# 5G Network Slicing Technology and Its Impact on COVID-19: A Comprehensive Survey

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**Abstract.** At the end of 2019, no one could have imagined how the world will dramatically change. A new outbreak has emerged causing millions of people to go into lockdown for their own safety. World Health Organization (WHO) has later announced this outbreak of Coronavirus Disease 2019 (COVID-19) as pandemic. This has caused huge stress to medical staff. The need for digital connectivity between communities and nations had arisen. Digital revolutionary services like telehealth, telemedicine, eVisit, etc. play a vital role in reducing the risk and fighting the spread of the pandemic.

The industry and academia accept 5G as the potential network capable of serving vertical applications of next generation with specific service needs. In order to achieve this dream, the physical network must be separated into several separate functional blocks of various sizes and systems devoted to specific kind of services depending on their needs (a full slice for large eHealth apps, healthcare servers, IoT apps, smart cities and so on).

Network slicing (NS) was described as the foundation of fast-growing 5G. Although, as its standardization advances and consolidation, few literatures which address main concepts, research challenges and service enablers, in a detailed way are available. In this paper these aspects should be provided and discussed. This study covers industry trends and requirements for 5G including both business drivers and performance requirements. Network slicing Key enabling technologies, architectures and implementations, standardization and future challenges will be discussed and briefly viewed.

**Keywords:** 5G · COVID-19 · Pandemic · Slicing · Telehealth · Telemedicine

## 1 Introduction

Over the ages people around the world has met with different epidemics [1]. On 31st December 2019, Hubei province of chine in Wuhan city has informed the World Health Organization (WHO) about what has been called Coronavirus disease 2019 (COVID-19) [2–4]. Later in the beginning of 2020, World Health Organization (WHO) has announced this universal event as pandemic [5]. Factors like staying home, social distancing and


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good hygiene has made possible by the reduction of transmitting the disease [6]. Furthermore, individuals that are not diagnosed by COVID-19, notably those Who seem to be at higher risk of contracting the disease (e.g. older people as well as those with medical conditions) can receive regular treatment in hospitals without the risk of exposure to other patients [7]. In addition, inappropriate staff, like professional therapists, firmly deny to reach the patient division of COVID-19 under strict infection control [8]. Natural disasters and pandemics cause additional barriers to health care delivery. As an outcome, to meet both the basic needs of COVID-19 patients and other individuals who need healthcare services, creative and transformative solutions are needed. Technological breakthroughs offer additional options in this regard [9]. The use of technologies like Internet of Medical things [10], telemedicine, telehealth and e-Education with the help of IoT during pandemic circumstances (COVID-19 outbreak) seems to have the ability to strengthen epidemiological studies, disease prevention, clinical case management and studying via online [11, 12].

The amount of Internet-connected devices is predicted to reach above 45 billion at some point from 2025 onwards [13, 14]. As the world adapts to a new norm of a global remote workforce due to COVID19, users and data transfers are growing very fast. The current mobile network generation does not give much versatility to independent manufactures which require a connection to link their devices. Such businesses, for most part, adjust their networking specifications to suit the multifunctional mobile network, thus leaving them attainable [15]. In smart interconnected networking landscapes, the fifth generation of mobile technology is supposed to assemble users, healthcare providers, devices, data, apps, and cities. Previous networks contemporarily face obstacles in providing the mentioned solutions [16–18]. NS has being suggested by academia and industry as a key enabler to facilitate personalized 5G technology resources for customers to incorporate multiple spatial-specific information in response to enhanced mobile broadband networks with the existing cellular network [19].

In 5G sense, NS is a set of technologies for the development of advanced, devoted logical networks as a service (NaaS) to facilitate the convergence of internet infrastructure and meet the globally competitive specifications of industry domains [20].

The NS idea has come as a result of the ongoing development in technology i.e. Software-Defined Networking (SDN) [21, 22]. SDN controllers configures SDN switch routing tables, and spectrum sharing for the RAN, In addition to that NFV which network functions are introduced by software and distributed to request on versatile hardware [23–25].

In NS a physical network is sliced into many logical networks, every slice should come up with tailored activities for a specific use case scenario [26]. In order to support multiple business-driven application scenarios concurrently over the same data centers, 5G NS posed through possibly autonomous and self-contained networks which are versatile and fully interactive. In order to effectively achieve planned network services, decomposing the current large monolithic network functions paired with different modern systems to various smaller modular network interfaces based on software with variable complexity is crucial. These cloud-native functional requirements would then be assembled upon request in versatile forms to produce various network segments that support various 5G standards. NS would allow companies in building various types of care for different vertical businesses, encouraging them better optimize everyone's services. [27, 28].

