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The use of 5G slicing for public and private networks

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Contents

Definition of terms

Defining key terms is an important starting point for the rest of the study and for its practical implications.[1]

Network Slicing (NS). Network Slicing is a technology that enables service providers to create virtual networks optimised for the specific needs of particular users or applications. This concept allows the physical network infrastructure to be literally divided into virtual segments that can be managed independently and provide specific levels of performance, throughput and security. The original English term (well-established in professional practice) is used interchangeably with the Czech term ‘network slicing’ (not widely used in practice), or simply ‘NS’ for short.

Slice / Segment. An independent logical network running on the same physical network infrastructure. Each slice/segment is an isolated end-to-end network tailored to meet the specific requirements of a particular application.

SLA. A Service Level Agreement is a formal agreement between a service provider and a customer that specifies the level of service the provider is contractually obliged to deliver. It is therefore crucial to define the service level (Service Level).

Service Level is a measure of the quality of the services provided, specifying the expected performance and availability parameters of the service. It includes specific characteristics of the service, which may be functional or non-functional requirements for the service.

CSP. Communication Services Provider. Communication Services Provider (CSP) is a broad term referring to any company providing communication services. These services may include internet access, telephony, data transmission, cloud services and other forms of digital communication.

MNO. Mobile Network Operator. A Mobile Network Operator (MNO) is a specific type of CSP that owns and operates its own mobile network infrastructure. MNOs provide wireless communication services to end users via their own radio spectrum, transmitters and other mobile network infrastructure. They are responsible for the maintenance and management of the mobile network and the provision of services such as voice, SMS and mobile data.

[1] Note: Czech vs. English terms. As in many specialist fields, there are a number of terms in the field of 5G and related solutions for which no suitable Czech equivalent has been established. As a matter of principle, new terms will also be in English. This is the case with most specialist literature. It is therefore sometimes necessary to use the original English term, or to use both the English and Czech equivalents. Another reason for using English terms is to enable users to search for further information on the topic. This is straightforward when using the original English term; using an unestablished Czech equivalent could prove problematic.

Other terms:

Use case	Use case is a term that plays a significant role in the field of 5G applications for business digitalisation. It is therefore worth paying attention to its definition. The general definition of a use case is as follows: The term "use case" refers to a specific situation or scenario in which a product or service can be used. In software and systems engineering, a use case is a list of steps that typically defines the interaction between a so-called role and a system. The role may be a person or an external system. This definition is well known to those working in the field, but it is not suitable for the area of digitalisation and innovation. From the perspective of digitalisation, which is essentially an innovation process, it is appropriate to use a definition based on JTBD, or Jobs Theory. A use case can then be defined as follows: "A task that a company needs to carry out in order to achieve a specific result." This definition is suitable because it highlights the fact that a use case serves to achieve a specific outcome, or a range of different desired outcomes (such as increasing work efficiency, minimising risks to employees, minimising waste, etc.). Furthermore, it is possible to apply other suitable JTBD procedures to use cases, such as breaking the task down into stages and sub-tasks, creating a task map, increasing or decreasing the level of abstraction of the task, etc.
5G use case	A 5G use case is then a logical extension of the above definition: "A task that a company needs to carry out in order to achieve a specific result. And for which it makes sense, from both a technical and commercial perspective, to use 5G technology."
Case Study study	A specific implementation of a use case. Within the case study, a specific solution is used to fulfil the task defined in the use case. That is, a particular technology, products and services from a specific provider. Regardless regard to whether this implementation is already in commercial operation, or whether it is a demo implementation or a Proof of Concept.
Digitalisation	• Digitalisation usually focuses on specific processes or operations within a business. • The aim of digitalisation is to replace traditional, analogue and paper-based procedures with digital technologies in order to increase efficiency, reduce costs and improve operational management. • Digitalisation may involve automation, the transition to digital systems and processes, the elimination of paperwork, and the optimisation of specific areas of the business.
Business digitalisation	Digitalisation uses digital technologies to transform business processes and creates new opportunities for value creation. It involves converting existing analogue information into digital formats, as well as identifying processes that companies can perform more effectively using the latest technologies and tools. The aim of digitalisation is: • increase productivity, • to improve service quality and thereby creating a competitive advantage for the business through the use of information and communication technology (ICT) to streamline processes.
Digital transformation	• Digital transformation is a broader and more comprehensive concept that involves a complete overhaul of a company's strategy, culture and operations through the use of digital technologies. • It is a strategic approach that may involve restructuring business models, changes to business processes, the implementation of new technologies and the transformation of corporate culture. • Digital transformation need not be limited to specific operations; it can involve radical changes across the entire business ecosystem to ensure the business is better adapted to the digital environment and innovation trends.
Edge Computing	Edge computing refers to the practice of processing data near the edge of the network, where the data is generated, rather than in a centralised data processing facility. 'Edge' in this context can refer to any computing and networking resources along the path between data sources (such as IoT devices) and cloud data centres. Edge computing reduces the need to send data back and forth to a central server, thereby reducing latency and bandwidth usage.
MEC (Multi-access Edge Computing)	Multi-access Edge Computing (MEC) is a network architecture concept that enables cloud computing and IT service environments at the network edge. MEC brings computing resources closer to where data is generated and consumed, reducing latency, improving processing speed and enhancing the user experience. It is often associated with mobile networks, particularly 5G, where it can process data in the vicinity of mobile base stations or other network access points.

	The difference between MEC and Edge Computing: MEC is a subset of edge computing, specifically designed to optimise network architectures and improve application performance in mobile networks, including 5G. It focuses primarily on the mobile edge, extending services within mobile network environments. In contrast, edge computing is a broader concept applicable across various networks and industries, including IoT, manufacturing, healthcare and others, regardless of whether they are mobile or fixed networks. Integration with mobile networks: By its very nature, MEC is designed to integrate closely with the operation of mobile networks, particularly 5G, facilitating services such as content caching, real-time processing and context-aware services. Edge computing, whilst it can operate on mobile networks, is not inherently tied to these networks and can be implemented in any local environment. Both MEC and edge computing are key to the digitalisation of societies, particularly with the advent of 5G (see further in this document).
Vertical	In a business context, the term ‘verticals’ is used to describe the categorisation of businesses or industries according to their specialisation or focus on a specific market segment. Verticals are typically industries or sectors comprising businesses that specialise in a specific type , services or market segments.

Executive Summary

Network slicing (NS) has the potential to completely transform the paradigm of service provision in mobile networks. From the current model based on 'best effort' (i.e. without guarantee) and 'one-size-fits-all' (i.e. essentially the same service regardless of the application or user) towards a model that will enable the provision of services with guaranteed parameters and tailored to meet the requirements of various applications, customer segments and verticals. This will bring greater value to service users and, at the same time, may become a source of new revenue for communication service providers (CSPs); in the case of network slicing, these will predominantly be mobile operators.

For this reason, 5G network slicing is one of the most important innovations within 5G technology. It is on a par with enabling MEC/edge computing and making private 5G networks available to business customers. Whilst in previous generations of mobile services, progress was primarily marked by increased transmission speeds, in the case of 5G it is mainly changes in architecture and support for virtualisation and software-defined networks that enable these innovative services to be implemented. The introductory section of the study explains how network slicing works from the perspective of architecture, orchestration and the lifecycle.

From the perspective of network slicing types and their subsequent use, it is important to distinguish between deployment methods:

- NS as a virtual private network (VPN) on a public network. In this case, NS can serve as a form of private network that will likely be more accessible to small and medium-sized enterprises.
- NS for deployment across a wide area (wide area NS) on a public network. This method of NS will enable the provision of guaranteed services across the entire territory, for both businesses and end users.
- NS on a private 5G network. This will be appropriate for large-scale deployments such as transport hubs or for businesses utilising multiple distinct use cases.

NS in various forms will be a suitable solution for a wide range of use cases in the B2B, B2G, as well as B2C and wholesale sectors. For use cases implemented outside a limited perimeter and requiring mobile or flexible connectivity, NS is practically the only way to deliver guaranteed service parameters.

The most promising verticals for the use of NS are likely to include healthcare, energy, transport and logistics, agriculture, and the entertainment industry. NS can also play a significant role in the smart city sector and in services for emergency responders (PPDR). There are also interesting use cases for residential customers, for example in the fields of gaming or infotainment.

A key aspect of implementing network slicing-based services will be finding a suitable business model. This study presents several possible business models for corporate customers, residential customers and wholesale partners.

Identifying and implementing a functional business model will be one of the main challenges for the successful deployment of network slicing technology. Further challenges may lie in the areas of operational management, regulation and cybersecurity. Just as important a challenge as the technology itself and mastering it is the necessary shift in mindset among communications service providers. A paradigm shift in service provision will require a much deeper understanding of the needs of individual customer segments. It will therefore be important to create a functional ecosystem with partners focused on the relevant verticals.

To analyse network slicing and its future development, we conducted in-depth interviews with key players in this field, namely technology manufacturers and suppliers, mobile operators and representatives of the regulatory authority.

There is a general consensus within the industry regarding the potential of network slicing. However, there is still a relatively long way to go before this potential is realised. Next year, we can expect to see the first simple implementations of static slicing; only then will advanced dynamic and open models follow. All of this is contingent upon finding suitable business models that justify the high investment.

This study can help on this journey by presenting the benefits of network slicing and possible ways of utilising it to potential customers, particularly among businesses and institutions.

Management summary

Network Slicing (NS) has the potential to completely change the service delivery paradigm in mobile networks. It transitions from the current "best effort" and "one-size-fits-all" models to one that provides guaranteed service parameters tailored to meet the requirements of different applications, customer segments, and verticals. This shift will bring higher value to service users and can become a new revenue source for communication service providers (CSPs), mainly mobile operators.

5G network slicing is one of the most important innovations within 5G technology, on a par with enabling MEC/edge computing and providing private 5G networks to corporate customers. Unlike previous generations of mobile services, where progress was marked primarily by increased transmission speeds, 5G emphasises architectural changes and support for virtualisation and software-defined networks, which enable these innovative services.

From the perspective of the types of network slicing and their subsequent use, it is important to distinguish between deployment types:

- NS as a Virtual Private Network (VPN): This form can serve as a private network, making it more accessible for small and medium-sized businesses.
- 5G for Wide Area Deployment: This type enables guaranteed services across entire regions, suitable for both businesses and end-users.
- Private 5G Networks: Useful in large-scale deployments such as transport hubs or enterprises with multiple distinct use cases.

NS in various forms will be suitable for a wide range of use cases in B2B, B2G, B2C, and wholesale markets. For use cases requiring mobile or flexible connectivity beyond a limited perimeter, network slicing is virtually the only way to provide guaranteed service parameters. The most promising sectors for network slicing usage include healthcare, energy, transport, logistics, agriculture, and the entertainment industry. Network slicing will also play a significant role in smart cities and services for public protection and disaster response (PPDR), with interesting applications for residential customers in areas such as gaming and infotainment.

Finding the appropriate business model is crucial for the successful implementation of network slicing technology. Several possible business models are presented in this study for corporate, residential, and wholesale customers. Identifying and implementing a functional business model will be one of the main challenges for the successful utilisation of network slicing technology. Additional challenges include operational management, regulation, and cybersecurity. Equally important is the necessary change in the mindset of communication service providers, requiring a deeper understanding of the needs of individual customer segments. Therefore, it will be important to create a functional ecosystem with partners focused on the respective verticals.

To analyse network slicing and its further development, we conducted in-depth interviews with key players in this area, namely technology manufacturers and suppliers, mobile operators, and representatives of the regulatory authority.

The industry agrees on the potential of network slicing, but a considerable journey remains to fully realise it. Initial simple implementations of static slicing are expected next year, followed by advanced dynamic and open models, assuming suitable business models justify the high investments. This study aims to assist by presenting the benefits of network slicing and possible ways of its utilisation to potential customers, particularly companies and institutions.

1 Introduction to 5G Network Slicing

1.1 Objectives of the study

5G network slicing may be a suitable and, in some cases, the most effective solution for carrying out a range of tasks undertaken by companies, cities or state institutions as part of their digital transformation, when optimising their processes and providing services to their customers and users.

The use of this groundbreaking tool can therefore lead to increased competitiveness for businesses and improved quality of services provided by central and local government bodies.

However, this is only possible provided that

- potential users understand the capabilities of this tool
- communications service providers are able to identify a viable business model and deliver operationally efficient solutions
- there are no regulatory or other barriers to the application of network slicing in public or private 5G networks.

The aim of this study is therefore to provide the necessary information to all stakeholders to help promote the future use of network slicing:

- To familiarise potential users from businesses, local authorities or government institutions with the potential benefits of network slicing from their perspective, and to present them with suitable use cases and case studies that may inspire them in the implementation of their own projects.
- To help communications service providers find suitable business and operational models and draw inspiration from international implementations.
- To identify potential regulatory challenges for government bodies and propose ways to support use cases related to 5G network slicing.

1.2 Explanation of 5G network slicing

The advent of fifth-generation mobile networks heralds a new era of groundbreaking possibilities in the world of telecommunications. One of the key innovations with the potential to transform the way we understand and use mobile networks is the concept of network slicing. This technology brings flexibility, scalability and efficiency that were previously impossible, opening the door to a wide range of new applications and services.

Until now, in previous generations of mobile networks, a ‘one-size-fits-all’ approach has prevailed. In other words, all users and all applications received the same service, regardless of their often very different needs and requirements.

Note: An exception in previous generations of networks were attempts to ensure different levels of service using QoS/QCI management. However, this concept was not very successful, for the reasons outlined below.

In contrast, network slicing is a technology that enables communication service providers (CSPs) to create virtual networks optimised for the specific needs of particular users or applications. This concept allows the physical network infrastructure to be literally divided into virtual segments that can be managed independently and provide specific levels of performance, throughput and security.

In other words, 5G network slicing is a network architecture that enables the multiplexing of virtualised and independent logical networks on the same physical network infrastructure. Each network segment is an isolated end-to-end network tailored to meet the various requirements of a specific application.

In practice, network slicing means that a 5G network operator can create different virtual networks that guarantee the various parameters required for different customers and applications. The logical part of the network therefore serves only a specific purpose or a specific customer.

5G technology and networks built on this technology are designed to efficiently provide various services with very different Service Level Requirements (SLR). And the concept of network slicing plays a key role in ensuring this capability.

1.3 A brief history and the evolution of networks towards 5G network slicing

5G network slicing is a revolutionary concept that can provide potential users and customers with SLAs and guaranteed QoS. However, this is not the first attempt to deliver QoS to customers. Previous generations of mobile networks also sought to provide guaranteed QoS, as this is a logical requirement, particularly for certain types of customers and applications.

Here is an overview of how mobile networks have evolved towards 5G network slicing:

2G (GSM): 2G networks, introduced in the 1990s, focused primarily on voice services and simple data communication using circuit-switched data with limited support for data services at low speeds.

3G: This brought improvements in data capabilities with speeds suitable for web browsing and email. 3G networks introduced the concept of Quality of Service (QoS) more explicitly, but were still limited in their ability to distinguish between different types of traffic or offer reliable performance guarantees.

4G and LTE: Introduction of QoS classes.

4G networks based on the Long Term Evolution (LTE) standard introduced more sophisticated QoS mechanisms. In particular, the so-called QCI classes.

QCI is a mechanism in LTE networks that classifies data traffic into different categories (classes). Specific performance characteristics, such as packet delay, data transfer rate and priority, are defined for these categories. Each QCI class corresponds to a specific type of traffic (e.g. voice, video, real-time data, background data), which allows standardised QoS levels to be defined for that type of traffic in the LTE network.

The granularity of QCI is relatively coarse. Although it allows for differentiation between service types, it does not create customised network environments. Operators set predefined QCI levels that apply uniformly across services falling within these categories.

Although QCI classes represented a step forward in the provision of Quality of Service (QoS) in 4G LTE networks, they did not achieve a fundamental breakthrough in service delivery for several reasons. It is worth recalling these, given that 5G network slicing may face similar challenges.

