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5G Edge Slicing in Next-Generation Virtual Private Network

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White Paper

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Executive Summary

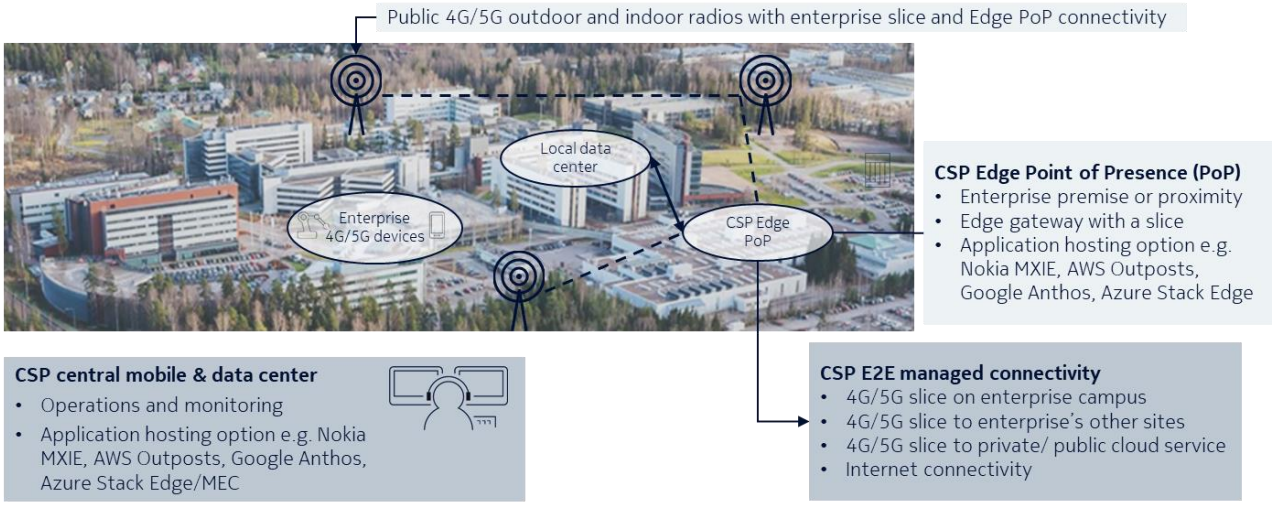
After the successful launch of 5G, Communication Services Providers (CSPs) are now moving their focus on new revenue opportunities and looking for new ways to monetize their network investments further. For many CSPs this includes also finding successful strategies for partnering with Cloud Services Providers.

The following white paper outlines Nokia's latest 5G business and technology innovation that allows CSPs to create major new value to enterprise customers. This innovation combines 5G Virtual Private Network (VPN) service with Edge Slicing and Edge Cloud Applications.

With Nokia's solution enterprises can easily and fast start using CSP-supplied 5G Virtual Private Network services where they need. 5G Edge Slicing brings new opportunities for enterprise cloud application deployments and user experience improvements.

In 5G Virtual Private Networks CSPs can provide similar performance levels and security advantages as in dedicated private networks while using their existing 4G/5G public network with service scalability, coverage flexibility, and cost-efficiency. With 5G Edge Slicing CSPs can keep critical enterprise traffic and data at a customer's premises or nearby area as well as bring enterprise cloud applications close to end-users, 4G/5G terminals, and devices.
Virtualized 4G/5G network enables CSPs to sell a variety of new services to enterprise customers with security, management, assurance, and performance, in line with enterprise's requirements.

Figure 1. 5G Virtual Private Network with Edge Slicing in enterprise campus



A 5G VPN can be deployed flexibly - in an area with one or more base stations or a campus, a city, or a wider area. Edge Slicing provides a virtualized network in the selected area across RAN-Transport-Core-Enterprise where business critical enterprise data traffic is isolated from public Internet traffic. Distributed cloud core can be deployed at customer's premises or nearest CSP's Edge Point of Presence (see Figure 1). The same sliced public 4G/5G network infrastructure can serve multiple companies in the same area.