**Table 1.** List of abbreviations.

| No. | Abbr. | Meaning of the words | No. | Abbr. | Meaning of the words |
|---|---|---|---|---|---|
| 1. | 5G | Fifth Generation of mobile communication | 22 | URLLC | Ultra-Reliable and Low Latency Connectivity |
| 2. | 4G | Fourth Generation of mobile communication | 23 | mMTC | massive Machine Type Communication |
| 3. | 3G | Third Generation of mobile communication | 24 | HD | High-Definition |
| 4. | NS | Network Slicing | 25 | AR | augmented reality |
| 5. | NaaS | Network As A Service | 26 | VR | virtual reality |
| 6. | IoT | Internet of Things | 27 | FMC | fixed mobile convergence |
| 7. | NFV | Network Function Virtualization | 28 | 5GPPP | 5th infrastructure public partnership project |
| 8. | SA | Service and System Aspects | 29 | IMT | International Mobile telecommunication |
| 9. | WG | Working Groups | 30 | QoE | Quality of Experience |
| 10. | OSS | Operation Support System | 31 | RAN | Radio Access Network |
| 11. | BSS | Business Support System | 32 | PLC | PlanetLab Central |
| 12. | MANO | Management and Orchestration | 33 | NSF | National Science Foundation |
| 13. | MEC | Multiple-Access Edge Computing | 34 | E2E | End-to-End |
| 14. | IoV | Internet of Vehicle | 35 | MVNO | Mobile Virtual Network Operator |
| 15. | SLAs | Service-Level Agreements | 36 | CriC | Critical Communications |
| 16. | 3GPP | 3rd Generation Partnership Project | 37 | EV2X | Enhanced Vehicular to Everything |
| 17. | KPI | Key Performance Indicator | 38 | MIoT | Massive Internet of Things |
| 18. | eMBB | enhanced Mobile Broadband | 39 | WWRF | Wireless World Research Forum |
| 19. | IETF | Internet Engineering Task Force | 40 | 5GAA | 5G Automotive Association |
| 20. | ETSI | European Telecommunication Standardization Institute | 41 | COVID19 | Coronavirus Disease 2019 |
| 21. | NGMN | Next Generation Mobile networks | 42 | IoE | Internet of Everything |

### 1.1 Scope and Contributions of This Paper

This survey aims to offer and provide a deep understanding about the new advancements in network slicing which will give the readers a comprehensive, advanced and available solutions regarding NS in 5G that can be benefited during this COVID19 outbreak.

First, we will highlight how 5G can fulfill the demands of mobile network consumers and how effective is it. Then we will briefly define network slicing in order to provide the reader an idea about the concepts related to 5G network slicing in general and how will it enable a tremendous effect in the future of mobile networks. Before we deeply go to the main topic, we will give the service requirements of 5G in both business and quality drivers. We will also cover many aspects in this technology including 5G NS concepts, applications etc.

This paper as well presents 5G NS architectures and implementation by providing some projects. On the other side, standardization activities of 5G NS is given in this paper. Moreover, challenges in network slicing are given.

Generally, this survey aims to gather and highlight the critical architectural aspects which could be an interest to readers from all over the world, as well as service providers or industries. It gives multidimensional information to those who have desire in understanding the 5$^{th}$ generation's enabling technologies. It can also help to those who are in need to do research projects and implementations about this topic. For readers to have desired attention, this survey paper provides Table 1 that lists all abbreviations and their meanings.

### 1.2 Comparison to Similar Surveys

The technology related to 5G NS was firstly proposed by Next Generations of Mobile Networks (NGMN) [29]. Since then several survey studies have been carried and proposed. These papers include [26, 27, 30–34] and [35]. In paper [26] it proposes network slicing for 5G systems, it reviews some of the achievements of 3GPP, Service and system aspects (SA2) and RAN3 Working Groups (WG) which relates to the genesis of NS and previous 4$^{th}$ Generation of mobile network technical solutions. This paper proofs how NS shall be put into real networks and highlights some wanted steps to additionally contribute on this technology. The main goal of that article was to highlight the 4G endowment on NS and also evaluates the condition of 5G system standardization. Lastly it highlights the main open points in 5G standardization. On the other hand, another survey that carries similar topic has been proposed in [32] which gives a general view about how NS plays an important role in SDN and NFV. Some clear definitions of NS and its enabling ideas like SDN and NFV is provided, also the evolutionary values SDN and NFV for NS architectures are given in it. The paper also focuses on the architectural analysis of NS which includes OSS/BSS, (MANO) and operation and management.

In 2017 A study of NS in 5G was also proposed in [31] which the core of it is value is to provide a clear explanation about the existing knowledge of network slicing in 5G. The aim of the paper was to look other available works on NS in 5G ideology and also verifies the obstacles that need to be addressed. The authors also gave some 5G architectural proposals to highlight the crucial advantage that NS is predicted to play in providing the requirements of different use cases. In [30] Network slicing and softwarization survey

was presented, which highlights some major aspects that identify network slicing as the backbone of the rapidly growing 5th Generation of mobile network technology. This study elaborates NS concepts by an end-to-end point which details the historical heritage, the main ideas, some of the empowering technologies and elucidations and different use cases of NS. The study has also given some details about particular slicing elucidations for different sections for 5G systems. Moreover, A review that is composed of architectures and future challenges about NS was proposed in [27]. The study provides survey about current solutions related to 5G NS, they have also provided a validation of 5G system softwarization and slicing patterns which includes some major theories, history and variety of Applications.

