A Review on NS Beyond 5G: Techniques, Applications, Challenges and Future Research Directions

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***Abstract*—With the advent of the fifth generation (5G) era, many emerging Internet of Things (IoT) applications have emerged to make life more convenient and intelligent. While the number of connected devices is growing, there are also differences in the network requirements of each device. Network slicing (NS) as an emerging technology, provides multiple logical networks for infrastructure. Each of these logical networks can provide specialized services for different needs of different applications by defining its logical topology, reliability and security level. This article provides an overview of the basic architecture, categories, and life cycle of network slicing. Then summarized two kinds of resource allocation methods and security problems based on three kinds of network slicing technologies. With the investigation of recent studies, it is found that network slicing is widely used in Industrial Internet of Things (IIoT), Internet of Medical Things (IoMT), in-vehicle systems and other applications. It improves network efficiency, improves service quality and enhances security and privacy by optimizing indicators such as latency, resource management and service quality. At the end of this study, according to the challenges faced by different research methods, the future research direction of network slicing is proposed.**

***Keywords*—5G; network slicing; resource allocation; dynamic allocation; security**

I. Introduction

5G and higher networks are predicted to have high throughput, low latency, and the power to concatenate many devices [1]. With the popularization of 5G, more and more new services appear in our lives. These different services put forward a variety of requirements for the quality of service (QoS) of the network [2]. For healthcare, autonomous industry, and smart vehicle services, networks need to offer lower latency and high reliability, security, and privacy [3]. Smart city and grid services have many applications, requiring the network to be highly scalable and provide large data sets [4]. Smart home needs safe short-distance service, and smart weather station needs long-distance communication with low bandwidth [5]. Therefore, 5G networks need to establish a more flexible and guaranteed dynamic network to meet different needs of all walks of life [6].

In this context, NS technology comes into being. NS can divide the physical network into multiple logical networks, and each logical network can formulate its own functions and characteristics to provide an independent network for a specific application [7]. However, in the highly fragmented network environment, vast demand for specific traffic leads to overload, which affects the quality of service of the network [8]. Therefore, many NS researches achieve real-time dynamic resource allocation and prediction by using artificial intelligence (AI) or machine language (ML) algorithms [9]. The algorithm predicts traffic patterns and historical data based on future demand, thereby adjusting resources ahead of time to ensure that the slice maintains stable performance during peak periods [10]. The creation of different slices, configuration updates, etc. become more complex as the number and types of slices increase. AI-driven network orchestration and autonomous management tools to adjust the lifecycle of slices, and propose automated orchestration systems and intelligent management platforms to reduce the complexity of human intervention and management [11].

In addition, NS has compatibility problems with existing network infrastructure, and operators use virtualization and software-defined networking (SDN) technologies to transfer traditional hardware functions to programmable virtual platforms to achieve flexible network control and rapid deployment [12]. This strategy not only improves the adaptability and security of the network, but also lays a technical foundation for the realization of large-scale NS in the future.

This paper introduces the architecture, function and practical application of NS. Summarizes the function and architecture of NS by reviewing the progress of research on NS in recent years. In this paper, reviews the practical applications of NS, pointes out the challenges of applying NS, and prospects the future research directions. On this basis, the major contributions of this paper are as follows:

- Introduces the architecture and life cycle of NS and classifies it according to different criteria.
- Investigate two resource allocation methods based on NS, introduce the methods in detail and summarize the test results.
- Surveys and summarizes how NS can be applied to healthcare, industrial application and in-vehicle system services.

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- Introduces the security challenges of basic functions of NS such as SDN, network functions virtualization (NFV) and their hybrid models.

This paper summarizes the development of NS and the research projects and achievements based on different methods. The remainder of this paper is as follows. Section II surveys the existing literature on NS and compares the classification from the technical point of view. Section III introduces the 5G NS architecture, classification based on different criteria, life cycle and introduces two resource allocation problems based on NS. Section IV introduces some technology based on NS. Section V introduces the security issues under the three techniques. Section VI further discusses the prior research. Section VII proposes the future research directions and challenges. Section VIII summarizes the paper.

II. Related Work

In [13], summarizes the basic concepts and analyzes implementation of NS. According to the standard given by NGMN, the network slice is divided into the infrastructure layer, network slice instance layer and service instance layer. Two categories of functional NS, Radio Access Network (RAN) subslices and core subslices, are also introduced. The authors summarize the four life cycles of NS: preparation, debugging, operation and decommissioning. The last part analyzes the application of NS in IoT and other emerging technologies such as blockchain, AI, and ML, and finds the challenges faced by each part and the direction that can be tried in the survey.

In [14], makes a summary of the six advantages of NS and their problems. The dynamic allocation of free resources among slices optimizes the scalability of the network. Use ETSI's zero-touch Network and Service Management (ZSM) to reduce human intervention and automate network operations to address scalability challenges. Or use a distributed Artificial Intelligence (DAI) approach to solve orchestration requests in the NS manager. Each slice has different network functions (NFS) and attributes to satisfy the different requirements of different applications. The reinforcement learning algorithm is used to identify slice attributes and recursion to achieve this goal. The isolation mechanism of dedicated slices can mitigate IoT security attacks. Research on design security and operational security will be expanded in the future. At the same time, it uses the verification function of the slice itself, Bayesian network, and autoencoder for intrusion detection and anomaly development, as in the case of the Application Programming Interface (API) used by the third-party tenant. Dedicated slices are assigned to each application, and isolation mechanisms and communication schemes are optimized to protect privacy. Zero-knowledge proof and argumentation tools for knowledge can optimize inter-slice communication. NS assigns each application a specific slice with sufficient resources to guarantee QoS.

