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End-to-End Network Slicing: Maximizing 5G Networks' Capabilities to Cater Different Use Cases

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Abstract *- Wireless communication networks have gone through years of evolution and development, which will be in continuum to cater the varying needs of users, many of which are still unknown. These diverse requirements and use cases are expected to grow to cause traffic to increase rapidly. For this reason, fifth-generation (5G) technology emerges which could accompany varying demands of multi-tenant networks. 5G communication networks are expected to guarantee Quality of Service (QoS) end-to-end (E2E) service deliveries for Internet of Things (IoT) devices. 5G network requires various types of features and networks in terms of mobility, policy control, latency, reliability, etc. and Network slicing is a key concept to address this issue by partitioning the physical network at an end-to-end level to allow optimum grouping of traffic, isolation from other users or tenants, and configuring of resources at a macro level. However, this innovative technology cannot be realized without a paradigm shift from hardware-based to flexible software-defined networks (SDN). This paper introduces the 5G network, its use cases and the concept and benefits of network slicing. State-of-the-art management and orchestration of network slicing are provided in this paper. A piece of brief background information on Network Function Virtualization (NFV) incorporated with Software-Defined Networks is presented with a focus on the aspects that are necessary to understand how to leverage these technologies to implement the network slicing concept.*

Keywords *- network slicing, 5G networks, software-defined network, network virtualization, Network Architecture, Network Protocols, Network Services*

1 INTRODUCTION

The state-of-the-art networks rely on the static and inflexible configuration to satisfy user demands. With the explosive and rapid growth of mobile data traffic, the rise of various kinds of new applications, futures wireless networks need to be agile, programmable, and open. Moreover, fifth-generation (5G) networks are nowadays expected to satisfy different requirements of numerous new services and support vertical markets [1]. There are current networks providing the means to serve different types of services through network traffic prioritization according to the needs. However, this way of managing network equipment resources has proven inefficient, inflexible, and expensive as it lacks the mechanisms to evolve continuously and adapt the allocation resources and their configuration according to the current service and customers' requirements [2].

Fifth generation (5G) systems are nowadays being investigated to satisfy the consumer, service, and business demands of 2020 and beyond. One of the key drivers of 5G systems is the need to support a variety of vertical industries such as manufacturing, automotive, healthcare, energy, and media and entertainment. Such verticals originate very different use cases, which impose a much more extensive range of requirements than existing services do nowadays. Today's networks, with their "one-size-fits-all" architectural approach, are unable to address the diverging performance requirements that verticals impose in terms of latency, scalability, availability, and reliability. To efficiently accommodate vertical-specific use cases along with increased demands for existing services over the same network infrastructure, it is accepted that 5G systems will require architectural enhancements with respect to current deployments. [4]

The state-of-the-art way of building and operating a mobile network is inflexible, static, and difficult to adapt. These characteristics limit the ability of a network service provider to create novel network-based services than support the diverse requirements. Operators need to transform the way how they design, deploy, and upgrade networks to support the novel mobile applications.

Network slicing refers to partitioning of one physical network into multiple virtual networks, each architected and optimized for a specific application or service. Specifically speaking, a network slice is a virtual network that's created on top of a physical network in such a way that it gives the illusion to the slice tenant of operating its own dedicated physical network [5].

The concept of network slicing came with Network Functions Virtualization (NFV) and Software-Defined Networking (SDN) mechanisms that have been progressively introduced in the Third-Generation Partnership Project (3GPP).

Wireless Network Virtualization uses five (5) different means namely – radio spectrum sharing, infrastructure sharing, network slicing by service, user or application, abstractions layer definition which simplifies wireless access from a heterogeneous network, and programmability and management of to achieve network sharing [6]. Virtualization uses virtual networks to achieve wireless network virtualization. Another key enabler of network slicing is SDN, which separates the control plane from the data plane [7]. Software-define networking dedicates a set of network modules to act as the controller. The isolation or separation between the control plane functionalities from the data forwarding functionalities brings the flexibility needed to achieve a near-perfect slicing implementation. It could ease complexity that could accompany the management of wireless networks if SDN is carefully deployed. Network Function Virtualization (NFV), on the other hand, promotes the idea of removing network functions from dedicated physical network hardware equipment to run on any virtualization environment deployed in any network location. This could make it possible to decouple network functions running on proprietary network devices to run on decentralized and virtualized network servers, which could be deployed at anytime in the network in accordance with the network needs and service requirements.