On the other hand, they have provided some tutorials regarding to 5G NS enablers that include SDN, NFV, Multiple-access Edge Computing (MEC) and many other. A comparison to different 5G architectural approaches was also presented. This study also evaluates the standardization of NS about 5G systems. In [33] NS as enablers of 5G service survey is proposed which provides a review of the standardization efforts of NS and identifies big obstacles for mobile operators. Another survey is presented in [34] this covers solutions for all network domains as well as management of network slices. Lastly a survey which is about resource slicing in virtual wireless networks was proposed in [35]. This study focuses definitions of problems, discussing challenges and analyzing how SDN and NFV can assist in the slicing. Below is a Table 2 which summarizes all similar studies with description.

### 1.3 Organization of the Paper

The remaining part of this article is arranged as the follows: Sect. 2 Covers all service requirements of 5G which will include in both quality requirements and business drivers of 5G. In Sect. 3 Network slicing concepts and use cases including definitions, history and applications will be covered. Network slicing architectures and implementation shall be covered in Sect. 4. In Sect. 5 standardization efforts in 5G network slicing will be covered which we shall look different standardizing efforts from different industries. Challenges and future work and conclusions will be given on Sects. 6 and 7 respectively. Figure 1 also gives a detailed summary about the organization of the paper and provides all the sections we will cover.

## 2 5G Industry Trends and Requirements

The 5G systems was not designed only as infrastructure to the “Internet of Things” (IoT), but as a way of giving rise to an enormous size of new technologies, instilling in forthcoming telecommunications an everlasting vitality. IoT needs funding for a variety of servicing categories like Telehealth, e-Health, e-Education, Internet of Vehicle (IoV), Smart Buildings, organizational Safety, Environmental checking etc. Such services would drive IoT’s rapid growth and encourage the connectivity of billions of systems connected to the network, that on the other hand comes up with the “Internet of Everything (IoE)” dream particularly over the vertical markets [36].

5G service requirements are clustered mainly into these categories: a) performance requirements, including things like Speed, throughput, coverage, availability and so on, b) Functional requirements like service assurance, isolation, security e.t.c. c) Operational requirements like charging, billing, Key Performance Indicators (KPI) which is monitored to assure Service-Level Agreements (SLAs) [37].

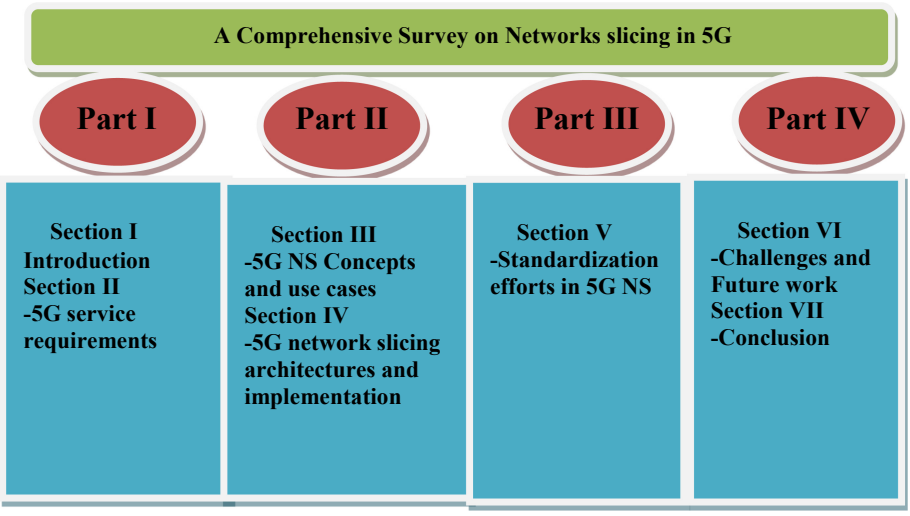


**Fig. 1.** Organization of the paper

### 2.1 Performance Requirements

The networks proposed in 5G period fell to three common schemes: Ultra-Reliable and Low Latency Connectivity (URLLC), enhanced Mobile Broadband (eMBB), and Massive Machine type communication system (mMTC). The eMBB specializes on broadband services such as HD clips, VR, augmented reality AR, and FMC networks.

URLLC works on services which are prone to latency, like self-driving, remote surgery or drone control. MMTC focuses on services with high link density specifications, like those popular in smart cities use cases. Each situation requires for a completely different network [38].

Summarizing all the requirements provided by 5GPP on 5G vision [39], IMT-2020 vision [40, 41] and [42] gives a conclusion to these points: Low latency (1 ms delay), 1000x bandwidth, Increase number of connected devices, Availability up-to 99.999%, Reliable Secure connection [43], Coverage perception of 100%, Service continuity [44], reduced energy usage in the network, Long-life battery up-to ten years [45] and Quality of Experience (QoE) [46–48].

### 2.2 Business Drivers and Vertical Industry Requirements

5G is expected to provide service into different business ecosystems which shall give innovative services and high network competence to the newly industry shareholders. Hence, it requires to adapt business models and new partnerships.