In [15], the research on solving NS management in recent years is summarized. Due to the high-speed and multi-connection characteristics of 5G networks, as well as the flexibility and cost of its architecture. The authors propose that one of the challenges of NS is to completely isolate NS, in which each slice instance has its own function and is not shared between slices. But at the end of the survey, the authors put forward many shortcomings about NS. For example, the resource allocation fast mobile service cannot meet the needs of all the slicing networks, so that the compatibility of this service has drawbacks. 5G does not support inter-slice communication when performing isolation, and information propagation will be subjected to security attacks. Limited end-to-end slice orchestration also becomes an obstacle to solve this challenge simultaneously. Future work attempts to use network simulation to analyze the 5G NS architecture in different mobility scenarios, divide the 5G network into a large number of slices, and let these slices operate independently.

In [16], the scarce overview of NS's security aspects is summarized, and new security and privacy challenges based on NS are introduced for the first time. The investigation points out that when NS processes a large number of data sets because tenants use public resources, it will lead to information leakage and cause privacy security issues. The authors propose a security taxonomy based on NS, Categories include NS attack scenarios security threats, challenges and issues security solutions and trust and privacy in NS. At the same time, attack scenarios such as location tracking, impersonation attack, traditional interworking, and sealing between multiple slices are introduced. Finally, the security solutions based on AI/ML are summarized. Examples include domain isolation against DoS, authentication against identity spoofing, and access control for intrusion detection.

In [17], the author introduces some ML methods about wireless access network slice resource management. Evolutionary algorithms, supervised and unsupervised learning, reinforcement and distributed learning are used to solve the problems of slice resource sharing, dynamic management and isolation security in 5G/B5G. These ML methods are dynamic online techniques which can interact with dynamic network changes and select the most effective decision. To guarantee the QoS, the resources of a slice should be kept constant during a certain time to avoid its traffic load changes affecting other slices. Using Long Short-Term Memory (LSTM) to predict the user's demand for resources to reserve resources can reduce the number of resource reconfiguration. Many projects fixes the transmission power of user equipment, and the dynamic power allocation method combines the channel environment and interference conditions through iterative and online algorithms to optimize the drop situation and anti-interference ability. The user mobility management of slices can be optimized by predicting the user mobility to optimize the resource allocation rate and guarantee QoS. Priority queues prioritize slices to ensure service quality.

In [18], it is pointed out that the attacker attacks the network by using the NS function, which leads to the system failure. The authors divide the attacks on NS into inter-frame attacks, intra-frame attacks and lifetime attacks. At the same time, the solutions are divided into three types: RAN, core network and general solution. At this stage, NS security is mainly maintained using resource isolation, ML and encryption algorithm. This paper evaluates the performance of solving malicious attacks using open interfaces. The experimental results show that the RAN with performance isolation only needs half of the resources of the RAN without performance isolation to achieve the same throughput. The incoming requests of mobile users were processed by first in First Out (FIFO) queue, and the statistical distribution and isolation forest were used to detect outliers. The results show that isolation forest produces more outliers. NS's end-to-end isolation can achieve security in complex systems, and blockchain can prevent data breaches and automatically manage Service Level agreements (SLAs). The existing cryptosystems cannot well protect NS from security intrusion and using quantum secure encryption method as an alternative is a future research goal.

In [19], the study explored the implementation of cloud-native NS based on SDN and multi-access Edge computing (MEC). These two approaches enable NS by virtualizing and dynamically configuring network resources. The authors discuss the design principles of cloud-native 5G core networks, how to optimize network function modularity and service chain through microservice architecture simultaneously. This paper proposes an SDN-based MEC architecture to realize low-latency and Ultra-reliable Delay Communication (URLLC) services. The feasibility of the proposed architecture in terms of NS mobility and service migration is verified through an initial evaluation in multiple edge cloud deployments in Southeast Australia. Cloud-native NS has four main challenges: federated slicing, dynamic service chaining, edge computing, and federated resource management. To address these challenges, the main goals of future research on NS are to enhance the slice federalization mechanism, optimize the dynamic service chain management, promote edge intelligent computing, and realize 4C resource joint management. Blockchain and AI technology are used to enhance resource management and isolation mechanisms. Develop more efficient dynamic service chain management algorithms in 5G architecture, and design new neural network and ML algorithms to meet low latency, high computing requirements and the management of communication, computing, caching and control resources in the joint edge environment, so as to optimize resource utilization. A summary of each literature is shown in Table I.

It is found that different methods have different advantages and disadvantages in terms of effectiveness, efficiency, scalability and applicability. For example, literature [13] focuses on the basic concept and implementation of NS, which, despite its high effectiveness, lacks in terms of scalability. The reinforcement learning method proposed in literature [14] has excellent performance in improving efficiency and scalability, but there are still security challenges. Literature in [15] presents the high efficiency and applicability of independent slices under the high connection characteristics of 5G networks. Nevertheless, the inadequate resource allocation for mobile services and the absence of end-to-end slice orchestration result in NS being unable to exert its maximum effect. Literature in [16] reveals that when NS processes a large amount of data sets, information leakage and privacy issues give rise to trust problems in information sharing between slices. The multiple machine learning methods introduced in [17] can effectively cope with dynamic resource changes, yet it is still necessary to ensure that the resource allocation among different slices does not impact QoS. Literature in [18] indicates that the RAN with performance isolation can achieve the same throughput with fewer resources, but the ability of this mechanism to counter security intrusions still requires further improvement. Literature in [19] explores the virtualization and dynamic configuration of network resources, enabling the network to possess flexibility and low-latency capabilities. In order to further improve the overall performance of network slicing, future research should focus on optimizing these aspects, especially in large-scale network deployment and cross-slicing operation scenarios, to find more efficient and secure solutions. Table II summarizes the comparison of seven articles in these aspects:

TABLE I. SUMMARY OF THE NS LITERATURE SURVEY

Reference	**Summary of the Survey**		
	Object	***Challenges***	***Future***
[13]	Concepts Implementation Lifecycle stages Application	Implementation complexity, interoperability, security concerns	Security exploration Efficiency Application-specific optimizations
[14]	Advantages Problems DRA Automation Configurations Security Privacy protection	Scalability Efficient resource allocation Security Privacy	Resource management with AI/ML Improved security mechanisms
[15]	Resource management Security mechanism	Ensure complete isolation Handle mobility scenarios	Simulate different mobility scenarios enhanc slice independence
[16]	Security Privacy Attack scenarios	Information leakage, securing inter-slice communication	Develop advanced AI/ML security solutions Enhance privacy protection mechanisms security solutions, enhancing privacy protection mechanisms.
[17]	Wireless access network slice resource management Dynamic resource management Isolation security	Predicting user mobility, maintaining QoS	Improving resource prediction accuracy, optimizing power allocation, enhancing mobility management
[18]	Security Attack scenarios Resource isolation	Ensuring end-to-end isolation, handling quantum security threats	Develop quantum-secure cryptographic schemes Enhance blockchain-based security measures
[19]	Cloud-native NS implementation Design principles Edge deployments	Low-latency and reliable communication, dynamic service chaining, federated resource management	Enhance slice federation Optimize service chaining Promote edge intelligent computing Integrating AI and blockchain

TABLE II. RECENT STUDIES COMPARED WITH DIFFERENT PROPERTIES

Reference	Performance Indicator			
	Effectiveness	*Efficiency*	*Scalability*	*Applicability*
[13]	High	Medium	Low	Medium
[14]	High	High	High	High
[15]	Medium	High	Medium	High
[16]	High	Medium	Medium	Low
[17]	High	High	Medium	Medium
[18]	Medium	Medium	High	Medium
[19]	High	High	High	High

NS technology has greatly optimized network resources through ML, but the current dynamic resource allocation and the isolation mechanism of dedicated slices still cannot ensure the integrity of the isolation function between NS. For example, improving interchip communication without compromising security as mentioned in [14] and [15] still lacks a comprehensive solution. In addition, as discussed in [16] and [18], applications of AI and ML in enhancing NS security have shown promise. However, the actual implementation of these solutions, especially in terms of real-time data analysis and intrusion detection, is still in the testing phase. As highlighted in [18], exploring advanced encryption methods is a promising way to address NS security vulnerabilities. In addition, although the research and development of cloud-native architecture and MEC framework for optimizing NS has begun [19], its integration with the current infrastructure is also a huge challenge to be faced.

III. NETWORK SLICING

As a novel architecture, NS can divide the physical network into multiple virtual networks. Each virtual network provides specialized services for different applications and optimizes the services continuously. NS is divided into two components, network function and Virtualized Network Function (VNF), which provide network functions for specific applications and use cases [20]. NS is supported by three main software-based network functions, namely SDN, NFV, and cloud computing[21]. When the needs of users change, cloud computing and virtualization technology can efficiently allocate shared resources to each slice of the logical network [22]. NS creates end-to-end network slices on RAN and core network to run multiple logical networks, enabling different vertical industries to run simultaneously on the same physical network infrastructure [23]. NS with complete functions can route and control packets throughout the network without being affected by other slices [24]. NS has pioneered original business conception such as Network Slicing as a Service (NSaaS) to increase revenue for mobile network operators (MNO) and hand control of networks to third parties [25].

A. Architecture

Next Generation Mobile Network (NGMN) alliance divides NS into three layers: infrastructure layer, network slice instance layer and service instance layer [26]. Fig. 1 shows the NS architecture.

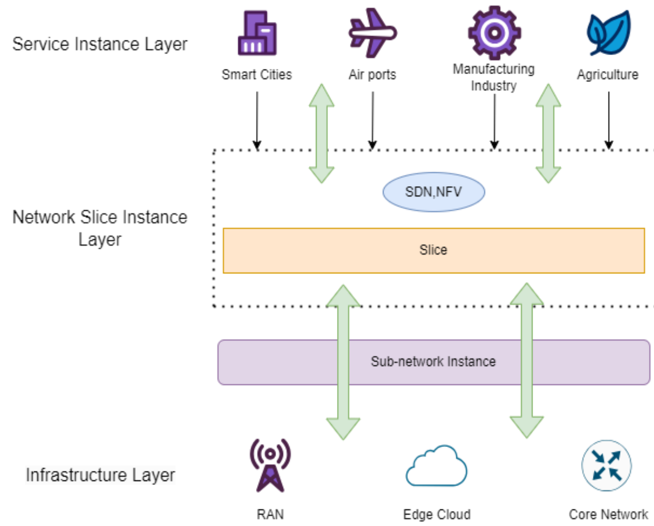

Fig. 1. NS architecture by NGMN.

1) Service instance layer: includes end-user and commercial service provided by network operators or third parties through service instances, such as applications such as virtual reality (VR), remote office, smart city, telemedicine, etc. This layer uses authentication to ensure secure access for users and devices. Distribute workloads across multiple servers to optimize resource efficiency and response time [27]. Real-time batch data processing and analysis to ensure that the data can be efficiently distributed to the terminal users. The service instance layer directly uses the network functions provided by the NS instance layer to satisfy the different needs of different applications in terms of low latency, high bandwidth, or high reliability [28]. The service instance layer includes service orchestration and management functions to ensure the running efficiency of service instances. Service orchestration manages the deployment and operation of different service instances to ensure that they cooperate. Leverage automated tools and techniques (AI/ML) to schedule resources, optimize performance, and handle failures [29].

