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5G transformation: 7 streams for success

White paper

There are seven transformational technology areas that underpin 5G network deployment and operation. Synchronizing the development of these technology streams is essential to achieve the performance promises of 5G, namely dramatically higher data rates than 4G networks, near zero latency response coupled with six-nines reliability and adaptability to support an extreme diversity of known and unknown use cases at massive scale.

With 5G today moving from the development labs into live network deployments delivering commercially profitable services, it is vital to achieve tight interworking between the radio access, core and transport network domains, as well as IT systems.

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Contents

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Executive summary: making 2019 ‘year one’ of 5G

> “Overall, I thought this was the most positive MWC (2019) in many years, with the realization that this is really ‘year one’ of 5G. Actual contracts, actual deployments, deals being done. I spent quite a bit of time in the main network equipment vendors’ booths and noticed a significant effort to start a meaningful conversation about the ‘next’ phase of 5G, which will be focused on the enterprise and IoT opportunities.”
>
> **Mark Lowenstein of Mobile Ecosystem**
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> Source: https://www.lightreading.com/mobile/5g/mwc19-recap-8-takeaways-from-top-analysts/d/d-id/749925?itc=lrnewsletter_lrdaily&utm_source=lrnewsletter_lrdaily&utm_medium=email&utm_campaign=03052019

Much is written in the communications media about 5G. Countless meetings within the industry discuss 5G’s technical foundations and business opportunities. The underlying technologies are becoming better understood across the industry.

However, the landscape of technologies is wide and understanding how they fit together can be confusing. Unlike previous mobile network generations, the success of 5G will depend on an end-to-end approach that ensures all network domains and their technologies are coordinated closely in their design, deployment and operation. To deliver ultra-fast, ultra-low latency performance, 5G networks must be tightly integrated, with every component and sub-system running in perfect harmony.

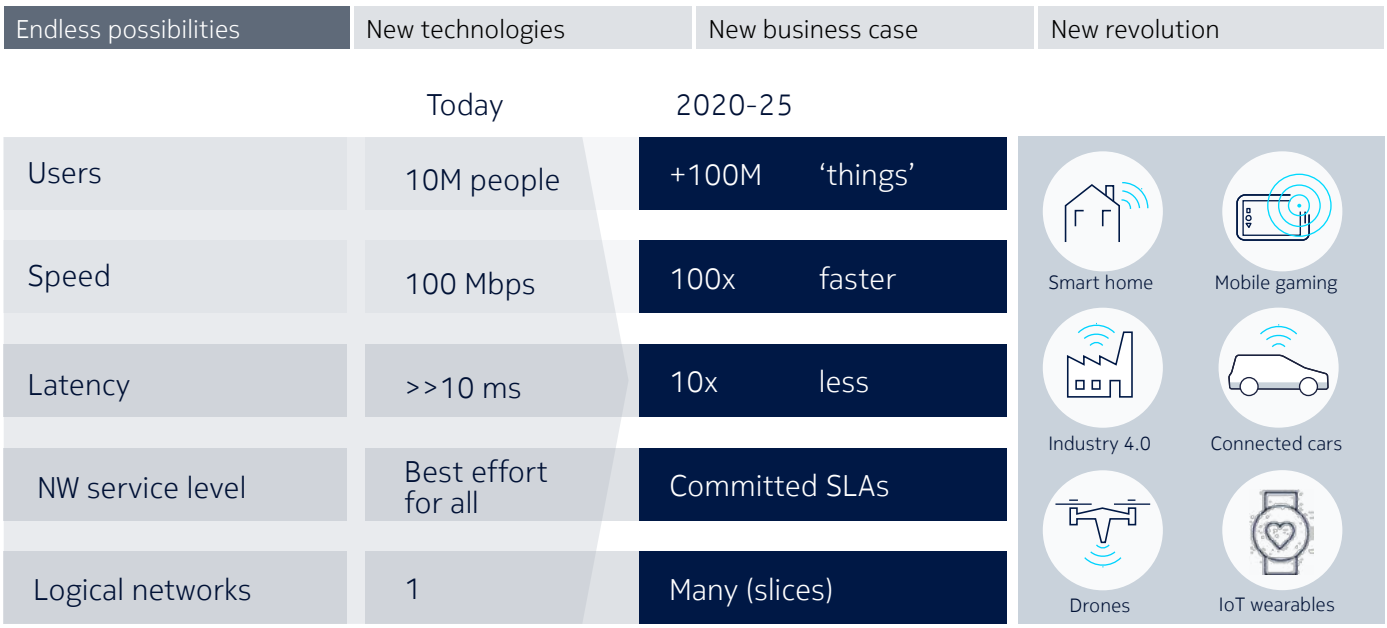
5G is more than just an innovative radio technology using new spectrum. There are seven synchronized technology areas that need to evolve in parallel. These transformational technology streams reveal what Communications Service Providers (CSPs) need to do to evolve their networks and create business-winning 5G services.