The role in which 5G will play in the market that it provides through virtualization and slicing include:

1. Cloud drivers: They offer computation and storage resources to their consumers including resources of cloud like Amazon's web service Elastic Computing cloud, Google Kubernetes and Linux's Openstack.
2. Infrastructure providers: Facilitate both physical network infrastructure and software resources.
3. Application providers: Provide many applications and services to their end consumers based on the demand they have.
4. Verticals: Cover many services to their third parties to utilize cloud and network resources from network operators and cloud providers.
5. virtual network operators: Works for infrastructure distributers to either compliments of its own capacity and/or coverage.
6. Service brokers: Mapping requests that came from application providers, it acts as mediator for mapping the services.

Connection between these partners could be done through resources from clouds and networks.

NS technology is one of the promising business enablers for 5G, providing increased network coverage to third party organizations in reliable way, promising an supplementary revenue for infrastructure, vendors and cloud distributors [30]. Table 3 also gives summarized information about the different requirements of 5G.

## 3 5G NS Concepts and Applications

### 3.1 NS History

Since IBM [49] has introduced it is first operating system (CP-40) in 1960s which supported virtual memory and time sharing, network slicing concepts is heavily linked to virtualization concepts [50, 51]. In computing, the design offered number of simultaneous users approximately up to 15 to individually use and work with separate hardware and software [52]. Hence, virtualization had generally adapted by data centres in 1970s and 1980s in which a virtual is created from a physical entity through methods of software then it introduced the idea of virtual networks through network resources, different platforms for computers and storage devices [50].

Overlay networks were proposed in the late 1980s Logical links linked network nodes to come with a Digital network running on growing fitness infrastructure. The overlaying systems were a previous way of cutting the network definition as they incorporate variety of tools of Control domains thus QoS is guaranteed to lastly end-users.

**Table 2.** Summary of available surveys

| Ref | 5G performance requirements | 5G Business drivers and vertical industry requirements | NS concepts, history and principles | 5G NS Standardization attempts | 5G NS architectures and implementations | NS Impact on COVID-19 |
|---|---|---|---|---|---|---|
| [26] | × | × | × | × | ✓ | × |
| [32] | × | × | × | × | ✓ | × |
| [33] | ✓ | × | × | ✓ | ✓ | × |
| [31] | ✓ | × | × | × | × | × |
| [34] | × | ✓ | × | × | × | × |
| [35] | × | × | ✓ | × | × | × |
| Our work | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Since they are adjustable, overlay networks don't have control and network programming Reviews. Reviews. In the nineties and the beginning of 2000s, Active and programmable network with a centre operating system that could give frameworks for resource control was presented. After that various principles such as PlanetLab USA (2002) [53] was adopted MyPLC [54].

Software package that enables distributed virtualization giving users the ability to obtain isolated usage of a unique slice. In this scenario a definition is given to what a slice is, it a u nit with specific allocated resources, these resources can either be a computing power or storage on hosts or other resources remaining in namespaces.

The development didn't stop in there, National Science Foundation's (NSF) GENI project initiatives pushed forward testbed development [55] by advocating studies on a clean condition network in consideration of combined resources and mobile network territories. Researchers got opportunity to run their experiments after SDN technologies were come to hand in 2009.

### 3.2 Concepts and Principles of 5G NS

NS relates to splitting a real network into many networks; it can be adjusted to your needs and configured for certain application set, or customer set through using leverage technologies on cloud computing and virtualisation. Shared physical resources on the network could Be dynamically, effectively and logically planned Slices of networks that related to changes of user demands. A slice of 5G system contains a group of Combined system functions and conditions for a particular application or profession type.

Network slicing promotes multiple distributed self-contained infrastructures in addition to a usual physical infrastructure universal scale engaging a reliable stakeholder environment which enables technically and businesses advancement to embed physically and/or logically built network and cloud's resources into a configurable, open software-disposed multi-tenant network environment [56]. The general concept of 5G

NS architecture is to include specialized tasks required for the particular use case traffic to be handled. Network slices have customized capabilities necessary for the corresponding services, also it has the ability to reshape the changing needs.

In accordance to the definition provided by NGMN [3], NS is mainly composed of three layers:

a. Service Instance Layer: which stands as the end user services or trade services which could be supported. Every service represents a service instance.
b. Network Slice Instance Layer: encompasses the network slice instance which could be provided. A network slice instance gives the network features which are needed in the service instances.
c. Resource Layer: promotes virtual or physical resource and network function which is necessary to build network slice instances.

Network slicing have the following main ideas which shape the principles and associated operations with each principle filling a demand:

1. Automation: This principle allows an on-demand configuration of NS while there is no need for fixed contractual deal and manual involvement. This operation enables third parties to create and place a slice from the network with the desired capacity, latency, jitter, etc.
2. Isolation: this is a prime part of network slicing which provides a guaranteed security and performance for each slice tenant [57].
3. Customization: guarantees that the provided resources are efficiently utilized with the requirements of the tenant [58]. This would be realized from a network which considers the abstracted configuration, on a data plane tailored service network functions, o the control plane that considers the introduction of operations, protocols and policies, and lastly on a service with value added.
4. Resource elasticity: this principle is perceived using an successful non-disruptive re-provisioning structure in which the provided network resource is categorised as on or off. It promises that the needed SLAs are regardless of the specified geographical location [59].
5. Programmability: This gives third parties the ability to manage the given network slice resources which includes network and cloud resources [60].
6. End-to-End (E2E): the property of E2E provides delivery of the allocated network slice from the providers to the end-users.
7. Hierarchical Abstraction: this need the NS to introduce an additional layer of Abstraction. To achieve this a separate logical and physical set of network resource and virtual network function are created [61]. This then facilitates the provision of service from the slice service to be the prior one.