Limited flexibility and granularity: QCI classes offer predefined QoS levels that are broadly applied to various types of traffic. This approach lacks the flexibility to adapt network behaviour to the specific requirements of increasingly diverse applications and services.

The static nature of QCI: The static nature of QCI settings means that once a specific QCI is assigned to a data flow, it generally retains that QoS level regardless of changing network conditions or application requirements. This inflexibility can lead to inefficient use of resources, where some services may consume more resources than necessary, whilst others may experience insufficient service levels during peak periods.

Complexity and scalability issues: Implementing QCI in various network scenarios can become complex, particularly as the number of users and services grows. Mobile network operators have often found it challenging to manage and scale QoS settings effectively without impacting overall network performance and the user experience.

Lack of end-to-end QoS guarantees: Although QCI is designed to meet certain QoS standards, it does not typically support explicit guaranteed SLAs. Performance may vary depending on overall network conditions and is not guaranteed individually for each service or user.

Evolving user expectations and technological advances: As digital technologies and user expectations have evolved, demand for more sophisticated and reliable network services has grown. Users and businesses increasingly expect network services capable of supporting a wide range of applications, from basic web browsing to interactive real-time gaming, Internet of Things deployments, and ultra-reliable low-latency communication (URLLC). The basic QCI framework was not designed to effectively handle such diverse and dynamic requirements.

Economic and operational constraints: From an economic perspective, the benefits of implementing advanced QoS management based on QCI did not always justify the operational complexity and associated costs.

LTE also introduced the concept of bearers, which are transmission paths with specific QoS attributes associated with them. Dedicated bearers could be established for services requiring guaranteed QoS, whilst default bearers would handle non-critical traffic.

Progress towards flexibility and scalability in 5G.

Further progress in ensuring QoS for users is made possible primarily by Network Functions Virtualisation (NFV) and Software-Defined Networking (SDN). These technologies, characteristic of 5G, have begun to transform the way network services are delivered and managed. NFV enables network functions to be managed as virtual instances running on commodity hardware. SDN provides dynamic management of network resources through programmability. These technologies have laid the foundations for more flexible and scalable network segmentation.

The initial concepts regarding network segmentation arose precisely from the possibilities offered by NFV and SDN.

5G network slicing takes the capabilities of previous generations of networks a step further by enabling operators to create multiple virtual networks (slices) over a shared physical infrastructure. Each slice can be tailored to meet the specific performance, security and latency requirements of various applications – from the Internet of Things and low-latency communications to high-speed broadband and beyond.

Guaranteed SLAs: A key difference from QoS in previous generations is that 5G network slicing supports explicit service level agreements (SLAs) that precisely tailor network performance to customer needs.

The 5G architecture and its slicing capabilities are standardised within the 3rd Generation Partnership Project (3GPP). These specifications detail how network slices are created, managed and decommissioned, thereby ensuring interoperability and consistency across different vendors and operators.

The progress towards 5G Network Slicing reflects a natural evolution of technology, similar to what we see, for example, in the field of IT infrastructure and cloud services. That is, a shift towards flexibility, efficiency and scalability, which enables the increasingly demanding and diverse requirements of users and their applications to be met.

2 How 5G network slicing works

2.1 Software-defined networks and NS architecture.

The transition from traditional network architectures to more modern, so-called software-defined ones aims to create systems that are efficient, flexible, scalable and high-performance. This progress is illustrated in Figure 1, which shows the key developmental steps in the transformation of mobile networks from a 'one-size-fits-all' approach towards a software-defined network capable of responding to the diverse needs of applications and users.

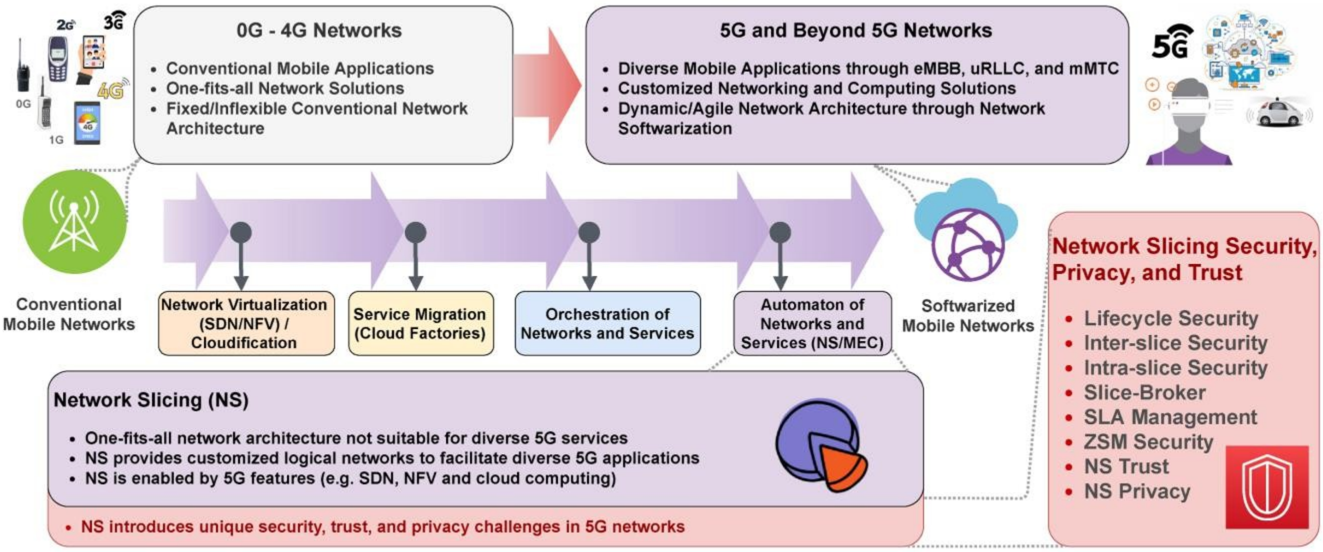

Figure 1: Evolution towards a software-based network enabling network slicing. Source: [2]

2.1.1 Steps towards the implementation of NS

Key steps in this evolution of mobile networks include[3] :

- **Network virtualisation and cloudification**: Here, network functions are transformed so that they can be managed as software rather than hardware. Key technologies in this area include:
  - Software-Defined Networking (SDN): This technology separates the control plane (which decides where data should be routed) from the data plane (which actually transmits the data). It enables software-controlled management and administration of the network.

[2] R. Khan, P. Kumar, D. N. K. Jayakody, and M. Liyanage, "A survey on security and privacy of 5G technologies: Potential solutions, recent advancements, and future directions," *IEEE Commun. Surveys Tuts.*, vol. 22, no. 1, pp. 196–248, 1st Quarter, 2020.

[3] P. Rost et al., "Mobile network architecture evolution toward 5G," *IEEE Commun. Mag.*, vol. 54, no. 5, pp. 84–91, May 2016.

- Network Function Virtualisation (NFV): This technology moves various network functions from specialised hardware and runs them as software on standard (commodity) servers. This makes the network more flexible and cost-effective.
- Cloud Computing: Network functions are moved to the cloud, meaning they can be accessed and managed online, rather than on physical devices at specific locations.

- **Service migration:** Once network functions have been moved to the cloud, network services are also hosted in the cloud rather than on local servers.
- **Network and service orchestration:** This involves the coordination and management of all the different parts of the network to ensure they work together seamlessly and efficiently end-to-end (E2E).
- **Network service automation:** Automation technologies such as Multi-access Edge Computing (MEC) and Network Slicing are used to improve network efficiency. MEC moves computing resources closer to the edge of the network, for example near mobile transmitters (RAN), to reduce latency and speed up data processing. Network Slicing divides the network into several virtual networks, allowing each part to be optimised for a specific type of service, thereby increasing overall performance

2.1.2 5G Network Slicing Architecture[4]

The general architecture of network slicing (NS) in 5G networks consists of three functional layers: the service instance layer, the slice instance layer and the resource/infrastructure layer. The network controller/orchestrator coordinates the operation of each layer to ensure efficient and effective management. These layers are shown in Figure 2.

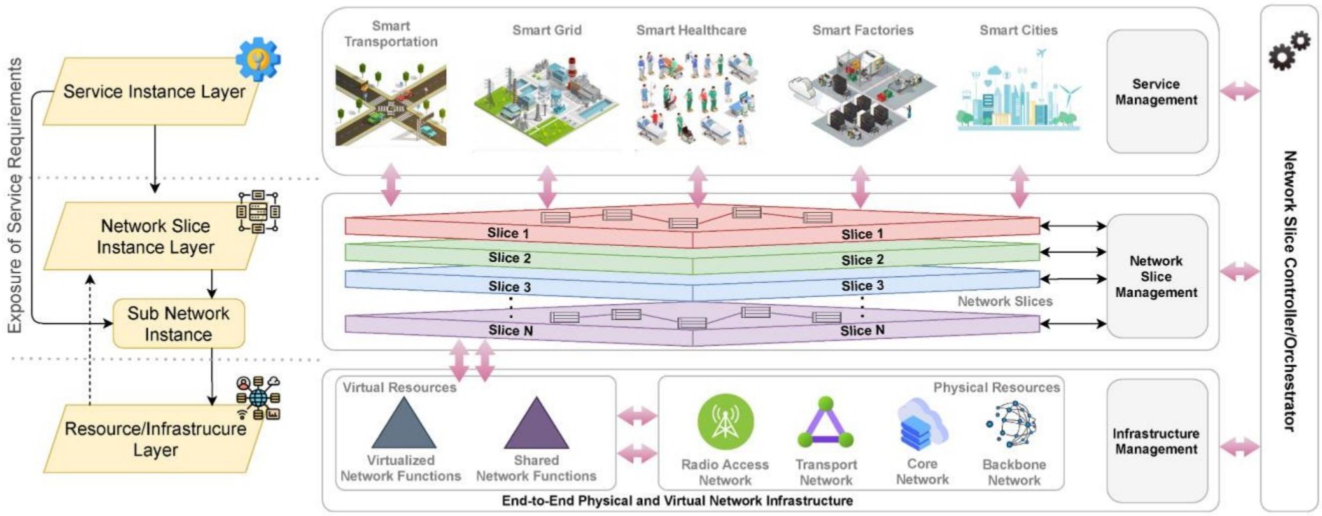

Figure 2: Network slicing architecture. Source: [5]

1. **Service instance layer**

The service instance layer is the topmost layer and provides services to end users. These services may be offered by a third party or by the network provider. The layer supports a service instance, the design of which is derived from configurations or templates. Each requested service is represented as a service instance that combines network characteristics according to SLA requirements, which are met by creating a suitable slice. This layer ensures that services meet the required performance and operational standards.

[4] C. De Alwis, P. Porambage, K. Dev, T. R. Gadekallu and M. Liyanage, "A Survey on Network Slicing Security: Attacks, Challenges, Solutions and Research Directions," in IEEE Communications Surveys & Tutorials, vol. 26, no. 1, pp. 534–570, First quarter 2024, doi: 10.1109/COMST.2023.3312349.

[5] *Description of the Network Slicing Concept*, NGMN Alliance, Frankfurt, Germany, 2016, pp. 1–7.

2. **Slice Instance Layer**

This is the layer situated between the service instance layer and the resources/infrastructure layer. This layer is responsible for creating and managing slices based on the requirements of the application layer. The network operator uses a slice blueprint to create a slice instance. These instances provide the required network characteristics for service instances and can be shared between different service instances. Furthermore, slice instances can share sub-network instances with other slices, thereby forming logical or physical network functions based on sub-network blueprints.

3. **Resource/Infrastructure Layer**

This layer is responsible for the provisioning and management of both physical and virtual network resources, such as connectivity, computing power and storage. The network functions present in the virtual network infrastructure create an end-to-end slice based on service requirements. Network operations configure these functions to manage the entire lifecycle of a slice, from its creation to deallocation when it is no longer needed. These network functions can be shared by multiple slices simultaneously for efficient resource utilisation, which increases the complexity of traffic management. These functions can run on physical or virtual resources available on the network.

4. **Orchestrator (network controller)**

The network controller/orchestrator interfaces with every layer in the NS architecture to effectively manage and coordinate their various functions. This ensures flexible and efficient slice creation, which can be reconfigured during different phases of the NS lifecycle. Key functions of the network controller include:

- End-to-end service management: Mapping multiple service instances according to SLA requirements to corresponding network functions that meet the service requirements.
- Virtual resources: Virtualisation of physical network resources to facilitate operations in managing the resources that allocate network functions.
- Slice lifecycle management: Monitoring slice performance across all layers of the architecture to reconfigure each slice to adapt to changes in SLA requirements.

2.1.3 Network slice lifecycle

The network slice lifecycle consists of four phases: the preparation phase, the commissioning phase, the operational phase, and the decommissioning phase.

1. Preparation phase.

The preparation phase includes:

- Creating and validating network slices based on customer requirements.
- Preparing the necessary network environment to support the network slice lifecycle.
- Planning the capacity of network slices.
- Deployment of network slices.
- Assessment of the specific requirements of each network slice.
- Identifying and preparing additional network requirements.

2. Commissioning phase.

Once preparation is complete, the commissioning phase follows, which prepares the network slice for operation:

- Allocation of network resources.
- Configuration of the slice to meet its operational requirements.

3. Operational phase.

During the operational phase, the network slice is active and managed via:

- Activation: This includes processes such as database provisioning and redirecting traffic to the slice.
- Supervision: Continuous monitoring of the network slice.
- Monitoring of key performance indicators: Continuous monitoring of the network slice based on key performance indicators.
- Modification: Includes tasks such as reconfiguration, upgrades, topology updates, scaling, and the association and disassociation of network slices.

4. Decommissioning phase.

This final phase involves terminating the network slice by:

- Returning allocated resources.
- Rolling back configurations from shared or dependent resources.
- Ensuring that all security and privacy vulnerabilities are addressed throughout the lifecycle, with a focus on inter-slice security, intra-slice security and SLA management, to ensure the security of the network and users.

2.2 NS Orchestration and Operational Management

NS orchestration and operational management can take various forms with differing levels of complexity.[6] Here are **three types of network slicing from a lifecycle management perspective**, which differ significantly in terms of complexity and orchestration requirements:

1. **Static / pre-configured slicing**

This involves predefined network segments that are configured based on the needs of specific use cases. The emphasis is on static configurations that can be reused in similar use cases.

2. Dynamic slicing

In this approach, network segments (slices) can be dynamically configured and optimised in response to changing requirements. This requires more advanced automation and orchestration capabilities.

3. Open slicing

The final step is to expose network segments to third-party developers, enabling them to build their own applications and services on the network. This requires open APIs and a fully mature ecosystem.

Enterprise customers can gain control over key parameters such as the number of connected devices, required bandwidth levels, security and latency within contractually agreed limits. The new flexibility and possibilities based on network slicing enable a 'Network as a Service' (NaaS) business model, which provides the customer with greater visibility, control and adaptability to meet their changing needs, as if they had their own network. For example, for a broadcaster, the operator's capacity could

[6] Ericsson study: 'Essential building blocks of E2E network slicing' (2023)

providing live video services could be expanded to meet the expected UL/DL bandwidth requirements generated by a major sporting event and the number of cameras needed to cover the event. Based on a prior commercial agreement between the customer and the network operator, the customer can make the required service changes on the fly via self-service, or by enabling or disabling HD video quality in targeted cameras with reliable and stable performance. By implementing virtualisation and orchestration, customers can gain control over their services.[7]

The orchestration and operational management of slicing is not merely a technical process (see the four phases of the lifecycle from a technical perspective described above), but also a business process. And a relatively complex one at that. It is illustrated in the following figure.