The introduction of the 5G VPN with Edge slicing boosts the 5G ecosystem and creates significant revenue opportunities for CSPs, Cloud Service Providers (e.g., Amazon Web Services, Google Cloud, and Microsoft Azure), co-location firms (e.g., Equinix, etc.), and many others in the

fast-growing Edge market. According to Gartner[1], “Edge, including hardware, software and services, will grow to a USD 450 bn market by 2025”. Nokia believes that 5G Edge Slicing will be a significant enabler for Edge services and Edge cloud applications.

Nokia is already working with leading CSPs and enterprises in live 5G Edge Slicing deployments. The companies are testing different enterprise use cases and business applications such as

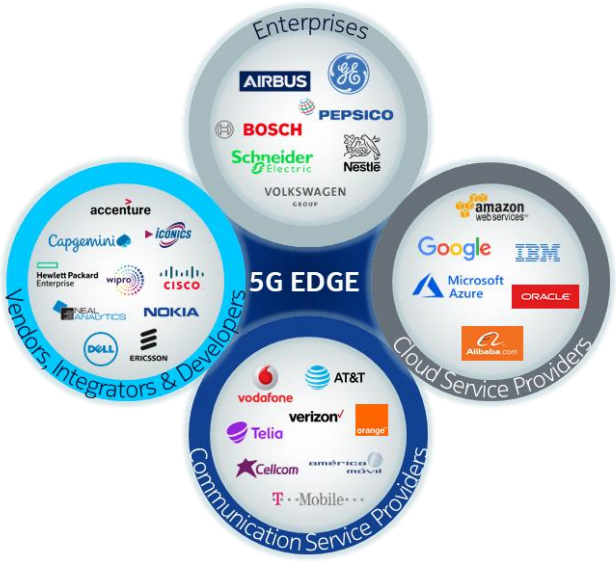
- sliced factory applications with video analytics, remote-controlled robot, and telemetry.
- electric plant monitoring, control, and management.
- vehicle locations, sensing, and visual data, and live streaming in mining campus areas.

With 4G/5G slicing at the Edge CSPs can provide enterprises valuable end-to-end managed network services from devices to private and public application clouds. Based on the enterprise needs, CSPs can deploy a 5G private network or a 5G virtual private network or in some cases both as a service.

5G Edge market dynamics

5G Edge is one of the hottest telecommunication topics in the industry today. It’s a strategic investment area for CSPs, Cloud Service Providers and enterprises as well as for different vendors, system Integrators and application developers (see Figure 2). All key industry players are looking for new business, revenue, and value creation opportunities for their customers at the 5G Edge. According to Gartner*, Edge revenue is estimated to be 450 bn USD by 2025.

Figure 2. 5G Edge business landscape



Enterprises

Business applications continue to move to public and private clouds at an accelerated pace. An increasing number of enterprise ICT applications are running on public Internet clouds hosted by local and global Cloud Service Providers such as Amazon Web Services, Google Cloud, and Microsoft Azure. At the same time business-critical applications in manufacturing, energy,

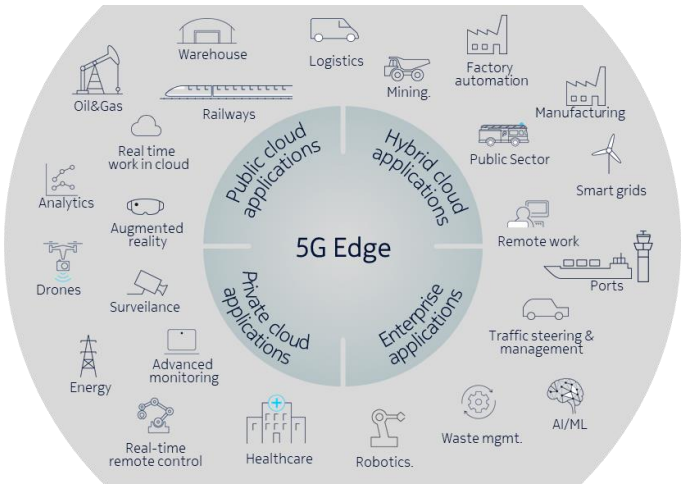
healthcare, industry, warehouse, ports, public sector, IoT, augmented reality, real-time analytics, AI/ML, and robotics in private data centers and private clouds.

