Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 9169568, 10 pages
https://doi.org/10.1155/2022/9169568

Research Article

Analysis of Network Slicing for Management of 5G Networks Using Machine Learning Techniques

Randeep Singh,[1] Abolfazl Mehbodniya ,[2] Julian L. Webber ,[2] Pankaj Dadheech ,[3] G. Pavithra,[4] Mohammed S. Alzaidi ,[5] and Reynah Akwafo [6]

[1]*Department of Computer Science & Engineering, IEC University, Baddi, Solan, Himachal Pradesh, India*
[2]*Department of Electronics and Communication Engineering, Kuwait College of Science and Technology (KCST), Doha, Kuwait*
[3]*Department of Computer Science & Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan (SKIT), Jagatpura, 302017, Jaipur, Rajasthan, India*
[4]*Department of Computer Science and Engineering, M.Kumarasamy College of Engineering, Thalavapalayam, Karur, Tamil Nadu, India*
[5]*Department of Electrical Engineering, College of Engineering, Taif University, Taif 21944, Saudi Arabia*
[6]*Bolgatanga Technical University, Department: Electrical and Electronics Engineering, Ghana*

Correspondence should be addressed to Reynah Akwafo; reynah.akwafo@bolgatu.edu.gh

Received 17 March 2022; Accepted 30 April 2022; Published 2 June 2022

Academic Editor: Kalidoss Rajakani

Consumer expectations and demands for quality of service (QoS) from network service providers have risen as a result of the proliferation of devices, applications, and services. An exceptional study is being conducted by network design and optimization experts. But despite this, the constantly changing network environment continues to provide new issues that today's networks must be dealt with effectively. Increased capacity and coverage are achieved by joining existing networks. Mobility management, according to the researchers, is now being investigated in order to make the previous paradigm more flexible, user-centered, and service-centric. Additionally, 5G networks provide higher availability, extremely high capacity, increased stability, and improved connection, in addition to quicker speeds and less latency. In addition to being able to fulfil stringent application requirements, the network infrastructure must be more dynamic and adaptive than ever before. Network slicing may be able to meet the present stringent application requirements for network design, if done correctly. The current study makes use of sophisticated fuzzy logic to create algorithms for mobility and traffic management that are as flexible as possible while yet maintaining high performance. Ultimately, the purpose of this research is to improve the quality of service provided by current mobility management systems while also optimizing the use of available network resources. Building SDN (Software-Defined Networking) and NFV (Network Function Virtualization) technologies is essential. Network slicing is an architectural framework for 5G networks that is intended to accommodate a variety of different networks. In order to fully meet the needs of various use cases on the network, network slicing is becoming more important due to the increasing demand for data rates, bandwidth capacity, and low latency.

1. Introduction

Network slicing is a smart application idea for the Internet of Things that is becoming more popular. There are a variety of factors that affect network slicing [1], including resource levels and physical infrastructures, critical enablers, and security. Edge computing, cloud computing, the Internet of Things, virtualization, Software-Defined Networking, and smart services are just a few examples of the technology that has emerged in recent decades. The many logical and physical network infrastructure needs that exist make it feasible to slice networks for smart services. When intelligent transportation technologies are deployed, automobile accidents involving autonomous driving may be recorded in VANET

[2]. As soon as a collision occurs, it is vital that you notify it so that the amount of damage is minimized. The latency requirements for smart agricultural services are lower than those for smart transportation services, which is a positive development. If agricultural intelligent transportation system (AIS) slices are delayed, then the slices of intelligent transportation systems (ITS) must be delayed much more (L. U. Khan, 2019). Several smart services [3] are presently able to handle network slicing [2, 3].

5G network slicing is made possible by the use of Software-Defined Networking, network service virtualization, and cloud computing technologies. It is possible to provide flexible solutions to a broad variety of business situations and network traffic groups that are operating on the same networks using a network slicing architecture [4]. Because of network slicing, it is possible to build many 5G networks with the same topology but varying degrees of efficiency and functionality. In addition to health care, intelligent transportation systems, voice communication, and other use cases, network slicing technology provides a broad variety of services for a wide range of applications. The network slicing diagram in Figure 1 illustrates the process. When it comes to virtual networks, network slicing was a strategy for integrating many virtual networks onto one physical networking infrastructure [5].

As a guide for communication among members of a development team, the software architecture acts as a model. The software industry is expanding at a rapid speed, which means that testing and maintenance may begin almost immediately after a program is built and launched. I have learned via my interactions with several team leaders, project managers, and solution architects over the course of several years [6] that change management in software is a challenging task. Consequently, it is critical to highlight the significance of quality assurance throughout the software development process in order to guarantee that reliability and performance are not compromised in any way.

There are a variety of fields of knowledge that may benefit from the same kind of reasoning, including testing, maintenance, analysis, quality assurance, and program debugging. Using slicing, the process is made more controllable and efficient as a result of its overall effectiveness. Customer service is crucial to a company's long-term existence and profitability after it has completed product development and distribution. Slicing appeals to me since it focuses on connected services rather than development, which is something I value. I consider it a huge pleasure to have done anything in such a thriving area of thesis research [7] as thesis research.

When it comes to software, slicing may be used at a range of levels, including inside individual programs as well as within the general software architecture of large distributed systems. The influencing situation that decides whether or not to flow the backward or forward slicing [8] has an effect on the calculation of slicing as well as the computation of slicing.

