Network Slice Provisioning Approaches for Industry Verticals:
New Business Models and Feasibility

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ABSTRACT

Network slicing is widely studied as an essential technological enabler for supporting diverse use case specific services through network virtualization. Industry verticals, consisting of diverse use cases requiring different network resources, are considered key customers for network slices. However, different approaches for network slice provisioning to industry verticals and required business models are still largely unexplored and require further work. Focusing on technical and business aspects of network slicing, this article develops three new business models, enabled by different distributions of business roles and management exposure between business actors. The feasibility of the business models is studied in terms of; the costs and benefits to business actors, mapping to use cases in various industry verticals, and the infrastructure costs of common and dedicated virtualization infrastructures. Finally, a strategic approach and relevant recommendations are proposed for major business actors, national regulatory authorities, and standards developing organizations.

KEYWORDS

5G, Communications Ecosystem, Management Exposure, Network Slicing, Network Virtualization, Service Provisioning, Strategic Approach, Value Networks

1. INTRODUCTION

Traditionally, connectivity operators have focused on voice, text messaging, and data services and have relied on adding more networking capacity to serve an increasing number of devices. The ongoing digitalization in industry verticals demands new and evolved use case specific services with vastly different connectivity requirements than before. Industry verticals consist of multiple tenants, with multiple use cases that have been served using multiple dedicated physical networks in the past,

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leading to economic and management overheads. With the advent of 5G and network virtualization, it is possible to deploy multiple network slices over the same physical network instead of deploying multiple dedicated physical networks.

Network slicing is enabled by network functions virtualization and software-defined networking, to create end-to-end virtual networks consisting of the required network function chains (3GPP, 2021b). These network functions can be deployed on off-the-shelf server hardware in dedicated or common virtualization infrastructures. With advancements in various industry verticals, 5G network slice provisioning must not only meet connectivity requirements but also provide specialized network and management exposure between business actors per slice.

The global market for network slicing is expected to reach 5.8 billion USD by 2025, and will be led by enterprise and industrial applications (Mind Commerce, 2020). While network slicing brings new opportunities for the telecommunication business it also requires the business actors to allocate, utilize, and manage network resources efficiently, flexibly, and cost-effectively. Novel business models are needed to be developed for network slicing in order to provide new services (Khan, Yaqoob, Tran, Han, & Hong, 2020). The new business models need to be applicable to existing customer segments and emerging industry verticals with multiple tenants. The support for multi-tenancy through a network slice broker, as a new actor has been studied by (Samdanis, Costa-Perez, & Sciancalepore, 2016). Network slice provisioning over multiple network domains has been studied in (Badmus, Matinmikko-Blue, Walia, & Taleb, 2019; Montero, Agraz, Pagès, & Spadaro, 2020). Further, operators can utilize different network slicing strategies for interworking between local and wide area networks (Walia, Hämmäinen, Kilkki, & Yrjölä, 2019). However, uncertainty exists over the distribution of business roles and interfaces between business actors and required business models.

The business actors involved in different use cases require different management exposure to request, configure, and manage their network slices. Further, different business interfaces can be enabled between the business actors to facilitate their respective policy and charging (3GPP, 2019). While network slicing is a key enabler, it requires both feasible technical architectures and business models. Telecommunication business needs re-engineering as the virtualized network resources can be provided with different management exposure between business actors, who can flexibly participate by applying alternative approaches for network slice provisioning. Thus, the main research aim of this article is to develop new business models for 5G network slice provisioning.

The main contributions of the article are as follows:

- Develops new business models for network slice provisioning.
- Compares the feasibility of the developed business models for different business actors.
- Maps the required slice types and business models to use cases.
- Compares the costs of dedicated and common virtualization infrastructures.
- Provides strategic approach and recommendations.

The rest of the article is organized as follows. Chapter 2 provide relevant background, by reviewing the standardization related to network slice provisioning, and an overview of various industry verticals, use cases, and opportunities for network slicing. Chapter 3 develops new business models for network slice provisioning. Chapter 4 compares their feasibility, maps them to slice types and use cases from various industry verticals, and compares costs of dedicated and common virtualization infrastructures. Chapter 5 provides a strategic approach towards applying network slicing and relevant recommendations for major business actors, standards and regulatory authorities are proposed, followed by conclusions in chapter 6.