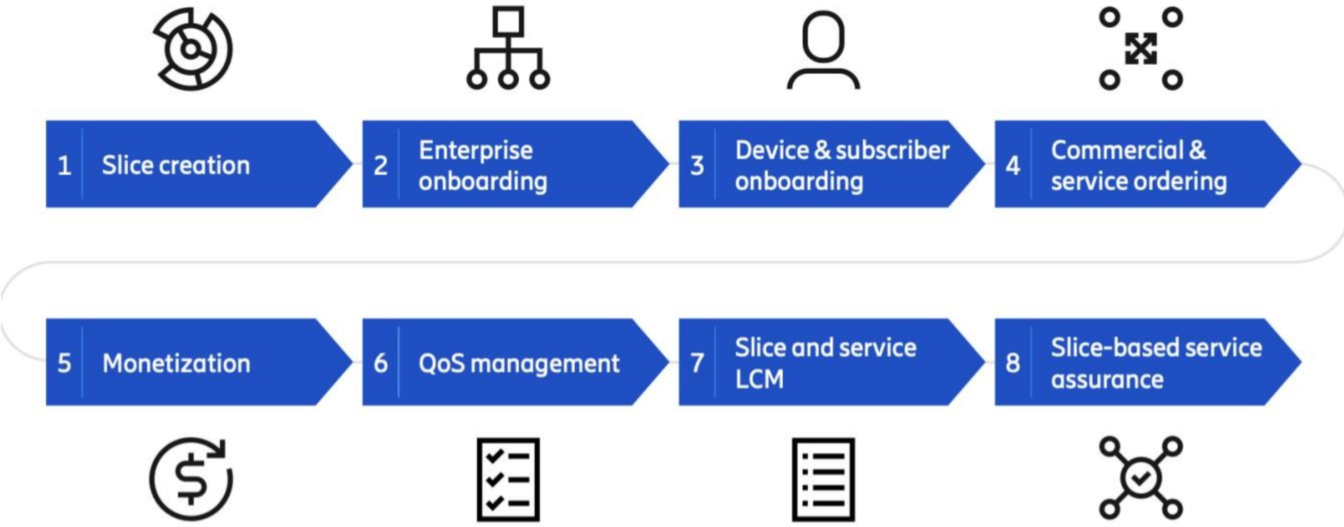

Figure: End-to-end (E2E) network slicing lifecycle management. Source: [8]

The individual phases of the lifecycle management process, and their respective content, naturally vary depending on the type of lifecycle management (static, dynamic, open). This is summarised in the following table.

[7] Ericsson study: 'Essential building blocks of E2E network slicing' (2023)

[8] Ericsson study: "Essential building blocks of E2E network slicing" (2023)

Process phase	**Static (pre-configured) slicing**	**Dynamic slicing**	**Open slicing**
Creating slices	Creating multiple slices and providing services on them; service templates are optional	Defining a network service and enabling service templates for the creation and dynamic orchestration of on-demand network slices	Creating slices and services using the API
Deploying companies	Deploying one or two organisations by manually configuring organisational parameters	Automatic provisioning of corporate users and other corporate parameters	Partner management (adding a partner, updating partner services) via the API
Deployment of devices and subscribers	Adding a range of devices and subscribers to new slices using an attribute (e.g. APN) in manual mode	Enabling the service catalogue and creating on-demand network slices based on data from the service catalogue	Provisioning subscribers via the exposed API
Service ordering and business management	Using the resource catalogue for basic order management.	Configuration, pricing and offering of network services from a single shared commercial catalogue	Exposing the commercial catalogue to application functions
Monetisation	Support for real-time billing via the SBI interface	Provides a common location for CDR generation and facilitates policy decision-making	Support for multi-party models (services provided by both the CSP and the enterprise) and various business models on a single invoice
QoS management	Enables pre-configured QoS parameters and their manual modification via the service slice type	On-demand modification of QoS parameters via the service catalogue	On-demand triggering of QoS parameter changes via API
Slice and service lifecycle	Enables basic operations (creation, read, update, delete) using a preconfigured slice profile	On-demand creation, update and deletion of network slices and related services using the service catalogue	On-demand slice lifecycle management via an external application using an API
Provisioning slice-based services	Retrieval of basic data for fault management and performance management for a preconfigured slice	Ability to specify KPIs that can be monitored for a slice and how these KPIs are calculated	Enables a standardised API for service consumption.

Within the NS commercial offering, the ability to provide services with defined parameters (SLAs), monitor these parameters and, where necessary, compensate the customer for non-compliance plays a key role. This is made possible by NS's advanced and automated orchestration:

Service design enables the creation of service templates and dynamically orchestrates network slices on demand within the service catalogue. Onboarding of a slice begins in the service catalogue, where it becomes a building block for a network service. A commercial product is then created in the commercial catalogue, and the products are made available for viewing via defined channels. When a customer selects a service based on a network slice and places an order, service ordering breaks the order down into all related technical commands and actions for the network activation provisioning and management layer. Through automation, it orchestrates the deployment of the network slice across all network domains and delivers the network services and resources that realise the commercial product offering. Finally, service monitoring tracks service performance and system status to ensure SLAs are met. This is achieved primarily through closed-loop processes and secondarily through notifications sent when key business KPIs are breached and customer compensation is required. SLA definitions and service level specifications are integrated with service orchestration and service monitoring and linked to the agreed commercial SLA with customers.

From a 3GPP perspective, functions ranging from service design to service assurance are implemented in the NSMF and NSSMF for the RAN, transport and network core.[9]

As a starting point for NS management, it is certainly advisable to begin with globally predefined network slice types. These are described in the following table:

Slice/Service Type	**SST (service slice type)** value	**Description**	3GPP release
eMBB	1	A slice suitable for supporting eMBB, i.e. services with high data throughput requirements, particularly in mobile scenarios. An example would be cameras on AMR.	15
uRLLC	2	A slice suitable for extremely reliable, low-latency communication. Examples include the remote operation of robots and other devices.	15
MIoT	3	A slice suitable for massive IoT, i.e. connecting a large number of sensors within a given area; typically, a smaller amount of data is transmitted.	15
V2X	4	A slice for 'Vehicle to X', i.e. for communication between autonomous vehicles and various other elements of the infrastructure.	16
HMTC	5	A slice suitable for 'High-Performance Machine-Type' communication, i.e. communication between machines with high performance requirements.	17

[9] Ericsson study: "Essential building blocks of E2E network slicing" (2023)

2.3 Types of NS: NS in public and private networks, local break-out.

2.3.1 NS in public vs. private 5G networks.

Network slicing can be applied in both public and private 5G networks.

Most use cases associated with NS, as well as most literature dealing with orchestration, lifecycle management and operational management of NS, implicitly assume the use of NS technology within public networks. After all, the vast majority of CSP revenue is generated in public networks, and for public networks, NS can also completely transform the service delivery paradigm. The significance of NS is therefore undoubtedly much greater for public networks than for private networks.

A private 5G network is, by its very nature, dedicated to a specific customer and designed according to their needs. Typically, it also has sufficient resources for defined use cases, which it does not need to share with other customers.

This does not mean that NS would not make sense for private 5G networks. Technically, implementing NS in private networks is not only possible but, in practice, will be simpler than in public networks. This is due to the lower overall complexity of the solution. From a technical perspective, implementation in public and private networks is practically no different.

2.3.2 Types of NS by deployment method.

There are two main ways of deploying NS in public networks:

1. NS as **a virtual private network** (VPN)
2. NS for deployment in a wide area (**Wide Area NS**).

A virtual private network is characterised by the fact that it is implemented within a limited perimeter. It provides the customer with dedicated resources, similar to a 'physical' private network, here in the form of a dedicated network slice.

In this form, a virtual private network can function and meet certain use cases. However, there are two pitfalls:

- Internal coverage
- Latency

In the case of a private network, even a virtual one, use cases are often implemented within the customer's premises, such as a production hall, logistics centre or hospital. Often, due to the building's structure, the signal is not perfect or sufficient throughout all internal areas. The virtual private network solution therefore needs to be supplemented with indoor coverage. If this indoor coverage is dedicated solely to a specific customer, typically a large company, then it is essentially a hybrid network, as it combines elements of a public network and a private network.

The basic VPN solution utilises public network infrastructure, including the network core. This logically leads to higher latency, which may not be sufficient for certain use cases. Furthermore, user data is not entirely under the customer's control, as it does not remain on their premises.

For these reasons, a virtual private network can be supplemented with a so-called 'local breakout'.

"Local breakout" means that the UPF (user plane function) is used, and as a result, user data is not routed to a central remote network but is processed locally at the customer's premises (or at the edge). This results in lower latency and higher data security.

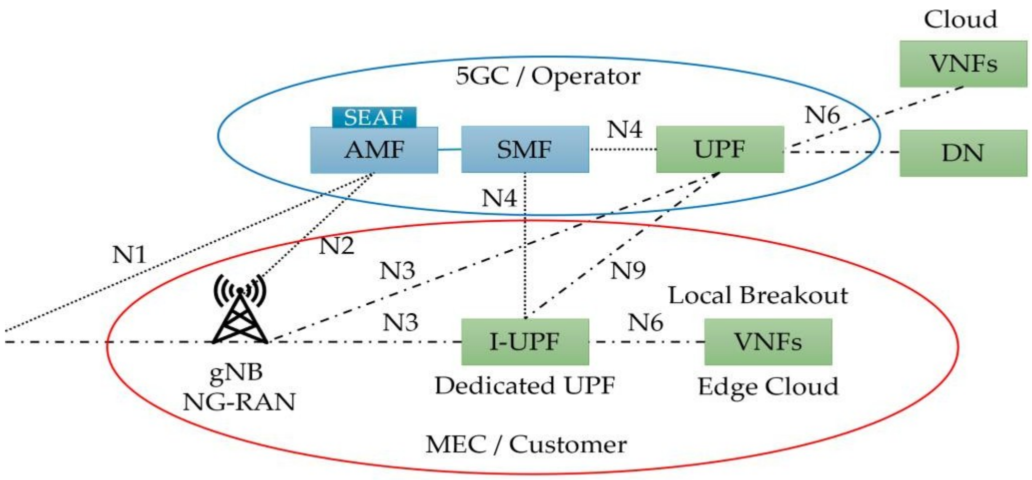

Figure: Diagram of "local breakout". Source: Ing. Michal Poupa.

However, this edge point does not necessarily have to be dedicated to a single customer and located on their premises. As a compromise, it can serve multiple companies in a given location and be situated on the CSP's premises, typically a few kilometres away from the companies' premises. NOKIA refers to this concept as "edge slicing", and it is illustrated in the figure below.

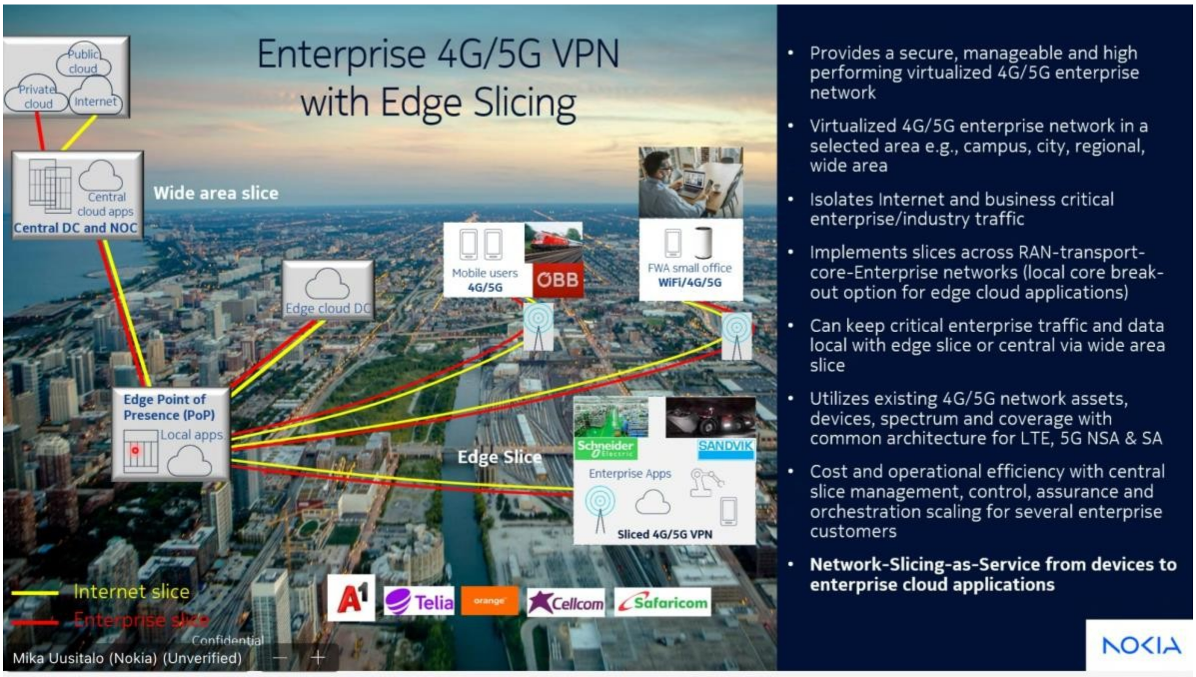

Figure: edge slicing. Source: Nokia.

In the case of virtual private networks, the network slice is usually permanent. This is particularly true if it is intended for corporate use. There may be exceptions here too, and the slice may be temporary, for example for services in a sports arena.

Conversely, a wide-area NS cannot, of course, have a local breakout. It may be a nationwide slice, for example for gaming or PPDR. The resources of such a slice are utilised dynamically, i.e. only when needed.

3 When is NS suitable for use – use cases

3.1 Defining the areas for which network slicing is a suitable choice.

The suitability of using NS for various use cases is closely linked to the fact that it is possible to define and implement several types of NS, as described in the chapter Types of NS.

For the use of NS in implementing various use cases, it is possible to distinguish three main types of NS from a deployment perspective. Two of these are in public networks:

1. NS as a virtual private network (VPN) / edge slicing.
2. NS for deployment in a wide area (wide area NS).
3. NS in private networks.

A virtual private network, i.e. an NS supplemented with local breakout and an indoor coverage solution, is a direct substitute for a private 5G network. In principle, therefore, a virtual private network can be used for all use cases for which a private 5G network is suitable. This means use cases limited by a defined perimeter that require a high and guaranteed level of service, whether in terms of performance parameters, availability or security.

But in which cases should one actually use a private 5G network, and in which a virtual private network?

There is clearly no binary answer to this. In practice, the customer (a company or other entity) will ideally choose between both options, weighing them up against specific price quotes and guaranteed parameters on the one hand, and a precise definition of their needs on the other.

In general terms, the advantages of a private network will include:

- Complete dedication of resources, including the ability to scale them according to the customer's needs (in the case of a public network, at least some resources, such as the network core, are shared).
- Design tailored directly to the customer's needs and use cases (a public cloud is not typically a bespoke solution).
- Security tailored to the customer's requirements and ownership of the infrastructure (some companies strongly prefer to own all the infrastructure directly, which is not possible with a public cloud).

The advantages of virtual private networks/edge slicing will include:

- Speed of deployment (VPN should be a standardised solution).
- Interoperability with the public network (this is also possible with a private network, but with NS it is a native feature).
- Implementation costs (at least in theory, as with NS there is no need to procure a significant portion of the infrastructure, particularly the network core).

Although there are already several implementations of private 5G networks in the Czech Republic, their variability in terms of the technology used is still very limited. Network slicing in 5G networks has not yet been implemented. Therefore, only real-world practice will show whether these theoretical assumptions will be fulfilled.

Network slicing for deployment across a wide area (wide-area NS) is practically the only option for providing mobile connectivity with an SLA beyond a limited perimeter, for example across the whole of the Czech Republic. Moreover, this will be a virtually entirely new capability. Previous attempts to provide QoS using QCI classes have not been very successful and, in principle, did not allow for a key function: connecting to an overloaded network. In the event of congestion, signalling became overwhelmed, meaning that even prioritised users typically could not access the network. In contrast, NS should enable defined users to be allocated dedicated resources even in the event of a congested network. This could lead to use cases for which wide-area NS is an excellent choice. Primarily for emergency services, but equally for businesses needing to provide services at mass events that lead to network congestion.

Deployment of NS in private networks.