Enterprises need better mobile connectivity as they continue digitalizing and automating their operations. Business and mission-critical processes require high performance, reliability, and low latency mobile networks that are secure and can be managed and monitored. Enterprises also want flexibility – support for new use cases, support for new users and devices, and support for coverage in new places and areas. 5G Edge, when deployed with the right architecture and functionality, can address the new mobile network requirements enterprises have.

Cloud Service Providers

Global Cloud Service Providers such Google Cloud, Azure, and AWS have comprehensive Edge Cloud offerings, and they are very active at the 5G Edge. They have globally distributed hyper-scale data centers and cloud application platforms. For cloud application deployments at the 5G network and enterprise edge, Cloud Providers offer hybrid and private solutions such as Google Anthos, AWS Outpost/Wavelength, and Azure Stack Edge/Private MEC (see Figure 3).

Figure 3. Edge cloud applications



Cloud Service Providers have a very diverse enterprise customer base. The fast development of new applications and services is enabled with application ecosystems that have many software developers. Some of the Global Cloud Service providers have also extended into the networking business e.g., Microsoft with Affirmed Networks & Metaswitch acquisitions in core domain and AWS with 5G private network offerings.

Communication Service Providers

5G Edge is a significant business opportunity for Communication Service Providers. Leading CSPs see that end-to-end managed mobile connectivity from devices to applications running in the Edge Cloud is a critical enabler for new enterprise 5G use cases and services. CSPs like AT&T, Verizon, TMO US and Vodafone have 5G Edge/Multi-Access Edge Compute offerings for their enterprise customers. Many CSPs have been also building dedicated private networks (that support 4G and 5G) for customers requiring mission-critical communication. Network infrastructure, spectrum licenses, enterprise communication solutions, customer base and relationships are key CSP assets in the 5G market.

CSPs have a strategic position at the Edge and many of them are planning how to best use this critical asset. Orange Business Services, NTT, and Verizon are currently providing different business cloud services from their national and international Data Centers. In addition, many CSPs are partnering with global Cloud Service Providers e.g., Verizon, TEF, Bell Canada and Swisscom with AWS, AT&T, Verizon, DT, and TEF with MS Azure and Vodafone, TIM, and Jio with Google Cloud. Some-CSPs are also partnering with infrastructure providers e.g., TMO US with Lumen and Verizon and Orange with Equinix.

Vendors and Integrators

Vendors and system integrators are playing a key role in providing network and cloud infrastructure products and solutions for 5G Edge. With deep know-how and experience, they can help enterprises and CSPs in planning how to implement 4G/5G networks, cloud applications, and new services.

5G Virtual Private Network with Edge Slicing

Network slicing is one of the key 5G capabilities that brings new services and business opportunities for Communication Service Providers. With slicing CSPs can provide new value for enterprise customers while leveraging existing network investments.

Nokia's CSP customers are already working on a variety of enterprise slicing use cases including energy, transportation, smart traffic, manufacturing, public sector, port, private line Fixed Wireless Access, live media stream, smart city, and dedicated business applications.

Enterprises and 5G Virtual Private Network

Slicing enables CSPs to offer their enterprise customers next-generation Virtual Private Network services in public 4G/5G networks that are secure, managed, and high performing. With Edge Slicing, critical enterprise traffic and data stays at the customer premise/proximity. Enterprises can define the area where they want the virtual private network to be deployed – it can be a small area covered by just one 4G/5G base station, or a campus area covered by several base stations with outdoor & indoor radios, a city area, or a wider area with locations where the customer has operations.