2. BACKGROUND

Standards Developing Organizations (SDOs) such as 3GPP, ETSI and commercial organizations such as GSMA and NGMN have contributed to network slicing standardization. NGMN proposed a three-layer model, consisting of a service instance, slice instance, and resources layer, and that different domains of the network can be utilized to form end-to-end slices (NGMN Alliance, 2018). GSMA introduced generic slice templates defining slice attributes to instantiate slices (GSMA, 2019). ETSI proposed virtual network slice instance to be composed of slice subnet instances composed of virtual network function chaining (ETSI, 2017). 3GPP, the main SDO responsible for 5G specifications, defined slice types and the required network functions for slice selection and management (3GPP, 2021b). The 5G core is defined by a service-based architecture to enable dynamic selection of network functions per service.

2.1 Service-Based Architecture

5G Service-Based Architecture (SBA) follows the principle of separation of network entities into network functions, based on the services they perform, to enhance modularity, flexibility, and scalability (3GPP, 2021b). Further, the separation of Control Plane (CP) and User Plane (UP) network functions enable their independent deployment, scalability, and management (3GPP, 2021c). Thus, compared to previous generations, 5G better supports virtualization as Virtual Network Functions (VNFs) can be independently deployed in the cloud, providing independent scalability and management, and potential cost savings through virtualization.

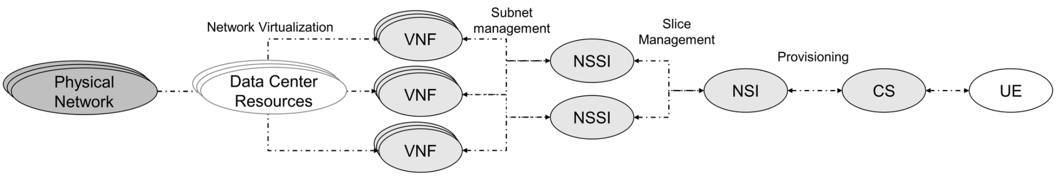
5G SBA includes new functionalities such as Network Exposure Function (NEF), Network Slice Selection Function (NSSF), and network slice management and orchestration functions, namely, Communication Service Management Function (CSMF), Network Slice Management Function (NSMF), and Network Slice Subnet Management Function (NSSMF) (3GPP, 2021b). The management functions provide the ability to expose management capabilities at different levels. NEF provides exposure between internal and external network resources and sharing information related to network functionalities to third parties (3GPP, 2021b). Network and management exposure are relatively new concepts necessary to enable dynamicity in configuring and managing network slices enabling new business relationships in a multi-actor ecosystem (3GPP, 2018; Ting, Lin, Shen, & Chang, 2019). Through NEF, other business actors can be exposed to available network functionalities for configuring network slices. The required network functions form the constituents of Network Slice Subnet Instance (NSSI). Further, NSSIs can belong to different network domains creating the end-to-end Network Slice Instance (NSI). The NSSF is responsible for selecting the network slice to be provisioned to slice customers.

2.2 Network Slice Provisioning in 5G

Network Slices in 5G are selected based on identifiers consisting of an 8-bit Slice/Service Type (SST) for the slice type and an optional 24-bit slice differentiator to differentiate among slices of the same SST (3GPP, 2021d). Further, user equipment can request 8 slice types at the same time. 3GPP has standardized five SSTs: enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC), massive Internet of Things (mIoT), Vehicle-to-Anything (V2X), and High-performing Machine Type Communications (HMTC), with V2X and HMTC being recent additions to the commonly known three types (3GPP, 2021b). These SSTs differ in service requirements such as bandwidth, reliability, latency, mobility, and density of users.

Based on the requested SST, and customer's subscription data, NSSF selects the suitable NSI. The network slice provisioning is managed through CSMF, NSMF, and NSSMF that follow a producer-consumer relationship (3GPP, 2018). The CSMF is responsible for managing Communication Service (CS) and translating CS requirements to NSI requirements. The NSMF is responsible for managing

Figure 1. Network Slice Provisioning



NSI and translating NSI requirements to NSSI requirements. The NSSMF is responsible for managing the NSSIs and instantiating NSSIs with required VNFs. The network slice provisioning architecture is shown in Figure 1. Each use case can be provisioned with the requested slice type(s) using the standardized slice types as defined in (3GPP, 2021b) or configuring the slice templates as defined in (GSMA, 2019) or by defining new slice types.