### 3.3 Applications and Use Cases of 5G NS

5G's main goal addresses many upcoming operations and business needs for the future, the 3GPP started a (SMARTER) called study in the 3GPPP Services Working Group

**Table 3.** Summary of 5G Service requirements and Business drivers.

| | 5G service requirements and business drivers | Objectives |
|---|---|---|
| Performance requirements | Speed and Latency | Features that provide instantaneous network connectivity with 10 Gbps data rates and low latency of 1 ms |
| | Security, Service continuity and coverage | Features that provide robust, reliable and resilient support of services for all consumers |
| | Connectivity | A Feature that provides wireless connections for sensor and actuator bearing hundreds of thousands of devices per cell |
| | Quality of Experience (QoE) | A feature that gives minimal interference, disruptions, and fluctuation in network quality and performance |
| | Reduced Energy usage and battery life | Features that will enable billions of cellular enabled IoT applications to be connected with minimal energy usage and longer battery life |
| Business drivers | Cloud providers | Facilitate consumers with enough cloud services, storage resources and computation |
| | Infrastructural providers | provide both Hardware and software services/Connectivity to different kinds of consumers |
| | Application providers | Propose high data rates application providers a performance that will meet their demands to make sure rewarding user adventures |
| | Vertical | Provides many services to non-telecom industries, utilizing networks and cloud resource from different vendors and cloud distributors |
| | Vertical network operators | Compliment their own capacity and/or coverage by hiring resources from infrastructure providers, they also gain network coverage if they don't have physical infrastructure |
| | Service brokers | Communicates with physical network, gathers expedient details and behaves as a medium mapping the service for request from vendors |

SA1. Several applications targeting new trade departments or distinct business chances which should be opened with the advent of 5G were grouped and mentioned. These categories include;

i. eMBB which provides high data rates to survive from vast traffic capacity and user equipment connections per area.
ii. Critical Communications (CriC) [62] that focuses on the critical mission services like the protection of people, management of disasters and emergencies, AR/VR and tactile Internet [63]
iii. Enhanced Vehicular to Everything (EV2X) which mainly supports on welfare linked issues like autonomous, collision avoidance, remote driving and vehicle platooning by giving them direct vehicular communication.
iv. Massive Internet of Things (MIoT) [64] that mainly focuses on the connectivity for multiple amount of devices which are stationary with non-time critical service requirements, yet though it needs security, configuration and operational simplicity.

A multi-tenant architecture linked using OpenFlow switches above a virtual overlay network is provided on Fig. 2. This application shows how multiple tenants can have a similar accessibility to virtual slices, each tenant for example Mobile Virtual Network Operator (MVNO) has an access to a network slice without an interference from others.

NGMN also shares a large number of use case that should take part the emerging 5G technologies that mainly focus on; Enhanced broadband access every place and in

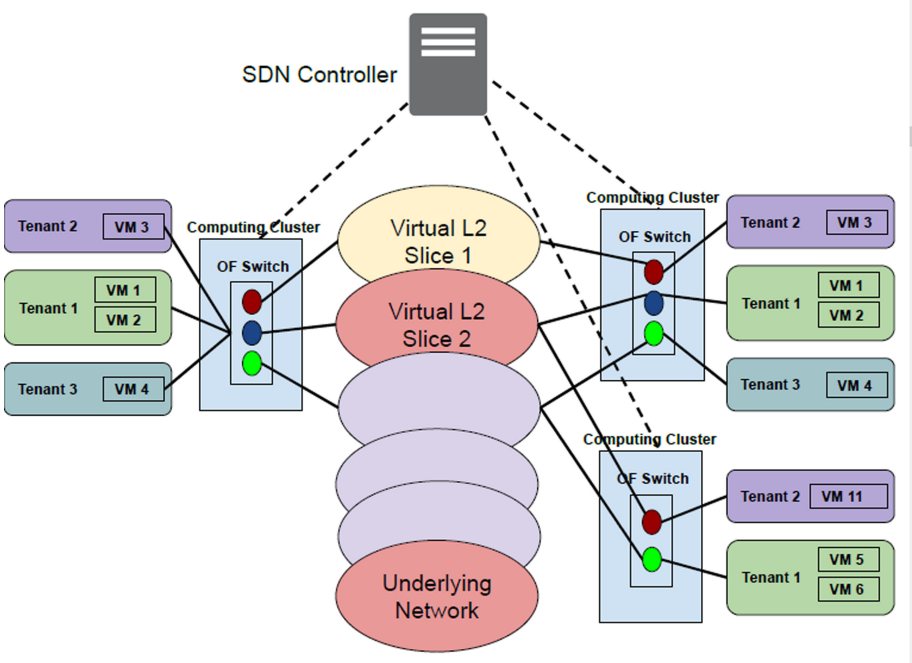


**Fig. 2.** Network slicing use case [67].

heavy traffic areas, higher customer mobilities, massive IoT, lifeline communication, acute real-time connection, ultra-reliable communication [65], broadcast-like services, light weight communication [66] and multi-connection.

