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NETWORK SLICING FOR 5G AND BEYOND 5G: A COMPREHENSIVE SURVEY

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***Abstract*:**

With so much conjecture regarding the performance of a new wireless communication standard (5G), further study was required to take into consideration the difficulties it poses. 5G is regarded as a multi-system support because of its capacity to supply the benefits of vertical industries and the huge interconnection of devices. We must provide the infrastructure to link the wide range of devices and applications we have today. Because of this, network slicing has become a vital technology for the communications network to meet its requirements. Of better understand the many approaches to cutting the next-generation mobile network (NGMN) into smaller, more manageable pieces, this article looks at the use of technologies like "Network Function Virtualization (NFV)" and "Software Defined Networking (SDN)." ML methods to network slicing for networks beyond 5G and the benefits of resource management and mobility prediction by applying ML techniques are also discussed and addressed in detail. ML approaches are also studied and explored.

Keywords: *Network Slicing, 5G networks, Quality of Service (QoS), Radio Resource Management(RRM)*

1. Introduction

It will be necessary for next-generation wireless networks to have networks that are diversified in terms of devices, as well as technology and applications (RATs) (NGWNs)[1]. An effective RAT selection mechanism is needed when network capacity or size increases. When many wireless networks coexist in the same area, it is necessary to implement Joint Radio Resource Management (JRRM) to improve QoS and make the best use of radio resources. In NGWN, radio resource management (RRM) is a major concern. To ensure that customers get the right quality of service, one of the RRM solutions is called Joint Radio Resource Management (JRRM) (QoS). Each application has a unique set of quality-of-service (QoS) requirements, and the NGWN [2] can manage all of them. There is no intelligent management solution in the JRRM, which was developed to handle the common set of radio resources that are available in each of the present RATs. In terms of management, the JRRM has to be streamlined [3]. The proper management of radio resources is essential for preserving interoperability. So that heterogeneous networks may benefit from increased capacity and provide better QoS to their consumers, JRRM must dynamically assign various services to the most suitable network [4].

The NGWN is no longer focused on the Base Station (BS), but will be centered on the Device Station (DS), allowing you to meet specific service requirements. Meeting the specific requirements of each user / device for this service is a major challenge for NGWN and opens new avenues for researchers. To achieve this goal, the optimization of the architecture and the reconstruction of the existing cellular network is necessary. From the IEEE 5G technology seminar it was understood that the expectations and requirements for NGWN will be very different from current wireless networks. In this forum, many researchers and industry experts introduced the need for network segmentation and highlighted the importance of network segmentation to meet NGWN requirements [5].

The present 4G network is unable to keep up with the increasing use of wireless sensor networks and remote devices in our everyday life. Every facet of communication has been reshaped in recent years due to the rise of the Internet of Things (IoT). Next-generation wireless networks may have a significant impact on how IoT devices are used in the workplace because of their high data rates and low latency connection (URLLC). ZigBee, SigFox, and LoRa have all been used to build IoT networks. To accommodate these new technologies, however, the cellular network has to be fixed. As a result, today's mobile networks don't have the diversity, scalability, or speed that previous generations of networks had. The fifth-generation (5G) network was designed in response to these problems, and it is capable of supporting three distinct use cases, each with its own set of requirements for data speed, latency reliability, and massive interconnectedness. 5G services are divided into three categories:

• "Improve mobile broadband (eMBB).
• Massive machine type communications (mMTC).
• Ultra reliable low latency communications (URLLC)".

