Machine Learning Techniques to Analyze Network Slicing for 5G Network Management

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Abstract

Abstract

The upcoming fifth-generation (5G) wireless networks are expected to revolutionize the existing fourth-generation network in order to accommodate the massive number of devices that will eventually be linked over the web. 5G networks are going to bring about brand new and enhanced abilities to facilitate high-speed data transmission, improved connectivity, and increased network capacity. For a network to effectively satisfy demanding application needs, it is imperative for its infrastructure to possess a great degree of flexibility and adaptability. A network's architecture can be enriched with dynamic and flexible attributes through the implementation of network slicing. An existing 5G network can be improved by implementing a network slicing architecture, which will enable better network dynamics and flexibility to cater to contemporary network applications. The expansion of devices, applications, and services has led to an increase in consumer expectations and requirements for network service providers to deliver high-quality service. An outstanding investigation is currently being carried out by network architecture and top-notch research professionals as more and more devices, services and applications are being increased. To be able to make the preceding paradigm more adaptable, user-centered, and service-centric, the researchers claim that mobility management is now being studied. Network slicing may be able to meet the demanding application requirements for the network layout now in place if done so efficiently. The traffic and mobility management algorithms developed in the current work employ sophisticated fuzzy logic to provide maximum flexibility and high performance. The development of NFV (Network Function Virtualization) and SDN (Software-Defined Networking) technologies is crucial. An architectural framework for 5G networks called "network slicing" is designed to support a range of different networks.

Keywords: 5G Network Slicing, SDN, NFV, Fuzzy logic

1. Introduction

Network slicing is one intelligent application technique that is becoming more and more popular for the Internet of Things. Resource levels, physical infrastructure, crucial enablers, and security are only a few of the variables that have an impact on network slicing [1]. A few examples of recent technological advancements are software-defined networking, edge computing, cloud-based computing, the Internet of Things, the use of virtualization and smart services. Sliced networks for smart services are possible due to the numerous logical and physical network infrastructure requirements that exist. When smart transport technologies are used, auto accidents involving self-driving automobiles may be recorded in VANET [2]. It is crucial that you alert the other party right away once an accident happens to limit the harm. This is a good development since it means that smart agricultural services have lower latency needs than smart transportation services. Slices of an AIS (agricultural intelligent transportation system) must be delayed substantially more if ITS slices are delayed at all (L. U. Khan, 2019). Network slicing [2, 3] is currently supported by a number of smart services [3].

Software-Defined Technology advancements in networking, network service virtualization, and cloud-based computing enable 5G network slicing. Using a network slicing architecture, it is feasible to offer adaptable solutions for a variety of business issues and network traffic classifications using the same networks [4]. The ability to create many 5G networks with the same architecture but various levels of functionality and efficiency is made feasible by network slicing. In addition to voice communication, intelligent transportation systems, and other use cases, network slicing technology offers a wide range of services for a wide range of applications. The network slicing diagram in Figure 1 depicts the process. When it comes to computerized networks, network slicing was a mechanism for integrating many virtual networks onto an individual physical networking architecture [5].

Within a development team, communication is modeled after the software architecture. Since the software sector is expanding quickly, maintenance and validation work may begin almost immediately after a product is created and made available. Over the course of several years [6], through my interactions with many leaders in teams, project supervisors, and the solution architects, I have come to the conclusion that change management in software is a challenging task. Because of this, it's crucial to stress the importance of assurance of quality across the process of developing software to make sure durability as well as performance are not compromised in any way.

Different areas of knowledge, encompassing such activities as testing, upkeep, analysis, quality control, and program debugging, may profit from the same style of thinking. Because of slicing's general effectiveness, the procedure is made more manageable and effective. Once product development and distribution are complete, a company's long-term viability and profitability depend heavily on customer service. I like slicing because it emphasizes connected services above development, which is something I cherish. It gives me great pleasure to have contributed to such a dynamic field of thesis research [7].

Software can be sliced at a number of different levels, including within specific applications and throughout the overall architecture of software of vast distributed systems. The factor that decides whether or not to flow the backward or forward slicing [8] affects computation of slicing.

Below is a more thorough explanation of the application procedure. Cutting may be either static or dynamic, depending on how the software behaves, and vice versa. Numerous works, such as Mastering Software Structure and Dependency Analysis, Software Architecture Slicing, and Dynamic Software Architecture Slicing, go into great length on this subject.