The application process is described in further detail below. Depending on the behaviour of the program in question, cutting might be either static or dynamic, and vice versa.

Several publications, including Understanding Software Architecture and Dependency Analysis, Software Architecture Slicing, and Dynamic Software Architecture Slicing, provide in-depth coverage of this subject.

Debugging time may be lowered by using slicing to limit the amount of code that has to be inspected, and it may also assist in understanding how variables affect programed computations [9]. Analysis of a collection of sample instances and test suites, which were all reviewed as part of this research, was also carried out using slice-and-dice methods. It was also possible to produce software measurements by using the slicing technique. Later on, we will go into further depth about software portability and how it works. It has the same functionality as architectural slicing and the same advantages. In the next part [10], we will go through the vast majority of the slicing applications.

(1) Differencing is a method for discovering semantic differences between two or more sentences

(2) Software maintenance is the act of making changes to software while avoiding the occurrence of unexpected consequences

(3) In regression testing, by doing regression tests after changes, you may reduce your expenditures (run just the necessary tests)

(4) Parallelization is the process of converting sequential programs into parallel ones in order to increase performance

(5) Debugging is the process of examining and analyzing software

(6) Tests for safety-critical component interaction (SQA) look at how safety-critical components interact with one another

(7) Design choices are abstracted from the source code, and the outcomes are examined in order to acquire a knowledge of the design

(8) Software, programs, and systems are all subjected to testing. By two or three times, the quantity of state space (SPIN/SMV) may be reduced in size

(9) System and program integration is the process of bringing systems and programs together

(10) Check the collision between nodes

(11) Probability of node junction is determined

(12) Fault tolerance is determined using the specialization of nodes in the network

(13) Mobility of node is determined in the network

This technique employs hybrid macro-, micro-, femto-, pico-, and relay nodes in addition to the traditional ones. It is envisaged that an integrated network ranging from the WAN-LAN to the PAN levels would provide unprecedented amounts of storage capacity.

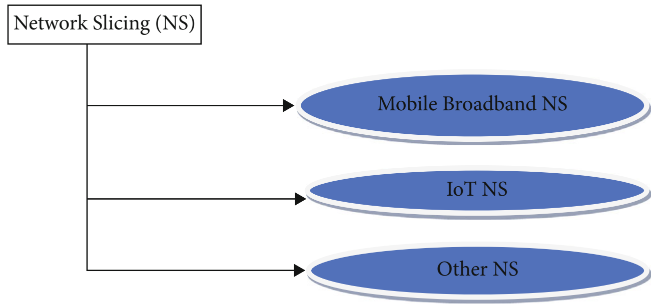

Figure 1: Network slicing in 5G network functionality.

When it comes to handling a large number of connections while preserving user happiness, the transition from homogeneous to heterogeneous networks was considered crucial [10].

In recent years, homogeneous networks have been plagued by issues such as limited data capacity and deteriorating spectral efficiency [11].

Heterogeneous networks will be used to improve network coverage, service quality, and throughput by increasing the number of nodes on the network [12]. Heterogeneous networks are capable of supporting a wide range of applications, all of which are network-friendly and adaptive.

The development of networks starts with the first generation, which is comprised of wireless telephones, often known as cell phones, and continues through the successive generations of technology. The 1G standard made use of mobile radio-telephone technology that was developed in the 1980s. The 1G standard included enhancements to the IMTS, AMTS, MTS, and push to talk systems (PTT). Radio waves were used to connect the first computers to the Internet. With the use of a technique known as frequency division multiplexing, the voice call was modulated to 150 MHz and sent between two radio towers at the same time (FDMA). It established cellular networks by causing disruptions in current network technologies, providing the framework for today's wireless mobile communication infrastructure.

This system featured a restricted amount of capacity, poor voice quality, inconsistent handoff, and no security protection [13]. Intruders and hackers took advantage of the weaknesses in the networks. Because of the smoothness of the analog curve, it was able to be transmitted across vast distances even when the speech quality deteriorated with time. In contrast to 2G calls, the quality of 3G calls dropped but did not fail [14].

5G incorporates all advanced capabilities, establishing the framework for the integration of all previous generations and the fulfillment of the massive data demand of the future [15].

These technologies form an integrated paradigm that is reliant on Internet Protocol (IP) communication protocols for their operation. Users may connect with one another over a network in a number of scenarios using this paradigm. 5G's technology will surely solve concerns like as frequency slicing and data rate [16] that have been raised. Massive channels will be accommodated without the need for streaming in 5G thanks to software-defined radios (22, 23).

Quality of service (QoS) has transferred from the level of the equipment to the level of the network throughout time, and this trend will continue in the future generation of networks. Prioritizing traffic, particularly, video and VoIP traffic will aid in the management of traffic congestion. To address the algorithm-driven mob performance issue, software solutions and network intelligence will be crucial in the proposed effort [17].