2) Network slice instance layer: One of the core layers responsible for building virtual network instances over the top of the infrastructure layer. In this layer, each NS instance can be customized and run independently to satisfy the needs of different applications. NFV technology virtualizes the functions of traditional network devices into software modules, which optimizes the network to make it more flexible and scalable [30]. SDN and NFV are important components of the NS instance layer. SDN achieves the flexibility and dynamics of network management by separating the control plane from the data plane [31]. The control plane is managed by a centralized SDN controller. The controller communicates with network devices through an open interface to dynamically configure and manage network traffic. The data plane consists of physical and virtual network devices and performs the forwarding work of data packets. The data plane device receives the instructions issued by the control plane, and carries out the forwarding, filtering, and processing of data packets [32]. NFV decouples the network functions and dedicated hardware devices, then runs them in the form of software on standardized hardware, thus achieving flexibility in network function deployment and management [33].

3) Infrastructure layer: Provides the physical and virtual resources required to support NS instances and service instances. This layer realizes the flexible allocation and management of resources through virtualization technology and SDN technology, which ensures the efficient operation of NS and the satisfaction of business requirements [34]. The physical hardware is the core of the infrastructure layer, with high-performance servers running VNFs and applications [35].

B. Type

NS can be classified by multiple scene: vertical and horizontal, static and dynamic, and RAN and core.

1) Classified by application scenarios: Vertical NS can establish multiple independent virtual networks can be set up on a standalone physical network infrastructure. Each slice is customized and optimized according to the different requirements of different applications. Vertical slicing allows assets to be shared between different applications and services to improve the network's service quality [36]. Each node of the network realizes the comparison capacity in a specific slice, and the traffic of different applications is isolated to complete the on-demand transmission of clients [37]. Horizontal NS distributes resources among system nodes to balance the capabilities of each node. This method provides resource isolation and edge processing [38].

2) Classified by implementation: Static NS configuration is done before the network is deployed or at an early stage of operation. Once deployed, the sliced resources will not change. The resource allocation of static slice is fixed and cannot be adjusted in real time according to the needs of applications [39]. However, its network performance and service quality are relatively stable, and its management and maintenance are also relatively simple. Therefore, it is more suitable for scenarios with stable demand such as private networks. Fixed resource allocation cannot be adjusted in real-time demand scenarios, leading to resource waste [40]. Dynamic NS can adjust resources in real time according to application requirements and network conditions, which greatly increases resource utilization and service quality [41]. It is more suitable for streaming media, healthcare, smart vehicles and other scenarios where the demand changes frequently and the flexibility and availability need to be guaranteed. However, the dynamic adjustment of resources will also bring challenges to network stability and service quality [42].

3) Classified by network architecture: RAN NS mainly manages and optimizations the resources of base station, radio spectrum, radio frequency resources and other radio access parts [43]. It can customize services for the access layer of different applications and handle mobility issues such as handover and roaming of user devices [44]. RAN NS is mostly used for some high bandwidth, low latency applications. And can connect to large-scale Internet of things like smart city sensor networks. Core NS mainly solves and optimizes the resource problems of the core network, such as data routing, session management and security control [45].

C. Lifetime

NS life cycle can be divided into four stages. The basic flow chart is shown in Fig. 2.

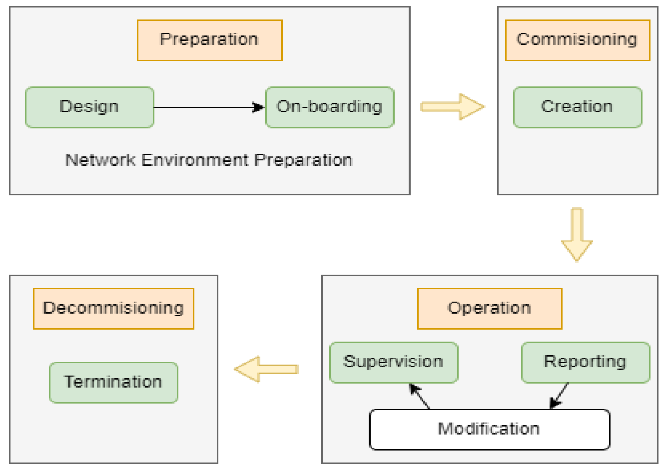

Fig. 2. NS life cycle.

1) Preparation: Network slices are planned and designed to ensure the allocation of resources and configuration. This phase needs to collect and analyze the requirements of different applications, such as bandwidth-delay reliability [46]. According to the application's requirements, the corresponding planning is made to ensure that the slice's resource allocation and service quality meet the requirements. Part of the network resources are reserved so that the dynamic allocation in the subsequent stages can proceed smoothly [47].

2) Commissioning: Setting the relevant network parameters and functions according to the specific network slice designed in the preparation phase [48]. The test verifies that the function of the slice can work properly. After ensuring that the slicing function is normal, the integration test with other services is carried out.

3) Operation: Ensure the efficient and stable operation of slices, and monitor the running status, performance indicators and service quality of slices in real-time [49]. According to the monitoring data and performance analysis results, the optimization is carried out to ensure the utilization of slice resources.

4) Decommissioning: To release the resources occupied by the network slice, clean up the data related to the deleted slice, and avoid security risks [49].

D. Resource Allocation

This section introduces two NS-based resource allocation methods.