Slicing can be used to reduce coding density that must be examined while debugging, moreover it can help in comprehending how various factors influence programmed computations [9]. Slice-and-dice techniques were also used to analyze a set of sample cases and testing environments that were all examined as a component of this study. Using the slicing method, it was also able to construct software measurements. We will later get into greater detail concerning software portability and the way it works. The advantages and functionality are identical to those of architectural slicing. We will discuss a significant number of slicing applications in the following portion [10].

a. Finding semantic distinctions between two or more sentences is done by differentiating them.
b. Making updates to software while preventing unanticipated consequences is known as software maintenance.
c. Regression testing allows you to cut costs (run only the essential tests) by doing tests after modifications.
d. In order to improve performance, sequential programs are transformed into parallel ones through the process of parallelization.
e. Software inspection and analysis is the process of debugging.
f. Examining the interactions between safety-critical components is the focus of tests for safety-critical component interaction (SQA).
g. In order to understand the design, design choices are separated from the source code and the outcomes are examined.
h. Systems, programs, and software are all put through testing. The size of the state space (SPIN/SMV) may be lowered by two or three times.
i. The procedure of combining systems and programs is known as system and program integration.
j. Assess the likelihood of node collisions.
k. The likelihood of a node junction is calculated.
l. Utilizing the network's nodes' specialty, fault tolerance is established.
m. In the network, node mobility is determined.

Along with the standard nodes, this method also uses hybrid macro, micro, femto, pico, and relay nodes. Unprecedented amounts of storage capacity are expected to be made possible by creating a seamless network that connects the WAN-LAN and PAN levels.

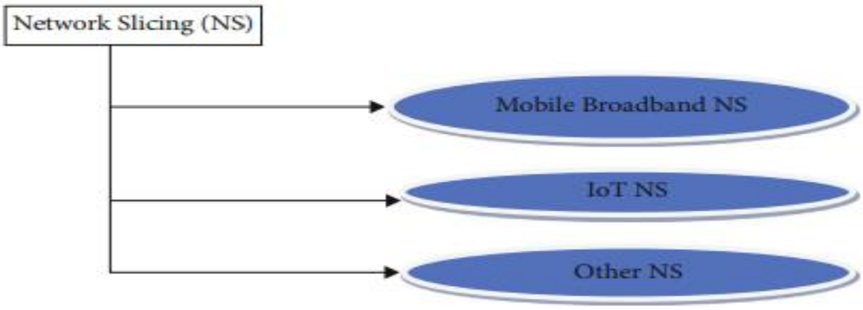

FIGURE 1: Network slicing in 5G network functionality.

The switch from homogeneous to heterogeneous networks was regarded as essential for managing a large number of connections while maintaining user satisfaction [10].

Homogeneous networks have experienced problems like constrained data capacity and declining spectral efficiency in recent years [11].

By adding more nodes to the network, heterogeneous networks to be employed to increase network performance, quality of the service, and coverage [12]. There are many applications that heterogeneous networks may handle, and they are all network-friendly and adaptable.

Network development begins with the initial wave of cellular phones, also referred to as mobile phones, and persists through the ensuing technological generations. Mobile radio-telephone technology from the 1980s was used in the 1G standard.

The push-to-talk systems (PTT), IMTS, AMTS, and MTS were all improved by the 1G standard. The initial Internet connections were made via radio waves. The voice call was modulated to 150MHz using a method called frequency division multiplexing (FDMA), and it was sent simultaneously between two radio towers. By disrupting existing network technology, it created cellular networks, laying the groundwork for the wireless mobile communication infrastructure we have today.

This system had no security protection, low speech quality, a small quantity of capacity, and unpredictable handoffs [13]. Hackers and intruders take advantage of the networks' flaws. Even though the speech quality declined over time, it could still be communicated across great distances due to the analog curve's smoothness. Contrary to 2G calls, 3G calls experienced a quality decline without failing [14].

Incorporating all cutting-edge features, 5G creates the platform for integrating all previous generations and meeting future huge data demands [15]. These technologies work together as an integrated paradigm and rely on the Internet Protocol (IP) for communication. Using this paradigm, users can connect with one another over a network in a variety of circumstances. The issues highlighted about data rate and frequency slicing [16] will undoubtedly be resolved by 5G technology. Software-defined radios will enable massive channels in 5G without the need for streaming (22, 23).