The VNFs can be deployed in virtualization infrastructures that are dedicated per actor or common for multiple actors. Edge computing and micro data centers can be deployed to enable low latency and faster processing of data closer to customers (Bruschi, Davoli, Lombardo, & Sanchez, 2018; Zhao et al., 2019). The number of slice types to be provisioned depends on the number of services and customers, while multiple services can use the same slice type, given they meet the requested service constraints. The provisioning of a network slice for a use case requires setting up a Service Level Agreement (SLA), including an agreed-upon exposure to resources and management interfaces. Additionally, business actors should be able to select required management roles in end-to-end slice provisioning.

2.3 Industry Verticals, Use Cases and Opportunities

An industry vertical consists of multiple latency critical and non-critical use cases that require different slice types (3GPP, 2021a). The smart factory vertical includes use cases, such as manufacturing, mobile robots, and logistics. The smart grid vertical includes use cases such as, power generation, distribution, metering, and fault detection. The smart city vertical consists of use cases such as, mobile broadband, public safety, and road traffic management. These industry verticals include existing well-known use cases currently provisioned over different physical dedicated networks, for example, mobile broadband, logistics, and public safety, served using 3G/4G, Long Range, and Terrestrial Trunked Radio (TETRA) technologies respectively. Adoption of cellular networks by industry verticals has been increasing in recent years (Finley & Vesselkov, 2019). The public safety use case is also planned to be fulfilled by cellular networks for high bandwidth requirements to enhance critical data sharing such as emergency location/situation awareness and drone assistance (Erillisverkot, 2019; Marabissi & Fantacci, 2017). The existence of different dedicated networks per use case points to the existing technical and business opportunity to provide network slices against deploying dedicated physical networks. With the widespread use of broadband and emergence of new use cases, operators enjoy significant economies of scale and scope, to provide network slices cost-effectively. In a fully automated network slicing scenario serving multiple use cases, the costs of network slices are significantly lower than that of dedicated networks (Nokia Bell Labs Consulting, 2019).

3. BUSINESS MODEL DEVELOPMENT

As different industry verticals and business actors advance in digitalization, it is crucial to develop business models considering both technical and business aspects (Venkatesh, Mathew, & Singhal, 2019). The network slice management functions can be utilized by different actors in different deployment scenarios (3GPP, 2020). Further, different business interfaces can be enabled between the business actors to facilitate policy and charging based on services and roles performed (3GPP, 2019). The interfacing for management exposure can occur at the CS, NSI, or NSSI level, providing different levels of management control to business actors (3GPP, 2018). From a business perspective, such modularity enables structured service portfolios, reduces complexity, improves service creation/differentiation, and enables faster development of new service offerings, providing value to multiple business actors through service usage (Voss & Hsuan, 2009).

3.1 Method

The introduction of a new product or service requires the development of feasible technical architectures and business models for value creation. The technical architectures required for enabling the services are often defined by standards. The capabilities of the technical architecture are realized through key technical components and interfaces. However, uncertainties exist over the distribution of business roles to be performed by business actors for value creation. Business actors can perform one or multiple roles or multiple actors an perform overlapping roles. In such a case, the Value Network Configuration (VNC) method can be applied to investigate alternate configurations of identified technical components, business roles, and business actors as well as required interfaces between actors (Casey, Smura, & Sorri, 2010). After describing new business models using VNC method, the feasibility of each model is studied, followed by mapping of use cases and slice types to required business models, and cost comparison for dedicated and common virtualization infrastructures.

3.2 Technical Components, Business Roles, and Business Actors

The main technical components and required business roles for network slice provisioning (specifically operation, provisioning, and management) are summarized in Table 1.

