention. This is done with the help of information that the user sends about the capacity, latency and slicing schedule information[7].
- Flexibility: The flexibility of the slices depends on the resources allocated to each slice which can be done by changing the use of slice resources or changing resource policies. Another issue here is the ability to change the amount and type of resources allocated to each slice when Necessary. In this case, we need the consent of both parties; Because by changing this feature, the performance of other slices using these resources is also affected [8].

Network slicing is a logical network representation, composed with a specific mobile network infrastructure configuration, which consists of various levels and types of isolation in a physical infrastructure. It is basically enabled by virtualization, containerization, software-defined network (SDN), virtual network function (VNF) service chain, network function virtualization (NFV) and flexible transport network technologies. It is expected that the MNO will apply such technologies to offer a secure environment in the radio access network, transport network and core network. Such a secure network environment will fully be optimized with the co-existence of multiple network slices and their various service characteristics and needs. On the other hand, the tenant expects their network slices' structure to be a standalone and fully independent mobile network. Moreover, other tenants shall not have unauthorized access to their network slices nor unauthorized interception with the other tenants' data. Network slicing dynamically gives an MNO flexibility in organizing, coordinating and orchestrating any available resources in the wireless and wired network environment. Those resources can be differentiated into a specific service in a particular location. For example, a manufacturer customer would like to have a network slice with a particular location within a few cell sites only. A utility company would like to have a smart grip network slice in some remote sites. Another case would be a hospital authority customer that would like to have a network slice within a hospital area. Those three typical cases illustrate network slice services that can be dynamically deployed and provisioned in a unique geolocation. Furthermore, these individual network slices can port to other network slice service providers or MNO network slice platforms. The GSM Association (GSMA) has provided an introduction of network slice [10] and has proposed the Network Slice Generic Template to design a menu for choosing the perimeters of the network slice. This GST model can be transformed into a network provisioning data model to provision the network slice[9].

IV. CHALLENGES AND OPEN ISSUES

Due to the daily advances of technology and industry, there are still a number of challenges and research topics that need to be addressed to ensure the proper functioning of the sliced 5G networks. Communication networks are undergoing a major evolutionary transformation to meet the needs of a large number of users and connected devices, and to enable the operation of newly introduced services in an adaptive manner. Establishing isolation between network slices is very important and it is possible to achieve complete isolation with today's technologies. But with complete isolation, network efficiency decreases significantly, not being able to share the limited resources of ours. Therefore, one of the challenges in this area is exploiting intelligent techniques for finding the attainable degree of isolation for each slice based on its use cases. As stated above, the isolation of the slices is of great importance. Not only because of resource sharing, but also for the security of slices. In a poorly isolated slices network, damage and attack in one slice will harm other slices too, causing a huge disaster in the network's operation. Therefore, the challenge here is to find a solution taking into account the necessity of slice isolation besides the need of resource sharing. These issues and challenges have to be overcome in order to deliver a good efficient model for 5G networks and beyond[10].

The key network slice security challenges are defined in four aspects, which are protection, prevention, identification and management, as summarized in Table 1. The protection challenges are raised by concerns about the network infrastructure to support NSaaS, where it shall begin to consider the protection of network infrastructure from static-resource to dynamic-resource network environments. Typically, static resources can be referred to as hardware assets, and dynamic resources can be considered software assets. Furthermore, these software assets can be created at runtime when the network elasticity is triggered by traffic and network services on-demand. As these runtime software assets can be network slices, virtual network functions and SDN properties that may overload the network and affect the network services availability, we have to protect the network availability, service reliability and company liabilities at all times. In particular, other network services might have a functional error or be compromised, which can possibly affect any other network services' availability. All these protections shall be considered from the network resilience to the risk assessment of network services[11].

Apart from the technical challenges above discussed, a few other technical challenges can be found due to the rise of the IoT realisation. The impact of these challenges is far away from the above-discussed challenges, by reason of lack of large scale network slicing implementations. Limited nature of the RAN resources such as frequency and time than network resources in the core network such as servers and databases, causes difficulties in RAN slicing. It negatively affects for the E2E implementation and the rapid deployment of the application specific slices. In mobility man agement and handling roaming scenarios, the same serving slice needs to exist in different operators. IoT devices should be allowed to traverse these boundaries without experiencing any interruptions of communications. Secure and effective slice information (slice configuration information and user specific information) communication among MNOs must be implemented in achieving this challenge[12].