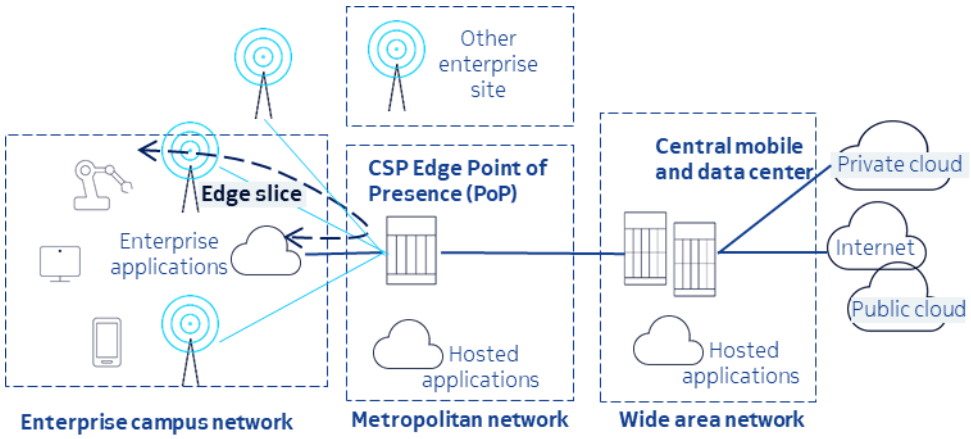
Enterprises want to have control of their virtual network including coverage and capacity. They will decide which devices and users have access to the slice available for enterprise applications, groups, or services. In the 5G VPN service, CSPs need to assure adequate service levels and provide visibility to the virtualized enterprise network performance with different monitoring and reporting tools. There are also enterprise security policies and requirements that the service and network must meet. The Edge deployment enhances network performance for low latency and high bandwidth use cases. Customers also expect that slicing-based services are provided to them at a competitive cost level. The deployment needs to be easy enabling small, medium, and large companies to start using the new services.

Edge Slicing deployment

The Edge Slicing provides in selected area a virtualized network across RAN-Transport-Core-Enterprise with a distributed cloud core deployed at the Enterprise customer premise/proximity (see Figure 4).

Nokia's-customers have live network deployments where selected RAN sites at an enterprise campus area are connected to an Edge PoP (Point of Presence) at/near the customer. In the Edge PoP the CSP is running distributed cloud core user plane for the enterprise 4G and 5G traffic. The Edge PoP is connected to a high-speed metro network that supports interconnectivity for enterprise customers using e.g., private IP/MPLS and SD WAN technologies. The Edge Slicing enables to keep critical business data traffic local while slice management, control, and assurance are run on existing central mobile & data centers to ensure cost and operational efficiency.

Figure 4. 5G Edge Slicing deployment

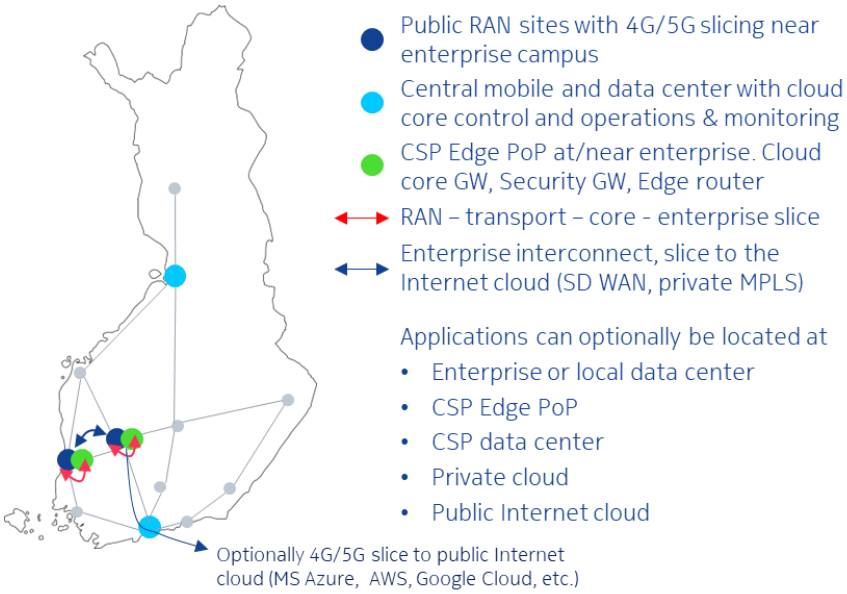


A CSP Edge PoP can be located at the enterprise campus or in a nearby area depending on customer requirements, network architecture, and the available facilities. The same virtualized network infrastructure can be also used for CSP's other customers in the same area. An enterprise may also have sites in other physical locations e.g., in other cities where 5G virtual private network can be deployed as well (see Figure 5).