### 3.4 Key Enabling Technologies of NS

The NS technology as mentioned in previous sections is among the key features of NFV and SDN. These two are the leading enhancing technologies that support network slicing.

**Software Defined Networking (SDN)**
Software-defined network (SDN) is a contemporary context of network design for the forthcoming time, these networks could be configured or controlled; two features can be managed and divided in the Internet and wireless communication and different areas, solving the problem in the network is not versatile and static, speeding up the new application of network implementation and online implementation [22]. SDN's key role is the ability to control network planning, open and versatile call forwarding separation and centralized control, the transfer of plane and control plane separation of network equipment, flexible scheduling and network traffic control, network automation and intelligent management.

**Network Function Virtualization (NFV)**
NFV was first presented by the biggest TOs in the world, such as AT&T, BT and DT. In line with ETSI, this concept of NFV was known as a network architectures that transform the behaviours that network are designed and managed by using existing IT virtualization ideas and integrating proprietary hardware-based networks into common business equipment [68].

## 4 NS Architecture and Implementation

### 4.1 Implementations and Architectures of NS

In a simple manner network slicing is to benefit from virtualization technologies, i.e. NFV or SDN for the architecture, partitioning, organization and optimization of physical infrastructure of communication and computation resources into multi-logical networks to enable a variety of services [69]. A 5G slice promotes a specific type of connection communication service in a unique method of solving the C- and U-plane for these services. For that purpose, a 5G slice consists of number of 5G network functions and specific RAT settings which are integrated for the specific case of use or business model [29]. Thus, a 5G slice will contain all domains of the network: software packages that attempt to operate on cloud nodes, specific transport network implementations that enable versatile placement of functions, a separate radio configuration or a unique RAT, along with configurations of 5G devices. Not most slices get the same functionality, but other functions might even be lacking in several of the slices that seem important for a mobile network today.

An example of several 5G slices operating on the same network concurrently is shown in Fig. 3. For example, by providing full-fledged functions distributed across the network, a 5G slice can be realized for regular smartphone use. It will be crucial for the safety, dependability and jitter of a 5G slice which serves autonomous use cases. At the cloud edge node, all necessary (and potentially devoted) software, such as the appropriate vertical model due to latency limitations, can be allowed. There are many devoted slices that can run simultaneously, and also as generic slice which offers easy connectivity with the maximum approach to reconcile with unknown use cases and congestion situations. The 5G technology will have flexibility which ensures end-to-end, and under all circumstances, operated and protected network operation, despite of the slices to be covered by the network. In order to achieve such a 5G architecture, the C- and U-plane functions must be clearly differentiated in compliance with SDN standards, with open interfaces established between the two. In addition, it is important to identify flexible interfaces among communication-specific and authenticate-agnostic functionality so that additional access technologies, including static and wireless, can easily be incorporated into 5G network in the coming years. Moreover, interaction across modules will allow multi-vendor reconfiguration of numerous uses.

### 4.2 5G Network Slicing Projects

Various collaborative research projects of 5G network slicing have been proposed and they are undergoing with each aiming to meet with the tremendous industry requirements that we have mentioned. Several standard bodies (i.e. IEEE, 3GPP, ITU), Associations (i.e. ETSI, TIA) alliances (i.e. NGMN and Wireless World Research Forum (WWRF) have admired some initiatives to running research on 5G and beyond future mobile networks. These research projects include: 5G Exchange (5GEx) [70], MATLIDA [71], SliceNet, 5GTANGO [72], 5GNORMA [73], SONATA, 5G-MoNArch, 5G!PAGODA [74], NECOS [75] and 5G-Transformer.

## 5 State-of-the-Art Standardization in 5G Network Slicing

Network effects prevail in telecommunications and thus systems must be interoperable in order to fully exploit the communications networks' capacity. In this context, technology standardization is crucial and the state-of-the-art standardization of network slicing must be analysed in such a way that both mobile operators and vendors know where to provide input covering their interested domains [33]. The current market discussions focused on the notion and demands of network slicing, evaluation of its impact on various levels or network stack layers (e.g., CN, the RAN, etc.). For example, from the vertical industry perspective; The 5G Automotive Association (5GAA) operates with several other automotive, technology, and telecommunications (ICT) companies to develop E2E ideas for sustainable mobility and transport solutions. To date, 5GAA WG5 has established the first workstream to Value the business model aspects of network slicing in the automotive sector. On the other hand, Manufacturing organization have been looking for the implementation and the development of smart Manufacturing solutions that are based on 5G.