NS will be particularly significant in private 5G networks in the context of large-scale projects. A typical example would be a private 5G network covering a logistics terminal, such as a port. There are very different use cases within such a network. Some, by their nature, require an eMBB-type slice, such as CCTV systems. Others require a URLLC-type slice, such as the remote operation of cranes or autonomous vehicles. And others require an mMTC-type slice, particularly a sensor network monitoring status variables in the area.

According to a study conducted in collaboration between Ericsson and Arthur D. Little[(10),]NS is suitable for approximately 25–30% of 5G use cases. It may, for example, be suitable for medium-sized businesses as an alternative to a private 5G network, which is more likely to be chosen by large corporations. According to this study, approximately 90% of NS revenue is expected to come from six main sectors: healthcare, public administration, transport, energy and utilities, manufacturing, and media.

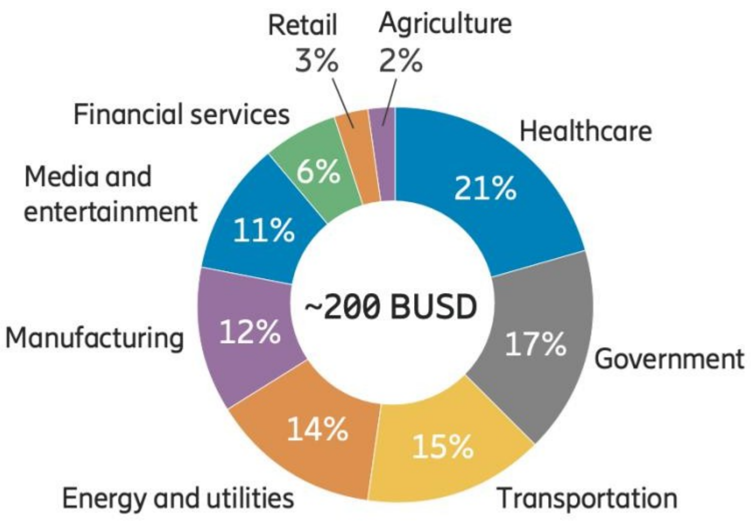

Figure: Sectors with the highest revenue potential for network slicing for CSPs. Source: [11]

NOKIA has already implemented several commercial network slicing projects, such as a premium fixed wireless access service in collaboration with Telia. NOKIA sees the following as the main areas of application for NS:

- Virtual private corporate networks.

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[10] Ericsson and Arthur D. Little: Network slicing: A go-to-market guide to capture the high revenue potential (2021)

[11] Ericsson and Arthur D. Little: Network slicing: A go-to-market guide to capture the high revenue potential (2021)

- Slicing for industrial verticals, for example in the form of critical communications.
- Fixed wireless broadband for households and small businesses.
- Slicing for specific applications (e.g. AR, gaming) available via premium tariffs for both residential and business customers.
- On-demand slicing for residential and business customers, with the option of online activation.

Image: Areas of NS application. Source: Nokia

However, **the suitability of choosing NS for a specific** use **case** will, as with other connectivity options and types, depend primarily on whether NS can meet the parameters required by the customer. The key factor will therefore be whether NS can actually deliver a guaranteed level of service. In the case of B2B customers, the level of service may be formalised in the form of an SLA.

The required parameters (SLI – Service Level Indicators) will include, in particular:

- Downlink and uplink speeds per user.
- Maximum latency (delay).
- Stability (jitter).
- Number of concurrent connections (in a specific location).
- Total system capacity.
- Service availability level (e.g. 99.99%).
- Required level of mobility, etc.

The following chapters outline selected use cases for which it may be appropriate to utilise NS (depending on the ability to offer guaranteed parameters on the one hand and acceptable commercial terms on the other). These use cases are categorised into B2B, B2C, B2G and wholesale.

3.2 Use cases for businesses (B2B)

3.2.1 Vertical: Healthcare

According to a study by Ericsson, healthcare is one of the six most interesting verticals from a network slicing perspective. It is estimated that it could account for up to 21% of addressable network slicing revenue.[12]

Category: Telemedicine

Telemedicine is defined as the remote transmission of medical information from patient to doctor via telecommunications and information technologies. High-quality connectivity and flexibility of movement are critical requirements in this context. There are a number of use cases here that are not limited to a defined perimeter. This means they cannot be addressed via a private network, making NS a logical choice due to its ability to ensure an SLA in this scenario as well.

UC Name	Description	Perimeter	5G features
Remote diagnosis and consultation between doctor and patient	Two-way HD video is used between the patient and a primary/secondary care specialist to conduct initial screening examinations, routine check-ups (which do not require physical procedures), therapeutic/rehabilitation sessions and, increasingly, visual diagnoses (e.g. conditions and symptoms). By conducting these appointments remotely, patients do not need to travel to see healthcare professionals and vice versa, which reduces the burden on the patient and lowers the cost of each appointment.	No	eMBB
Patient monitoring using wearables and other devices	Remote patient monitoring is considered a key factor in delivering healthcare services more efficiently and proactively and in managing chronic conditions. Using sensors, wearables and e-health devices, patient data can be collected and analysed without patients having to travel to a primary care facility for a face-to-face appointment with a doctor.	No	mMTC
Connected ambulance	A connected ambulance and its crew act as a means of collecting and transmitting patient information – whether via wearable devices, sensors or HD video/body camera streaming – back to the hospital A&E department whilst the patient is being transported. Hospital staff can thus better understand the patient before their arrival. Network slicing is the ideal solution for this use case.	No	eMBB, URLLC

[12] Ericsson study – Network slicing: Top 10 use cases to target. An overview of industries and use cases that will drive the majority of the revenue potential (2021).

Remote consultation between doctors, including AR, e.g. during remote surgery.	In the context of 5G, a frequently mentioned use case for healthcare is “telesurgery”, where a specialist can perform an operation from a remote location. A more realistic short-term opportunity is the use of 5G-enabled AR/VR headsets, which will allow a specialist to monitor an operation taking place in real time, guide the surgeon on the ground and comment on what they see based on their own experience.	No	eMBB, URLLC

Other use cases in healthcare are tied to a specific healthcare facility and limited to its premises. In such cases, a private 5G network or a virtual private network (VPN) can be utilised. It is not possible to determine which of these solutions to choose in general terms; it will always depend on the specific requirements and priorities of the customer on the one hand, and the provider’s offering on the other.

These use cases include:

- The transmission and processing of diagnostic and other data within the facility.
- Monitoring of patients’ vital signs in bed.
- Monitoring patient behaviour within the facility using video analysis.
- Group communication among healthcare staff.

3.2.2 Vertical: Logistics and transport

Transport is another potentially significant vertical from an NS perspective. According to the aforementioned Ericsson study, this vertical could account for 15% of addressable revenue in the NS sector.

There are a number of use cases in this vertical that cannot be implemented within a limited perimeter, and 5G is thus one of the few options for utilising connectivity with guaranteed parameters at the required level for these use cases.

The table lists three use cases of this type.

Use Case Name	Description	Perimeter	5G Features
Fleet management	Fleet management is not a new use case, but 5G (in this case public, ideally with network slicing) brings a new level of data connection quality, thereby expanding its possibilities. 5G connectivity will enable transport and logistics companies to utilise real-time diagnostic data via digital dashboards, which provide insights into driver behaviour, as well as route and fuel consumption. By utilising smart sensors and on-board computers that monitor and transmit location, speed, fuel consumption, vehicle wear and tear, and component failures, organisations can improve operational efficiency across all areas.	No	mMTC, eMBB

V2X communication	Communication between vehicles and other infrastructure elements, or between vehicles themselves, provides the necessary element of safety and reliability for autonomous operation. It can be used, for example, for platooning, i.e. the operation of a convoy of vehicles, which saves fuel and costs.	No	URLLC
Asset tracking	Tracking items during transport is an important part of managing the entire supply chain and a prerequisite for its efficiency. Nationwide coverage technology is required, specifically from the LP-WAN category. In the case of 5G, this could therefore be RedCap.	No	mMTC

Other use cases in this sector are usually associated with a defined perimeter, for example:

- Smart warehouse
- Assisted work in logistics
- Smart logistics complex (port, transhipment terminal).

It is therefore possible to choose between a private network and a virtual private network for these applications.

3.2.3 Vertical: Agriculture and food

Agriculture is not listed among the leading verticals in the aforementioned Ericsson study, but T-Mobile, for example, considers it one of the most interesting verticals and opportunities.

Even in the case of a country, there are use cases that lie completely outside a defined perimeter. And then there is a whole range of use cases that, whilst within a defined perimeter, can cover a very large area, such as a farm spanning many hectares. In addition to the area, cabling would also be complex. In such a case, a private network could be very costly, and network slicing appears to be a much more logical solution.

Outside the defined perimeter, there is a group of use cases related to supply chain tracking in agriculture.

This UC category aims to track the supply of agricultural products from the source to retail chains. This is done both to record the origin of products and to ensure and monitor appropriate transport conditions.

Use Case Name	Description	Scope	5G Features
Tracking products from farm to point of sale	This UC addresses a key aspect of the agricultural supply chain: ensuring transparency, traceability and efficiency from the point of origin to the consumer. Products are tagged at farm level using barcodes, RFID tags or smart sensors capable of capturing and recording various data, including harvest time, origin, treatment and quality assessment. Stakeholders can track the status and progress of goods as they move through the supply chain. This monitoring helps with logistics management, route optimisation, responding to delays and ensuring compliance with safety and quality standards.	No	mMTC
Monitoring of transport conditions of agricultural products	UC focuses on maintaining the integrity and quality of agricultural goods during transport from farms to markets or processors. Sensors are integrated into transport vehicles or individual product packages. During transport, these sensors monitor various environmental parameters such as temperature, humidity, vibration and atmospheric pressure – factors that are crucial for maintaining product quality. The data is transmitted to a central unit, evaluated and subsequently used to generate relevant reports.	No	mMTC

Within the defined scope, there are a number of applications related to smart farming and precision agriculture, for example:

- Livestock monitoring.
- Autonomous agricultural machinery.
- Monitoring soil conditions or pests
- Automated harvesting systems.

3.2.4 Vertical: Energy and utilities

According to the aforementioned Ericsson study, this vertical could account for 14% of addressable revenue in the field of network slicing. This means it is among the most interesting target verticals. Many use cases cover a large area, and some require simultaneous support for mobility; NS is therefore practically the only solution that can provide a guaranteed level of service for them. Four selected use cases are listed in the table below.

UC Name	Description	Perimeter	5G Features
Inspection of power and utility distribution networks using drones	Inspecting substations is an important yet demanding task, and drones can be of significant assistance. Reliable connectivity, including video transmission, is essential.	No	eMBB, URLLC
PTx (Push to talk/ Push to video) for work teams	Work teams carry out inspections and repairs in the energy sector. Managed group communication enabling the transfer of large data files (documentation) and video will streamline their work and enable remote assistance.	No	eMBB
Connection of remote energy sources	Wind farms and other distributed energy sources may be located in areas where it is not cost-effective to build fibre-optic connections, yet they still require reliable connectivity.	No	eMBB
Virtual power plants (VPPs), their interconnection and control.	VPPs typically aggregate a large number of distributed energy resources (DERs). These resources may include natural gas piston engines, small wind power plants (WPPs), photovoltaics (PV), run-of-river hydropower plants, small hydropower plants, biomass, backup generators and energy storage systems such as domestic or vehicle batteries (ESS), etc.	No	URLLC

In the energy sector, too, there are use cases limited to a specific area. A typical example would be ensuring security and communication within a power station. In such a case, however, it is more likely that a standalone private network would be used, rather than a virtual one.

3.2.5 Vertical: Broadcasting

Broadcasting is another promising area for NS. This is also the view of T-Mobile, which is already carrying out its first pilot projects in this field in collaboration with Czech Television.

Broadcasting and streaming services face significant challenges when it comes to live transmission. Current setups for live broadcasting are expensive and require satellite connections to support production at HD/UHD broadcast quality. Live broadcasting is also sometimes difficult to produce due to insufficient connectivity, particularly for events taking place outside city centres. And yet, the demand for live broadcast production continues to grow.

There are a number of use cases in this area that network slicing could enable in the near future:

1. Remote broadcasting and production:

   In this use case, most staff involved in the live broadcast of an event can operate cameras, mix and edit content, and switch camera angles on the fly, even whilst working from a location hundreds or thousands of kilometres away from the event.

2. VR/UHD second-screen broadcasting:

   This is similar to live broadcasting of an event on a giant screen at a secondary location, but here broadcasters would do so using virtual reality (VR), UHD and 4K.

3. Live event experience on-site: This use case is similar to second-screen broadcasting, but in this instance, the UHD video would be broadcast at the live event venue, for example for immediate playback.
4. Ad-hoc / temporary mass events:

These types of broadcasts require the rapid and flexible allocation of additional bandwidth to the event venue.

3.2.6 Vertical: Industry and manufacturing

In this sector, there are numerous use cases for 5G technology, which can be grouped into the following categories:

- Smart factory.
- Connected worker.

In principle, these use cases are implemented within a limited perimeter, so the choice will always be between a private network and a virtual private network using network slicing.

3.3 NS for end users (B2C)

Business-to-Consumer (B2C) refers to the process (or sector) where companies sell products or provide services directly to individual consumers. This model typically involves transactions where goods and services are sold to end users for personal use.

In the case of NS, this does not necessarily mean that the CSP (mobile operator) sells services directly to the end customer. In some cases, there may be an intermediary (typically a wholesaler). For example, a gaming platform, a provider of advanced services at stadiums, etc., which uses the NS provided by a mobile operator to deliver its services to end customers. However, in a B2C scenario, the end user is always an individual customer, not a business.

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Examples of B2C use cases:

UC Name	Description	Perimeter	5G features
Premium connectivity for gaming	This area is associated with high expectations from the NS perspective, and the first real-world projects are already emerging. Currently, gamers rely primarily on fixed networks, which, however, forces them to be tied to their homes. Furthermore, high-quality video transmission requires high bandwidth support; otherwise, video compression degrades the user experience for gamers. VR and other highly interactive games, in particular, require very high throughput and low latency for an enjoyable gaming experience. Network slicing can help the gaming industry overcome most of the obstacles preventing the play of advanced mobile and AR games.	Not	eMBB, URLLC
Fixed wireless broadband for homes.	The use of mobile networks for fixed wireless internet access in the home is nothing new. In some cases, such as remote locations, it is practically the only economical solution. That is why it is quite popular in Scandinavia, for example. The first commercial projects utilising mobile networks for fixed wireless connections are also being implemented there. Mobile networks enable this service to be taken to a higher level. Households use a range of services for which high stability and guaranteed performance are crucial. For example, streaming or services related to home automation (smart home). For these reasons, 5G is not only suitable, but some households will be willing to pay premium rates for guaranteed services.	No	eMBB
Infotainment and vehicle connectivity	Passengers in vehicles often require high-quality and stable mobile connectivity for navigation, listening to music, and also playing videos for children during long journeys. For this reason, vehicle connectivity services with guaranteed performance are a good target market.	No	eMBB
Connectivity at stadiums, festivals and similar one-off events.	Visitors to sporting, cultural and social events often use video streaming or sending photos to share their experiences. However, connectivity can be a problem at mass events under such circumstances. Some customers will therefore want to pay for a special service with guaranteed performance parameters.	No	eMBB

3.4 Government and Smart Cities (B2G)

Private networks are not designed for use in public and large-scale areas. From this perspective, NS offers itself as a solution that can potentially provide the necessary connectivity for smart cities or state emergency services (IZS), which must operate across the entire territory of the state; these are the two main categories of use cases in government and local government.

3.4.1 PPDR category ('Public protection and disaster relief')

This category covers a range of use cases carried out by emergency services ('first responders') such as the police, fire brigades and the ambulance service.