A key strategic asset

CSPs can create significant new enterprise value and services by combining the 5G Virtual Private Network with the Edge Slicing and Edge Cloud applications. A high-performing 5G VPN service with Edge slicing functionality that is used by several enterprise customers creates an attractive environment for application partnerships with local and global cloud service providers such as Google Cloud, AWS, and MS Azure. Cloud platforms and enterprise applications can be for example hosted at the CSPs' Central Data Centers and Edge PoPs (see Figures 4 and 5). CSP can also integrate edge cloud networking solution as part of the enterprise 5G VPN service supporting automated deployment of the edge clouds for example across data centers and Edge PoPs. There are also many partnering opportunities between CSPs and co-location as well as infrastructure (e.g., tower) companies.

Figure 5. 5G Virtual Private Network with Edge Slicing



Service Building blocks

To ensure maximal CSP business and enterprise customer value as well as fast time to market following 5G Virtual Private Network building blocks are important

- Utilize existing 4G/5G network assets, spectrums, coverage, and capacity
- Leverage the huge existing 4G/5G device ecosystem and the large customer base
- Design one common solution architecture for LTE, 5G NSA,-5G SA and different use cases
- Build slicing as an evolution on existing End-to-End network across RAN, transport, and core
- Proceed step by step starting with new network functionalities, slice management & assurance
- Ensure secure, reliable, manageable, and a high performing 4G/5G network
- Keep enterprise traffic and data on premises/in proximity with Edge Slicing
- Isolate enterprise business critical data from internet traffic
- Per slice traffic engineering for performance, quality, security, and KPIs in end-to-end network
- Slice interconnectivity to enterprise and private/hybrid/public cloud with IP/MPLS and SD WAN
- Utilize existing subscriber profiles in registers and subscriber data management
- E2E orchestration needed for wide-scale network slicing deployments
- E2E slicing in a multivendor environment
- E2E slicing based on industry standards

Enterprise services must be designed to be future proof and have long term support. Consequently, it is important that they are based on industry standards, best practices, and openness.

For mobile and IP network slicing, key standardization and architectures are driven by 3GPP and IETF. For edge computing, the ecosystem is still more fragmented. ETSI has a multi-access Edge Computing (MEC) initiative targeting to standardize an open environment for multivendor MEC

platforms. There is also a CSP driven initiative on the GSMA Operator Platform Telco Edge. In the meanwhile, different industry players are moving fast with their own Edge Cloud developments and deployments.

Nokia's solution for 5G Edge Slicing and Virtual Private Networking

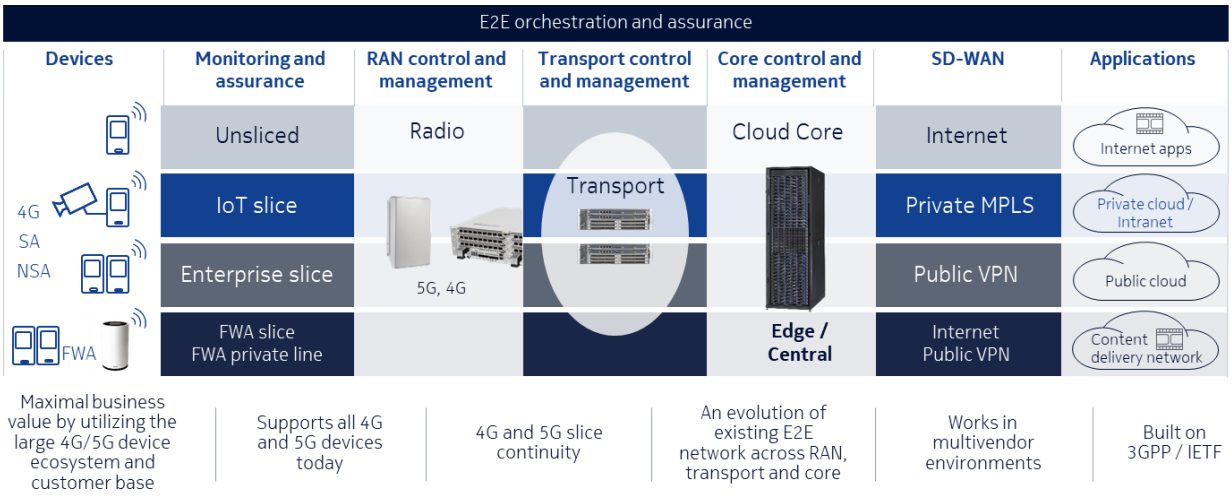
Network slicing enables CSPs to isolate, end-to-end, mobile networks into multiple virtual networks, each of which can be optimized for the specific target application, group, or service. Developed in partnership with the leading CSP customers, Nokia's slicing solution provides connectivity from 4G and 5G devices over the sliced network across RAN-transport-core to private and public cloud applications. Cloud applications can be located at a private cloud, a public Internet cloud, a CSP 5G Edge (Edge PoP/Data Center), and/or an enterprise edge.