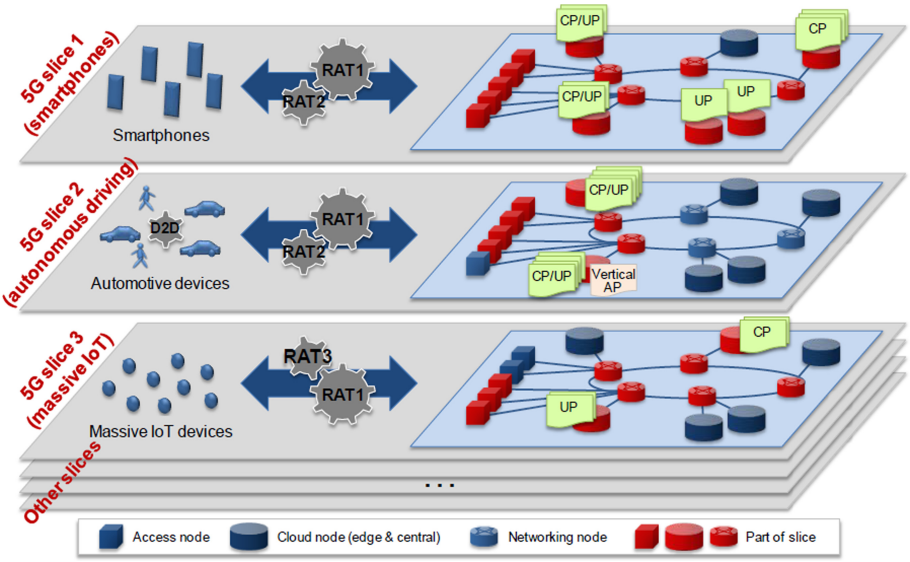


**Fig. 3.** 5G network slicing architectural implementation [29].

To cope with all these demands the operators were focusing on the exploration of the concepts, business drivers and high-level specifications of E2E Network slicing. The GSMA [15] Network Slicing Task Force (NEST) programme was started to reconcile slicing concepts, define slice types with distinctive advantages and simplify specifications for parameters and functionality. The NGMN [29] Alliance was the first to embrace the idea of network slicing as stated in its white paper, called "5G slicing" Since then the NGMN has established, consolidated, and communicated specifications for 5G network slicing and its architecture. As network slicing technology is among the forthcoming networking technologies, several organizations are associated with the standardization efforts. These efforts are generally categorized: i) Organizations approaching from the business point of view, Organizations approaching from technical aspects, Open-source organizations and Organizations that develop traditional standards. A summary of all standardizing bodies is provided in Table 4.

**Table 4.** Summary of standardization activities for 5G network Slicing.

| | Standardizing bodies | Coverage |
|---|---|---|
| From business point of view | GSMA | GSMA primarily encourages compatibility and roaming between mobile operators by identifying standardized technologies and guiding business/relationship principles (e.g., charging principles and roaming agreements) |

(*continued*)

**Table 4.** (*continued*)

| | Standardizing bodies | Coverage |
|---|---|---|
| | NGMN | NGMN focuses on technology architectures (for example, network slicing Design) allowing each use case is identified for 5G |
| From Technical Aspects | TIP | Telecom Infra Project (TIP) [79] aims to make network infrastructure quite accessible and therefore concentrates on implementation rather than on holistic design |
| | TMF | TM Forum (TMF) [80] assesses business strategies and network slicing situations, and is therefore likely to contribute to architectures addressing customer needs in the near term |
| | BBF | Broadband Forum (BBF) is an infrastructure forum focused on intelligent and faster broadband networks. BBF offers a virtualisation conceptual model for business/residential purposes together with virtual gateways |
| | xRAN | extensible Radio Access Network (xRAN) covers the overall architectural design and fronthaul networks which are becoming even more meaningful to small cell proliferation. It also seeks to make the network infrastructure quite widely available and cost-effective |
| From Open-source communities | ONF | Open Networking foundation (ONF) is an open-source entity that leverages SDN principles and disaggregation, it uses open-source systems and structured Standards to build operator networks. it focuses on applying SDN and NFV on transport networks (backhaul or backbone) by providing Central Office Rearchitected as a Datacentre (CORD) platforms |
| | OpenStack | OpenStack is an open-source organization that creates a datacentre-wide platform and API for controlling and managing diverse pools of computing, storage, and network resources. Hence, OpenStack is focused on mobile network datacentre-like environments |

(*continued*)

**Table 4.** (*continued*)

| | Standardizing bodies | Coverage |
|---|---|---|
| | ONAP | Open Network Automation Platform (ONAP) ONAP is a project of the Linux Foundation, working with AT&T. It provides a complete platform for real-time, policy-driven orchestration of virtual and physical network services and automation. Additionally, ONAP focuses on key features of the network and MANO |
| From Traditional standard development Organizations | 3GPP | 3GPP is a significant player in wireless telephony as it defines the wireless network architectural design and technologies. in under 3GPP, the Service and System Aspects (SA), Radio Access Network (RAN) and Core Networks and Terminals (CT) standardize network slicing for mobile networks |
| | IETF | IETF is a massive outdoor international community of network operators, service providers, vendors and researchers involved in the transformation of internet architecture and the effective operation of the Internet. In network slicing, IETF concentrates on the rearchitecture of network features, network slicing management systems, as well as slice analysis and benchmarking |
| | ETSI | ETSI NFV plays a key role in network slicing. ETSI NFV offers the architectural basis for NFV and generates relevant and related specifications. The reports have moved from pre-standardization research to comprehensive requirements with early Proof of Concept (PoC) activities and interoperability events (Plug tests) since their introduction in November 2012 |

## 6 Future Challenges for Network Slicing

This section elaborates the challenges in achieving an E2E slice, which in-turn migrates from physical networks to virtual networks. To achieve an End-to-End slice with the interoperability of different slices, there will be several challenges, these challenges are discussed in the following sub-sections.