On the other hand, network slicing seeks to assure service customization, isolation and multitenancy support on common physical network infrastructure by enabling logical as well as physical separation of network resources [8].

This paper presents various strategies and architecture for fast and effective deployment of end-to-end network slicing in the emerging 5G communication systems to address the network traffic issues caused by enormous, diverse user demands and requirements.

2 METHODOLOGY

The primary goals of this research are to identify the variety use cases of state-of-the-art 5G networks and to provide related literature regarding the concept of end-to-end network slicing leading to cater the current use cases with the 5G networks and the challenge of implementing such network mechanisms. In order to achieve these goals, in this section, the methodology and the procedures applied.

Several online research databases were utilized to discover and access journal articles, conference proceedings, technical standards, and related materials on 5th Generation (5G) networks and end-to-end network slicing.

Online Research Database	Website
Google Scholar	scholar.google.com
Research Gate	researchgate.net
IEEE Xplore Digital Library	Ieeexplore.ieee.org

Table 1.0 List of Utilized Online Research Databases

In browsing for researches online, the following procedure, as stated by Manu Bhatia [9] in the Humans of Data website was applied:

Getting familiar with the data: Since most qualitative data are just words, the researchers started by reading the data several times to get familiar with it and start looking for basic observations or patterns. This also includes transcribing the data.

Revisiting research objectives: Here, the researchers revisits the research objective and identifies the questions that can be answered through the collected data.

Identifying patterns and connections: In this process, the research looked for the most common responses to questions, identifying data or patterns that can answer research questions, and finding areas that can be explored further.

3 RESULTS AND FINDINGS

3.1 5th Generation Networks

The term 5G refers to fifth generation of mobile communication systems. [16] They belong to the next major phase of mobile telecommunication standards beyond the 4G networks. 5G provides much faster data rates with very low latency compared to the systems up to 4G. It thus facilitates the adaptation of highly advanced services in wireless environment.

5G networks are anticipated to revolutionize the user experience introducing new requirements to shape network platforms for launching new innovative services. These services have diverse requirements, involving higher data traffic volumes and potential number of devices. The initial roll out of 5G is expected by 2020 in order to meet the emerging business and consumer demands [17].

5G communication networks are expected to guarantee QoS E2E service deliveries for Internet of Things (IoT) devices [10]. These devices might include intelligent home appliances, smart sensors, and actuators supporting diversified use cases; the applications include smart homing, industrial automation, intelligent transportation, and e-health-care systems. In recent technical reports, the Third-Generation Partnership Project identifies three main features for the future networking paradigm – enhanced mobile broadband, massive IoT, and critical communications.

3.2 5G Uses Cases

The Next Generation Mobile Network (NGMN) White Paper [12] anticipates a number of emerging 5G use cases focusing on:

- **Enhanced broadband access everywhere** that envisions a minimum amount of bandwidth, at least 50Mbps, ensuring a connected global society, via high speed Internet. This asset can serve a default general purpose usage.

- **Enhanced broadband access in dense areas** that provides broadband access with up to 10Gbps bandwidth in densely populated areas, e.g. stadiums or open-air festivals, enabling multimedia services, e.g. ultra-high definition video streaming.

- **High user mobility** that offers broadband support for mobile users in extremely fast-moving vehicles such as high-speed trains.

- **Massive Internet of Things (IoT)** that supports broadband access for ultra-dense networks of sensors and actuators, considering devices in need of super low-cost, long range and low power consumption, e.g. providing utility measurements.

- **Extreme real time communication** which assures ultra-low latency connectivity, e.g. for interactive tactile Internet.

Another 5G use case by [14] is ultra-reliable communication which provides ultra-low latency, reliability and availability of network connectivity supporting, e.g. autonomous driving. Not to forget, lifeline communication which supports connectivity in case of natural disasters and emergencies capable to accommodate flexibly a sudden tremendous traffic increase, while assuring resilient connectivity [15]. Toyota identified Broadcast-like service as a 5G use case which provides network connectivity for broadcasting, e.g. news or firmware updates for instance to improve the breaking system of a car or braise up a detected security hole in cars.

Light-weight communication and multi-connection are among the variety of uses cases of 5g. The former provides network connectivity for supporting essential instantiation, configuration and maintenance service information while the latter assures network connectivity for users with different smart devices, e.g. smart glass and smartphones, using multiple access technologies [3].

Some of the aforementioned use cases may cause conflict on requirement however, through network slicing, use cases with different performance requirements can be realized.