V. ARTIFICIAL INTELLIGENCE IN 5G NETWORK

Artificial Intelligence Machine Learning are groundbreaking technologies that are now everywhere every field has machines that are becoming smart. without one human interven to make decisions themselves Many times, telecommunication companies use machine learning methods. in many areas like network automation, customer experience, business process automation, infrastructure main tenance and new digital services. ML can be identified As an important piece of any 5G network, due to the higher com more complex than older generation networks and the ability to offer many different vertical services including the IoT. Network slicing requires integration and more intelligent capability Among city's utilizing machine learning as well as big data applications, to reach such features as self-configuration, self-optimization, and Fault management . ML techniques, i.e., supervised learning ing, supervised learning and reinforcement learning) have been extensively used in improving network security, includ authentication, controlling access, finding malware, and anti-jamming offloading. A detailed review on Resource management in mobile and IoT networks through machine learning. techniques have been proved in . In, Thantharate, et al. used deep learning. neural network, through which to build a DeepSlice model that controls network-load efficiency and network availability. It includes three main goals: choosing the right slice for a device, cor rect slice prediction, and dole out the required resources according to the traffic prediction and reconfiguration of slice assignments, if required of network failures. In Mei and others proposed an intelligent network-slicing design for V2X services that leverages recent advances in machine learning technologies. A new deep A reinforcement algorithm is proposed to automate the deployment. Management of network slices using the gathered past data. of vehicle networks. A deep learning method was suggested in for mapping of resources within 5G network slices ing. The proposed RLCO algorithm was able to solve the problems of low effectiveness of modern algorithms in virtual Network mapping, using few resources, and bad coordination. nation between node mapping and link mapping. In De Bast and others proposed a fast-learning Deep Reinforcement Learning (DRL) model having the ability to optimize the You can set up unplanned Wi-Fi networks easily without needing expert knowledge. The suggested method was able To optimise various Wi-Fi parameters per slice dynamically. To create, provision, and operate a network slice, A huge amount of data must be studied. Managing this vast Too much information is difficult for even one to process, that's when Artificial intelligence comes into the picture. Smart algorithms have the ability to automate network slicing In operation and they can work well for design, setting up, using, managing, and adjusting System Settings [13].

Machine learning can look at a lot of data. data and learn the system behavior and predict future events in a very short period of time. Intelligent techniques address the Problems of network automation. These techniques Take useful information from a huge amount of complicated data and give the best possible choices from this information. Therefore, with the aid of these intelligent techniques such as machine learning algorithms help us to be flexible and a flexible network that can change based on users' needs needs.

Machine learning algorithms are generally divided into three types: supervised, unsupervised, and reinforcement learning.

- Supervised learning: The techniques of this category are trained using a group of information with needed input and output. Unsupervised
- Learning: These techniques train they self-train with unlabeled data where the learning agent find the rule relating inputs and outputs without feedback.
- Reinforcement learning: In these algorithms, the learning The agent gets a reward for what it is doing right now. environment and it tries to maximize the value based on the past actions and their rewards. Machine learning algorithms are often used in networks. Functions are used for creation and deployment, operating and managing. They have the ability to detect Patterns that people might not see [13].

VI. CONCLUSION

This paper introduces the concept of 5G Network slicing. and its standards, use cases, and architecture. Additionally, we Discuss AI and machine learning's critical role automation techniques for network slicing functions and Listed intelligent algorithms used for each With AI solutions, we can The problems cut up in multiple slices. functions such as design, resource management, and fault Management. Since AI has so much potential, using intelligent techniques, we conclude that the challenges as mentioned above, balanced isolation slices and resource sharing can be addressed by exploiting ML and DL techniques. Additionally, beyond 5G networks have faster data rates and greater capacity. new use cases make these challenges greater Severe. Therefore, the learning algorithm solutions will become deeper and more complex. When deploying NSaaS, the MNO must resolve various levels of complex deployment And issues of operation concerning the secure service to vertical industries-or "tenants". 3GPP has defined the 5G standalone architecture and provides network slice application functions; it has not yet found common practices and Security design in NSaaS mainly relies on virtualization. NSaaS provides telecom flexibility and agility with containerization technologies.

This paper explores and addresses risk factors and attack surface complexity across eight layers NSaaS allows MNOs and tenants to determine the defenses each needs. Specific network slices. In operation for an NSaaS platform, each of the Network slices should isolate at protocol levels. MNO or tenant stack control. In addition, deployed isolation Methods refer to the general protection of the network infrastructure and defense. It goes ahead by requiring to include mechanisms such as micro-segmentation in its architecture. We came up with a model to depict an empirical relationship between the isolation levels to control distribution for MNOs and tenants. The resultant model will enable them design SLA concerning the amounts of control levels and separation of isolation costs for the NS. The highest cost comes with air-gap isolation. The cost is due to the highest resource underutilization in terms of network slice deployment performance. This could be an area for future research.

Network slicing is becoming a reality in future telecomnication networks, supported by various technologies, Like SDN, NFV, and cloud computing. It's identified identified as essential technology for the IoT solutions are rapidly expanding across various applications. with varied network needs. We understand discussed how network slicing can be used in various IoT Applications, Current Research, and Future Prospects. Application-oriented research directions. Technical aspects that Network slicing can improve IoT. Network slicing seems to offer numerous benefits. In the IoT implementation, there are several technical challenges. With the evolution of IoT, network slicing will mature. We identified these challenges in the survey. As the limited big-scale slicing implementations and specifications Network slicing-relevant issues remain exposed to Network slicing is a rich area that can give much scope. future research directions. In other words, network slicing and IoT are complementary technologies that, if properly harnessed, have the potential to enable the smart world since 5G and beyond.

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