From enhanced mobile broadband to a platform for all types of digital services

With 5G, network performance will take a giant leap forward. New applications and services will be created. 5G networks promise to deliver many times higher data rates than 4G, achieve near zero latency response and be adaptable to an extreme diversity of use cases at massive scale.

While the first 5G network deployments will be focused on enhancing the mobile broadband experience for customers, the future possibilities are far-reaching. Enabling more than mere network connectivity, the same 5G infrastructure will provide connected performance tailored for almost any application, no matter how stringent the Service Level Agreement (SLA) imposed.

Figure 1. 5G's high performance characteristics will open new business opportunities for CSPs



Having enhanced their existing mobile broadband services, CSPs can focus on new opportunities. One early option is to serve new dedicated user groups or locations such as smart stadiums, enhanced mobile broadband (eMBB) coverage of enterprise sites, eMBB in vehicles and video surveillance for smart cities.

Another natural option is to use 5G's low latency characteristics to offer new services to existing customers. Examples include augmented and virtual reality, online gaming and fixed-mobile services.

Looking further ahead, 5G network slicing enables CSPs to evolve into Digital Service Providers (DSPs) by offering innovative services to new vertical markets. Success here involves the tight linking of the IT and network domains.

Examples of potential services enabled by network slicing include:

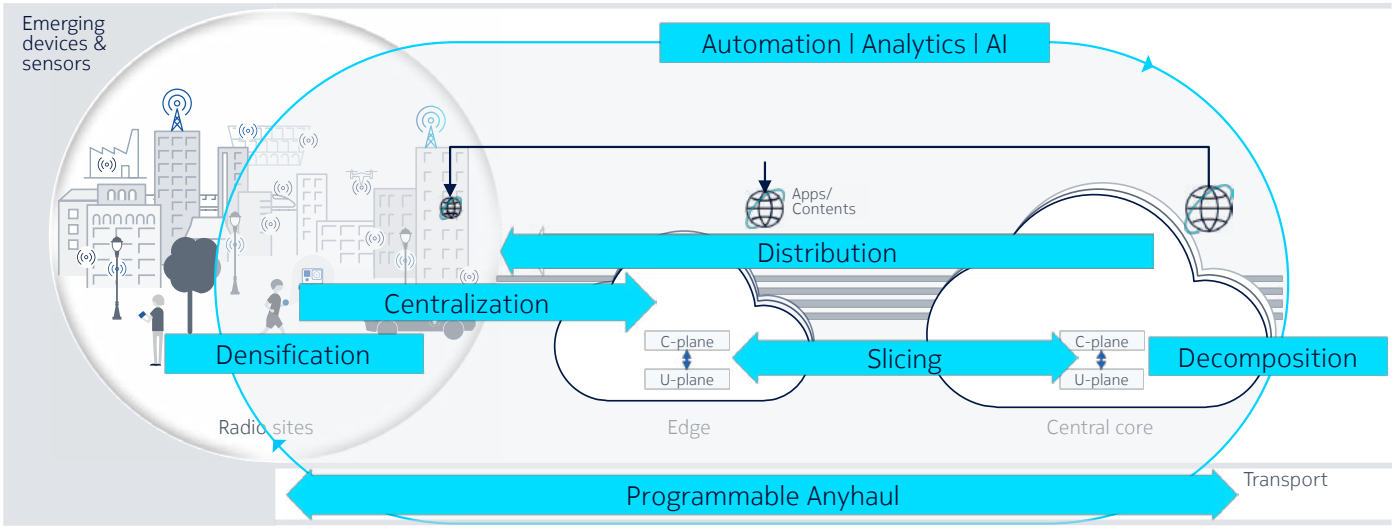
- **5G for automotive – new driving experiences:** 5G offers new possibilities for connected cars, such as providing online infotainment or improved networking between cars and infrastructure for automated driving. Nokia and the BMW Group have shown dedicated use cases, enabled by 5G network slicing - updating HD maps, vehicle-to-vehicle communication for enhanced automated driving, and streaming videos in HD quality for infotainment.
- **5G for logistics – new processes in complex environments:** A major trial is being run by the Hamburg Port Authority, Deutsche Telekom and Nokia to test 5G architecture at the Port of Hamburg. A variety of applications are enabled, such as better traffic flow by connected, intelligent transport systems, more secure operations using augmented reality expert assistance and improved pollution control by connected sensors on barges.
- **5G for Industry 4.0 – boosting productivity by making factories mobile:** The future smart factory will depend on vastly increased connectivity to link machines, processes, robots and people to create more versatile and more dynamic production capabilities. Nokia and Bosch have shown that by coupling advanced interactive robots with wireless perimeter intrusion detection, 5G enhances the safety of factory employees.