Use Case Name	Description	Perimeter	5G features
PTx (Push to X) for first responders	Dispatcher-controlled group communication remains the most effective way to coordinate the activities of emergency services. These services still use narrowband technologies dating back to the 1980s. In the case of the Integrated Rescue System (IRS), this is the proprietary Tetrapol technology, similar to the TETRA technology used, for example, by the Czech Army. Modern broadband technologies such as 5G, combined with a comprehensive application solution, offer entirely new possibilities in the form of transferring large data files and streaming video, whether from user terminals (handsets) or from cameras mounted on rescuers' helmets and bodies. At the same time, however, it is necessary to ensure high availability and reliability of these services, which traditionally operate on dedicated networks. Network slicing is one way to guarantee these parameters, including resource availability even when the local network is overloaded, whilst ensuring nationwide coverage.	No	URLLC, eMBB
Connecte d patrol vehicles	Patrol vehicles require connectivity with high demands on transmission capacity, low latency and high availability, as this connectivity supports a whole range of important tasks. From video transmission from on-board cameras, through connections to internal systems, to data transmitted by the vehicle's communication unit. All of this across the entire country and whilst on the move. Network slicing is therefore the ideal solution.	No	eMBB, URLLC
Surveillance systems	Thanks to high-resolution cameras and increasingly sophisticated AI-powered analytics, video transmission is an essential component of ensuring security in various locations and scenarios. A separate issue is the need to use these resources in accordance with privacy rights and other ethical standards, so that advanced democratic states do not employ methods similar to those used in communist China. Network slicing cannot help with this. However, it can certainly help with the technical provision of these services at the required level and with sufficient flexibility.	No	eMBB

3.4.2 Smart cities

Smart cities is a very broad category. For a city to be smart, it needs to implement a whole range of use cases in the areas of transport, security, the environment and services for citizens.

Selected examples of these use cases are listed below.

Use Case Name	Description	Scope	5G Features
Traffic management	Real-time traffic monitoring and management can reduce traffic congestion and improve urban mobility. Another application is the monitoring of parking spaces and dynamic vehicle guidance based on occupancy. NS will provide suitable connectivity for this use case wherever it is not possible or efficient to use fixed connectivity.	No	URLLC
Connection of public transport vehicles	The connectivity of public transport vehicles is already needed now, for a number of reasons. Communication with control centres and management systems, transmission of data from cameras, provision of information services to passengers, and possibly even connectivity for passengers, etc. NS can help improve the quality of all these tasks and services.	No	eMBB, URLLC
Environmental monitoring	There is a wide range of environmental parameters that are beneficial to monitor – air quality, water quality, CO_2 concentrations, humidity, waste, etc. This is typically an IoT scenario, and the use of the mMTC network slice is therefore appropriate.	No	mMTC
City security	City security is managed by surveillance systems and applications used by the city police. In these cases, guaranteed service availability with defined parameters is again crucial.	No	URLLC, eMBB
Energy and utilities for the smart city	Energy expenditure often constitutes a significant cost item in the city budget. Modern approaches to managing energy resources and consumption can significantly reduce costs. These include, for example, advanced facility management of municipal buildings, including smart metering and public lighting control. Reliable connectivity is a prerequisite for all these modern solutions.	No	mMTC

3.5 Wholesale and MVNOs

In the context of network slicing, the wholesale category refers to the provision of network slicing capabilities by a communications service provider (CSP/mobile operator) to other businesses or service providers, rather than directly to end users. This enables smaller providers, managed service providers (MSPs) or other businesses to utilise the advanced capabilities of the 5G network to provide tailor-made services to their customers. The wholesale model often involves the sale of network segments with specific characteristics to these intermediaries, who then use or resell them as part of their own service offerings.

In the case of the wholesale model, there is an increasing need to address the wholesale relationship between the CSP/MNO and the wholesale end-service provider. A functional model will therefore likely require an open slicing model, i.e. the ability to control it via an API, as well as a robust billing and operations platform.

A number of use cases for B2B and B2C can also be provided via the wholesale model. In such cases, the requirements of end users – whether businesses, individuals or households – regarding the level of service provision remain unchanged.

For example, these may include:

- Gaming platforms that provide services to end users/players.
- Specialised companies providing services at stadiums.
- Companies providing critical communication services for the city police or other user groups.

Network slicing could have a significant impact on the area **of virtual operators, or MVNOs (Mobile Virtual Network Operators).** The term itself suggests that the operator operates on a virtual network. However, this is not the case. Existing virtual mobile operators provide services on a mobile operator’s network. There are various models for this:

The branded reseller model means that the mobile operator remains the service provider. The branded reseller merely resells its services and receives a commission in return. It uses its own brand, so these are often companies with a strong brand and distribution network. In the Czech Republic, an example of such an MVNO operating under the branded reseller model is BLESK mobil.

The wholesale model means that the virtual operator purchases services from the mobile operator and sells them under its own name and on its own responsibility; it is the service provider to end customers. An example of this model in the past was Sazka mobil.

A joint venture, on the other hand, is a joint venture between a mobile operator and another company; together, they leverage their respective strengths when offering services. An example in the Czech Republic is Tesco mobile.

However different these MVNO models may be, they have one thing in common: namely, that in reality, the virtual operator does not have a virtual network of its own. The current MVNO model is based on a ‘one-size-fits-all’ approach. An MVNO has no special dedicated resources for itself or its customers. It is therefore not in a position to provide genuinely differentiated and, where applicable, guaranteed services. Typically, the only guarantee an MVNO receives from an MNO is that its customers will not be discriminated against. The MNO usually undertakes to treat the MVNO’s customers as its own.

Network slicing could and should change all this. It is the first technology that should enable individual MVNOs to provide truly differentiated services. MVNOs specialising in certain segments could emerge, for example:

- MVNOs for enterprise customers.
- MVNOs for the healthcare sector and patients.
- MVNOs focused on the IoT.
- MVNOs focused on providing virtual private networks.

However, to realise this vision, the following two conditions in particular will need to be met:

- Technical implementation of a wholesale model enabling open and dynamic slicing. In this case, this could even involve creating slices within a specific MVNO slice (i.e. a hierarchical NS structure).
- The willingness of MNOs to implement such a model. MNOs often view MVNOs as competitors. It is therefore necessary to find a business model that will be viewed positively by both parties, or to create a regulatory environment that allows MVNOs to provide services within network slicing, so as to foster a competitive market environment.

In any case, when network slicing becomes the new standard for service provision in mobile networks – i.e. when the 'one-size-fits-all' model is abandoned and services tailored to customer requirements are provided – it will be essential for MVNOs to have access to NS as well, as otherwise their services will not be competitive.

4 What value does NS bring – business models

4.1 Business models for NS

In the case of NS, there will certainly not be a single business model. On the contrary. There will be a whole range of business models, and they will differ according to various criteria.

The question, however, is whether and which business models will be successful. This remains

theoretical for now. One of the key classifications of business models will be by customer type:

- B2C
- B2B
- B2B2C/Wholesale

Let's first look at what a model actually is and what it consists of. The general definition of a business model is as follows:

A business model defines how a company creates value, delivers it to customers and receives value in return from them.

A business model therefore has three main areas:

1. **Value creation** – here, the main role is played by the product or service you provide to your customer, through which the customer gains value. This value is defined as the Value Proposition. And if possible, it differs from the value provided by competitors; it is unique, i.e. a Unique Value Proposition.
2. **Value delivery** – how you sell and distribute the product or service. Marketing and sales play a key role here.
3. **Capturing value** – the way in which the company recoups value for itself. This is determined by its revenue model.

For a business model to work, the following rules must apply:[13]

- The value perceived by the customer must be higher than the value returned to us. This is the essence of a proper Value Proposition.
- At the same time, the value the company recovers must be greater than the cost of delivering that value.

These general rules will, of course, also apply to network slicing and all propositions and services based on it.

[13] Maurya, A. (28 February 2012). *Running Lean*. "O'Reilly Media, Inc."

Specifically, this means that if a CSP (or other service provider) wishes to charge a customer incremental fees for services related to network slicing, the customer must clearly perceive the added value of this solution, and that value must be greater than the fees charged.

At the same time, the incremental revenues generated by services associated with network slicing will have to exceed the costs associated with the implementation and operation of network slicing.

This will not be a simple task, particularly given how complex a technology network slicing is, especially in conjunction with OSS and BSS systems, which will need to support advanced forms of dynamic and open slicing.

When searching for and defining a business model, the Business Model Canvas can also be used for services related to network slicing.

The author of this model is Alexander Osterwalder.[14] The Business Model Canvas comprises nine areas which, according to this methodology, are key to defining a business model: customer segments, value proposition, sales channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure.

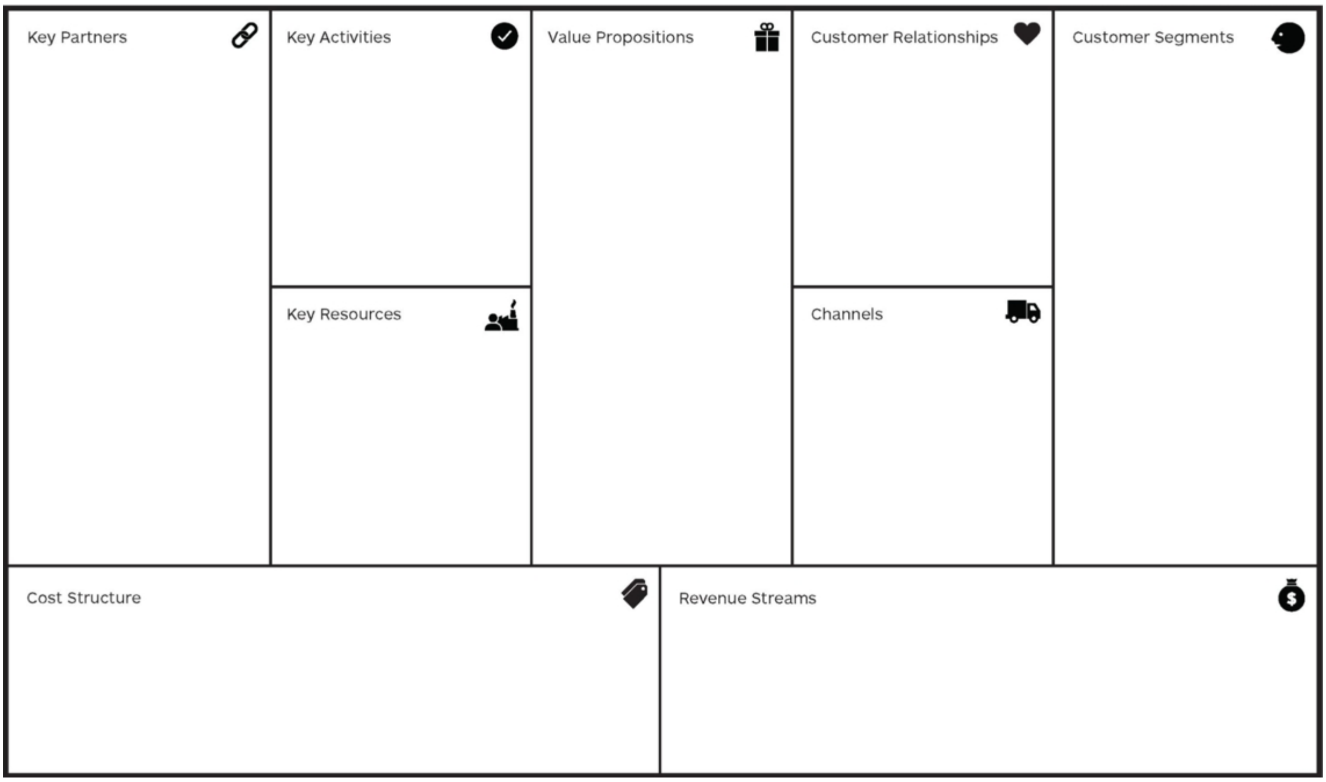

Figure: Business Model Canvas. Source: Osterwalder (2013).

[14] Osterwalder, A., & Pigneur, Y. (1 February 2013). *Business Model Generation*. John Wiley & Sons.

4.2 B2C Business Model

For non-business end customers, such as individuals and families, there are a wide range of use cases that network slicing can take to the next level. Examples of these use cases are listed above: gaming, in-vehicle infotainment, services at stadiums and mass events, fixed wireless home connectivity, etc.

From a business model perspective, the key question is whether end customers currently perceive a specific problem without network slicing and whether network slicing will help them solve this problem. If so, there is a realistic chance that they will be willing to pay an incremental price for this solution.

In some of the cases mentioned above, problems certainly do exist at present, for example:

- Standard mobile connections do not provide sufficiently low latency for smooth gameplay, particularly for AR games.
- At large events, it is difficult to make a call, let alone reliably stream video to friends.
- Infotainment works without a hitch – until you hit a traffic jam and the network becomes overloaded.

Network slicing has the technical capability to solve these problems.

But how should we charge for solving the problem?

It must be a simple, transparent and generic model if it is to have any chance of success.

There have been negative experiences in the past with ‘content-based charging’, where CSPs attempted to set specific conditions for certain types of content and applications. For example, Facebook (and, to avoid discrimination, other social networks too, though in practice it was primarily Facebook) was not counted towards the data limit, unlike other content. However, all it took was a click on a link for the user to leave the original application, and data was charged without their knowledge. A highly non-transparent and user-unfriendly approach.

Charging specifically for 4G or 5G also failed. After all, which end-user knows exactly what that means? And practically no one is able to tell whether they are currently using data via 4G or 5G, etc.

On the other hand, even today there is a division of tariffs into ‘higher’ and ‘lower’ tiers. In other words, more or less premium. The distinguishing factor, however, is typically:

- Data allowance (the amount that can be transferred).
- Transfer speed (used mainly for fixed wireless services).

These parameters are, however, slowly losing their significance. Customers want to be online all the time. Data allowances are therefore constantly increasing, or there are so-called unlimited tariffs. Speed, in turn, ceases to be a limiting factor beyond a certain point. Speeds of 20–50 Mbps are sufficient for most applications. In practice, there is no difference in user experience between tariffs offering 100 Mbps or 200 Mbps.

Once a certain required speed is achieved, a set of other parameters becomes important for the user experience. And it is precisely these that network slicing should deliver:

- Minimum downlink/uplink speed (Mbps)
- Connection stability (jitter).
- Low latency (RTT).
- The ability to connect with high reliability even on a locally congested network.

It may therefore make sense for customers to pay higher prices for premium tariffs that guarantee the above parameters. However, it cannot be expected that end customers will be familiar with these parameters and know what values to demand. CSPs/mobile operators therefore face the challenge of how to communicate and explain the value conveyed by these parameters to customers so that they understand it correctly and are willing to pay for it.

The simplest option would be to create premium tariffs with clearly defined parameters and guarantees.

However, a complication (apart from how to communicate the parameters) is the fact that the premium nature of the service only becomes apparent when a specific problem arises. Consequently, the willingness of at least some customers to pay extra for a premium service may be limited to such moments. A solution could therefore be the option of an immediate one-off
"booster" that the customer could purchase in a given situation. Its price would then be relatively higher than in the case of a long-term discounted tariff. For such a solution, the CSP will need to support truly flexible provisioning.

Another option could be the creation of specific tariff products for certain types of applications. This may be easier for customers to understand. For example, premium tariffs for gaming, streaming, etc. Here, however, the challenge lies in avoiding the aspects that led to the less-than-successful "content-based" billing in the past.

At the same time, it is worth noting that offering premium tariffs means creating a 'fast lane' for customers with a premium service. A fast lane, however, means fewer resources for the remaining customers. Such an approach may pose a problem in the event of a very rigid interpretation of net neutrality (for more, see the chapter on Regulatory Conditions). The prevailing interpretation of net neutrality should, however, allow for such a model, because:

- Every customer has the option to pay extra for the fast lane; it is a service available to all.
- There is no restriction of competition, as no selected providers or applications are given preferential treatment.

Summary:

For the B2C sector, the following business models may exist, for example:

- Premium tariffs with guaranteed parameters.
- A 'booster' product to address customers' ad-hoc needs.
- Special tariff products for application areas such as gaming or streaming. The

main challenges will include:

- Identifying a problem that customers perceive and that is significant enough for them to be willing to pay for a solution.
- Communicating and explaining the benefits of guaranteed parameters.