Quality of service (QoS) has evolved throughout time based on level of the hardware to the level of the network, and the next generation of networks will follow this trend. Prioritizing traffic, especially VoIP and video traffic, will help with traffic congestion management. Software – based solutions and network intelligence are essential to the proposed effort's success in addressing the algorithm-driven mob performance problem [17].

2. Historical Overview

5G networks are expected to be able to manage huge quantities of data and services in a manner that is equivalent to that of present networks as complexity and demand increase [18]. A limitless number of worldwide connections and constant access to information will be possible thanks to new technology. Technology advancements and automation are pervasive in the course of our regular lives because technology is developing more quickly than ever before. Even if there are now a lot of services available, it is predicted that the next generation of wireless networks will provide new and unique services [19]. Prior generations placed a lot of emphasis on the concept of "Always Best Connected" (ABC), which was widely adopted in practice at the time of its invention. The Wireless World Wide Web (WI-Wi) protocol is used by fifth-generation (5G) networks to give the most dependable connection possible [6]. To encourage the adoption of future broadband services, it's going to important to create prerequisites for high-quality services. In the coming years, transmission costs are expected to decline, making the current methods and strategies less competitive. If, as predicted by the projection, the number of networked devices increases further, there will undoubtedly be opportunities for technology disruption. Increasing the quantity of spectrum or infrastructure that is available to teleoperators won't be adequate any more to address the problem of teleoperators [19, 20]. Network technology needs to advance to be able to meet the needs of the current generation while also providing services to the following one. Develop innovative concepts based on outmoded technologies to help protect and thrive the nascent (5G) wireless communication sector [9]. Utilizing the results of three case studies on the construction of wireless networks, the ideal positioning of functional components that support mobility in relation to one another was established [21]. Installing the functional block that will be most closely associated to the end-user requires advance planning because end-users are on the move and the wireless environment is changing. Users will have more options when selecting their network if such a system is implemented [22].

The authors of [5] provided a quick overview of various mobile networks and future network communication issues while emphasizing the importance of 5G networks throughout their presentation. [5] The expansion of numerous new mobile networks is another subject discussed in this article. The most crucial traits were contrasted [23]. Cloud computing and architecture for combining various resource allocation methods (RATs) have been developed as a way of centralized control when it comes to real-world services provided to users. They thought it was really fascinating that the scholars in [6] investigated the issues and solutions related to upcoming innovations and 4G wireless digital infrastructure, and they came to the conclusion that cooperative networks, multicast offerings, small cell implementations scheduling, and allocating resources were all quite fascinating. An overview of these studies' findings is given. They were developed in an effort to satisfy future network demands [24]. The authors of this study specifically highlighted five technologies that could disrupt architectural and component-level design [25] and describe them as follows: The article discussed a number of design approaches, from those centered on the device were guided by the base station's operation. This study's objective is to provide a description of millimeter wave technology and the various ways in which it could be used. Examples of these improvements as well as a full explanation of the structural changes needed for large MIMO and multiplexing for smarter products are given in [26].

Each technology's basic concepts, along with their effects on 5G and future study difficulties, has been thoroughly explained. The evolutionary approach has been criticized, and a ground-breaking plan for 5G networks has been advocated in its place (9). Our proposals should boost further research exploring future services and wireless network design. In order to prove their point, the authors analyze and contrast many years of networking technology, emphasizing their significance and benefits compared to past generations. Study topics such actual wireless environments, novel gadgets, and protocols, among others, are given in-depth consideration. The issues and challenges that potential researchers can face are well covered [27].

3. Network slicing's operational procedure

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

The isolation of a network slicing layer may be physical, based on a language, or based on a virtual machine. Physical isolation is still possible at the network infrastructure layer, even though language-based isolation is preferred at the network slice and service instance layers.

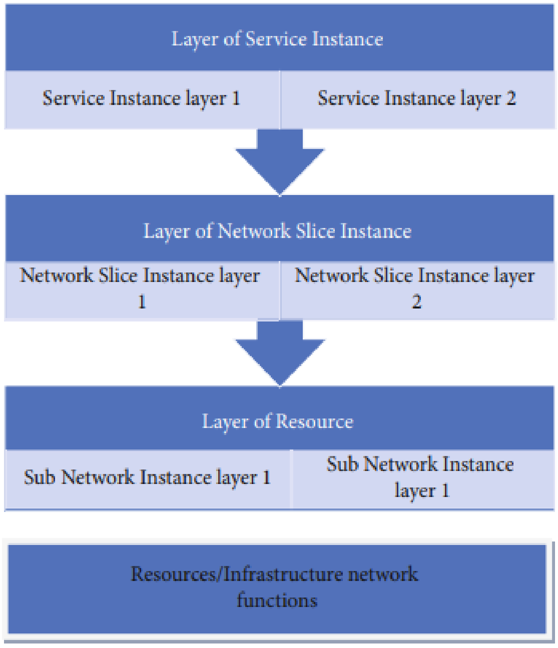

Figure 2: Network slicing layer.