1.1.Motivation

A decade ago, the telecommunications business was the fastest-growing industry in the world, thanks in large part to wireless connectivity. For NGWN, a great deal of study has been done on JRRM, and many of the results have shown new issues and difficulties for JRRM. There were very little resources available in the early mobile phone networks. When it came to channel planning, the number of channels accessible to each segment or cell was a predetermined quantity. CAC methods in these systems have to deal with the fact that there are only so many channels available. In order to allocate the channels properly, the guard channel technique was used to evaluate the present cell and its neighbours (priority). Obtaining spectrum licences has cost a lot of money. Because of this, it is imperative that these resources be used effectively. In wireless and mobile communication systems, RMR is a major technical challenge since radio resources are a scarce commodity. NGWN is projected to perform 10 times better than the current system's fundamental needs. 1 to 10 Gbps data transfer rate, 1ms round-trip latency, high drive area bandwidth, the ability to connect many devices, the perceived availability should be 99.9999 percent, 100 percent coverage at any time, anywhere, nearly 90% lower power consumption and long battery life [6] are included in this specification.

To support the maximum number of users per unit of resource, RRM schemes have been a broad research area to support growing consumer demands. The NGWN user wants information in different forms, anytime, anywhere without compromising QoS. This motivates to design a model that meets the evolving requirements of the NGWN user and their applications.

A. Evolution of Radio network
B. Need for novel approach for Radio Resource

Organization of the Paper:
The remaining sections of this paper are presented as follows: Section 2 describes the work related to the research that is carried out. Section 3 explains the different ways of RAN slicing. In Section 4, challenges of NDWN is explained and also the objectives of the work are highlighted. Finally, the work has been concluded in the section 5 followed by the references in the last section.

2. Related Work

It has been suggested to identify the many ways in which network slicing may be used to discover viable techniques, use cases, and architectures and the huge advantages that cutting technology delivers to fulfil the demands of vertical applications in 5G networks.

Optical systems may be controlled, managed, and orchestrated by Falowo et al [7]. In order to dynamically build Virtual Tenant Networks instances, Serrador et al. [8] present an SDN/NFV-based orchestration and management architecture (VTN).

For the network slice, Ding Zhe et al. [9] analyse SDN and NFV to give an overview of resource segmentation in virtual wireless networks. In [10], the 3GPP standardisation process is examined in terms of the split of the 5G network. Network slicing is discussed in detail by author in [11], who focus on the commercial aspects of profit modelling in their analysis of the idea and system design. Profit modelling has two distinct aspects: (a) the execution of its own segment and (b) the leasing of resources for subcontracted segments.

The number of wireless service providers (operators) is increasing fast, and the number of wireless service consumers is also increasing. As a result, an effective and scalable RRM method is required, one that can suit the needs of both operators and users. Different hierarchical and decentralised JRRM designs may be compared on the basis of their costs and benefits via the use of a hybrid simulation and modelling framework. For each situation, the system's steady-state and transient behaviour were investigated [12].

The implementation feasibility of a novel JRRM approach based on the optimization of linear programming and its real-time computing costs are examined [13]. JCAC for JRRM is the focus of the majority of the suggested study. The JCAC algorithm's objective is to allow an incoming call to be supported by two or more RATs. Incoming calls are supported by the remaining bandwidth available on the configured RATs. The call's packet flow is divided across the specified RATs, reducing the probability of calls being blocked or abandoned. On a complicated heterogeneous network that includes numerous realistic RATs, JRRM is used to develop a radio access strategy that allows several users equipped with multimodal terminals to concurrently connect to the available RATs and, in particular, pick the best among them.

optical systems may be orchestrated with the help of L.X. Wang et al. [14]. In order to dynamically build Virtual Tenant Networks instances, Lucas-Estañ et al. [15] present an SDN/NFV-based orchestration and management architecture (VTN). Saraee et al. [16] examine SDN and NFV for the network slice to offer an overview of resource segmentation in virtual wireless networks. The author in [17] provides an evaluation of the 3GPP standardisation process in terms of the 5G network division. A study by Xuan Zhou et al. [18] examines the judicial network's idea and system design from a business perspective. e Earnings Forecasting and Prediction Modeling profits on both the installation of the company's own segment and leasing resources for subcontracted segments were explored. A study by JINGWEI et al. [19] identified some of the network disruptions in the context of 5G. Service-oriented 5G has certain challenges. Flexible network slicing for 5G was proposed by Jian Chen et al. (20) with a focus on strategies that eventually allow flexible mobility, service-aware (QoS/QoE) control, as well as efficient substrate use for cutting. Proposals are analysed by author in [21] proposes using software and virtualization for network design and deployment of 5G networks.