2. Background Analysis

As complexity and demand increase, 5G networks should be able to handle vast volumes of data and services in a manner comparable to that of existing networks [18]. The new technology will make it feasible to have an unlimited number of international connections as well as continuous access to information. Due to the fact that technology is progressing at a faster pace than ever before, digitalization and automation are becoming more prevalent in our daily lives. It is predicted that the next generation of wireless networks will provide new and unique services [19], despite the current abundance of services. A major emphasis was put on the concept of "Always Best Connected" (ABC) by previous generations, which was widely acknowledged in practice at the time of their formation. Fifth-generation (5G) networks are aim at delivering the most reliable connection possible by using the Wireless World Wide Web (WI-Wi) protocol [6]. It will be necessary to develop high-quality-of-service requirements in order to facilitate the spread of future broadband services. As transmission costs are predicted to fall in the next years, current techniques and approaches will become uncompetitive. Technology disruption will very certainly be exploited if the number of networked devices continues to expand, as projected by the forecast. Increasing the quantity of spectrum or infrastructure available to teleoperators to accommodate excess consumer demand will no longer be sufficient to address the issue of teleoperators [19, 20]. In order to address the demands of the present generation while simultaneously offering services to the future generation, network technology must continue to grow. Build on old technology to provide innovative concepts that will assist to protect and prosper the next wireless communication sector (5G) in the future (9). The findings of three wireless network installation case studies [21] were used to identify the optimal location of functional units that contribute to mobility in relation to one another. In light of the fact that end-users are mobile and the wireless environment is dynamic, it is necessary to plan ahead of time when installing the functional block that will be most closely associated with the end-user. In the event that such a system is implemented, it will present users with extra alternatives when it comes to picking their network [22].

A brief review of different mobile networks, as well as future network communication challenges, was offered by the authors of [5], who stressed the significance of 5G networks throughout their presentation. [5] Another topic covered in this article is the growth of various additional mobile networks. The most important characteristics were compared [23]. When it comes to real-world services given to consumers, cloud computing and architecture for mixing a variety of resource allocation methods (RATs) have been created as a means of centralizing control. They considered it really intriguing that the researchers in [6] looked into the difficulties and solutions linked to future technologies and 4G wireless digital infrastructure, and they concluded that they were highly interesting opportunistic and cognitive communications, cooperative networks, multicast services, small cell deployments, scheduling, and resource allocation, and a summary of research outcomes in these areas is provided. They are intended to satisfy the network's requirements in the future [24]. Specifically, the authors of this research identified five technologies that have the potential to cause architectural and component-level design disruption [25] and explain to them as follows: the article addressed several design methods, ranging from those driven by the base station to those that are device-centric. It is the purpose of this study to offer an overview of millimeter wave technology and how it may be used in a wide variety of applications. [26] provides a thorough discussion of the structural alterations necessary for massive MIMO and multiplexing for smarter goods, as well as examples of these improvements. The underlying ideas of each technology, as well as their implications for 5G and future research challenges, were discussed in detail. In contrast to the evolutionary technique, a revolutionary strategy for 5G networks (9) has been promoted in opposition to the evolutionary method. A further study into wireless network design and services in the future is encouraged, according to our recommendations. For the sake of demonstration, the writers compare and contrast multiple decades of network technology, highlighting their relevance and benefits over preceding generations in order to make their thesis. In-depth treatment is offered for study subjects such as real-world wireless settings, new devices, and protocols, among other things. A thorough discussion of the problems and obstacles that prospective researchers may encounter is provided [27].

3. Working Process of Network Slicing

Figure 2 depicts the three levels of network slicing: resource, network slice instance, and service instance.

Network slicing layer isolation might be physical, language-based, or virtual-machine-based. While physical isolation is possible at the network infrastructure layer, language-based isolation is preferred at the network slice and service instance layers

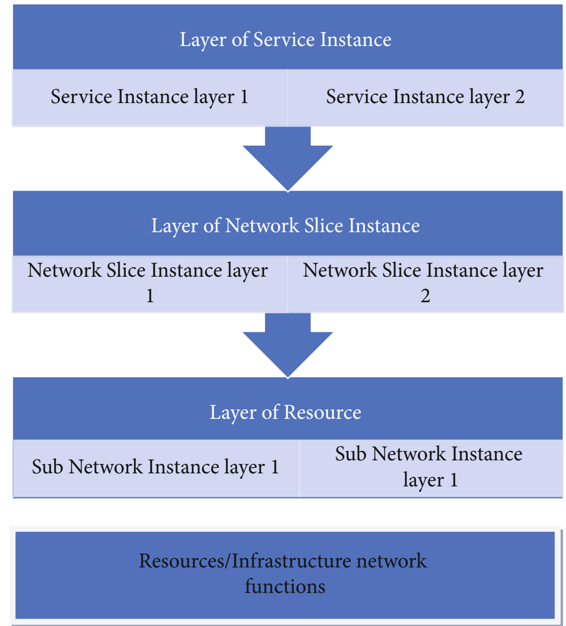

FIGURE 2: Network slicing layer.

[28]. Finally, virtual machine-based isolation may occur at the resource and network slice instance layers [29].

Network slicing is used to produce separate slices of a network based on various qualities such as low latency, high bandwidth (network capacity), and mobile broadband. Network slicing may be utilized to meet the needs of diverse use cases. The advantages of these slices may be utilized for many purposes [30].

5G network slicing has various concerns. For example, in 5G networks, radio-access networks must integrate network slicing and advanced network architectures. So, network design must be improved to meet network slicing model needs. Adapting the 5G network slicing concept to user demands requires modifying the network architecture [31].

NS is used to generate network slices for distinct end users. End-user requirements differ from one end-user to another, and the network services delivered to them should also vary. Physical infrastructure networks are more complicated to service user demands, whereas user-based networks are likewise difficult to build and need a lot of expertise, time, and money. Also, user-based network services make network infrastructure affordable [32].

Virtualization is vital in 5G networks to accommodate a broad range of use cases. So it is critical to incorporate network slicing in 5G networks.