Finally, the chunk of the network and resources may allow for virtual machine-based isolation [29]. Utilizing network slicing, several network slices can be created based on characteristics like a great deal of bandwidth (network capacity), minimal latency, and mobile broadband. To meet the needs of various use cases, network slicing can be implemented. Numerous uses can be made of these slices' advantages [30]. There are several issues with 5G network slicing. For instance, innovative network topologies and network slicing must be integrated into radio-access networks in 5G networks. As a result network architecture needs to be enhanced to accommodate network slicing model requirements. The 5G network slicing approach needs to be modified in order to meet consumer expectations [31].

To create network slices for different end users, NS is utilized. Since end users' needs vary from one to the next, so too should the network services that are provided to them. Individual-based networks are very challenging to establish and require much of knowledge, time, and money, but they are also more difficult to service user demands than physical infrastructure networks. Additionally, network infrastructure is made more economical by user-based network services [32].

4. Supportive Technology

The 5G-NSUE paradigm suggests building unique NS (network slices) in accordance with various use cases employing virtualization software and the underlying network architecture.

The following provides a description of the various construction points for 5G network slices.

(i) Put network slicing into practice using the chosen network area.

(ii) Examine the distribution of network slices in light of various use scenarios.

(iii) Analyze the network slicing technology being utilized.

The current slicing methods are effective when compared. Some of the similarities include the use of slicing criteria, dynamic software design, style, and descriptive language. It serves as an example of the fundamental prerequisite for software architecture slicing approaches [33]. Software architecture alteration is allowed here since these architectural slicing methodologies impose restrictions on the underlying architecture and forbid dynamic changes during execution. Even though the outcome is uncertain, they only worry about slicing. We employed architectural slicing to enable software dependability and other elements of program reliability. The 5G network is made up of end users, base stations, switching hubs, and mobility management devices. The next five elements are more essential for the 5G network to build slices, both separately and collectively. Executing network or overall slicing is the second step [34].

To support multiple network use cases, the third component ought to provide NS (network slices). To accommodate various use cases, 5G network slicing produces a number of slices with distinct features. The third factor takes resources, low latency, high bandwidths, high mobility, security, and low latency into account. The fourth element makes use of software and virtualization techniques. Here are some more methods for enabling 5G network slicing.

(1) Cloud-based tools

(2) Computer fog

(3) E-commerce

(4) Virtualization

(5) Docker

Figure 4 shows that the integrated proposed techniques used both NFV (Network-Function Virtualization) and SDN (Software-Defined Networking) technologies. The aforementioned objective can be accomplished by applying SDN (Software-Defined Networking) and NFV (Network Function Virtualization) to physical infrastructures like Radio Access Networks (RANs), user equipment, and the core network. Using the Radio Access Network (RAN), the user's equipment is linked to the network, which is linked to the core network.

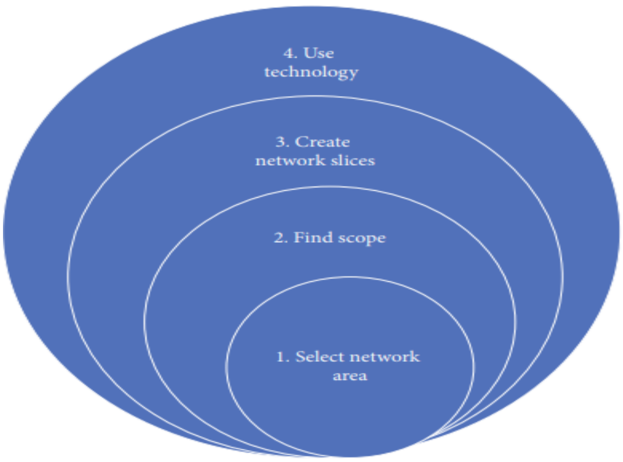

FIGURE 3: Overall processing.