Wireless communications has three components of JRRM: the distribution of time resources, such as channel assignment, scheduling, baud rate control, and bandwidth reserve systems. The base stations and terminals' transmitter power is allocated and managed by power allocation and control techniques. Access port connections are controlled by base station assignment, call admission control, handover/handoff schemes, and location management. The characteristics of QoS for distinct service-specific needs are not differentiated by the present radio allocation systems.

In general, several strategies are used to manage 4G and beyond radio resources. These schemes may be divided into three primary groups. Scheduling is an example of a frequency/time resource allocation technique included in the first group. Power allocation and control techniques for terminals and base stations make up the second group. In the third set, call admission control and base station assignment are included. With the single method to wireless networking now being implemented most resources are underused or not suited for high-bandwidth, low latency applications. Multi-criteria decision-making is not handled by the current system. Traditional base station-centric networks (BSCs) will be replaced by device-centric networks (DCs), which will be based on particular service needs. The user is no longer a deciding factor in a wireless network's success. Content storage, transmission, distribution, and processing should all include the user [22]. Emerging applications including D2D, M2M, Internet of Things (IoT), Internet of Vehicles (IoV), Smart Homes, Cities, and networking constitute a huge challenge for the NGWN. Inter Cell Interference Coordination (ICIC) is critical in coordinating and controlling the high traffic generated by these applications.

Virtualized network segments that are devoted to certain use cases are possible thanks to network segmentation. Using network resources by allocating fixed resources to several apps with varying needs may not be the most effective way to do it. NGWN operators must make a dramatic adjustment in their thinking in order to develop intelligent dedicated grids that are suited for offering a variety of services tailored to the individual customer. Horizontal network slicing may help with this by making it simpler to satisfy device-specific service needs [23].

Dedicated networks may be created at a lower cost by splicing the networks. Virtual networks are created utilising a similar physical infrastructure, but each one has its own distinct virtual network. Virtual network segments are made up of logical network functions that are tailored to a particular use case. In order to offer the resources and QoS (quality of service) necessary, each network segment may be improved in terms of latency, throughput, capacity, and coverage. Using network segmentation, functional components may be shared across different network segments while limiting interference between the segments. Segmenting a network allows for more network adaptability, scalability, and resource efficiency.

A. Background Work

1. Each network segment can be optimized to provide the required resources and quality of service (QoS) with respect to latency, throughput, capacity, coverage, etc. interference prevention. In addition, network segmentation offers flexibility, network scalability and efficient resource management. At the same time, a different network segment could be offered to provide high performance, high data rates and low latency.
2. The logical architecture of NGWN systems should be based on network partitioning. The technology will enable network operators to provide differentiated services at user access levels close to radio access networks (RANs).
3. The network slicing will be used mainly to divide the core network. It can also be enacted in the RAN by pooling resources. The process involves abstraction and partitioning of logical network segments from physical resources.
4. Network Segment Management solutions can also help operators implement network segment lifecycle management in preparation for NGWN. However, the primary motivation behind the technology is the ability to deliver networks as a service, minimizing overheads and CAPEX, and increasing operational efficiency.
5. Network slicing allows access based on device capacity, a device that is simple and requires access to only one segment [24].

B. Network Slicing

Slicing can be handled in two different ways:

i. **Vertical Slicing:** In this type of slicing, each of the network nodes typically implements similar functions between sections.
ii. **Horizontal Slicing:** With horizontal slicing, you can create new functions on a network node, when slicing is supported.

Figure 1.1 illustrates the concept of vertical and horizontal cutting. In the vertical section, the physical computation / storage / radio processing and the physical radio resources are divided to form end-to-end vertical sections. The criteria may be different when cutting radios, RANs and NCs. Segment matching functions are defined to match radio, RAN and CN segments to form end-to-end segments for different services and applications. In the horizontal slice, the physical resources in adjacent layers of the network hierarchy are split to form horizontal slices [25].