Business roles performed by traditional telecommunication business actors need to be redefined for network slice provisioning, with the addition of some new actors. Further, a clear distinction between operators and network slice providers is required because network slice provisioning opens the possibility for the distribution of overlapping roles to distinct business actors. The business actors for network slice provisioning are described as follows:

- **Connectivity Operators:** Typical connectivity operators own and operate the physical network infrastructure, including Radio Access Network (RAN), Edge and Core network. Further, the operators own spectrum licenses and can lease their capacity as part of the network slice provisioning to involved business actors. The connectivity operator's network resources are

Table 1. Technical components and business roles for network slice provisioning

Technical Component	Description	Business Roles
Physical Network Infrastructure	Includes Radio Access Network (RAN), Edge and Core network.	-Operation, provisioning, and management of physical network resources
Virtual Infrastructure	Includes VNFs deployed in the data center resources.	-Operation: ownership and operating data center resources -Provisioning: provisioning data center resources to specific actors -Management: network virtualization, managing the VNFs and their exposure to specific actors
Network Slice	Includes communication service, slice and subnet instances.	Operation, provisioning, and management for -Communication service management utilizing CSMF -Network slice management utilizing NSMF -Network slice subnet management utilizing NSSMF
User Equipment (UE)	The user equipment can belong to any slice customer use case.	-Network slice usage, request and monitoring based on level of management control.

virtualized as VNFs in data centers. The connectivity operators can offload the virtualization of network resources to virtual network operators, making a virtualized network for connectivity available to slice providers, to configure and provide the requested slices to slice customers. National, regional, and international mobile operators are existing examples of connectivity operators. A connectivity operator can act as a slice provider by being responsible for designing, provisioning, managing, and terminating the network slices.

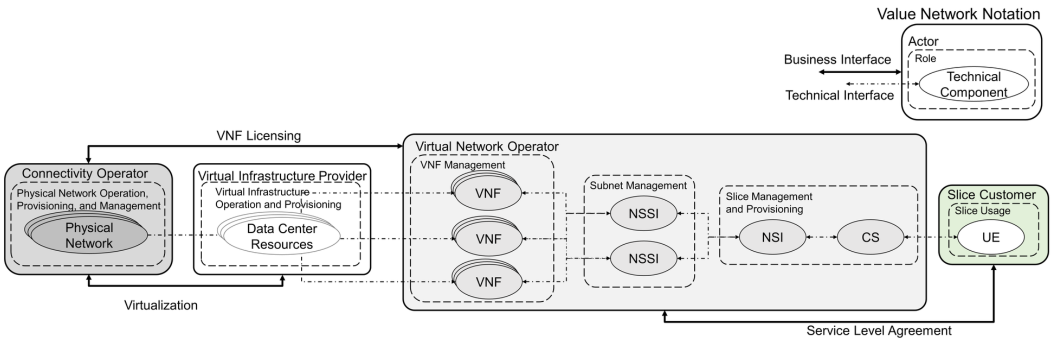
- **Virtual Network Operator:** A virtual network operator is responsible for the virtualization of connectivity operator's network resources to VNFs and managing the VNFs deployed in data centers. Virtual network operators can own parts of the network, for example, the core network. A virtual network operator can be an independent actor or a subsidiary of a large connectivity operator. Alternatively, a virtual network operator can be a joint effort from server vendors and software vendors to develop an open-source 5G core, simplifying resource management across multiple networks (Robuck, 2020). Further, a slice provider can act as a virtual network operator and vice-versa.
- **Network Slice Providers:** A slice provider provisions the requested network slices according to the SLAs. Slice provider is a new business actor taking up the roles of provisioning the slices with the required computing, networking, and storage resources and service-specific applications. The slice provider can also be a joint venture between existing business actors, since network equipment vendors, server hardware and software vendors take major roles in network virtualization. These actors may also eventually provision network slices to slice customers. An industry vertical may act as a slice provider to manage its local network by interfacing directly with the connectivity operator and virtualization infrastructure provider. A connectivity operator or a virtual network operator that provisions use case specific network slices can also become a slice provider.
- **Slice Customers:** Slice customers request access to network slices from the slice providers. The slice customer-provider relationships depend on the business model. For example, an industry vertical consisting of specific use cases would establish an SLA with the slice provider who either owns and operates the network or only configures and provisions the slices. Alternatively, a slice customer can take up slice management roles.
- **Virtualization Infrastructure Provider:** The virtualization infrastructure providers own data centers and are responsible for operation and provisioning of the data center resources. They provision their computing, storage, and networking resources to operators, slice providers, and customers. Operators and slice providers can take up the roles performed by virtualization infrastructure providers, given the investment and operational capabilities. Existing actors such as Google, Amazon, Microsoft, and other national and regional data center providers can be virtualization infrastructure providers, keeping in mind the public and private context of the provided services. The data center providers can further offer virtualization and management support to operators (Bicheno, 2020).