3.3 The Network Slicing Concept

Network slicing is one of the crucial technologies that enable flexibility, scalability and that improves security as it allows creation of multiple separated logical networks spanned over a shared hardware infrastructure. The first idea of network virtualization and slicing was introduced in the paper of Peterson, L., et.al [20], where the authors described an overlay network, the PlanetLab, which was able to produce slices of the network to provide environment for simultaneous design and utilization of different services. Since then this concept has grown considerably and has become the subject of extensive investigations. In recent studies and designs the network slicing idea is based on the three-layers model:

- Service Instance Layer,
- Network Slice Instance Layer, &
- Resource Layer

The Service Instance Layer describes the services which should be supported. Each service is created as a Service Instance. Usually, the Service Instance can be created by both operator services and third-party services.

A Network Slice Instance is a set of (virtualized) network functions implemented at resources that enable running these network functions. It forms a complete instantiated logical network to meet certain network characteristics (e.g. ultra-low-latency, ultra-reliability, etc.) required by the Service Instance. A network slice instance could be isolated from another network slice instance in several ways, e.g., full or partial isolation and logical or physical isolation.

The Resources Layer contains both physical and logical resources. The Network Slice Instance can consist of Subnetwork Instances, which can be shared with multiple network slice instances. The Network Slice Instance is defined by a Network Slice Blueprint. For creating every Network Slice Instance are required dedicated polices and configurations [11].

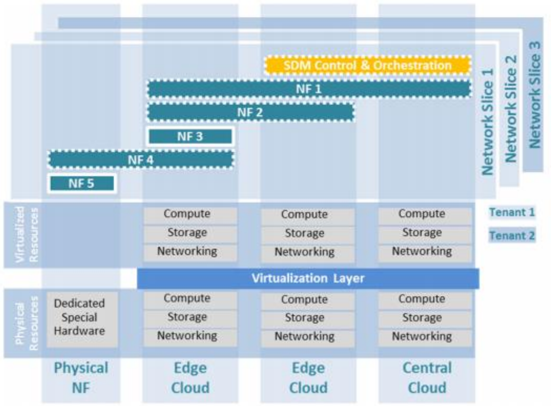

Figure 1.0 Network Slicing Concept

Beyond multi-tenancy, network slicing additionally serves as a means to deploy multiple service- tailored mobile network instances within a single MNO, each addressing a particular use case with a specific set of requirements, e.g., mobile broadband or IoT. In that context, it enables the joint optimization of mobile access and core network functions. Each network slice is composed of functions according to service needs, e.g. low latency services require the allocation of most
network functions at the edge [21].

3.4 Enablers of Network Slicing

A driving factor of network slicing is *softwarization* – an overall transformation trend for designing, implementing, deploying, managing and maintaining network equipment and components by software programming, exploiting flexibility and rapidity of design, development, and deployment throughout the lifecycle of network equipment and components [13].

The key enablers of network slicing are introduced and discussed in detail. They are Wireless Network Virtualization, Software Defined Networking, and Network Function Virtualization [6].

3.4.1 Wireless Network Virtualization

WNV uses five different means, namely: radio spectrum sharing, infrastructure sharing, Network slicing by service, user or application, abstraction layer definition, which simplifies wireless access from heterogeneous network, and programmability and management of wireless networks to achieve network sharing and RAN slicing especially. Virtualization, which happens to be a principal technology behind network slicing uses virtual networks to achieve wireless network virtualization.

3.4.2 Software Defined Networking (SDN)

It is also an enabler as it separates the control plane from the data plane. Thereby dedicating a set of network modules to act as the controller, which is known as the SDN controller. The separation between the control plane functionalities from the data forwarding functionalities bring the flexibility needed to achieve an almost perfect RAN slicing implementation. If SDN is carefully deployed to manage wireless network slices, it could turn out to be the necessary tool needed to ease the complexity that could accompany the management and programmability of wireless network slices.

3.4.3 Network Function Virtualization (NFV)

This promotes the idea of removing network functions from dedicated physical network hardware equipment to run on any virtualization platform environment deployed in any location on the network. This could make it possible to decouple network functions running on proprietary network devices to run on decentralized and virtualized network servers, which could be deployed anytime in the network with respect to the network needs and service requirements.