### 6.1 Radio Access Network Interoperability, Scalability and Roaming Manner

The end-to - end design, not even just the RAN, should be expected to manage ambiguities in the radio interface yet at the same time guaranteeing customers service levels as accepted through business deals. There are previous solutions regarding to these matters which have been promoted and researched by the academia like the one of Eurocom, which radio resources are able to maximize the unallocated network resources by satisfying as much requests as possible in a given time [76]. Another example is Orion [77], It exposes a base station hypervisor to the physical base station's transitional data plane and the virtual data plane of the slices, where the virtual Control plane is a logically separate case assigned to the tailoring and management of the unique slice for every slice. Another major difficult is the roaming of network slices. Roaming is more significant in the Internet of Things (IoT) era, as it unlocks the maximum potential of network slicing to allow communication technology (e.g., cars, asset management, monitoring and business development for multi-national corporations). Major telecom operators have proposed trials for testing roaming in the network slicing environment. So that, to achieve these slicing scenarios it is very difficult and challenging task which needs the consideration of more studies.

### 6.2 Software Functions and Hardware of Network Interoperability

The interoperability of network functions and hardware can be ensured when there are standard approaches for network slicing. Indeed, the precise statement of open interfaces between some of the 3GPP-specified network nodes facilitated a multi-vendor atmosphere that encouraged innovation and creativity within traditional mobile networks [78]. In the age of network slicing, cellular networks are no exception to this, and interfaces between network software functions, hardware and various layers of the virtualisation of the network should be transparent and interoperable. 5GPPP also underlines the significance of interoperability, since different types of network slices coexist in a mobile network reaching from one layer to the next. Also, in the interoperability GSMA suggests for scopes to ensure virtual network functions and Hardware's interoperability these include: Software upgrade. Vertical integration, service assurance and network service deployment.

The interoperability allowed by standardized format of various network components is very important in in maintaining a multi-vendor ecosystem. It is very challenging to resolve difficulties regarding the interoperability importance in vertically examining the impact of software upgrade.

### 6.3 Movement from Physical to Virtual Networks and Development of Innovative Features

Mobile networks are mainly physical and there have been a lot of arguments and descriptions that assume these networks will totally migrated to virtual. There is a big challenge in this migration and we need to consider a lot about these migrations to make mobile networks virtualized. For commercial mobile networks, it is indispensable to maintain a versatile migration that assures reliability and performance of mobile networks.

To migrate from physical to virtual, the traditional mobile network operator's community should consider different and numerous stakeholders in network slicing standardization activities. Finally, network carriers would have the option of migrating various layers (network function, infrastructure and operations & management) in relation or in diverse sequential order. While order will not seem to make much difference on the surface, real experiences suggest migrating first then the other layers of infrastructure.

The adaption of network slice will also relate to the aspects from techno-businesses. Therefore, in order for the mobile operators to quickly adopt network slicing, attributes beyond that of modern mobile networks still have to be tackled and embraced through network slicing. The attributes must also provide for the generation of Increased income, and/or incremental implementation costs are expected.

## 7 Conclusion

Network slicing will worth encouraging various 5G applications and use cases. Although, network slicing provides innovative networking technologies like Software Defined Networking (SDN) and Network Function Virtualization (NFV), the complexity of cellular networks will potentially increase and operators will face greater challenges. This is similar to the complexity in standardizing the network slicing.

This paper has provided a clear and understandable and updated information about 5G network slicing and the impact it could have on COVID-19, first we have drawn the requirements of 5G including both service and quality requirements from vertical industries and added the business key drivers of 5G. We also comprehensively provide a state-of-the art history, definitions, concepts and principles of 5G network slicing. In addition to these parts several applications and use case were added from several projects, also, the key enabling technologies of network slicing were mentioned which are SDN and NVF with each giving clear descriptions. Thus, the implementations and architectures of network slicing were presented in this study to give the readers a complete information from these technologies. Furthermore, a great deal of standardization efforts was summed up with other sections providing various standardizing bodies and their aims in this technology including 3GPP, IETF, ETSI, ONF, TMF, TIP NGMN, GSMA, OpenStack, xRAN and BBF. To conclude the study, state-of-the-art future challenge were presented by looking various aspects including Interoperability between mobile networks, scalability of radio access networks, Roaming, interoperability of software functions and hardware, migration from physical to fully virtual and the development of innovative features.

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