3.3 Network Slice Provisioning Business Models

Different network slice provisioning models can be developed based on different levels of management exposure and control between the connectivity operators, slice providers, and slice customers. Network slice provisioning follows a producer-consumer relationship using the CSMF, NSMF, and NSSMF for CS, NSI, and NSSI respectively. Following this approach, three network slice provisioning business models are developed:

- **Operator driven:** Connectivity operators and virtual network operators utilize network slicing to optimize their network internally while provisioning the communication service, as shown in Figure 2. The customers buy a subscription with their respective SLAs, and the operators

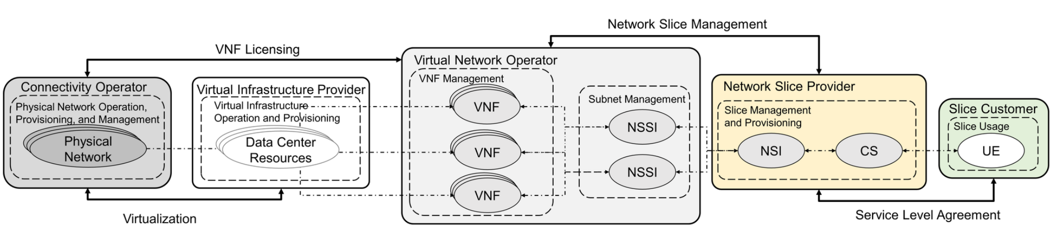
Figure 2. Operator driven network slice provisioning



optimize the network resources, VNF placement, edge caching, and centralized/distributed processing. The connectivity operator's network resources are virtualized either in own data center or provisioned by the virtualization infrastructure provider. This business model is similar to the traditional business model since customers do not configure and manage slices but can request changes in the communication service. The operator-customer interfacing occurs at the CS level. This model does not include infrastructure and revenue sharing with slice providers, as connectivity operators/virtual network operators directly serve slice customers. This business model is suitable for large operators with primarily broadband slice customers.

- **Network Slice Provider driven:** Operators offer their resources to slice providers, who in turn, provide use case specific slices to the slice customers as shown in Figure 3. The operators exercise control by limiting management exposure to slice providers. The slice provider exercises control based on an agreed level of exposure and share of resources. The operator controls the NSSMF, being responsible for VNFs and subnet management, while the slice provider controls the NSMF and CSMF, being responsible for slice management and provisioning of the service to slice customers. The operators can provide their subnets to multiple slice providers. The slice provider can be an independent new actor or a joint venture by network equipment vendors, server hardware vendors, software developers, for example, a joint venture between HPE, Intel, and Linux (Robuck, 2020). Slice customers can be provided limited control to monitor and request changes. The slice customers benefit from well-tailored slices without the management effort. The operators then charge the slice providers based on their share of resources, and the slice providers sell tailored slices to their slice customers. The operator-slice provider interfacing occurs at the NSI level, while the slice customer-slice provider interfacing occurs at the CS level. The contractual relationship between the slice provider and the operator requires an agreed level of management exposure in addition to traditional SLAs.
- **Slice Customer driven:** The slice customers have access to configuring network slices with the virtualized network resources offered by the operators. The operators provide the customer

Figure 3. Network slice provider driven network slice provisioning



with an agreed level of control over network slice configuration and management as shown in Figure 4. The operator-slice customer interfacing occurs at the NSSI level. The customer in this business model takes up the roles otherwise performed by slice providers and partially by the virtual network operator. The customer takes control of CSMF, NSMF, and NSSMF functions, being responsible for communication service, slice, and subnet management. The operators are still responsible for physical and virtual network infrastructure but enjoy new revenue sources. The slice customer driven model is also suitable for micro-service architectures to enable more granular slice configuration. The customers and the operators establish an SLA, as well as an agreed level of management exposure to enable the required level of service and management control. The slice customer, for example, a public safety organization, can thus exercise control over the slice management over cellular networks (Erillisverkot, 2019). Further, the customers can build their own dedicated virtualization infrastructure or utilize required resources from other actors.