The end customer of each network slice can be served with different priorities, routing, levels of network performance, and security capabilities. The slices can be managed and deployed in minutes. CSPs can assure service levels provided to their enterprise customers by collecting per slice Key Performance Indicators from the network elements.

Evolution for existing network

Nokia enables CSPs to utilize existing 4G/5G network assets, spectrum, and coverage for the 5G Virtual Private Network services. CSPs can build a single 4G/5G slicing solution for different use cases using the same architecture and building blocks. The solution covers 4G, 5G NSA, and 5G SA including seamless evolution between the technologies. (see Figure 6).

Figure 6. Nokia 4G/5G E2E Slicing Solution for 5G VPN with Edge Slicing



Unlike commercial solutions to date Nokia Edge Slicing is scalable, and the same virtualized network infrastructure can be used for multiple CSP enterprise customers in the same area, for example in a business campus area with multiple companies. By deploying distributed cloud core Edge PoPs to other campus and city areas 5G virtual private network services can be extended to new enterprise customers who require on premises/proximity edge functions.

CSPs can create additional new value for enterprise customers with Nokia's Adaptive Cloud Networking (ACN) solution. With ACN CSPs can easily provide automated networking capability in the edge cloud. The capability also expands the data center across the Wide Area Network for example edge clouds deployed across different CSP Edge PoPs and Data Centers (see Figure 4). Adaptive Cloud Networking solution can integrate edge clouds as part of the enterprise 5G VPN service with automation and assurance.

Interconnection from the CSP Edge PoP to enterprise premise and to private and public clouds can be implemented using e.g., MPLS Segment Routing and SD WAN technologies (see Figures 4 and 5).

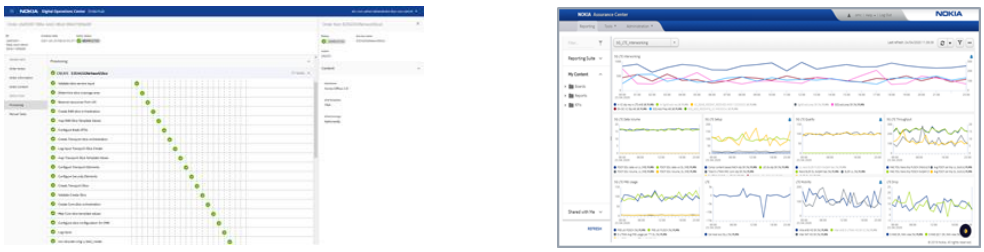
As a result,-Nokia's Edge Slicing solution brings greater return on investment for CSPs by using and scaling available network resources for a variety of new, high quality enterprise services.

Slice management and assurance

Nokia's slice management automation capabilities cover all network domains, including RAN, transport, and core. In line with 3GPP and IETF architectures network management, controller and orchestration capabilities enable CSPs to rapidly deliver and assure network slicing-based services for their customers.

Life cycle management supports real-time slice operations and automation for creation, modification, deletion, and scaling from a small to many of slices. Management solution enables the deployment of 5G virtual private network services in a local or a campus area, in a regional or a wide area depending on CSP enterprise customer needs.