3.5 End-to-End Network Slicing in 5G Networks

Network slicing in the context of 5G is a newly defined concept introduced by Next Generation Mobile Network in NGMN 5G White Paper [12]. Network slicing facilitates multiple logical self-contained networks on top of a common physical infrastructure platform enabling a flexible stakeholder ecosystem that allows technical and business innovation integrating physical and/or logical network and cloud resources into a programmable, open software-oriented multi-tenant network environment. 3GPP defines network slicing as a technology that "enables the operator to create networks, customized to provide optimized solutions for different market scenarios which demand diverse requirements, e.g. in terms of functionality, performance, and isolation. [17] For ITU-T, network slicing is perceived as Logical Isolated Network Partitions composed of multiple virtual resources, isolated and equipped with a programmable control and data plane.

Isolation can be deployed by using a different physical resource when separating via virtualization means a shared resource and through sharing a resource with the guidance of a respective policy that defines the access rights for each tenant – **customization**, **elasticity**, **programmability, end-to-end,** and **hierarchical abstraction**.

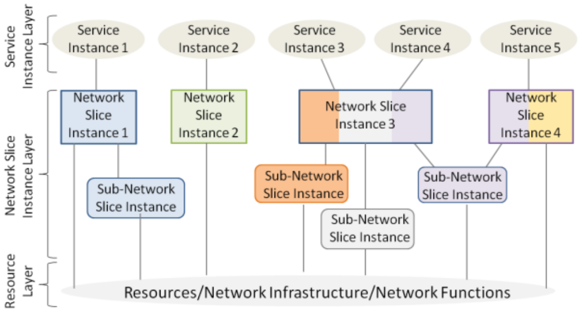

Figure 2.0 The NGMN Network Slicing Concept

End-to-end is an inherent property of network slicing for facilitating a service delivery all the way from the service providers to the end-user or customers. Such a property has two extensions, it stretches across different administrative domains, i.e., a slice that combines resources that belong to distinct infrastructure providers, and it unifies various network layers and heterogeneous technologies, e.g. considering RAN, core network, transport, and cloud. In particular, an end-to-end network slicing consolidates diverse resources enabling an overlaid service layer, which provides new opportunities for efficient networking and service convergence.

Researchers attempted to implement such challenging mechanism to cater the varying needs of users and their use cases. As seen in Figure 2.0, is an example of a 5G Network Slicing Architecture [18] depicts their approach to 5G network slicing. Use cases such as Smart Grid communication, Intelligent Transportation Systems (ITSs) or multimedia services are each assigned a network slice tailored to their specific requirements. An SDN-MANO (Management and Orchestration controller employs the OpenFlow protocol to create and orchestrate configured slices. However, each individual slice is managed by a dedicated SDN controller, granting tenants full control over their virtual infrastructure.

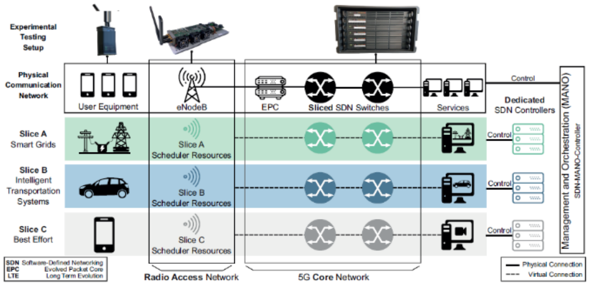

Figure 3.0 Architecture of the Developed Network Slicing System

The architecture and with the conducted measurements by the team shows that existing technologies like LTE support RAN slicing in a sufficient manner, which highly simplifies the transition to 5G New Radio. However, some-high performance applications like SG communication require low-latency enhancements in the uplink.

[19] presented in their paper a practical solution for end-to-end network slicing in 5G and they called it POSENS. It implements a "slice-aware shared Radio Area Network" solution, enabling effective and efficient sharing of the network resources between different tenants that can independently provide different services. While POSENS is based on state-of-the-art open source solutions for mobile networks, these are substantially extended with the following additional implementations: a multi-slice UE, a slice-aware shared RAN solution, and specific multi-slice management and orchestration (MANO) capabilities, all of which are needed to provide an end-to-end solution for network slicing. POSENS provides a complete solution to instantiate end-to-end slices, using commodity hardware and software defined radio (SDR) boards for development. POSENS have been validated in a lab deployment, showing how it can obtain per-slice customization without paying a price in terms of performance.

CONCLUSION

This article presents an overview regarding the current maturity state of network slicing in 5G. It provides insights into the historical heritage of network slicing from network sharing in the early days and its evolution as the major foundation of the 5G technology. It also discusses the main concept and principles, introducing the enablers of network slicing such as the NFV, SDN and WNV.