The above discussed business models are enabled by alternative network slice provisioning that can be applied for local and wide area, with single and multi-domain network resources, for serving both traditional customers and industry verticals. The business actors need to exercise agreed upon level of management exposure in addition to SLAs. The new business models can help create new revenue streams with different pricing options per use case based on resource usage, sharing, service levels, and offered level of management control. The feasibility of network slice provisioning depends on the experienced costs and benefits by the business actors in each business model and their applicability to use cases. Further, since virtualization infrastructures are a crucial building block for these business models, the costs of virtualization infrastructures also influence the strategic decision to build own data centers, share data center resources, or utilize required resources from an existing virtualization infrastructure provider.

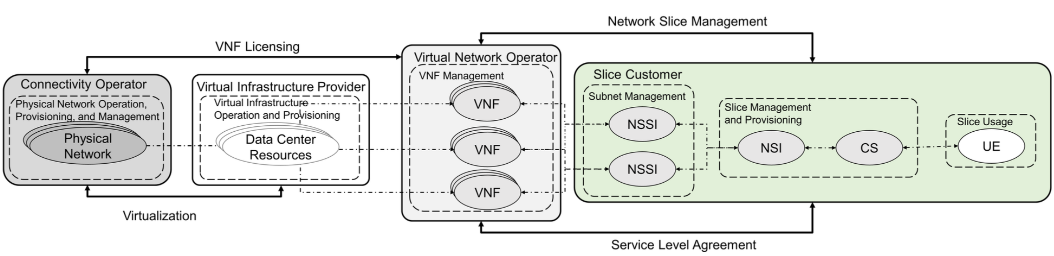
4. FEASIBILITY

The feasibility of the business models is studied in three parts: the overall costs and benefits for the business actors, the mapping of business models to use cases belonging to various industry verticals, and quantitative cost analysis of common and dedicated virtualization infrastructures.

4.1 Costs and Benefits for Business Actors

Each business model requires respective technical capabilities and investments and offers corresponding revenue opportunities. Operators can enjoy new revenue sources through slice provider and customer driven models given they enable the network and management exposure to other actors. Slice providers can enjoy different levels for charging the customers based on the requested services and priorities, given they devote resources to slice management. Similarly, slice customers can enjoy high dynamicity

Figure 4. Slice customer driven network slice provisioning



in slice configuration, given they possess the required technical and management capabilities. The business actors can employ the business models selectively in a multi-actor ecosystem, based on the costs and benefits summarized in Table 2.

4.2 Mapping Business Models to Use Cases

For mapping the new business models per use case, widely known industry verticals, smart factory, smart grid, and smart city, are considered, with a mix of critical and non-critical use cases. For example, smart grid involves power generation from the power companies as well as consumers, requiring high reliability and low latency communications between sensing and distributing power accordingly. The slice customer driven business model is a suitable option for dynamically configuring slices for such critical use cases, while slice provider or operator driven model can be suitable for less critical metering and billing. Further, the existing use cases served over dedicated networks could enable business actors to initiate the adoption of network slices by leveraging the existing business opportunities. The operator driven model is suitable for mobile broadband since customers do not require direct control of slice management. The slice provider driven model is suitable for wide area logistics, as a slice provider can provide seamless connectivity over large geographic areas across multiple operators' networks. The slice customer driven model is suitable for public safety to enable management exposure and control for dynamic configuration of critical service requirements.

The business model mapping for various use cases involved in the three verticals and possible slice types is listed in Table 3. It should be noted that this list is not exhaustive, and different combinations are possible depending on the service constraints from customers and deployment scenarios. Further, net neutrality might restrict some OTT services from social media and other content providers to

Table 2. Comparison of costs and benefits for business actors in each business model