Figure 7. Management, orchestration, and assurance



CSPs can create different customer policies and group profiles for slices with different network performance, quality, traffic engineering, and security capabilities. RAN, transport, and core domains embed assurance capabilities to automatically collect, monitor, analyze and report KPI data per slice. This enables verifying the service levels agreed between CSP and enterprise. Domain management and controllers can be integrated with end-to-end orchestration and assurance systems via open APIs. Slice management and assurance functionality are software upgrades/modules in Nokia's existing products.

Devices and slice continuity

Nokia's network slicing solution supports all standard LTE, 5G NSA, and 5G SA devices. This provides CSPs the opportunity to utilize a huge device ecosystem and address a very large customer base. Some CSPs plan to deploy slicing only with 5G standalone architecture. However, it is important to provide slicing both in 4G and 5G networks to bring new services to as many enterprises, people, devices, and places as possible.

Nokia is the first company capable of providing end-to-end slicing solutions both in 4G and 5G networks. The solution supports billions of LTE devices, hundreds of millions of 5G non-standalone (NSA) devices as well as the growing 5G standalone (SA) device ecosystem. Depending on the device ecosystem availability Nokia also already supports per application slicing deployments e.g., using Fixed Wireless Access CPEs as well as new Android devices with dynamic URSP network slice selection policies (User equipment Route Selection Policy).

Slice continuity between 4G and 5G networks allows CSPs to maximally utilize LTE and NR network coverage and network assets such as the available spectrum. For example, if the device moves out from the 5G coverage area a slice can 'fall back' and the service will continue in the LTE network.

Innovations with standards

Nokia's slicing solution is based on a novel innovation on user and service awareness in RAN, transport, and core domains (GTI 2021 Innovative Breakthrough in Mobile Technology Award). Nokia was the first in the world to show 4G/5G network slicing across RAN-transport-core with management and assurance. After that there have been engagements and dialogue with over 90 different customers on all continents. This has been followed by many live end-to-end network slicing field trials with CSPs. These include deployments of the new slicing capabilities such as 5G standalone network slicing, Fixed Wireless Access Slicing, slicing in 5G private networks as well as slice management automation and orchestration.
Nokia is now the first to bring network slicing to the Edge.

Nokia's slicing solution is built on 3GPP and IETF standards. RAN, transport, and core domains as well as E2E orchestrator are following the 3GPP and IETF architectures. The solution supports stepwise deployments and works in multivendor networks. For example, all ongoing customer slicing field trials are executed in multivendor environments. Nokia provides slicing as an evolution to the existing product portfolio. CSPs can deploy slicing in their networks with software upgrades, modules, and related configurations.

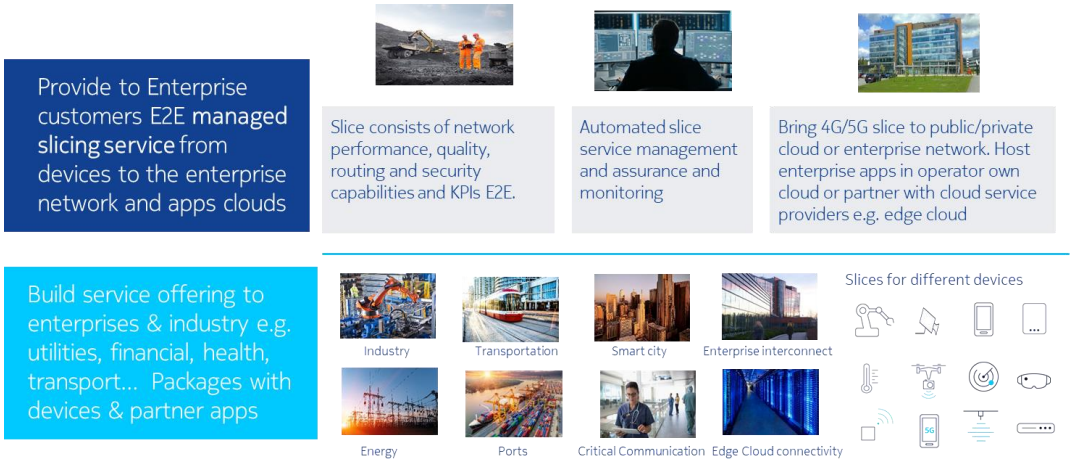
Business and revenue opportunities

Nokia has worked closely with several CSP customers and enterprises worldwide on the live network slicing trials as well as on technology, architecture, and business topics. The key CSP investment drivers are new customer value and revenue opportunities.