This paper presents the 5G services and business drivers as well as the impact of network slicing across the RAN, the core network. By presenting relevant projects with regards to the orchestration of end-to-end network slices and management, we successfully reflect the importance of network slicing as a major enabler for 5G. With regards to end-to-end network slicing, this paper describes how network slicing can be achieved by slicing the RAN and core networks, while describing practical example architectures.

With the papers presented, efforts are now being initiated to achieve the full-realization of 5G Network slicing for a smarter world.

REFERENCES

[1] Wanqing, G., Xiangming, W., Luhan, W., Zhaoming, L., & Yidi S. (2018). A Service-oriented Policy of End-to-End Network Slicing Based on Complex Network Theory
[2] P. K. Chartsias, A., Amiras I., Plevrakis, I. Samaras, K. Katsaros, D. Kritharidis, E. Trouva, I. Angelopoulos, & A. Kourtis (2017). SDN/NFV-based End to End Network Slicing for 5G Multi-tenant Networks
[3] T. Taleb, A. Ksentini, & A. Kobbane (2014). Lightweight Mobile Core Networks for Machine Type Communications.
[4] Lucena, J., Ameigeiras, P., Lopez, D., Munoz, J., Lorca, J., & Jesús Folgueira (2017). Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges
[5] Xin Li, Mohammed Samaka, H. Anthony Chan, Deval Bhamare, Lav Gupta, Chengcheng Guo, Raj Jain (2017). Network Slicing for 5G: Challenges and Opportunities
[6] M. Richart, J. Baliosian, J. Serrat &J. Gorricho (2016). Resource Slicing in Virtual Wireless Networks: A Survey
[7] A. Aissioui, A. Ksentini, A. Gueroui, and T. Taleb (2015). Toward Elastic Distributed SDN/NFV Controller for 5G Mobile Cloud Management Systems
[8] Afolabi, I., A., Miloud, B., Tarik, T., & Hannu, F. (2017). End-to-End Network Slicing Enabled Through Network Function Virtualization
[9] Manu, B. (2018). Your Guide to Qualitative and Quantitative Data Analysis Methods. Retrieved from https://humansofdata.atlan.com/2018/09/qualitative-quantitative-data-analysis methods/#Data_Preparation_and_Basic_Data_Analysis

[10] A. Ksentini & N. Nikaein (2017). Toward enforcing network slicing on RAN: Flexibility and resource abstraction.

[11] Kotulski, Z., Nowak, T., Sepczuk, M., Tunia, M., Artych, R., Bocianiak, R., Osko, T., & Wary, J. (2017). On end-to-end approach for slice isolation in 5G networks. Fundamental challenges

[12] NGMN Alliance, NGMN 5G White Paper (2015). Retrieved from https://www.ngmn.org/work-programme/5g-white-paper.html

[13] Akihiro, N., Ping, D., Yoshiaki, K., Fabrizio, G., Anteneh, A., Tarik, T., & Miloud, B. (2017). End-to-end Network Slicing for 5G Mobile Networks

[14] I. Farris, T. Taleb, H. Flinck, and A. Iera, (2017). Providing Ultra-Short Latency to User-Centric 5G Applications at the Mobile Network Edge.

[15] Lookup Safety Recalls & Service Campaigns by VIN (2017)

[16] Penttinen, J. (2019). 5G Explained: Security and Deployment of Advanced Mobile Communications.

[17] Afolabi, I., Taleb, T., Samdanis, K., Ksentini, A., & Flinck H. (2018). Network Slicing & Softwarization: Survey on Principles, Enabling Technologies & Solutions

[18] Bektas, C., Monhof, S., Kurtz, F., & Wietfeld, C. (2018). Towards 5G: An Empirical Evaluation of Software-Defined End-to-End Network Slicing

[19] Aviles, G., Gramaglia, M., Serrano, P., & Banchs, A. (2018). POSENS: A Practical Open Source Solution for End-to-End Network Slicing

[20] Larry L. Peterson, Thomas E. Anderson, David E. Culler, David E. Culler & Timothy Roscoe (2003). A Blueprint for Introducing Disruptive Technology Into the Internet

[21] P. Rost , A. Banchs, I. Berberana, M. Breitbach, M. Doll, H. Droste, C. Mannweiler, M.A. Puente, K. Samdanis, and B. Sayadi (2016). Mobile Network Architecture Evolution towards 5G