4. Enabling Technology

Using software and virtualization on the underlying network infrastructure, the 5G-NSUE paradigm proposes to construct distinct NS (network slices) according to different use cases.

The different points for 5G network slice construction are described below.

(i) Implement network slicing based on network area selection. The 5G network slice scope

(ii) Analyze how network slices should be distributed according to use scenarios

(iii) Find out which network slicing technology is incorporated

The existing slicing methods are effective when compared. The similarities include slicing criteria, dynamism in software design, style, and descriptive language. It illustrates the basic requirement of slicing methodologies for software architectures [33]. Because these architectural slicing approaches have limits in supporting architecture and do not allow dynamic changes during runtime, software architecture modification is permitted here. They just care about slicing, despite the fact that the result is not assured. We used architectural slicing to enable software dependability and other elements of software reliability.

The 5G network consists of base stations, switching centers, mobility management units, and end-users. The following five components are more crucial for the 5G network constructing slices either individually or together. The second component is to execute overall slicing or network slicing [34].

The third aspect should supply NS (network slices) to various network use cases. 5G network slicing generates several slices with varying features to satisfy different use cases. The third component considers features such as high mobility, security, low latency, high bandwidths, and resources.

The fourth aspect employs virtualization and software approaches.

Other 5G network slicing enabling approaches are given below.

(1) Computer fog

(2) e-commerce

(3) Cloud-based tools

(4) Virtual technique

(5) Docker

4.1. Framework of the Proposed 5G-NSUE Model. Figure 3 represents the overall processing of the 5G model.

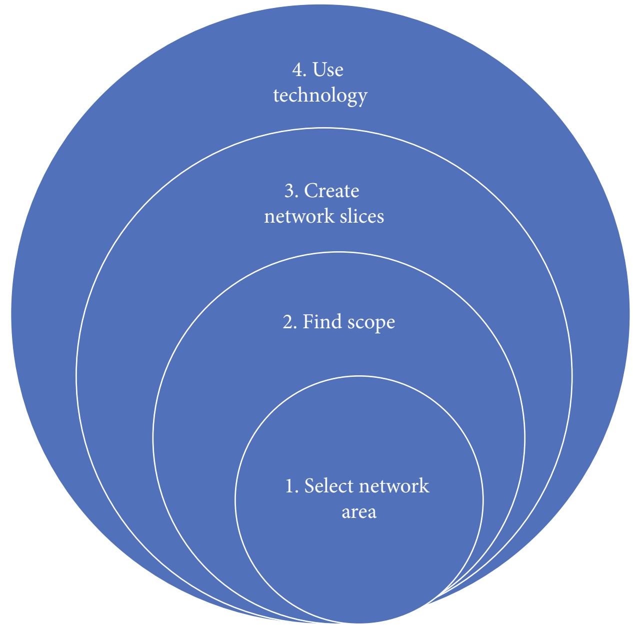

Figure 3: Overall processing.

4.2. Components of the Proposed Work. Table 1 shows the components of the proposed work 5G-NSUE model. The table consists of two-column components and attributes of each use case.

Figure 4 gives that the SDN (Software-Defined Networking) and NFV (Network-Function Virtualization) technologies were employed in the integrated suggested methodologies. It is possible to accomplish the aforementioned goal via the use of SDN (Software-Defined Networking) and NFV (Network-Function Virtualization), which are applied to physical infrastructures such as Radio Access Networks (RANs), user equipment, and the core network. It is via the Radio Access Network (RAN) that the equipment of the user is linked to the network, which is in turn connected to the core network. Finally, the core network establishes a connection with the general public Internet [35].

The network slicing component will cut the slices of the network by using the virtualized and software components, respectively. The NS (network slices) are formed in response to the demands of the numerous users who are connected to the network. The user needs are obtained via the use case's request for a slice, which is made by the use case itself. Following the construction of slices, the separation of slices must be completed based on the slice type. The subcomponent is responsible for carrying out the aforementioned procedure (isolation slice).

5. Network Slicing Issues

(i) Chaining of intelligent service functions is discussed in detail in Section 1 of this document (also known as service function chaining). The fundamental purpose of implementing intelligent service function chaining is to be able to operate on a variety of network services on a single node or across numerous nodes by using virtual machines running on different nodes, as described above. Each node has a limited amount of bandwidth and resources available to it for the purpose of connecting with the other nodes. It is necessary for the SFC to choose the most energy-efficient and computationally late nodes feasible in order to improve both energy efficiency and computational latency (service function chaining). Routing is utilized in combination with a reinforcement learning-based SFC (service function chaining) scheme (S. I. Kim 2017) as well as a deep learning-based SFC (service function chaining) scheme (J. Pei 2018) to enable SFC (service function chaining)

Table 1: Proposed work 5G-NSUE model components.