1) An intelligent fuzzy-based system: IoT can enhance the performance of facilities which is connected by 5G. However, due to small cell sites' large-scale and unplanned deployment, switching are key issues. Due to the large number of wireless access technologies and technologies in 5G, the switching operation is complicated. In reference [50], the author proposes a fuzz-based system for 5G wireless network switching decision in view of different parameters of slicing. Two fuzzy-based switching decision models (FHDM) are constructed. In the simulation evaluation, the two models select different input parameters to see the impact on the output parameter switching decision (HD). FHDM1 selects the parameters slicing delay (SD), slicing bandwidth (SB), and slicing load (SL). FHDM2 Select Parameter slice Reliability (SR). The results show that the parameters have different influence on HD. HD values increased with the growth of SD and SL values and decreased with the increase of SB and SR values. Although FHDM2 is more complex than FHDM1, but it uses fewer input parameters, so the HD performance of FHDM2 is better. The simulation results of FHDM2 show that when the SD value is changed from 10% to 90%, and the remaining parameters are selected as 50% SR and 90% SL, the HD value increases by 50%. This suggests that when a user connects to a slice with poor service quality, switching to a better QoS is a good approach.

2) Multi-armed bandit based approach in LoRaWAN: With the increasing popularity of wireless sensor networks, LoRa WAN networks have an increasing demand for networks. Efficient resource allocation is an important difficult problem for LoRa WAN. Literature [51] introduced three schemes for how to allot the resource, and these schemes used the Multi-Armed Bandit (MAB) algorithm to maximize the packet delivery rate. UCB-MAB scheme adopts an Upper Confidence Bound (UCB) to find ways to coexist exploration and exploitation. Q-UCB-MAB scheme use Q-learning to update the Q value continuously, and it is combined with the UCB strategy to achieve deeper optimization. The third strategy of ARIMA-UCB-MAB is based on the Autoregressive Integrated Moving Average (ARIMA) model in the UCB framework to predict rewards and enhance the network's integral performance [51]. The results reveal that the three solution strategies achieve the best way to allot resource for PDR and SLA satisfaction. At the same time, with the increase of the parameters, the performance of the three schemes is optimized to a certain extent. In general, the solution strategy of ARIMA-UCB-MAB significantly outperforms the other two schemes.

IV. Technology Based on NS

Since different applications have different network requirements, NS is widely used to customize the network environment for different applications [52]. This section introduces three applications that optimize services with NS, include IoMT, IIoT and Vehicle-based system. Table III summarized technologies, existing problems and limitations of network slicing in different 5G scenarios.

A. Based on Internet of Medical Things

NS is also starting to be used in real life. With the popularity of the healthcare system, IoMT has become popular. From real-time intensive care monitoring to telemedicine, these services have highly different QoS requirements on communication networks. At present, ML/AI technology are widely used to solve these problems [53]. ML/AI analyzes data to predict patient health trends, remotely monitors patient health status, and even protects patient privacy and security. Fig. 3 shows the architecture of IoMT.

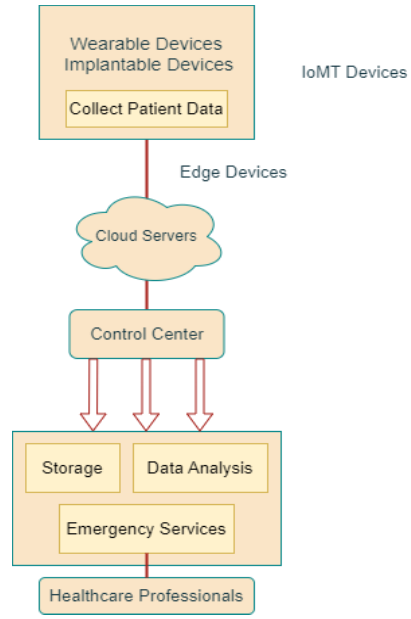

Fig. 3. IoMT architecture.

1) MT-VNE algorithm based on matching game theory: In reference [54], the authors proposed a Virtual Network Embedding solution based on two-sided matching theory (MT-VNE) to model network slices. In the NS model of medical system, each medical service is abstracted as a logical virtual network (VN), and these virtual nodes are connected by virtual links to Construct the virtual network topology. Each VN is equipped with resources that match its needs, such as processing, storage, and bandwidth resources. This innovate approach create many medical slices with different characteristics, which can be managed in one underlying network. Results show that MT-VNE performs excellently in service acceptance and resource utilization. Research will survey the impact of the underlying and virtual topology characteristics, and the future load variation of IoMT services.

2) Digital real-time health care system: During the spread of COVID-19 virus, a telemedicine system that can meet the real-time data transmission capability has become a research hotspot. But it is also a huge challenge. The authors of [55] propose an implementable architecture for digital health systems. To satisfy the needs of an end-to-end digital medical system, 5G NS is introduced to implement the system. Ensure the specificity of communication networks to satisfy the requirments for QoS in healthcare. During the architecture design process, select an URLLC with well availability and security, guaranteed QoS, to deliver real-time patient-centered data and mobility.

The digital health systems include user plane and control plane. User plane consists of a UPF that anchors user session interconnection and traffic based on QoS which is specific. According to the data collection rules and the feasibility study of the amount of data to be deal, the dynamic slice allocation mechanism is used to accomplish this. This will ensure a commitment to patient-centered service quality. The control plane components for controlling healthcare slicing, allocating dynamic resources, and interconnecting healthcare NS with traditional telecommunications networks for voice and data communication [56]. In the future, the model will be applied to two different types of slices. Another important direction is the confidence interval of the analysis results and how to calculate the confidence interval if the analysis is integrated. The utilization of predictive advantages depends largely on the accuracy of the analysis, which also depends largely on the algorithms used to mine and process the data.