The core network then creates a connection to the public Internet [35]. The virtualized and software components will be used, respectively, by the network slicing component to create the network slices. The NS (network slices) are developed to cater to the requirements of the numerous users connected to the network. The user requirements are satisfied by the use case's request for a slice, which is made by the use case itself. After the slices are created, slice separation according to slice type must be completed. The subcomponent is in charge of performing the isolation slice method indicated above.

5. Issues with Network Slicing

(i) The chaining of intelligent service functions, sometimes referred to as service function chaining, is covered in great detail in Section 1 of this article. Using virtual machines running on several nodes, intelligent service function chaining is typically used to operate on a variety of network services on a single node or across numerous nodes. Each node has a limited amount of bandwidth and resources at its disposal for the purpose of establishing connections with other nodes. The SFC must choose the most feasible nodes that are both computationally and practically energy-efficiently late in order to increase both energy efficiency and computational delay (service function chaining). Both a deep learning-based and a reinforcement learning-based SFC (service function chaining) scheme are combined with routing to enable SFC (service function chaining) (S. I. Kim 2017).

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

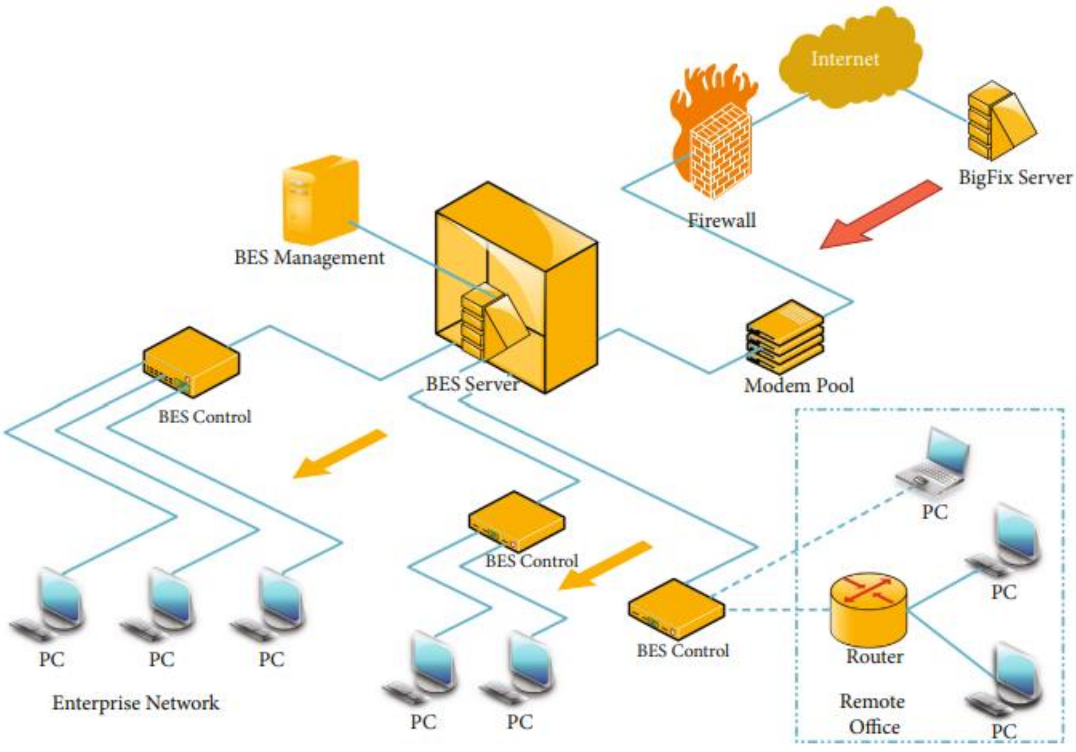

Figure 4: Methodology of proposed work.

ii. Network slicing, which involves allocating resources in smart applications while keeping mobility in mind, is one of the trickiest issues to resolve. Because of the incredibly high density of 5G networks and the handovers for various access networks, there are also a number of difficulties to be aware of. These issues are addressed by using a system of mobility-aware slicing, as opposed to installing augmented reality-based programs, though. The problems are not entirely solved. However, given the recurring transfers will take place on roads when autonomous vehicles are in use, successful on-demand slicing methods that are unique to each client are needed as a result. In addition to game-theoretic techniques, the researcher provided a Lagrangian dual-decomposition-based approach that was specifically created for resource distribution in network slicing scenarios (H. Zhang 2017).