S. no.	Input networks	Attributes
1	(1) User equipment	Fifth-generation cellular network The mobile base station, antennas Device
2	(1) Network slice (i) Creation of slice (ii) Isolation slice (iii) Management slice	Slice type Scheduling and management
3.	(2) Use case (i) High mobility (ii) More secure (iii) Decrease latency (iv) High bandwidth capacity (v) IoT	Vehicular Reliability Wait time, delay Speed Humans, machines

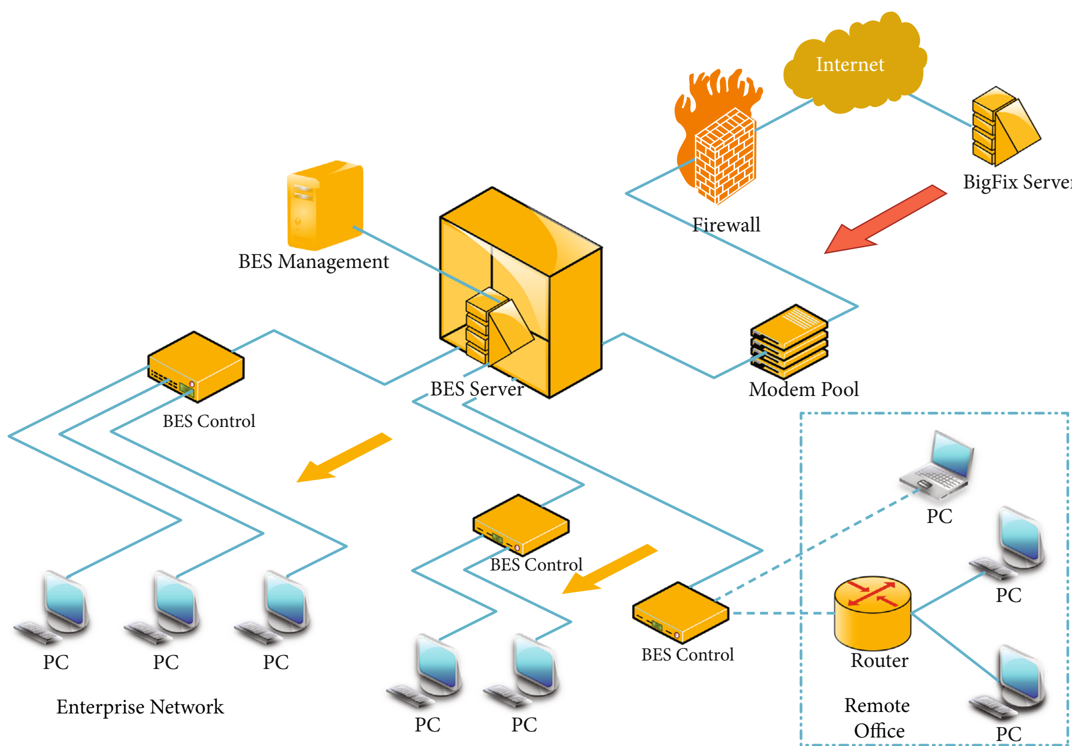

Figure 4: Methodology of proposed work.

(ii) Slicing while taking movement into mind, when it comes to resource allocation in smart applications, network slicing is one of the most challenging problems to solve. There are also a range of challenges to reckon with as a result of the very high density of 5G networks as well as the handovers for different access networks. Nevertheless, in comparison with the installation of augmented reality-based apps, these concerns are handled by the use of a system of mobility-aware slicing. The issues are not totally resolved; however, since periodic handovers will occur on highways when autonomous autos are in operation, on-demand slicing techniques that are specific to each customer are required to achieve success as a consequence. The researcher proposed a Lagrangian dual-decomposition-based solution as well as game-theoretic methodologies, which were especially designed for resource allocation in network slicing applications (H. Zhang 2017)

(iii) In network slicing forensics (also known as network forensics) (also known as network forensics), different security levels inside a network will increase the degree of the network's vulnerability to attacks as a result of network slicing. Current forensic procedures for the Internet of Things (IoT) and cloud computing (CC) must be updated and combined to provide new forensic techniques, notably for network slicing, in order to be effective. In addition to being useful in worst-case attack situations, these new forensic methodologies are also useful in the analysis of attack sources and the identification of attacks in uncertain contexts. As a consequence, various novel forensic methodologies to identifying network slicing attacks will be developed and implemented

Dynamic spectrum slicing is becoming more important for slicing networks as a result of the increasing demands of consumers. There will be underutilization or overutilization of the spectrum in the fixed spectrum slicing scenario, respectively. As a consequence, in order to avoid these challenges, we must use dynamic spectrum slicing. To react to changes in network traffic, it was proposed that a policy-based dynamic spectrum slicing approach be employed. It was also advised that Markov modeling be used to assign user traffic, which would assist to improve the overall performance of the slicing algorithm in general.

When it comes to security mechanisms, adaptive security mechanisms are a kind of security mechanism that changes depending on the circumstances.

In particular, network slicing raises significant and difficult security challenges, especially for systems that run at many infrastructures layer levels at the same time. A few of the security concerns that must be addressed are as follows: all of the following are possible: security-based multidomain, security-based interslice, and security-based intraslice. If you use a traditional machine learning-enabled network, you run the danger of having your information compromised.

In circumstances when we are concerned with discovering all dependencies on a certain application or architecture, we use a static slice to accomplish our goal. It is often used for the purposes of study and inquiry. This strategy is used to locate the relevant statements using a technique known as static slicing. The relevant statements are identified based on the slicing criteria that have been set, and the relevant statements are found using this technique. It is possible to do an analytical study of the program and software architecture in order to aid in debugging, dependency analysis, and other operations.