4.3 B2B/B2G Business Model

Based on the analysis of network slicing deployment types and use case categories in the B2B sector described in Chapter 3, we have identified the following four business models:

1. SLA model.
2. Private network/NaaS model.
3. Dynamic model.
4. Application/embedded model.

4.3.1 SLA model

This model can be applied practically universally to various use cases, including the deployment of NS across a wide range of areas.

The advantage of the SLA model is that companies are often accustomed to using SLAs and paying for them.

So let's take a look at exactly what an SLA (Service Level Agreement) is, as there are often rather distorted ideas about it. These lead to inappropriate definitions such as '24/7 SLA' and the like.

A Service Level Agreement is a formal agreement between a service provider and a customer that specifies the level of service the provider is contractually obliged to deliver. It is therefore crucial to define the service level itself.

The **Service Level** is a measure of the quality of the services provided, specifying the expected performance and availability parameters of the service. It includes specific characteristics of the service, which may involve both functional and non-functional requirements. Here is an example of the categories:

- **Availability**: How often the service is available for use.
- **Performance**: How quickly the service operates or how well it performs its functions.
- **Capacity**: The maximum volume of work that the service can handle.
- **Reliability**: How often the service fails or exhibits errors.
- **Security**: How well the service protects data from unauthorised access.
- **Functionality**: The completeness and correctness of the service's features.

In practice, it is ideal to define very specific parameters that influence and define the service level, along with their required values or ranges. In the case of network slicing for B2B, these could include the following parameters:

- Overall service availability (e.g. 99.99%)
- Minimum downlink/uplink speed per user (Mbps)
- Total system throughput (Gbps)
- Connection stability – maximum jitter value (ms)
- Maximum RTT latency (ms).

However, the SLA does not only contain service parameters, but also defines other aspects important for the proper provision of the service, in particular:

- Service description: A detailed description of the service provided.
- Service levels: see above.
- Roles and responsibilities: The obligations of the service provider and the customer under the agreement.
- Measurement and reporting: Methods and tools used to measure service levels and the manner in which results will be reported.
- Problem resolution: Procedures for escalating and resolving any issues that may arise.
- Penalties and compensation: Consequences for the service provider in the event of failure to meet the specified service levels, including any penalties or compensation for the customer.
- Term and revision: The duration of the SLA and the conditions for its revision and updating.
- In the case of a service based on network slicing, the customer will want to receive reports on the achieved service level and any deviations from the guaranteed parameters. This is to ensure it is clear what they are actually paying for and that it is not merely a marketing product, and that the SLA does not serve merely as a safety net in the event of problems.

This places further, relatively high demands on the operational management of NS.

Corporate customers may pay for an NS SLA as a separate item in addition to their standard service packages. Furthermore, the SLA may have different tiers based on the value of the guaranteed parameters, from which the customer can choose according to their requirements.

4.3.2 Private network/NaaS model

Given that network slicing enables deployment in the form of a virtual private network, it is also possible to create a business model that mirrors the private network business model.

When NS is deployed directly within a private network, this functionality has the potential to significantly increase value for the customer – that is, when deployed in a suitable type of private network, such as at a port or airport, i.e. a large-scale private network with a range of different user scenarios. In such a case, the CSP will be in a position to reflect the NS functionality of the private network in its pricing.

Private networks are typically provided today under two business models:

CAPEX model. The customer pays an initial investment, and the network equipment (HW and SW) is owned by them. They must still pay on an ongoing basis for support and maintenance, including software updates, debugging and L3 support from the supplier. In some cases, licence fees are also payable.

OPEX/NaaS (Network as a Service) model. The customer does not pay an initial investment and uses the private network under some form of lease. Usually for a fixed monthly price. The price then includes not only the hardware and software, but also network support and maintenance.

In the case of a virtual private network, the CAPEX model does not make much sense. Even a virtual private network may contain elements dedicated to a specific customer – UPFs and internal coverage elements. However, these constitute only a small part of the overall solution, which is implemented on the CSP's infrastructure.

From this perspective, the 'Network as a Service' model therefore seems a much more logical option. For the customer, a fixed monthly price for the network service will usually be the best option. This not only avoids a high initial investment but also allows them to budget costs with certainty. For this reason, pricing schemes based, for example, on data transferred, number of devices, number of connections and similar metrics would not be suitable, as they would lead to uncertainty on the customer's part.

4.3.3 Dynamic model

Business customers, much like residential end-users, may only need to use network slicing in specific situations and under specific circumstances.

Imagine a company selling its products and services at a trade fair, festival or other mass event. It urgently needs connectivity for a payment terminal, to showcase or demonstrate its services. Once the event is over, this need disappears; during the event, however, the company will be willing to pay a relatively high amount to meet its needs.

Alternatively, the company may be one engaged in temporary activities, such as a roadshow.

In all these cases, the concept of dynamic slicing makes sense. That is, the option for the customer to pay for a defined guarantee of data connectivity for a defined period of time and, where applicable, a defined geographical area.

This model may be operationally demanding for the CSP and will certainly require a fully automated online interface, ideally integrated into the customer self-service portal. However, mastering it can bring interesting competitive advantages and a source of incremental revenue.

4.3.4 Application / embedded model

Businesses primarily want to provide their services to customers, carry out their processes and utilise their suppliers' services. They do not want to think about what parameters their connectivity should have.

From this perspective, a business model that fully integrates (embeds) the capabilities of network slicing technology into the provided application/service makes sense.

For example, for IoT services, it is logically appropriate to use an mMTC slice. The CSP will offer a complete IoT solution that will include end devices in the form of sensors, data transmission from these sensors including the use of network slicing capabilities, a platform for data storage, and an application for data analysis and visualisation. In such a case, NS is fully embedded within the overall solution, and its cost is included accordingly.

A similar solution could work for other areas, such as the provision of complete CCTV surveillance services using an eMBB slice, etc.

4.4 Wholesale business model

A wholesale customer of a network slicing service is an entity focused on providing services to other users – in other words, a wholesale service provider. They often provide a wide range of services. These customers may be businesses or end-user residential customers. In such cases, the model is also referred to as B2B2C.

The wholesale service provider is the one who has a direct relationship with users, not the MNO/CSP. And it is the wholesale service provider who defines the service parameters, and thus the SLA. From an NS perspective, the wholesale service provider is already, or can be, in a position to perceive the value of slicing, i.e. not just the individual service parameters and their SLAs.

As mentioned in Chapter 3, this may involve, for example, the following wholesale providers:

- MVNOs, i.e. mobile virtual network operators.
- Companies providing critical communication services for the city police or other user groups.
- Gaming platforms that provide services to end users/players.
- Specialised companies providing services at stadiums.
- Municipal ICT providers delivering services within the framework of a smart city.
- And many others.

For the wholesale network services sector, we have identified the following business models between CSPs and wholesale service providers (WSPs):

1. **Reseller.**

In this case, the service provider resells the CSP's services and earns an agreed margin on the resale. This is a model in which the end-service provider has the least flexibility regarding its own pricing and service policies, as these are determined by the CSP or by mutual agreement.

2. **Wholesale.**

The WSP purchases services from the CSP in a defined structure at wholesale prices. It adds a mark-up to these prices at its discretion. The retail pricing policy is therefore within its remit. However, the structure of the services – in this case, connectivity with defined parameters, including, for example, various categories – is clearly set by the CSP.

3. **Platform as a Service (PaaS)**

In this model, CSPs (mobile operators) offer a platform that enables wholesale providers to build and manage their own services using the service provider’s network capabilities.

The platform may provide tools for billing, customer management and service delivery.

Wholesale providers can develop customised services at their own discretion to best suit the end services and the type of applications provided.

PaaS can be charged in various ways. For example, through a combination of usage-based charges and a flat fee for access to the platform.

This is the most comprehensive model. It requires the implementation of a specialised platform for wholesale partners. At the same time, however, it is the model with the greatest potential. This is because specialised companies in a given sector, such as gaming or critical communications, will always understand their segments and verticals better than a CSP serving the entire market.

5 Challenges associated with NS

5.1 Regulatory conditions

Network slicing has the potential to transform the entire paradigm of service provision in mobile networks, moving away from a
"one-size-fits-all" approach to more or less individualised service parameters based on various criteria. For example, depending on the type of application or the tariff level paid by the end-user or business customer, that particular type of application or customer is given priority.

However, this potential change logically raises questions as to the extent to which favouring certain customers or applications may conflict with regulatory rules. This is particularly true in a situation where resources in the form of spectrum and associated transmission capacity are always limited, and prioritising one type of traffic or customer therefore always means restricting resources for other types of customers.

This paradigm shift in service provision is reflected in two main areas of regulation:

- The provision of electronic communications services in accordance with the conditions for operating a public electronic communications network, the conditions for spectrum use, and other regulatory provisions.
- Net neutrality.

5.1.1 Provision of services on public electronic communications networks

In the case of NS provided on private networks, i.e. non-public networks, there is no need to address any regulatory issues in this regard. However, NS will predominantly be provided on public electronic communications networks operated by mobile operators.

The definition of a public electronic communications network states[15] :

"A public electronic communications network is an electronic communications network used wholly or predominantly for the provision of publicly available electronic communications services that support the transmission of information between network end-points."

In addition to the definition of a public electronic communications network itself, it is also appropriate to take into account the conditions associated with the granting of rights to use radio frequencies. In this case, the spectrum intended for 5G networks is particularly relevant, namely the 700 MHz and 3400–3600 MHz frequency bands.

According to the "Declaration"[(16)] ,the conditions are set as follows:

For the 700 MHz band:

A fundamental condition of the tender procedure will be the use of radio frequencies for publicly available electronic communications services in a manner that reflects the principles set out in this Notice.

[15] European Electronic Communications Code, DIRECTIVE (EU) 2018/1972 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018

[16] "Announcement of a tender procedure for the granting of rights to use radio frequencies for the provision of electronic communications networks in the 700 MHz and 3400–3600 MHz frequency bands" of 7 August 2020

With regard to European harmonisation, radio frequencies are designated exclusively for the nationwide provision of electronic communications services, subject to the flexible management of the rights granted to ensure the efficient use of and access to the radio spectrum, including for other potential interested parties on a commercial basis, in accordance with the conditions set out in the Announcement.

The allocation is also subject to development criteria. For example, for the 700 MHz band:

Within 10 years of the date on which the decision to grant the radio frequency allocation becomes final, the existing operator must ensure coverage of 99% of the population of each district of the Czech Republic and 90% of the territory of each district of the Czech Republic.

For the 3400–3600 MHz band:

A fundamental condition of the Selection Procedure is the use of radio frequencies for publicly available electronic communications services in a manner that reflects the principles set out in this Notice. In accordance with PVRS 7, the radio frequencies are intended for use throughout the territory of the Czech Republic by networks designed to provide high-speed electronic communications services, subject to the flexible management of the rights granted to ensure the efficient use of the radio spectrum and access to it for other potential interested parties on a commercial basis.

5.1.2 Questions arising in connection with public networks and NS:

- Is network slicing a publicly available electronic communications service?
- And if not, is it possible to provide network slicing on a public electronic communications network?

Regarding the first question: A publicly available electronic communications service is an electronic communications service from which no one is excluded in advance.[17]

Conversely, a non-public service is one that is intended solely for (usually a single) specific user.

Let us look at the various types of NS in this context.

- NS in the form of a slice intended for gaming, which is accessible to all users who pay a special premium tariff, is certainly a public electronic communications service.
- A network service in the form of a network segment intended for the Ministry of the Interior for PPDR services is clearly a non-public service. Access to this specific network segment would be deliberately restricted to a single customer.
- A private network in the form of a virtual private network, as a specific instance, typically supplemented by UPF local breakout and certain indoor radio elements to provide coverage within the premises of the company in question, is a solution for a single specific user and constitutes a non-public service.

Depending on how the NS is deployed, it may therefore constitute either a public electronic communications service or a non-public service.

However, it can be inferred from the definition of a public electronic communications network, from the Electronic Communications Act (ZoEK) and also from consultation with the Czech Telecommunications Office (ČTÚ) that non-public services may also be provided on a public network. It is therefore possible to operate all types of network slicing on a public network, including those that constitute a non-public service.

The above definition of a public network states that it is to be used predominantly for the provision of publicly available services. The term ‘predominantly’ clearly implies that this need not be 100% of the services provided.

[17] Act No. 127/2005 Coll. Act on Electronic Communications and on Amendments to Certain Related Acts (Act on Electronic Communications)

According to the definition in the Electronic Communications Act, a public electronic communications network operator may also provide non-public electronic communications services (beyond the scope of publicly available electronic communications services).

The CTU's approach is based on the principles of mutual trust, self-regulation and best practice. It is founded on regulation based on the principle of neutrality, both from a technological and a service perspective.

The CTO assumes that communications service providers (mobile operators) will be motivated to balance the satisfaction of all customers, also taking into account potential reputational risk.

For the area of network neutrality, this means that mobile operators should be allowed to offer various types of slicing without this area being specifically regulated. That is, at least until the above-mentioned principles actually work and no disputes or user complaints arise.

Net neutrality.

Net neutrality is the principle that all internet traffic should be treated equally, without discrimination based on the user, content, website, platform or application. It ensures a level playing field where no service or content receives preferential treatment.[18]

5.1.3 Regulation in the EU:

The European Union has a regulatory framework for net neutrality set out in EU Regulation 2015/2120.[19]

This Regulation enforces strict net neutrality rules that prohibit ISPs from blocking or restricting traffic, whilst allowing for reasonable traffic management to ensure network security and integrity and to maintain the general quality of service. Compliance and implementation are ensured by national regulatory authorities in cooperation with BEREC.

From the NS's perspective, Article 3(3) is particularly significant:

“Internet access service providers shall treat all traffic equally when providing internet access services, without discrimination, restriction or interference, and regardless of the sender and recipient, the content accessed or distributed, the applications or services used or provided, or the terminal equipment used.

The first subparagraph shall not prevent internet access service providers from implementing reasonable traffic management measures. In order for such measures to be considered reasonable, they must be transparent, non-discriminatory and proportionate, and must not be based on commercial objectives but on the objectively different requirements of specific categories of traffic regarding the technical quality of services. Such measures must not target specific content and must not be applied for longer than is necessary.”

The Regulation therefore assumes that, in the case of internet access services, traffic management will be used only at the level of traffic categories to ensure their quality. This means, for example, the possibility of prioritising the online streaming category to ensure its smooth operation, as opposed to FTP traffic, which is not as sensitive to transmission stability. Furthermore, such traffic management should not be motivated by commercial objectives. This is demonstrably the case with NS; CSPs expect NS to increase their revenues. This provision would therefore not allow for the use of all types of network slicing in accordance with net neutrality requirements.

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[18] Easley, Robert F.; Guo, Hong; Kraemer, Jan (8 March 2017). "Easley, R., Guo, H., Krämer, J. - From Net Neutrality to Data Neutrality, Information Systems Research 29(2):253–272".

[19] REGULATION (EU) 2015/2120 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services and Regulation (EU) No 531/2012 on roaming on public mobile communications networks within the Union

However, there is also point 5 of this Regulation, which provides:

"Providers of electronic communications services to the public, including internet access service providers, and providers of content, applications and services shall be free to offer services other than internet access services that are optimised for specific content, applications or services, or a combination thereof, where such optimisation is necessary to meet the requirements of the content, applications or services for a certain level of quality.

Providers of electronic communications services to the public, including internet access service providers, may offer or enable such services only where there is sufficient network capacity to provide them as a supplement to the internet access services provided. These services must not be used or offered as a substitute for internet access services and must not be to the detriment of the availability or general quality of internet access services for end-users."

This provision provides a good opportunity to offer VPNs in accordance with regulatory requirements, provided that the VPN is not considered an internet access service but a specific service. For some services, such as a virtual private network, this is clear; for others, it may be debatable. In any case, mobile operators should ensure that the allocation of resources for VPNs does not lead to disruption of internet access services for other users.