Network slicing investigations (also known as network forensics) states that different security settings inside a network will enhance the network's susceptibility to attacks. It is necessary to update and merge existing forensic methods for the Internet of Things (IoT) and cloud computing (CC) in order to give new forensic approaches, particularly for network slicing, in order to be successful.

These new forensic approaches are helpful in identifying attacks in ambiguous contexts and analyzing attack sources besides being useful in the worst-case threat situations. As a result, numerous innovative forensic techniques for locating network slicing intrusions will be created and used.

Due to rising customer demands, dynamic spectrum slicing is growing more crucial for network slicing. In the fixed spectrum slicing situation, the spectrum will either be underutilized or overutilized. So, we need to use dynamic spectrum slicing to get around these difficulties. It had been suggested that in order to adapt to alterations in network traffic, a policy-based dynamic spectrum slicing solution be implemented. Additionally, it was suggested that user traffic be assigned using Markov modeling, which would help the slicing algorithm's general performance. Dynamic security controls are a subset of controls in the security realm that change according to the environment.

More specifically, network slicing poses tough security concerns, in particular for systems that operate concurrently at several infrastructure layer levels. The following are some security issues that need to be resolved: Multi domain security, inter slice security, and inter slice security are all viable options. You face the risk of having your information compromised if you utilize conventional machine learning-enabled network.

We employ a static slice to achieve our goal in situations where we are interested in learning all dependencies on a specific application or architecture. It is frequently employed for research and analytical purposes. Static slicing, a method utilized in this strategy, is used to find the pertinent statements. The slicing criteria are used to identify the relevant statements, and this method is used to find the relevant statements. It is possible to do an analytical investigatio n of the software and program architecture to support operations such as dependency analysis and problem fixing.

Dynamic slicing might be able to help us meet our objective of knowing only the runtime relevant statements, for instance, if our interest is based on the values that are given of the slicing criterion. The dynamic slicing has an excessively high execution time cost and should be avoided wherever possible, especially when working with sophisticated programs that involve array and pointer variables. Static slicing is typically used to construct a sizeable portion of original programs. A combination of program statements, elements, and connections collectively referred to as a "dynamic slice" have the power to drastically alter the value of any arbitrary variable at a given architectural or program level in a specific architecture or program. Dynamic slicing has been shown to be useful for applications that attempt to increase the software's effectiveness, dependability, safety, and quality in recent years. These applications have all been highlighted as prospective candidates for adaptive slicing.

The primary objective of cutting in one direction is related to the first objective of needing pertinent statements first and foremost. The presence or absence of terms like "affecting" or "affected by" within a phrase determines which way it is cut. It uses graphs to visually represent the slicing method's calculating flow. On the other hand, the calculation of the forward and backward slices is done in the same way. The way the flow is carried through the system is the only distinction between the two.

Forward slicing is a computation flow strategy that can be used to find significant future statements that are impacted by an intriguing remark in a design or program. Slices in the forward direction are used to construct any control statements and predicates that the variable in question might have an impact on. To debug and comprehend a program or architecture, the debugging and understanding approach known as "forward slicing" is employed to show filtered code that is dependent on a single statement, component, variable, or relationship. Additionally, it's used to show unfiltered code that doesn't depend on a variable, statement, or other special element or link.

6. 5G Network Issues with Network Slicing

For us, security and privacy are the most important challenges that 5G networks' in-network slicing must overcome. The current approach does not deal with a number of problems that have persisted unresolved for a while. Mobility comes in second place among the most important problems that network service providers must deal with. Since then demonstrated that the mobility problem can be solved using mixed-integer linear programming and other methods (heuristics) offered by a variety of authors. In order to fully satisfy user requests and expectations, it is necessary to thoroughly examine complicated applications in the real world because there are still certain restrictions. Slice management is still in its early stages and has a number of problems, such as inter slice resource allocation is isolated from other inter slice resource allocation.

i. As mentioned in the section above, in order to maximize the availability and scalability of 5G services, multiple controllers should be made available in the control plane, and an SDN controller should be utilized to manage all services. The accuracy rate is shown in Figure 5.