For example, if we are interested in knowing only runtime relevant statements depending on the stated values of the slicing criteria, we may be able to achieve our goal of knowing only those statements by using dynamic slicing to achieve our objective of knowing only those statements. It is common to use static slicing to construct a significant portion of an original program, particularly when dealing with complex programs that contain array and pointer variables, whereas dynamic slicing incurs an inexcusably high cost in terms of execution time and should be avoided whenever possible. Specifically, a dynamic slice is a collection of program statements or components, as well as connections, that have the potential of substantially impacting the value of an arbitrary variable at a given architectural or program level in a certain architecture or program. In recent years, it has been revealed that dynamic slicing may be used for user-level debugging, as well as for applications aimed at improving the quality, reliability, safety, and efficiency of software, all of which have been identified as potential candidates for dynamic slicing.

The objective of needing relevant statements first and foremost in the first place is connected to the goal of cutting in one direction in the first place. It is determined which way the phrase is sliced by the existence or lack of words such as "affecting" or "affected by" inside it. It depicts the calculation flow of the slicing method in graphical form. The calculation of backward and forward slices, on the other hand, is carried out in a manner that is identical. The only difference between the two is the manner in which the flow is transferred through the system.

When looking for important statements in the future direction that are influenced by an exciting statement in a program or design, forward slicing, which is a method of computation flow, may be applied. Slices in the forward direction are made up of all control statements and predicates that may be influenced by the variable in question. Forward slicing is a debugging and understanding technique that is used to display filtered code that is reliant on a single variable, statement, component, or connection in order to debug and understand a program or architecture. Moreover, it is used in order to demonstrate unfiltered code that does not rely upon any single variable or statement nor on any unique component or connection.

6. Network Slicing in 5G Network Issues

The most pressing issues that in-network slicing in 5G networks must address are those of security and privacy for us. The existing method does not address a number of issues that have remained unsolved for some time. Immediately behind that, mobility is one of the most serious issues facing network service providers. It has been shown that mixed-integer linear programming and other approaches (heuristics) offered by a large number of writers are successful in resolving the mobility problem. The reality is that there are still certain limitations, and an in-depth examination of complex applications in the real world is required in order to properly fulfill the demands of users and their expectations.

Though still in its early phases, slice management faces a number of issues, including the isolation of interslice resource allocation and the isolation of intraslice resource allocation, which have yet to be overcome.

(i) Several controllers should be offered in the control plane, and an SDN controller should be utilized to manage all services, as mentioned in the preceding section, in order to improve the availability and scalability of 5G services. Figure 5 gives the accuracy rate

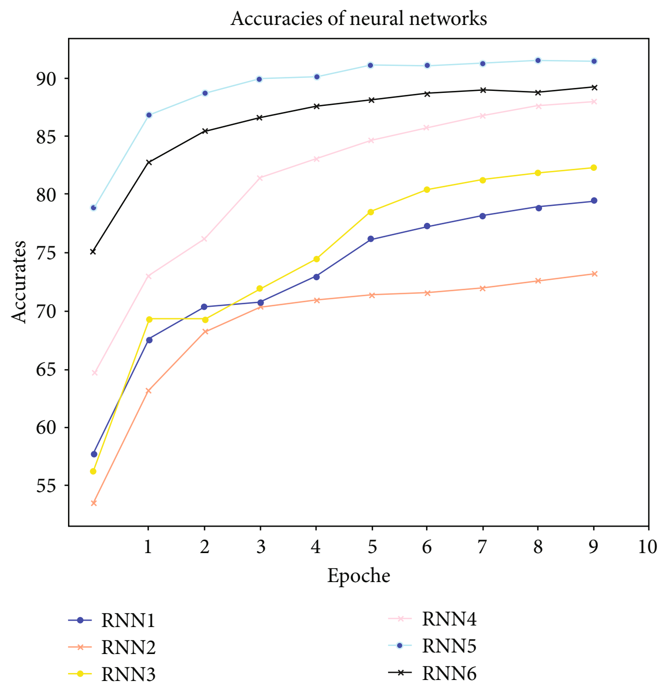

Figure 5: Accuracy of the sensor networks.

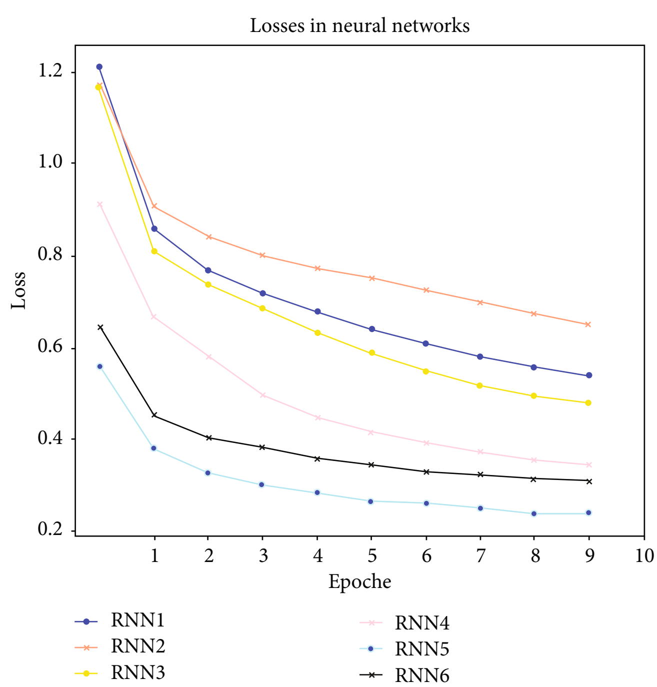

Figure 6: Loss of the proposed work with existing method comparison.