5.1.4 Regulation in the US [20]

The United States is not only a mature market in terms of telecommunications and 5G, but is also a clear leader in terms of technology companies and innovation in digital services. It is therefore worth examining the development of the relationship between net neutrality and network slicing in the US market, as developments there have global implications thanks to technology companies.

Whilst regulation in the EU is stable thanks to the aforementioned Regulation, net neutrality is a controversial topic in the US. It was originally introduced by the FCC under the Obama administration, which prevented ISPs from blocking or restricting lawful internet traffic and from prioritising traffic for a fee. These regulations were repealed in 2017 by FCC Chairman Ajit Pai under the Trump administration. With the Biden administration, there have been efforts to reinstate net neutrality rules, highlighting the ongoing debates and legal disputes surrounding this issue.

The fact that net neutrality and network slicing may be in direct conflict, and that net neutrality rules may directly threaten the development of NS, is evidenced by the fact that communications service providers such as T-Mobile, AT&T, Comcast and Verizon, as well as technology firms such as Nokia and Ericsson, have become directly involved in the debate on net neutrality and are seeking to achieve adjustments to regulatory measures. In its December submission, T-Mobile issued a 66-page response to the FCC's latest draft proposal on net neutrality, which focused largely on the topic of network slicing. The fundamental issue is whether the regulations will permit network management that encompasses all forms of network slicing, or not.

T-Mobile argues that: "A targeted update to the definition of 'reasonable network management' that takes into account new network management techniques will make it easier for providers to offer more valuable services to end-users, streamline service delivery, and facilitate the development and deployment of beneficial specialised services."[21]

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[20] *Net Neutrality*. (n.d.). Federal Communications Commission. https://www.fcc.gov/net-neutrality

[21] Jackson, D. (19 January 2024). *T-Mobile warns of friction between net neutrality and network slicing - Urgent Comms*. Urgent Comms. https://urgentcomm.com/2024/01/19/t-mobile-warns-of-friction-between-net-neutrality-and-network-slicing/

5.1.5 Summary of regulatory issues

The intersection of requirements for public network operators, the EC's publicly available services, net neutrality and network slicing presents a complex regulatory challenge. Balancing the principles of an open internet with the benefits of advanced 5G technologies will require nuanced policy decisions that support innovation whilst protecting consumer rights and ensuring fair competition.

A win-win scenario appears to be one in which the development of new services based on advanced network slicing technology is enabled, as these undoubtedly have the potential to deliver significant value to both users and providers. At the same time, this will be implemented in a way that does not have a negative impact on all users and their access to the open internet, and does not in any way favour or distort competition between internet service and application providers.

The approach of communications service providers will therefore play an important role; they should balance the interests of users and plan network capacity in such a way that the provision of NS does not lead to a deterioration in services for other users. The prioritisation that NS undoubtedly entails must be based on a non-discriminatory basis. It must therefore enable all users to access NS-related services on equal terms. And in the event of prioritising certain types and categories of traffic, this must be based on general categories so as not to favour specific applications and service providers.

5.2 Cybersecurity

5G technology is, in principle, very secure. No security is perfect; however, in the case of 5G, there has also been a significant improvement compared to previous generations, as shown in the following table:

Security features / mobile technology	2G	3G	4G	5G
Subscriber/device authentication on the network	Yes	Yes	Yes	Yes
Network authentication of device/subscriber	No	Yes	Yes	Yes
Inter-operator authentication	No	No	No	Yes
IPSec encryption	No	Optional	Optional	Yes
End-to-end data integrity	No	No	No	Yes
End-to-end data encryption	No	No	No	Yes
Subscriber identity concealment (SUCI/SUPI)	No	No	No	Yes

Table 1: Comparison of security features across generations of mobile networks. Source: Ing. Michal Poupa.

Unlike 2G, 3G and 4G networks, 5G networks now exclusively use web technologies and have completely abandoned the use of non-IP signalling protocols such as Signalling System No. 7; IP-based protocols such as RADIUS and DIAMETER have also been phased out.

Individual elements within the core of a 5G network have RESTful API (Application Programming Interfaces) interfaces – this architecture is referred to in 5G as 5G Service-Based Architecture (SBA) and the elements are interconnected via a so-called Message Bus. TLS, OAuth2 and IPsec technologies are used to secure this communication.

Network slicing (NS) could become one of the key technologies in 5G networks. However, its complexity presents a number of challenges that must be addressed for its effective implementation. One of these challenges is new vulnerabilities in the areas of security and privacy. These vulnerabilities can lead to significant problems, such as data leaks and disruptions to the network and other services.

Let us therefore take a closer look at these risks and possible solutions.

5.2.1 Ensuring security and privacy in network slicing

Security issues relating to NS can be divided into three main areas: lifecycle security (LC), inter-slice security and intra-slice security[22] .

1. Life cycle security (LC):

The lifecycle of a network slice instance (NSI) may span multiple networks, various virtual infrastructures and data centres. This extensive lifecycle entails various security threats, including identity theft, privacy attacks, denial-of-service (DoS) and distributed denial-of-service (DDoS) attacks, traffic tampering and unauthorised access.

Effective lifecycle security requires comprehensive measures to address these threats throughout the entire NSI lifecycle.

2. Inter-slice security:

Inter-slice security addresses security issues between different slices. This includes ensuring that interactions between slices do not lead to security breaches or vulnerabilities.

Measures include strong isolation between slices to prevent any mutual interference, maintaining robust authentication and authorisation protocols, and implementing strict access controls.

3. Intra-slice security:

Intra-slice security focuses on security within a single slice. It involves protecting the integrity and confidentiality of data and operations within the slice.

Protection strategies include the use of strong encryption methods, ensuring secure communication channels, and regular monitoring and auditing of slice activities.

5.2.2 Key security requirements for network slicing

A critical security requirement for NS is strong isolation between network slice instances. This isolation ensures that there is no interference between slices or any related entities within a slice, including network functions (NFs) and users. Key aspects for ensuring isolation include:

- Network architecture: Isolation should be ensured across the entire network, including hypervisors, operating systems, network hardware, network operators and application programming interfaces (APIs).
- Security techniques: The implementation of strong encryption, robust authentication methods, strict access control policies and comprehensive physical security measures is essential for maintaining NS security.

5.2.3 Addressing security and privacy threats in NS

NS inherits several security threats due to its reliance on software-defined networking (SDN), network function virtualisation (NFV) and cloud computing. A range of advanced security solutions can be employed to mitigate these threats:

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[22] R. F. Olimid and G. Nencioni, “5G network slicing: A security overview,” *IEEE Access*, vol. 8, pp. 99999–100009, 2020.

1. **AI/ML-based solutions**: The use of artificial intelligence (AI) and machine learning (ML) for dynamic threat detection and response.

2. **Security orchestration**: Implementation of coordinated security measures across various network components to ensure comprehensive protection.

3. **Blockchain-based solutions**[23] : The use of blockchain technology to enhance security and trust through decentralised and immutable records.

4. **Security Service Level Agreement** (Security SLA): Establishing clear security performance metrics and compliance requirements through a Security SLA.

5. Security by Design (SbD)[24] : Integrating security aspects into the design and development phases of NS to address potential vulnerabilities in advance.

5.2.4 Privacy in network slicing

Privacy is a key aspect of NS, particularly as it utilises shared resources across multiple tenants. Information leaks in such an environment can lead to significant privacy breaches. Key strategies for addressing privacy issues include:

- **Privacy isolation**: Implementing robust privacy isolation mechanisms through established privacy policies and adherence to principles such as privacy by design (PbD).
- **Trust management**: Addressing trust-related issues through blockchain/distributed ledger technology (DLT)-based solutions and the use of AI-powered trust brokers to facilitate secure interactions.

5.2.5 Cyberattack scenarios specific to NS-enabled networks

The research identified several attack scenarios specific to networks with NS enabled[25] :

The following table provides an overview of the identified attack scenarios, including potential threats and the corresponding NS lifecycle phases where these threats are most likely to occur.

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[23] M. A. Togou et al., “A distributed blockchain-based broker for efficient resource provisioning in 5G networks,” in *Proc. Int. Wireless Commun. Mobile Comput. (IWCMC)*, 2020, pp. 1485–1490.

[24] R. F. Olimid and G. Nencioni, “5G network slicing: A security overview,” *IEEE Access*, vol. 8, pp. 99999–100009, 2020.

[25] C. De Alwis, P. Porambage, K. Dev, T. R. Gadekallu and M. Liyanage, "A Survey on Network Slicing Security: Attacks, Challenges, Solutions and Research Directions," in IEEE Communications Surveys & Tutorials, vol. 26, no. 1, pp. 534–570, First quarter 2024, doi: 10.1109/COMST.2023.3312349.

NS Attack Scenario	Uniqueness of NS	Impact of the attack	Mitigation strategies
Location tracking attacks	NS makes networks more vulnerable	Disclosure of user location information	Correlation between NFs (network functions), fixed mapping between the application layer and the transport layer of identities in hybrid NFs, security/privacy by design
Fraud or data leakage	NS makes networks more vulnerable	Data leakage to unauthorised parties	Better slice isolation, trust models and reputation, computational trust, blockchain, zero-trust security
Interoperability security challenges with older versions	NS makes networks more vulnerable	Various security threats due to the lack of specific security features in pre-5G networks	Transition to 5G and B5G network architectures supporting specific slice security features
Sealing between slices when the UE is connected to multiple slices	An attack unique to the NS	Access to the NF of other slices; compromised slices can control the UE	Implementation of proper sealing between slices
Security challenges caused by configuration errors and missing layers	Attack unique to the NS	Attackers exploiting vulnerabilities in the NS to attack 5G networks	Careful configuration of the NS with regard to security, resource utilisation and costs
Security challenges caused by increased complexity	Attacks unique to the NS	These challenges present opportunities for attackers to exploit 5G networks	Proper configuration and deployment of 5G networks
Attacks exploiting trust	Attacks unique to NS	Disclosure of confidential data considered by trusted parties	Authentication of functions within slice instances, mutual authentication between slice managers
Security challenges caused by a lack of security granularity	NS makes networks more vulnerable	Leakage of critical information at the slice level	Strict identity verification of slices
Security challenges caused by missing security zones]	NS makes networks more vulnerable	Networks can be compromised if the entire core network is operated as a single trusted zone	Filtering, authentication and authorisation of communication between slices, implementation of different security zones
Exhaustion of security resources in other slices	Attacks unique to NS	Security threats to slices through attacks on slices with lower security and depletion of shared resources	Deep neural networks for DDoS attack detection, slice isolation, and resource separation to minimise impact.
Denial of service to other slices	Attack unique to NS	Denial of service to a single slice by draining resources shared across multiple slices	Attack detection techniques based on machine learning, blockchain for user access control
Side-channel attacks between slices	Attack unique to NS	Attackers obtain information	Strong slice isolation, avoiding hosting applications on slices with similar hardware

Table: Overview of attack scenarios and mitigation methods. Source: [26]

The successful deployment of NS in 5G and future generations of mobile networks depends, among other things, on successfully addressing the security and privacy challenges that NS presents.

This can be achieved by utilising advanced security solutions and adhering to strict privacy standards within the NC. Only then will the full potential of this technology be realised for 5G and future generations of networks.

5.3 Operational management of NS

The deployment of NS, particularly dynamic slicing and third-party open slicing, will place high demands on operators' (CSPs') OSS/BSS systems. This may lead to the need to upgrade or completely replace significant parts of these systems. For mobile operators, however, this represents projects that often take several years, almost always considerably longer than originally planned. The associated costs can run into the hundreds of millions of CZK. And even so, the outcome of the project is not always as defined at the start. This is due to the immense complexity of OSS/BSS systems, which have accumulated ever-new requirements over the years and contain a vast amount of data. Yet they form the backbone of mobile operators' business and are absolutely critical to them. Any intervention therefore requires the deployment of enormous resources. And operators must have a really good reason for it.

Will network slicing provide a sufficiently strong business case to justify changing the OSS/BSS systems?

Even if the answer is yes, a project involving an OSS/BSS upgrade could delay the actual effective deployment of NS by several years.

A possible solution to this challenge is to implement NS in gradual steps, gain experience, develop business models, and only then gradually move on to complex dynamic scenarios.

In practice, this means starting with static slicing, moving on to dynamic slicing, and subsequently to slicing open to third parties (see the Orchestration chapter).

The following table illustrates this phased process of deploying network slicing, divided into three phases, in greater detail.

The specific approach may be adapted to the situation of the given CSP and the state of its OSS/BSS systems, but in principle, such a phased approach is certainly a good starting point.

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[26] C. De Alwis, P. Porambage, K. Dev, T. R. Gadekallu and M. Liyanage, "A Survey on Network Slicing Security: Attacks, Challenges, Solutions and Research Directions," in IEEE Communications Surveys & Tutorials, vol. 26, no. 1, pp. 534–570, First quarter 2024, doi: 10.1109/COMST.2023.3312349.

Phase	Name	Description
Phase 1	Basic network slicing functionality	- Enabling basic slicing functionality in CSP networks - Focus on network slicing management, template management, domain orchestration and repositories - Deployment of several static slices (fewer than 20) with a basic level of automation or manually for simple use cases focused on connectivity
Phase 2	End-to-end slicing automation and scaling	- Development of slicing automation across network domains - Deployment of end-to-end orchestration, resource management and product management - Scaling for the deployment of hundreds of slices within the network
Phase 3	Advanced slicing business models	- Enhancing CSP capabilities through business and customer functionalities - Focus on channel and partner management, sales, marketing and marketplaces - CSPs deploy hundreds of dynamic slices with back-end system functionalities to enable advanced slicing use cases

Table: Network slicing deployment process, Source: [27]

5.4 Finding a suitable business model

Chapter 4 explained the business model and the principles that must be in place for a business model to be successful. It also described various possible business models for the B2C, B2B/B2G and wholesale sectors.

These are different variations of business models which make sense under certain circumstances; they can inspire and demonstrate that there is a whole range of possibilities.

The question, however, is which of these business models will be successful.

There is no immediate or definitive answer to such a question. The whole field of network slicing is in its infancy, so it is not even possible to define which business models will be successful in different markets. The answer may vary depending on the CSP's focus, the type of market, and the stage of network slicing services.

And, in particular, depending on the CSP's ability to implement the model, which may require a very deep understanding of the market, segments and verticals. At a much higher level than has previously been necessary for CSPs.

In any case, this represents a major challenge for CSPs.

To meet this challenge, it will be advisable to:

- Implement multiple business models in parallel. Continuously evaluate the success of the models and adapt flexibly. This is somewhat analogous to prototyping in product development.

[27] Ericsson. *Network slicing: A go-to-market guide to capture the high revenue potential*. 2021.

- Select a business model and adapt it according to the phase NS is in. See the previous chapter 5.3. This means starting with simple business models.
- Gain a good understanding of segments and verticals. These may be solutions specific to a given area. As long as CSPs effectively provide a ‘one-size-fits-all’ approach, their understanding may not have been at such a level.
- Build an ecosystem and develop a range of specific services in collaboration with partners.

With the paradigm shift and the ability to provide tailor-made services for different customer segments and applications thanks to network slicing, the entire service provision landscape will become significantly more complex. In reality, it will not be within the CSPs’ capabilities to fully understand all segments at the same level as companies specialising in that particular segment. And it doesn’t matter whether it’s gaming or critical communications. Therefore, wholesale collaboration and allowing sufficient flexibility for specialist firms may be the most beneficial policy for the entire ecosystem, from CSPs through service providers to, in particular, the end customer.

This will, of course, require a change in the CSP’s mindset compared to the current situation, which may ultimately prove to be a greater obstacle than the complexity of the technical solution.

6 Current state of NS and future outlook

6.1 Global status and case studies

Based on information from NOKIA, one of the world's top three telecommunications equipment suppliers, it can be stated that virtually all tier-1 mobile operators have a plan to implement network slicing. This signals enormous future potential for the further development of this technology. At the same time, however, network slicing is currently only being implemented by a limited group of early adopters among operators.