B. *Based on the Industrial Internet of Things*

Industrial automation is one of the most notable applications of IIoT. Many devices in the manufacturing industry require high reliability and low latency communication to ensure real-time control and monitoring of production lines [57]. Through NS, factories can create network slices dedicated to automation control, ensuring timeliness and stability of data transmission, thereby improving production efficiency and reducing downtime. Fig. 4 shows the IIoT transmission Architecture.

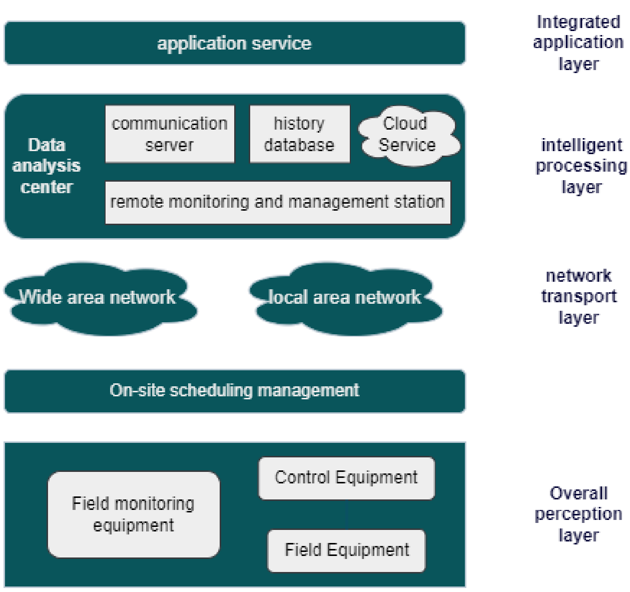

Fig. 4. IIoT architecture.

1) Resource allocation in digital siamese networks: Different services in the personalization industry place higher demands on the existing NS and resource allocation algorithms. At present, the efficiency of the algorithm is too slow and the cost is too high. In this context, the authors of [58] proposed a new network architecture in Digital Siamese Network (DTN). The architecture assists Industrial Internet of Things (IIoT) by integrating methods. The architecture is divided into three layers, three modules and two closed loops. In addition, proposes a new resource allocation system model and an solution to maximize the weighted net profit of service equilibrium. The dual-channel weighted (DCW) Critic network was introduced to realize the traffic balance and ensure the reasonable allocation of resources for personalized services. At the same time, an improved Priority Experience Replay (PER) structure was added to accelerate the convergence speed of the algorithm. This paper also proposes a PER-DCW Multi-Agent Deep Deterministic Policy Gradient (PER-DCW MADDPG) algorithm for allocating the resource in DTN-IIoT to ensure real-time operation while maintaining traffic balance.

The results show that it is necessary to ensure the service balance while dealing with the complex problem of personalized service resource allocation. The DCW network has a significant speed disadvantage, while the reliability of the network and automatic fault detection issues are also a great challenge [58]. It will continue to expand the research and use the scheme with Beyond 5G (B5G) and 6G networks. It optimizes the fault detection function of automatic network, the migration of virtual network functions and the link handover under fault conditions to make the network more reliable.

2) Non-orthogonal NS: The authors of [59] use non-orthogonal multiple access (NOMA) NS to improve the connection density of the network. In this study, the authors transformed the connectivity maximization problem into a mixed integer nonlinear programming (MINLP) problem. Subcarrier association and power allocation are jointly optimized to maximize the connectivity. The MINLP problem is first transformed into a mixed integer linear programming (MILP) problem. Then, it is further simplified into an integer linear programming (ILP) problem by formulating an effective pairing criterion. The Alternating Selection Best-Effort Pairing (AS-BEP) algorithm is used to improve the efficiency of solving the ILP problem and reduce the computational complexity. Non-orthogonal multiple access (NOMA) technology was used to share the same time-frequency resources for multiple users, and this technology improved the spectrum efficiency and network capacity.

Due to the need to support many connected devices with different service requirements, connection density and resource allocation become an important challenge. At the same time, high flexibility and high scalability are also an important requirement of industrial Internet of things for NS. In the future, simplify the complexity of MINLP algorithm to make it more suitable for real-world applications is necessary, and to continuously evaluate its feasibility and continuously optimize the algorithm in the application. Integration of NOMA and NS with other emerging technologies simultaneously, such as ML and artificial intelligence, continues to be explored to enhance decision-making processes and resource allocation strategies.

C. Vehicle-Based System

5G systems support many new things in verticals such as auto industry and power, which need more performance and cost requirements [60]. Through NS technology, vehicles can achieve real-time communication and data exchange with the cloud, to achieve intelligent navigation, remote monitoring and remote diagnosis. Fig. 5 shows the Vehicle Communication Architecture.