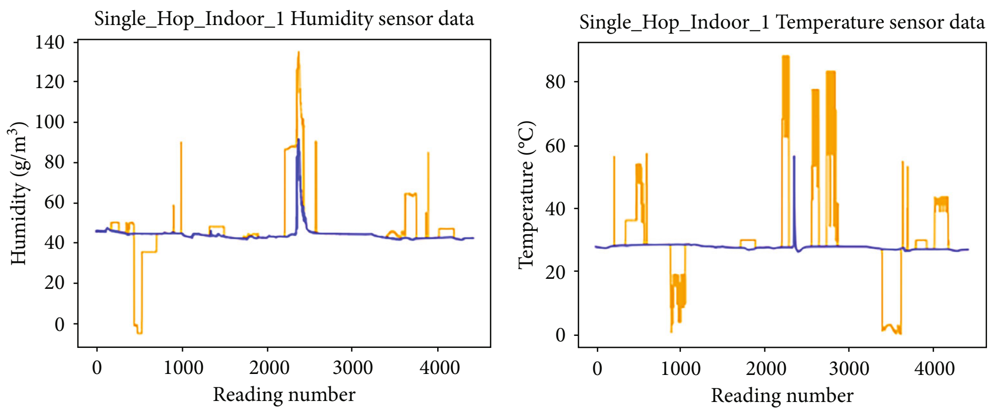

FIGURE 7: Sensor data.

(ii) In order to enhance the services, dynamic network slicing is necessary

(iii) It is necessary to pay more attention to the allocation of resources throughout the various slices

Figure 6 gives the comparison of proposed system with existing system. Figure 7 gives the sensor data of the proposed work.

7. Conclusion

The latest advances in the telecoms industry indicate that network slicing will be a major component of 5G networks in the near future. Network slicing techniques cannot function successfully unless the underlying network architecture is virtualized, and the appropriate software is installed. In order to make the architecture more flexible and dynamic, SDN (Software-Defined Network) ideas were included in 5G network technology. This allows for a broader range of applications to be built in today's modern environment. Network slicing is also a new technology that is enabling the strategy to change old cities into new smart ecosystem cities while also considerably improving the overall quality of life for the general people.

Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

The authors would like to acknowledge the Deanship of Scientific Research, Taif University, for funding this work.

References

[1] S. A. Kazmi, L. U. Khan, N. H. Tran, and C. S. Hong, *Network Slicing for 5G and Beyond Networks*, Springer, Berlin, 2019.

[2] M. Kaur, D. Singh, V. Kumar, B. B. Gupta, and A. A. Abd El-Latif, "Secure and energy efficient-based E-health care framework for green Internet of things," *IEEE Transactions on Green Communications and Networking*, vol. 5, no. 3, pp. 1223–1231, 2021.

[3] M. H. Abidi, H. Alkhalefah, K. Moinuddin et al., "Optimal 5G network slicing using machine learning and deep learning concepts," *Computer Standards & Interfaces*, vol. 76, p. 103518, 2021.

[4] N. K. Rathore, N. K. Jain, P. K. Shukla, U. S. Rawat, and R. Dubey, "Image forgery detection using singular value decomposition with some attacks," *National Academy Science Letters*, vol. 44, no. 4, pp. 331–338, 2021.

[5] U. P. Rao, P. K. Shukla, C. Trivedi, S. Gupta, and Z. S. Shibeshi, *Blockchain for Information Security and Privacy*, Auerbach Publications, 1st ed. edition, 2021.

[6] V. P. Kafle, Y. Fukushima, P. Martinez-Julia, and T. Miyazawa, *Consideration on Automation of 5G Network Slicing with Machine Learning*, 2018 ITU Kaleidoscope: Machine Learning for a 5G Future (ITU K), 2018.

[7] I. Vilà, J. Pérez-Romero, O. Sallent, and A. Umbert, "Characterization of radio access network slicing scenarios with 5G QoS provisioning," *IEEE Access*, vol. 8, pp. 51414–51430, 2020.

[8] M. Kaur and D. Singh, "Multiobjective evolutionary optimization techniques based hyperchaotic map and their applications in image encryption," *Multidimensional Systems and Signal Processing*, vol. 32, no. 1, pp. 281–301, 2021.

[9] G. Khambra and P. Shukla, "Novel machine learning applications on fly ash based concrete: an overview," *Materials Today: Proceedings*, 2021.

[10] S. K. Singh, M. M. Salim, J. Cha, Y. Pan, and J. H. Park, "Machine learning-based network sub-slicing framework in a sustainable 5G environment," *Sustainability*, vol. 12, no. 15, p. 6250, 2020.

[11] P. Pateriya, R. Singhai, and P. Shukla, "Design and implementation of optimum LSD coded signal processing algorithm in the multiple-antenna system for the 5G wireless technology," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 7628814, 12 pages, 2022.

[12] S. I. Kim and H. S. Kim, "A research on dynamic service function chaining based on reinforcement learning using resource usage," in *Ninth International Conference on Ubiquitous and Future Networks*, pp. 582–586, Milan, Italy, July 2017.

[13] J. Pei, P. Hong, and D. Li, "Virtual network function selection and chaining based on deep learning in sdn and nfv-enabled

networks," in *IEEE International Conference on Communications Workshops*, pp. 1–6, Kansas City, USA, 2018.