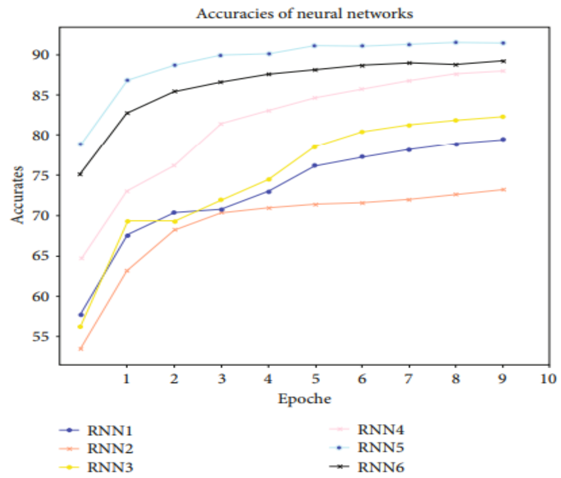

FIGURE 5: Accuracy of the sensor networks.

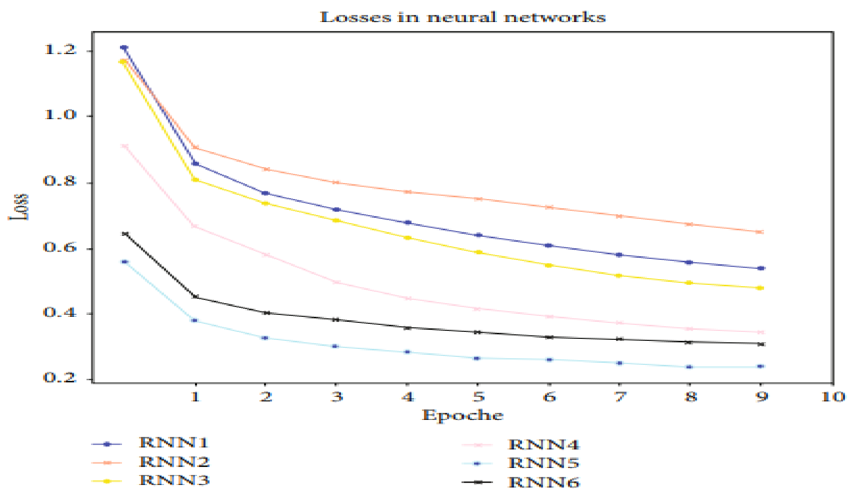

FIGURE 6: Loss of the proposed work with existing method comparison.

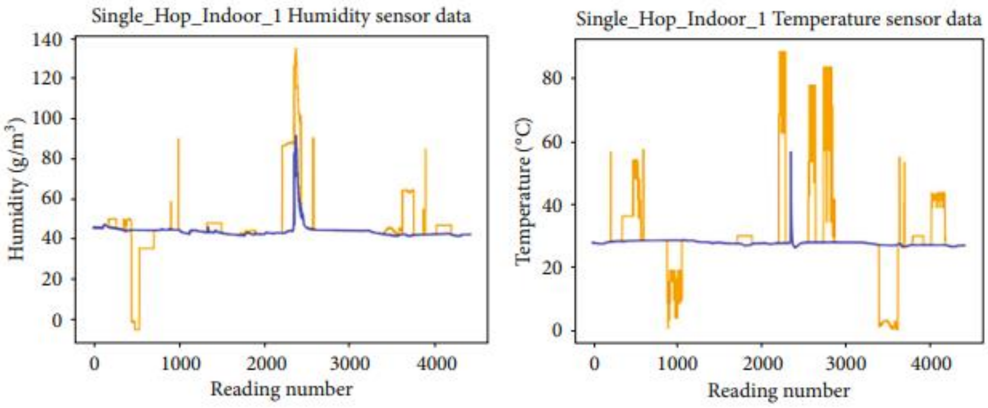

FIGURE 7: Sensor data.

(i) Dynamic network slicing is required to improve the service.

(ii) Resource allocation across the various slices needs to be more carefully considered

Figure 6 compares the proposed system to the current system. The sensor data for the suggested work is shown in Figure 7.

7. Conclusion

Recent developments in the telecom sector suggest that network slicing will soon play a significant role in 5G networks. In order for network slicing techniques to perform effectively, the underlying network architecture must be virtualized and the necessary software must be installed. 5G network technology incorporated SDN (Software-Defined Network) concepts to increase the architecture's flexibility and dynamic nature. This enables the development of a wider variety of applications in the contemporary setting. The approach to transform outdated cities into modern smart ecosystem cities is made possible by network slicing, a new technology that also significantly raises the standard of living for the general populace.

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