Seven streams of transformation for 5G success

While it is clear the many technologies behind 5G will deliver exciting capabilities, the big picture of what CSPs need to do to ensure successful 5G network roll outs is less clear. How do CSPs bring together all the different pieces of 5G to ensure network investments will meet their objectives and fulfil the technology's promises?

For the highest performance and best Return on Investment (RoI), CSPs will need to manage the complex interworking of network domains, technologies, components and services to ensure they work together effortlessly. An all-inclusive approach to 5G architecture is needed, encompassing seven transformational streams – densification, centralization, distribution, decomposition, transport, AI and network slicing.

Figure 2. Nokia has identified seven critical streams for CSPs to address as they prepare and deploy 5G networks



Densification: deploying mmWave small cells to boost capacity

Deploying small cells provides essential coverage and capacity indoors and outdoors, in public spaces, for enterprises and in homes. Strategically placed small cells also support innovation such as value-adding applications, local contextual applications and Internet of Things (IoT) services.

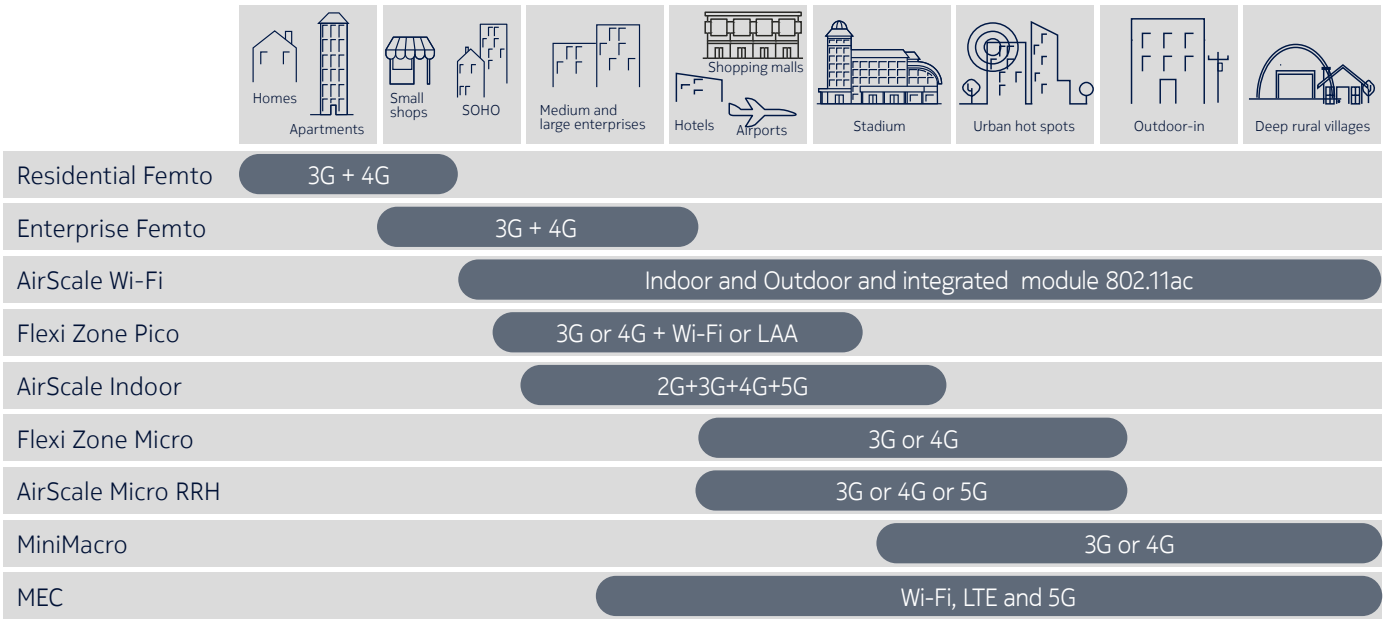
However, the deployment of small cells also calls for tighter control of traffic, careful interference management between the macro and small cell networks, and the need for appropriate backhaul. The complexity of mixed small cell and macro cell networks also demands automated network optimization.