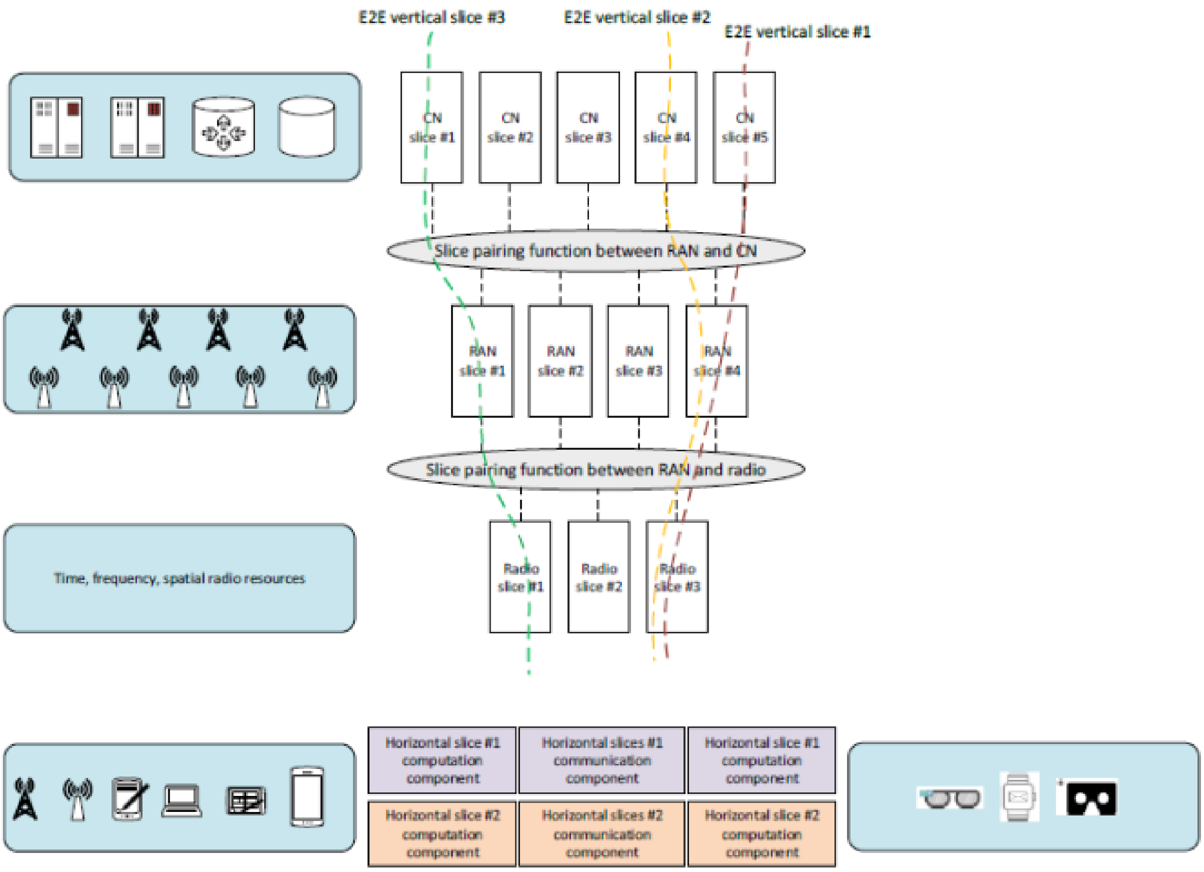

Figure 1.1 Illustration of Network Slicing: Vertical and Horizontal network slicing

3. RAN Slicing

Since 5G networks are characterized by a high level of complexity, which makes it traditional, there have recently been unsustainable mathematical approaches and thus there has been some work on smart RAN cutting.

Radio and Platform Resource Management at RAN:

- Entire RAN system resources are statically or dynamically partitioned for network sections.
- Controlling user association / dissociation modifies multiple network segments and their resources without contention.