The current state and future potential of network slicing are best illustrated by projects that have already been implemented and are currently running. We therefore present five case studies from implemented network slicing projects.

The first two case studies are from China. The fact is that Chinese technology firms are among the leaders in the field of 5G technology. Moreover, a number of ambitious projects are being implemented in China. The field of network slicing is no exception in this regard. Although the use of Chinese technologies may be problematic in certain types of projects given the geopolitical situation, the case studies from China are certainly inspiring. The first concerns the use of NS for smart grids, whilst the second focuses on the use of NS in a steel company's campus network.

The other two case studies involve the European technology firms Ericsson and Nokia. In Nokia's case, the project is also being implemented in Europe. This is a good example of how it is possible to carry out ambitious projects in Europe and be among the early adopters.

The final study is from the US and highlights a completely different type of project, one focused on application developers.

Overall, these diverse case studies demonstrate the truly vast potential of network slicing, ranging from a focus on individual mega-corporations, through potential benefits for a critical sector such as energy, to improving service quality for individuals and households.

6.1.1 Case study: the use of network slicing for smart grids (China Telecom, SGCC and Huawei)[28]

The collaboration between China Telecom, SGCC (State Grid Corporation of China) and Huawei, launched in September 2017, explores the use of 5G network slicing to streamline smart grid services. The project has demonstrated significant technological and commercial feasibility, highlighting the advantages of slicing over traditional optical networks in supporting differentiated services and reducing total cost of ownership (TCO).

Challenges in energy networks.

Smart grids rely on information and communication technologies to increase the efficiency and reliability of electricity distribution. Traditional power grids, particularly in the distribution and consumption phases, face challenges with communication network coverage due to the large number of dispersed nodes. The 'last

[28] GSMA, *Powered by SA: Smart Grid 5G Network Slicing SGCC, China Telecom and Huawei*, 2019.

5 km' is a major obstacle, as 95% of outages occur in this segment. Efficient last-mile access networks are essential for the deployment of smart grids, but fibre-optic solutions are costly and difficult to deploy.

5G Slicing for Smart Grids

5G slicing offers a cost-effective and flexible solution by dividing the 5G network into logically isolated slices. Each slice can be tailored to specific service requirements, ensuring different levels of service level agreements (SLAs). The project identifies four typical smart grid scenarios that benefit from 5G slicing:

- Intelligent distributed automation: requires ultra-low latency, a high degree of isolation and high reliability.
- Precise load control at the millisecond level: has similar connectivity requirements to distributed system automation.
- Low-voltage data acquisition: requires massive connectivity (mMTC), high frequency and real-time data.
- Distributed energy resources: require massive connectivity (mMTC), low latency and high reliability.

Technical perspective.

From a technical perspective, 5G slicing meets the connectivity requirements of basic industrial control services, providing ultra-low latency, massive access and high reliability at a lower cost compared to dedicated optical networks. From a service perspective, it divides smart grid scenarios into industrial control services and data collection services, with each benefiting from different types of slices such as URLLC (Ultra-Reliable Low-Latency Communication) and mMTC (Massive Machine Type Communication).

5G slicing enables the unified deployment and management of multiple slices, and the integration of legacy services with new industrial control services. Lifecycle management encompasses design, deployment, operation, optimisation and capability exposure, ensuring automated and efficient network management.

Practical implementation.

China Telecom and its partners have successfully conducted tests in Nanjing and Qingdao, demonstrating the feasibility of 5G slicing in a real-world power grid environment. The tests demonstrated millisecond-level latency, slice isolation and SLA assurance, which is crucial for critical power grid operations.

The project has also published commercial and technical feasibility analyses, which show a significant reduction in TCO and a positive return on investment (ROI) for energy companies utilising 5G slicing. The ecosystem includes various industry partners, highlighting the importance of slicing and MEC (Multi-access Edge Computing) technologies for the success of the 5G smart grid.

It can therefore be concluded from this case study that 5G slicing addresses the various requirements of smart grids, offering flexibility, high reliability and ultra-low latency. This innovative project serves as a valuable reference demonstrating the potential of slicing in vertical sectors.

6.1.2 Case study: the use of 5G network slicing in a steelworks (Hunan Valin Xiangtan Iron and Steel (XISC), Huawei, China Mobile)[29]

The deployment of a private 5G network by China Mobile and Huawei for Hunan Valin Xiangtan Iron and Steel (XISC), one of the world's largest steel producers, demonstrates the transformative impact of 5G, edge computing and network slicing on traditional heavy industry, such as steel production. This initiative has significantly improved productivity, efficiency and operational intelligence at XISC. It delivers significant economic benefits and sets the benchmark for similar industrial applications.

Digital transformation objectives: XISC has focused on eliminating information silos, improving interoperability between machines and automating production processes to increase efficiency, yield, product quality and profitability.

5G Deployment: The network covers a 5-square-kilometre campus with 200 cells operating in the 2.6 GHz and 4.9 GHz bands, supporting Super Uplink speeds of up to 700 Mbit/s. Edge computing nodes have been implemented to ensure near-real-time response and reduce latency from 26 ms to 9.9 ms.

Use cases and benefits:

- Process monitoring: Drones generate UHD video streams supported by augmented reality, requiring massive data uploads.
- Remote control: Cranes and robots are remotely controlled, requiring very low latency.
- AI and machine vision: Automated processes such as the rotation of steel plates and steel surface inspection utilise AI analysis, which increases efficiency and accuracy.

Impact and results:

- Productivity and cost savings: The implementation of network slicing and 5G led to a 30% increase in production efficiency, resulting in annual cost savings of USD 15 million. Output per employee rose from 920 to 1,380 tonnes of steel per year, and production costs fell by 10%.

- Quality and safety: Remotely controlled robots improve the uniformity of slag addition, thereby enhancing steel quality and reducing the need for manual labour in hazardous conditions. Detection of steel surface defects improved from 90% to 95%, increasing yield and customer satisfaction.

- Future development: The flexible platform enables ongoing digital transformation, supporting new use cases such as reducing energy consumption, collaborative design and expanded automation in warehouse management.

Deploying 5G in a demanding industrial environment presented significant challenges, including the integration of legacy systems and diverse connectivity requirements. The flexible platform enabled tailored solutions, demonstrating the necessity of an adaptable approach to meet specific industrial needs.

This case study highlights the significant potential of 5G network slicing to revolutionise traditional manufacturing processes, offering inspiration for future digital transformation across various industrial sectors.

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[29] Gabriel, Caroline. *The combination of campus 5G, edge and slicing has transformed the business of steelmaker XISC in China*. Analysys Mason. May 2021.

6.1.3 Case study: 5G network slicing on Android devices (Far EasTone and Ericsson)[30]

In November 2021, Far EasTone Telecommunications (FET Taiwan) and Ericsson achieved a significant breakthrough in 5G technology by conducting the first end-to-end (E2E) multiple network slicing trial on several commercial Android devices. This trial demonstrated the capabilities of Ericsson's Dynamic Network Slice Selection solution, utilising the User Equipment Route Selection Policy (URSP) feature. This development represents a major step forward in the field of 5G network slicing, offering new levels of flexibility, speed and opportunities for monetisation.

The trial demonstrated the functionality of URSP (User Equipment Route Selection Policy):

- It enables a mobile device to access multiple user profiles.
- It enables different profiles for enterprise and consumer applications on a single device.
- It increases service providers' flexibility in creating tailored service offerings and new business models.

Technical implementation:

- Use of Ericsson's 5G standalone (SA) network hardware and software, including solutions from their RAN and Core portfolios.
- Demonstration on several commercially available Android 12-powered Pixel 6 devices.
- Monetisation and business opportunities:
- Opens up new monetisation opportunities through network slicing without the need for dedicated network equipment.
- Enables service providers to offer customised, cost-optimised solutions based on public networks.
- Supports collaboration with hyperscalers, OTT players and app developers for new business models.
- Meets the expectations of the government and the private sector regarding digital transformation, particularly in areas such as smart manufacturing, telemedicine and smart cities.

Impact and future outlook:

- The test results demonstrated significant potential for E2E network slicing to revolutionise business models and monetisation strategies.
- FET plans to introduce solutions for the efficient creation and scaling of network slices, with automation and orchestration playing a key role.
- The technology promises to support a variety of applications, including separate personal and professional profiles on smartphones, which will improve the user experience and operational efficiency.

The successful trial by FET and Ericsson not only highlights the transformative potential of 5G network slicing but also sets a precedent for future innovations and business models in the telecommunications sector. The ability to dynamically manage multiple network slices on commercial equipment represents a significant milestone, paving the way for broader ecosystem development and new monetisation opportunities.

[30] Ericsson, *The recipe for 5G slicing success: Far EasTone and Ericsson's world-first 5G end-to-end multiple network slicing trial, 2022.*

6.1.4 Case study: Fixed Wireless Access (FWA) using 5G network slicing (Telia and Nokia)[31]

In September 2022, Nokia and Telia Finland launched the world's first commercial 5G standalone (SA) network with network slicing specifically for Fixed Wireless Access (FWA). This pioneering project aims to enhance Telia's 5G home broadband services by offering customers in Finland various broadband packages with guaranteed service levels.

The use of network slicing:

- The introduction of network slicing enables Telia to dynamically allocate parts of its network for 5G FWA services. This allows for flexible traffic balancing between FWA and mobile users.
- Different service levels can be specified, ensuring varied speeds, latencies and data capacities tailored to customers' needs.

Implementation:

- Nokia, as Telia's sole 5G supplier in Finland, has modernised Telia's entire Radio Access Network (RAN) infrastructure. This includes equipment from Nokia's AirScale portfolio, comprising 5G radio and baseband products.
- The network utilises Carrier Aggregation technology to optimise spectrum assets and improve coverage and capacity.

Benefits for the provider and customers:

- The deployment enables Telia to offer various broadband packages, each with specific performance characteristics, providing customers with reliable, high-quality internet services.
- Telia's CTO, Jari Collin, stated that the use of this technology will put Finland at the forefront of 5G development.

Impact and future prospects:

- This deployment represents a significant step in the commercialisation of network slicing in 5G across Europe.
- As the technology matures, Telia plans to continue innovating and expanding its service offerings. In doing so, it will leverage the capabilities of 5G to meet the growing demand for high-quality internet connectivity.

6.1.5 Case Study: 5G Network Slicing Beta Programme for App Developers (T-Mobile USA)[32]

In August 2023, T-Mobile launched a revolutionary beta programme for developers focused on 5G network slicing, with the aim of improving video calling applications. This programme represents a significant step in the commercialisation

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[31] Corporation, Nokia. "Nokia and Telia Finland launch world's first commercial 5G SA network with network slicing for Fixed Wireless Access." Nokia, 29 March 2023. https://www.nokia.com/about-us/news/releases/2022/09/09/nokia-and-telia-finland-launch-worlds-first-commercial-5g-sa-network-with-network-slicing-for-fixed-wireless-access/.

[32] Paulsen, Justin. "T-Mobile Launches First-Ever 5G Network Slicing Beta for Developers." T-Mobile Newsroom, 8 November 2023. https://www.t-mobile.com/news/network/t-mobile-launches-first-ever-5g-network-slicing-beta-for-developers.

5G network slicing technology, which enables the creation of virtual networks on shared physical infrastructure, each with customised parameters for specific use cases.

Network slicing is useful for applications requiring different levels of quality of service (QoS), such as ultra-reliable low latency communication (URLLC), massive machine-type communication (MMTC) and enhanced mobile broadband (eMBB). This is doubly true for video calling applications.

T-Mobile, the only operator in the US with a national 5G SA network, has launched a beta programme focused on video calls. Developers can test and optimise their applications using customised network slices that provide stable uplink and downlink speeds, low latency and high reliability. Customised slices ensure high application quality and performance, which is critical for real-time communication.

The beta programme is available to iOS developers in Seattle and San Francisco, with plans to expand to Android devices later this year. The programme includes major partners such as Dialpad, Google, Webex by Cisco and Zoom, who are already using this technology to enhance their applications.

T-Mobile plans to expand the beta programme to other types of applications and use cases, providing a wider range of options for developers and businesses. This initiative not only strengthens T-Mobile’s leadership in 5G technology but also opens up new opportunities for innovation in mobile and AI applications.

T-Mobile’s initiative represents a significant step forward in the commercialisation and development of 5G network slicing technology in the US.

6.2 Status and outlook for NS in the Czech Republic

To assess the situation in the Czech Republic and the outlook, the position of mobile operators is, of course, key, because in the case of NS in public networks – which is the dominant part of NS – further progress depends on them, on their ability to find business models and address the challenges that the introduction of NS brings.

All mobile operators in the Czech Republic are (in 2024) at the stage where they have selected their suppliers for the core of the public 5G network, namely Nokia, Ericsson and Mavenir.

This is a necessary (though not sufficient) prerequisite for being able to offer the 5G network. Following the selection process, which is by no means a short one in itself, the actual implementation phase will then take place.

According to a statement from T-Mobile, we could see the first offers based on static NS in the first half of 2025. This is because NS is one of the key technologies for T-Mobile within 5G and should therefore be deployed among the first functionalities of the 5G SA network core.

T-Mobile is already carrying out pilot projects which, for technical reasons, use LTE technology, with the aim of verifying the benefits of slicing services for users. These projects focus on broadcasting and connectivity for payment terminals.

So what opportunities does T-Mobile see in network slicing, and what use cases does it expect in the first wave?

It should certainly be a B2B use case. In addition to the aforementioned broadcasting, static slicing can be used as backup connectivity with a defined and guaranteed SLA. This will certainly be appreciated by all businesses that rely on data connectivity and provide their services across various locations. Payment terminals are certainly just one of many examples.

Another use case is generally considered one of the hot candidates for NS deployment, and T-Mobile shares this view: PPDR, i.e. services for emergency services.

An interesting, and not so often mentioned, area is the use of UAVs in agriculture. Agricultural machinery is nowadays expensive and sophisticated equipment with many autonomous features. However, this makes it all the more dependent on high-quality and guaranteed connectivity, often across a relatively large area. That is why T-Mobile sees potential for early adopters among UAV users in the field of smart agriculture.

Other users may include utility companies responsible for power lines, their maintenance and inspections. Drones can assist them in this often demanding and costly work. However, the data from these drones is ideally transmitted using connectivity with guaranteed parameters provided by the NS.

In certain cases, NS can be a dynamic solution that enables (primarily businesses) to secure connectivity in problematic situations and locations, such as festivals and similar gatherings of people that lead to network congestion. In such situations, businesses will be willing to pay relatively high additional fees to ensure they can deliver their services, process payments, etc. Note: the advantage of slicing over older solutions such as QoS/QCI classes should lie in the fact that a prioritised customer can connect even to an overloaded network.

In the case of B2C, T-Mobile is more cautious in its assessment of business benefits. It assumes that the end customer will be willing to pay specifically above and beyond the standard tariff only if NS ensures the functioning of a service that would otherwise be problematic, such as services related to AR.

As for the obstacles and challenges associated with NS, T-Mobile does not foresee significant regulatory issues provided the services are appropriately defined. NS should be linked to premium services – ensuring priority access, securing network resources defined by specific parameters – though any customer interested in doing so will be able to order and pay for these premium services.

The main challenge will therefore likely be the OSS/BSS system and its ability to support advanced forms of dynamic and open slicing.

If we look at case studies, it is clear that the Czech Republic is already lagging behind the most advanced markets by several years. In this context, it is worth noting that a number of services which network slicing can help deliver at a much higher level of quality are of significance to the entire Czech economy. Whether it be the use of distributed energy resources, support for Industry 4.0 through virtual private networks, or qualitatively new services for emergency services.

It is therefore good news that the situation is set to begin changing next year. As in any commercial sector, the pace of progress here will depend not only on technological development but also on demand for advanced services. It is therefore essential to raise awareness of the possibilities and benefits of network slicing among its potential users in the corporate and institutional sectors.