Actor	Business Model	Costs	Benefits
Operator	Operator driven	-Physical and virtual network costs	-Internal network optimizations
	Slice Provider driven	-Physical network costs	-Offloaded slice management -Increased network utilization through resource exposure to slice providers -Additional revenue source based on share of resources
	Slice Customer driven	-Physical network costs -Low internal network optimizations	-Offloaded slice management
Slice Provider	Operator driven	-	-
	Slice Provider driven	-Slice management costs	-High management control over shared resources -Multiple charging levels based on requested services and priorities
	Slice Customer driven	-	-
Slice Customer	Operator driven	-No management control	-No management effort
	Slice Provider driven	-Low dynamicity in slice configuration	-Tailored services
	Slice Customer driven	-High management effort	-High dynamicity in slice configuration

Table 3. Network slicing business models per use case

Industry Vertical	Use case	Network Slice Type					Business Model		
		eMBB	mIoT	URLLC	V2X	HMTC	Operator driven	Slice Provider driven	Slice Customer driven
Smart Factory	Manufacturing/Assembly		x	x		x			x
	Mobile Robots	x		x	x	x			x
	Augmented Reality	x		x					x
	Wide Area Logistics		x		x			x	
	IT Operations	x					x		
Smart Grid	Power generation		x	x					x
	Power distribution		x	x					x
	Metering		x					x	
	Fault detection		x	x					x
Smart City	Mobile Broadband	x					x		
	Over-The-Top services	x					x		
	Public Safety	x	x	x	x	x			x
	Video Surveillance	x						x	
	Road Traffic Management		x	x	x			x	

best-effort internet and possibly the operator driven model. The involved business actors and National Regulatory Authorities (NRAs) must collectively agree on specialized services to restrict throttling, so that only specialized services which cannot be served using best-effort internet are allowed any network optimizations (Frias & Pérez Martínez, 2018).

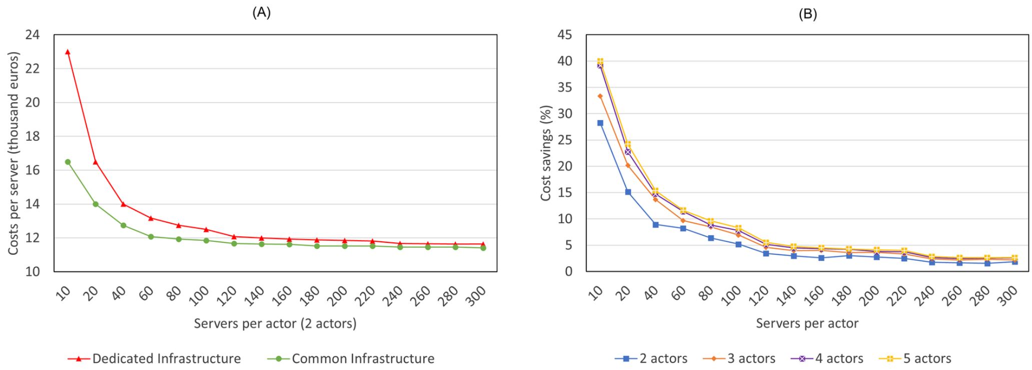
4.3 Common vs Dedicated Virtualization Infrastructures

In a multi-actor ecosystem, the virtualization infrastructure can be dedicated per actor or common for multiple actors. In a dedicated infrastructure all equipment is dedicated per actor, while in common infrastructure, only the servers running the required VNFs are assumed to be dedicated per actor, while the supporting equipment in the infrastructure is shared between multiple actors.

The main components considered for cost analysis are the servers, racks, cabling, access switches, aggregation switches, and core switches. A typical top of rack implementation is assumed for the data center where servers are connected to an access switch placed on top of the rack, connected to aggregation switches, further connected to core switches. Here we assume a deployment of 2 core switches, 8 aggregation switches, that can support up to 408 access switches, 408 racks, 9792 servers, with 24 servers per rack, as described in (Panduit, 2013). Thus, if 1-24 servers are required 1 rack is installed and if 25 servers are required 2 racks are installed and so on. The average capital costs from a data center deployment used for calculation are for servers (10000 euros), racks & cabling (20000 euros), and switches (10000 euros) (Lahteenmaki, Hammainen, Zhang, & Swan, 2016). Further, for direct comparison it is assumed that equal number of servers are required per actor.