With slicing CSPs can create new services for their enterprise customers (see Figure 8). These include for example:

- 5G Virtual Private Network services for enterprise campus e.g., Industry, Factory, Warehouse
- E2E managed slicing-based services for enterprises e.g., Utility, Financials, Transportation
- Sliced Fixed Wireless Access: private line for SME, fast lane Internet Access for home office

Figure 8. 5G Virtual Private Network Service for Enterprises



Nokia is collaborating with CSPs for a diverse set of enterprise slicing use cases such as:

- Enterprise slice for specific business users or applications
- Enterprise/university campus networks
- Private network deployments
- Airport, harbor slice for control, movements, and apps
- Remote distance “vehicle” management
- Traffic cameras that provide online information for traffic control & apps
- Electrical and smart grid using slicing for large installed base
- Mining vehicles
- Video surveillance/video analytics
- Railways, real-time train positioning, and data exchange (with slice continuity)
- Logistic/retail – warehouse for parcel transport within a region (with slice continuity)
- Oil & Gas connecting different stations in the country
- Manufacturing slices e.g., factory apps, monitoring & control
- AR & robot remote control
- Fixed Wireless Access private line access or application slice for enterprises
- VIP customer experience in events, arenas, and crowded places
- Critical communication to police or gov. agencies

Conclusion

5G Virtual Private Networks enable CSPs to offer new valuable, scalable, and cost-efficient services to their enterprise customers. This creates many new market, service business and revenue opportunities. With 5G Edge Slicing CSP can meet enterprise requirements for secure, reliable, manageable, and high performing network. 5G virtual private network with Edge slicing can be implemented as an evolution of the CSP’s existing 4G/5G network while supporting all standard 4G/5G devices.

Leading CSPs see end-to-end managed 4G/5G connectivity - from devices to applications running in edge cloud - as a critical enabler for new enterprise 5G services and business. 5G virtual private network with Edge slicing gives CSP the strategic position to orchestrate partnerships with local and global Cloud and Infrastructure Service Providers.

Nokia is the market-leading 4G/5G E2E slicing solution provider with an advanced product and services portfolio.

With Nokia CSPs can start 5G Edge Slicing business now.

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Abbreviations

Slice	Divides mobile network into the multiple logical/virtual networks
5G Virtual Private Network	Logical/virtual 4G/5G enterprise network e.g. in a campus or city area implemented on top of public mobile network
Edge Slicing	Sliced 4G/5G network across RAN-transport-core-enterprise with capability to keep enterprise traffic on premise/near proximity
PoP	Point of Presence. Place which typically houses routers, switches, servers
RAN	Radio Access Network
Edge PoP	Place where local RAN site transport connections are aggregated
ACN	Adaptive Cloud Networking
LTE	Long Term Evolution
NSA	5G Non Stand Alone Architecture
SA	5G Stand Alone Architecture
NR	5G New Radio
ICT	Information & Communication Technology
IoT	Internet of Things
AI/ML	Artificial Intelligence/Machine Learning
AR	Augmented Reality
MEC	Multi-Access Edge Computing
FWA	Fixed Wireless Access
IP	Internet Protocol
MPLS	Multi Protocol Label Switching
SD WAN	Software Defined Networking Wide Area Network
KPI	Key Performance Indicator
API	Application Programming Interface
URSP	User Equipment Route Selection Policy
3GPP, ETSI, IETF, GSMA	Mobile, Edge Computing and IP standardization bodies
CSP	Communication Service Provider
MVNO	Mobile Virtual Network Operator
SME	Small and Medium Enterprise

References

1. Gartner®, Tech Providers 2025: The Future of Edge, ID G00730572, Joe Skorupa, Sylvain Fabre, Thomas Bittman, Ephraim Baron, Published 5 October 2020. GARTNER is a registered trademark and service mark of Gartner, Inc. and/or its affiliates in the U.S. and internationally and is used herein with permission. All rights reserved.

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Adhering to the highest standards of integrity and security, we help build the capabilities needed for a more productive, sustainable and inclusive world.

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