[14] N. Jain, S. Rathore, and P. K. Shukla, "Designing efficient optimum reduced order IIR filter for smoothening EEG motion artifacts signals," *Design Engineering*, pp. 5080–5101, 2021, http://thedesignengineering.com/index.php/DE/article/view/390.

[15] B. Han and H. D. Schotten, "Machine learning for network slicing resource management: a comprehensive survey," 2019, https://arxiv.org/abs/2001.07974.

[16] R. K. Gupta, K. K. Almuzaini, R. K. Pateriya, K. Shah, P. K. Shukla, and R. Akwafo, "An improved secure key generation using enhanced identity-based encryption for cloud computing in large-scale 5G," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 7291250, 14 pages, 2022.

[17] H. Zhang, N. Liu, X. Chu, K. Long, A. Aghvami, and V. C. M. Leung, "Network slicing based 5G and future mobile networks: mobility, resource management, and challenges," *IEEE Communications Magazine*, vol. 55, no. 8, pp. 138–145, 2017.

[18] A. S. A. Aziz, M. M. Fouad, and A. E. Hassanien, *Cloud Computing Forensic Analysis: Trends and Challenges*, Springer, 2017.

[19] D. Jain, P. K. Shukla, and S. Varma, "Energy efficient architecture for mitigating the hot-spot problem in wireless sensor networks," *Journal of Ambient Intelligence and Humanized Computing*, 2022.

[20] I. Yaqoob, I. A. T. Hashem, A. Ahmed, S. A. Kazmi, and C. S. Hong, "Internet of things forensics: recent advances, taxonomy, requirements, and open challenges," *Future Generation Computer Systems*, vol. 92, pp. 265–275, 2019.

[21] A. A. Gebremariam, M. Chowdhury, M. Usman, A. Goldsmith, and F. Granelli, "Softslice: policy-based dynamic spectrum slicing in 5G cellular networks," in *IEEE International Conference on Communications*, pp. 1–6, Kansas City, Kansas, United States, 2018.

[22] A. Khare, R. Gupta, and P. K. Shukla, "Improving the protection of wireless sensor network using a black hole optimization algorithm (BHOA) on best feasible node capture attack," in *IoT and Analytics for Sensor Networks*, P. Nayak, S. Pal, and S. L. Peng, Eds., vol. 244 of Lecture Notes in Networks and Systems, Springer, Singapore, 2022.

[23] L. U. Khan, N. H. Tran, S. R. Pandey et al., "Federated learning for edge networks: resource optimization and incentive mechanism," 2019, https://arxiv.org/abs/1911.05642.

[24] I. Afolabi, T. Taleb, K. Samdanis, A. Ksentini, and H. Flinck, "Network slicing and softwarization: a survey on principles, enabling technologies, and solutions," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 2429–2453, 2018.

[25] L. U. Khan, I. Yaqoob, N. H. Tran, Z. Han, and C. S. Hong, "Network slicing: recent advances, taxonomy, requirements, and open research challenges," *IEEE Access*, vol. 8, pp. 36009–36028, 2020.

[26] S. B. Goyal, N. Pradeep, P. K. Shukla, M. M. Ghonge, and R. V. Ravi, *Utilizing Blockchain Technologies in Manufacturing and Logistics Management*, IGI Global, 2022.

[27] R. A. Addad, T. Taleb, M. Bagaa, D. L. C. Dutra, and H. Flinck, "Towards modeling cross-domain network slices for 5G," in *2018 IEEE global communications conference (GLOBECOM)*, pp. 1–7, Abu Dhabi, United Arab Emirates, Dec. 2018.

[28] A. Kaloxylos, "A survey and an analysis of network slicing in 5G network," *EEE Communications Standards Magazine*, vol. 2, no. 1, pp. 60–65, 2018.

[29] F. In Al-Turjman, A. In Nayyar, A. In Devi, and P. K. In Shukla, *Intelligence of Things: AI-IoT Based Critical-Applications and Innovations*, Springer, 2021.

[30] S. Prashant, A. Abeer, R. Sabih, G. Nabil, M. Imran, and A. Samrah, "Network slicing: a next generation 5G perspective," *EURASIP Journal on Wireless Communications and Networking*, vol. 2021, 2021.

[31] L. Zanzi, V. Sciancalepore, A. Garcia-Saavedra, and X. Costa-Perez, "OVNES: demonstrating 5G network slicing overbooking on real deployments," in *IEEE INFOCOM 2018-IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, pp. 1-2, Honolulu, HI, USA, 2018.

[32] C. Ssengonzi, O. P. Kogeda, and T. O. Olwal, "A survey of deep reinforcement learning application in 5G and beyond network slicing and virtualization," *Array*, vol. 14, p. 100142, 2022.

[33] L. U. Khan, I. Yaqoob, N. H. Tran, S. M. Kazmi, T. N. Dang, and C. S. Hong, "Edge computing enabled smart cities: a comprehensive survey," 2019, https://arxiv.org/abs/1909.08747.

[34] D. Acharya, S. Goel, H. Bhardwaj, A. Sakalle, and A. Bhardwaj, "A long short term memory deep learning network for the classification of negative emotions using EEG signals," *International Joint Conference on Neural Networks (IJCNN)*, vol. 2020, pp. 1–8, 2020.

[35] S. S. Kushwaha, S. Joshi, D. Singh, M. Kaur, and H.-N. Lee, "Systematic review of security vulnerabilities in ethereum blockchain smart contract," *IEEE Access*, vol. 10, pp. 6605–6621, 2022.