- The network segment scheduler monitors resource usage within the segment and optimally allocates system resources based on contention.

Slice Specific admission control at RAN:

- Check the number of users allowed per network segment.
- Using machine learning, analyze current operational usage and future usage of the network segment profile.
- Create heap buffers and user segment support based on future profile use [26].

Need for NGWN for Slicing

Instead of creating several distinct networks, Dynamic End-to-End 5G Network Partitioning (E2E) uses parts of a single big 5G network to allocate various services and use cases. Examples of these components include: mobile broadband, the Internet of Things (IoT), healthcare software, and physical infrastructure. It will be possible to enlarge and shrink a single slice of the 5G network as needed. As a result, in principle, the 5G host network will be able to use its resources more effectively while maintaining the performance of the single virtual network. It's possible that parts of the 5G network may become very resource-intensive. Networks that fail to properly design and appropriately implement the virtualized needs might become resource hogs, running slower than planned and becoming unreliable as a result. The 5G network is severed in Figure 2.1 [27]. Service providers and application developers will be able to envision their perfect network design for their individual needs thanks to the 5G network's reduced latency and great dependability.

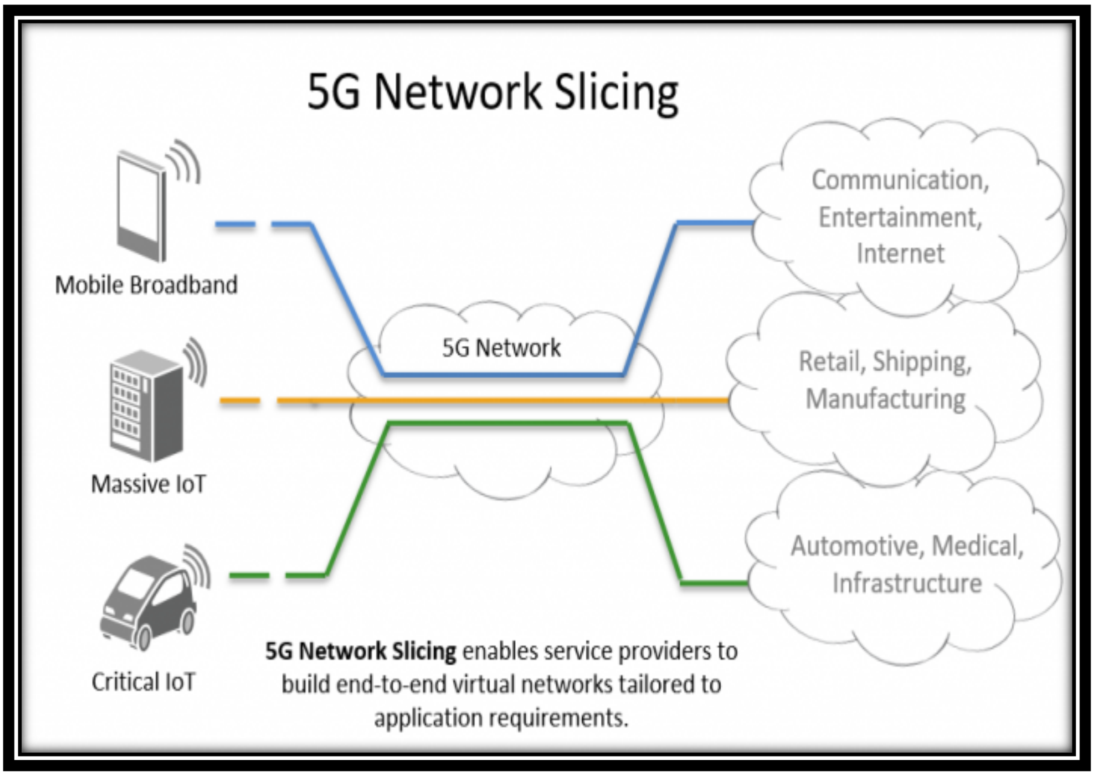

Figure 1.2 5G Network Slicing

4. Challenges of NGWN

Network slicing holds great promise for NGWN networks, but it's not without its hurdles. As 5G networks provide wireless connectivity, RANs will need to be redesigned to allow for network division. Both macros and small cells, for example, need to be able to work together and meet the needs of specific network segments. Additionally, while nearly everyone recognizes that network slicing will play a significant role in NGWN, there is a lack of industry consensus on how to best implement the technology. The isolated nature of the technology can prevent interference of network segments, but this is still difficult to achieve with a large number of network segments. Interoperability is also needed to ensure network cutting collaboration with other budding NGWN technologies as NGWNs become a reality [28]. Categorically, horizontal mesh slicing can be done in 2 ways, static horizontal slicing (SHS) and dynamic horizontal slicing (DHS).

Static Horizontal Slicing: Static Horizontal Slicing is basically concerned with slicing the network, where the user needs the specific fixed services and won't change them. SHS is less complex as user requirements are known in advance.
Dynamic Horizontal Slicing: Dynamic horizontal partitioning is essentially concerned with partitioning the network where the user keeps changing services of different sizes. DHS is relatively more complex as user requirements arrive dynamically and must adapt to dynamic changes. The challenge for DHS is making quick decisions to meet dynamic user requirements. This challenge can be addressed through multi-criterion decision making (MCDM), which uses computational techniques for the efficient use of limited radio resources. This could be the mechanism for satisfying the various QoS requirements of NGWN [29] applications. In the horizontal network section, you can add new features for a network node, when a specific network segment is supported.