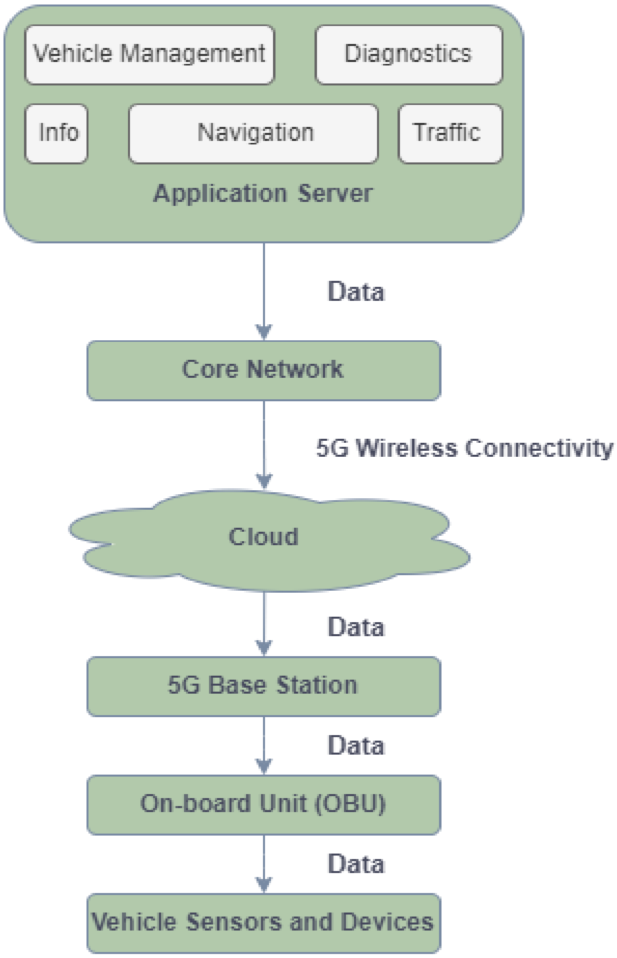

Fig. 5. Vehicle communication architecture.

1) Deep Reinforcement Learning based on Actor-Critic: A solution strategy which is appropriate for the standard 3GPP NS architecture is introduced in literature [61], which implements the Actor-Critic-based Deep Reinforcement learning (DRL) algorithm in the NS Subnet Management Function (NSSMF). The construction of this algorithm is based on the unrolling of in-vehicle applications. Because the limitation of resources, the standard slicing architecture is difficult to meet many heterogeneous service requirements without compromising the quality of service. Therefore, limited resources need to be structured in real time and efficiently to accommodate the traffic demands of different slices.

This computational approach allocates and manages resources between different generated slices in real time. In this paper, the algorithm was trained to enhance the QoS of service types in the network [61]. In the training evaluation of the computational method, the service level satisfaction of the slices is analyzed first. The results show that the satisfaction values for each slice never drop below 80% or 75%. However, the satisfaction value will decrease significantly if trained under a fixed allocation scheme. Therefore, the evaluation performance of the Actor-Critic DRL algorithm mentioned in this article is obviously better than that of the default fixed resource.

2) Vehicle-to-everything communication: A framework for V2X applications is proposed in [62]. The framework considers the coexistence of V2X communication with many other types of services to handle slice allocation. NS instances are defined within this framework. These slice instances need to interoperate and correspondence. The client instance must be configurated in each car and locked, counted, released and moved when connecting the session. The base station instance needs to accept the client request and forward it to the slice management instance; slice or slice management checks the availability of wireless resources and assigns corresponding resources to each one.

Research results show that network performance fluctuates in terms of resource consumption, switching, and blocking as the quantity of users in the region of interest changes. To provide optimal performance under a variety of network deployments and traffic conditions, resource allocation between slices must keep balanced [63].

TABLE III. NS TECHNOLOGY IN DIFFERENT APPLICATION SCENARIOS

5G Scenarios	Research Based on NS		
	Technology	***Problem***	***Limitation***
IoMT	NS ML AI	Meets different QoS require Predicts health trend of patients Monitors health status of patients remotely Protects privacy and security of patients	execution time of VNE is reduced, characteristics of underlying and virtual topology, Canges of medical service load
IIoT	NS DTN DCW PER MADDPG	Improve the reliability and low latency of real-time control and monitoring of production lines Eure service balance optisrce allocation	Resource management with AI/ML Improved security mechanisms
V2X	NS DRL MEC	Implement intelligent navigation, remote monitoring and remote diagnosis, allocates and manages resources of different slices in real time improves QoS of different service types.	Simulate different mobility scenarios enhance slice independence

V. NS Security Issues

An important part of 5G networks is to take apart network to provide different resource parts. If proper isolation is not provided for slices, the quality may be adversely impacted by flow and other factors [62]. During isolation operations, the safety of slicing becomes a central issue for most studies and studies. Softwareization using SDN and NFV in 5G networks is filling the gap in programmable control and management of network resources [64]. Table IV shows the advantages and disadvantages of each technology.

A. Software-Defined Networking

SDN technology reconstructs the traditional architecture, transforming from distributed to centralized control network architecture. SDN architecture is divided into three layers: application layer, control layer and facility layer [65]. SDN-based security threats are centered around a three-tier architecture. The first part is the data forwarding layer Switches are an important part of providing correct forwarding services for data packets at the data forward. The attacker can attach a link to one of the switch ports, threatening the end user's entry to the network [66]. The second part is the control layer translates the requirements of the SDN application layer to the SDN forwarding layer. When the controller is attacked, the whole network is affected. This is because when the switch does not receive the forwarding rule; It does not know how to forward the packet [67]. The third part is the attackers can modify the network configuration and steal network information through the application layer. This situation affects the control layer's operation and reduces the network's reliability and availability. Fig. 6 shows the SDN Security Architecture.

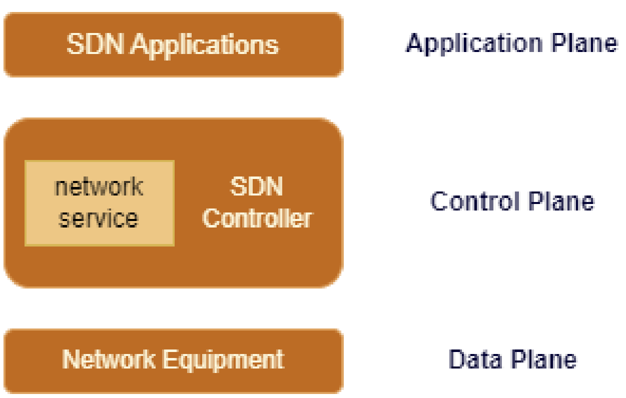

Fig. 6. SDN security architecture.