First, two actors are considered and number of servers per actor are scaled up, infrastructure costs are calculated and normalized per server as shown in Figure 5 (A). The common infrastructure is cheaper than a dedicated infrastructure per actor as it offers higher economies of scale even with a small number of actors. Next, the cost savings of common vs dedicated infrastructure with varying number of actors, are shown in Figure 5 (B). More actors utilizing a common infrastructure leads to

Figure 5. Cost comparison between dedicated and common infrastructure for two actors (A) and Cost savings of common infrastructure vs dedicated infrastructure for varying number of actors



higher cost savings per server. The actors requiring small number of servers can achieve significant cost savings through common virtualization infrastructure.

While the cost savings for an actor requiring large number of servers are low, the actor might still opt for common infrastructure, for example, based on site building costs, availability of potential use cases, customer base, and demand. A common virtualization infrastructure will be especially beneficial in geographical areas where the customer base is small, and virtualization requirements per actor are small. In addition to cost savings leveraging economies of scale, a common virtualization infrastructure offers management benefits as a common resource pool can support unified resource management in a multi-tenant environment, enable better resource utilization and statistical multiplexing as the resource scaling follows overall user demand rather than scaling per use case. It should be noted that the above calculations are limited to investments costs for servers, racks, cabling, and switches, and inclusion of use case dependent operational costs, such as site rental, electricity, software licenses, infrastructure management, and maintenance are expected to make common infrastructure an even more economical choice.

5. STRATEGIC APPROACH AND RECOMMENDATIONS

Network slicing transforms traditional business models from network-for-connectivity to network-of-services. Network slices can be modularized with resources from various domains and be replicated from service-to-service. Such modularization can help manage demand heterogeneity, complexity, scalability, and customization. The developed business models enable modularity for new service creation and differentiation using a unified underlying infrastructure. The business models also enable new business actors to participate and compete in service provisioning without physical network ownership. The business actors can create new revenue streams and exercise different pricing options per use case based on resource usage and sharing, offered service and management control. Thus, the adoption of a model for a use case is essential to the strategic approach of the business actors. Further, the adoption of supporting virtualization infrastructure can be influenced by the size of the actors, use case requirements, density of customers in certain geographical locations, technical and managerial expertise, and financial constraints.

The business actors must also decide on the number of slices and slice types. A high number of slices can produce management overhead, while a lower number of slices might not meet the demanded constraints. While four slice types have been included in standards at the time of writing, actors can define additional slice types. While the network can support hundreds of slice types and optional differentiations, a UE can request a maximum of eight slices at a time. Thus, the slice types to be provisioned depend highly on the customer base and operational capabilities of operators and slice providers. Strategically, operators can offload the burden of configuring slices to slice providers and verticals/customers. Further, multi-actor cooperation and multi-technology interworking is required to enable network slicing for public and private networks with non-standalone and standalone 5G deployments.

The authors recommend:

- Inter-SDO cooperation to achieve full end-to-end standardization for network slicing over multiple network domains.
- Business actors should leverage the existing business opportunities in the use cases currently served over different dedicated networks while building up infrastructure and expertise for new and upcoming use cases.
- Business actors should start by provisioning the standardized slice types and gradually add complexities to support further differentiation.
- Business actors should utilize common virtualization infrastructure to leverage economies of scale.
- Operators, slice providers and NRAs should work closely to identify and define specialized services vs. best-effort internet services, to maintain net neutrality for basic services.
- NRAs to enforce operators and slice providers to provide guaranteed level of service and management control to critical use cases through network slices.

6. CONCLUSION

Network slicing provides new opportunities for use case specific service provisioning. The article provides an overview of recent standardization efforts related to network slicing. Based on the management exposure and control between business actors and customers, three new business models were developed: operator driven, slice provider driven, and slice customer driven. The business models identify and define the required distribution of business roles for slice provisioning and define network slice provider as a new business actor.

The existence of multiple dedicated networks based on different technology standards points to the opportunity for 5G network slicing to fulfill use case specific demands over the same physical network infrastructure. Different business models are suitable for different use cases in various industry verticals. Further, a common virtualization infrastructure provides cost savings and can improve overall resource utilization.

With 5G networks being capable of supporting hundreds of slices, the operators and slice providers should carefully select and gradually expand their slice types further from already standardized types, if needed. Further, regulators and standards organizations have an essential role to play to enable the adoption and innovation in network slicing, as highlighted in the recommendations.

CONFLICTS OF INTEREST

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