From the literature survey, we find that horizontal section, static horizontal section and dynamic horizontal section are less explored for NGWN. This provides the opportunity to explore more about horizontal cut, static horizontal cut, and dynamic horizontal cut and leverage these techniques to meet NGWN's specific device-centric service requirements without compromising QoS.

Objectives of the work:
As noted in the literature survey, NGWN requirements will not be like current wireless networks. NGWN requirements can be met by changing our approach. In wireless networks, RRM is crucial and important. Equitable channel allocation and efficient use of radio resources without compromising QoS are a challenge in NGWN. The NGWN will be device / user focused to meet the specific service requirements of each device / user. Each device / user needs a specific type of service, for example if we consider a set of devices / users, some may be interested only in voice calls, some may be interested only in video calls, some may be interested in communicating text data, some they may be interested in watching videos online

and others may be interested in playing online. These varying requirements for each device / user require varying bandwidth for each device / user. These NGWN requirements can be met using the concept of network segmentation. If the device / user is using a fixed service, we can fix it using SHS. Otherwise, if the device / user consumes various and dynamically changing services, they can be addressed via DHS. The complexity involved in DHS for decision making is a challenge, we can overcome this challenge by using soft computing techniques for multi-criterion decision making (MCDM).

The main objective of this research is

(i) Design and develop a static horizontal cutting technique to meet the specific requirements of the service in NGWN.
(ii) Build a mathematical model for static horizontal cutting in NGWN.
(iii) Apply artificial intelligence and machine learning techniques to develop a dynamic horizontal cutting technique in NGWN.
(iv) Evaluate the proposed models (SHS and DHS) for effective use of bandwidth.

5. Conclusion

Network slicing has the potential to help fulfil the QoS demands of a variety of new applications. An initial assessment of the main difficulties and potential solutions is provided in this paper as part of the RAN slicing framework. Optimization control and design of the network slicing framework are currently focused on new physical layer technologies such as Orthogonal Time, Frequency and Space Modulation (OTFS), NOMA, Massive Multi-Access Input Multiple-Output (MIMO), metasurfaces, and the deployment of unmanned aerial vehicles (UAVs) in order to integrate network division with these technologies (UAVs). With this new physical life technology, transmission delays for service requests may be further reduced because of the highest possible spectrum efficiency. The self-contained RAN slicing structure is a major guideline for a 5G-beyond and 6G network.

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