B. Network Function Virtualization

Network Function Virtualization (NFV) is a technique that virtualizes network functions using dynamic allocation to share the same facility with different functions [68]. In this technology, security problems can be caused in the following ways. When a VM allocates limited memory but unlimited resources, DoS attacks occur. Due to the complexity of integration, the integrity of the infrastructure is threatened; Resource abuse occurs when the hypervisor and scheduler fail, or when there is a lack of hypervisor isolation [69].

C. Multi-Tenant NFV/SDN

Literature [70] proposed a 5G access network security architecture supporting multi-tenant NFV/SDN. The architecture consists of security policy manager, monitoring and analysis, and Virtual Security Function (VSF). This security architecture is compatible with existing network virtualization efforts and enables fast and secure automated configuration through NFV/SDN technology. The framework mainly aims at automatic security management and VSF-based virtualization security services. The implementation of automated management relies on the service policy manager and the service monitoring and analysis policy. Virtualized security services are executed using VNS and automatically provided through the orchestrator and Virtualization Infrastructure Manager (VIM) in the NFV environment.

TABLE IV. Security Events based on different Network Slicing Technology

Technology	Research Based on NS	
	Advantage	***Limitation***
SDN	Provides centralized network control Optimized network performance Deploy applications flexibly	Controller single point of failure Complex security management Configuration challenges
NFV	Improve resource utilization Enhance infrastructure stability and resilience	High management complexity Security vulnerabilities
Hybrid NFV/SDN	Support resource sharing Improve operation and maintenance efficiency Automate security configuration	Security management and monitoring mechanism is complex Cost and resource investment are high

VI. Discussion

Through the investigation of existing research found that NS improves network efficiency and service quality by dividing logical networks, to realize the optimization of latency, resource management and security privacy. Current research trends focus on the integration of AI and ML to automate network management, resource prediction, and allocation. NS technology will enhance its application in large-scale networks by means of intelligent and automated management.

The isolation effect between slices poses a threat when resources are allocated. The defect of slice isolation will cause mutual interference between slices, which will affect the application of NS in the high movement scene of 5G. In addition, most current studies mainly rely on simulation and experimental environments, and lack the operability of resource allocation and isolation methods in complex network environments. Especially in applications such as IoMT, IIoT and in-vehicle networking, the reliability and latency of NS do not fully meet the demand. Secondly, because the challenges of 5G slicing in dynamic service chain management, edge computing and joint resource management have not been fully solved, it is difficult to achieve efficient use of resources and continuous guarantee of service quality in practical applications.

VII. Challenges and Future Directions

NS technology faces major challenges such as efficiently and dynamically allocating resources according to demand, ensuring isolation effects, and avoiding interference. In this environment, accurate prediction of user mobility and demand to maintain quality of service and optimize resources is necessary to address these challenges [71]. Data leakage and unauthorized access in the isolation process will bring security risks to the slice information. Advanced encryption technologies such as blockchain can solve security problems such as location tracking and impersonation attacks [72]. Interoperability between different slices and integration with existing network infrastructure causes compatibility issues between vendors and carriers [73]. Developing common standards and protocols to ensure that each slice scales independently and maintains quality of service during peak load can effectively solve this problem. Orchestration and management frameworks can also be used to efficiently handle the dynamic scaling capabilities of slicing, which further optimizes low latency and reliability between services [74].

A. Challenges and Requirements

NS technology needs to allocate resources efficiently and dynamically according to demand, and ensure the isolation effect between slices [75]. This is a high requirement for predicting demand and allocating application resources. Accurately predicting user mobility and demand can also optimize the quality of service maintenance and the allocation of resources [76]. Data breaches and unauthorized access can create security issues in the isolation process.

B. Future Work

In the future, it is necessary to strengthen the application of AI/ML in resource management and develop more efficient dynamic service chain management algorithms to improve the accuracy of resource prediction [77]. Advanced security solutions are implemented using quantum secure encryption schemes and blockchain technology to enhance data protection against unauthorized access and automate SLA management [78]. Continue to explore AI/ ML-based security measures to detect and mitigate sophisticated attacks. At the same time, common NS standards and protocols are established to promote the interoperability between slicing and seamless integration with the existing network infrastructure [79]. Combine edge computing with NS to establish low-latency, efficient services, and optimize resource utilization and service delivery through AI-driven edge computing solutions [80].

VIII. Conclusion

This article explores NS technology in depth and demonstrates its strong potential for use in different 5G application scenarios. The analysis of NS architecture, resource allocation mechanism and application examples reveals the significant advantages of NS technology in the optimization of resource utilization, network latency, quality of service and security in IoMT and other fields. This research also found that the current NS technology has great challenges in cross-slice interoperability, security isolation and dynamic resource allocation. In the future, the optimization of NS architecture and the strengthening of security measures should be strengthened. Through the optimization of network slice management to improve resource utilization and network transmission performance. Use AI/ML to achieve intelligent and automated NS management, while introducing more advanced security encryption measures like blockchain and quantum encryption technology. As challenges continue to be discovered and solved, NS technology will continue to drive the digitization and intelligence of 5G applications.

Acknowledgment

This work was supported in part by the Universiti Kebangsaan Malaysia Fundamental Research Grant Scheme (FRGS) from the Ministry of Higher Education with the code: FRGS/1/2023/ICT07/UKM/02/1 and FRGS/1/2022/ICT11/UKM/02/1.

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