Nokia small cells help CSPs flexibly build out 5G

With the industry's most extensive small cells portfolio, Nokia is helping CSPs to address demand for capacity at public venues, in dense urban areas and deliver better indoor coverage. Nokia self-installed Femtocell access points address the fast-growing revenue opportunity from small office and enterprise indoor demand.

The latest Nokia AirScale small cells extend the high performance of 5G both indoors and outdoors and support a wide range of use cases. A compact millimeter wave (mmWave) radio offers cost-effective 5G outdoor coverage of extremely high traffic areas such as airports, stadiums and busy pedestrian zones. In addition, a 5G pico Remote Radio Head for the Nokia AirScale Indoor Radio System enables an upgrade of indoor coverage to 5G without replacing installed hardware, even in complex buildings such as hospitals and shopping malls.

Figure 3. Nokia offers an extensive range of small cell solutions for different deployment scenarios



Centralization: centralizing radio access processing functions in data centers

Radio Access Network (RAN) solutions in the cloud provide high scalability to address varying demand for capacity. The RAN must support both 4G and 5G, and by leveraging powerful new capabilities such as AI for real-time optimization to improve the subscriber experience, Cloud RAN is taking advantage of converged edge cloud deployments. This enables radio functions to be virtualized and run in a centralized cloud or a distributed cloud at the network's edge to deliver ultra-low latency and high bit rates. Other radio functionality can be centralized for the highest spectral efficiency and cell site simplicity. Full flexibility is achieved by running both centralized and distributed cloud RAN deployments in the same network.

CSPs are well positioned to transform their networks either through existing larger centralized data centers where they have control of local network connectivity, or by smaller centers that are more distributed at the edge of the network.

Nokia AirScale Cloud RAN supports RAN flexibility

The Nokia Cloud RAN solution provides CSPs with a choice of two AirScale cloud base station deployments. Both versions support centralized and distributed deployments that run Virtualized Network Functions (VNFs) where they can most cost-effectively meet application needs. Real time (RT) and non-real time (NRT) traffic processing can be split as required between centralized and edge cloud servers or base station hardware close to 4G and 5G Radio Access Points (RAPs).

AirScale Cloud RAN's flexibility of centralized and distributed deployment enables functions to be placed according to the needs in each area, particularly latency targets, as well as available and planned transport.

The same centralized data centers running AirScale cloud base station functions can be used to support other VNFs, such as a cloud-based core network.

Distribution: deploying core network functions on distributed edge clouds

Placing appropriate core network functions, content and services on the same distributed edge clouds that run RAN functions helps to reduce the latency of services, improve service quality and support efficient service deployment across access technologies.

With 5G, a cloud-native core network design is essential for highly automated network operations and minimum time-to-market for services. 5G cloud-native architecture enables CSPs to quickly and easily monetize their core network investment. The architecture allows centralized or distributed deployment across the network, with network functions interconnecting to deliver any services consumers, enterprise users or millions of IoT devices demand at that instant.

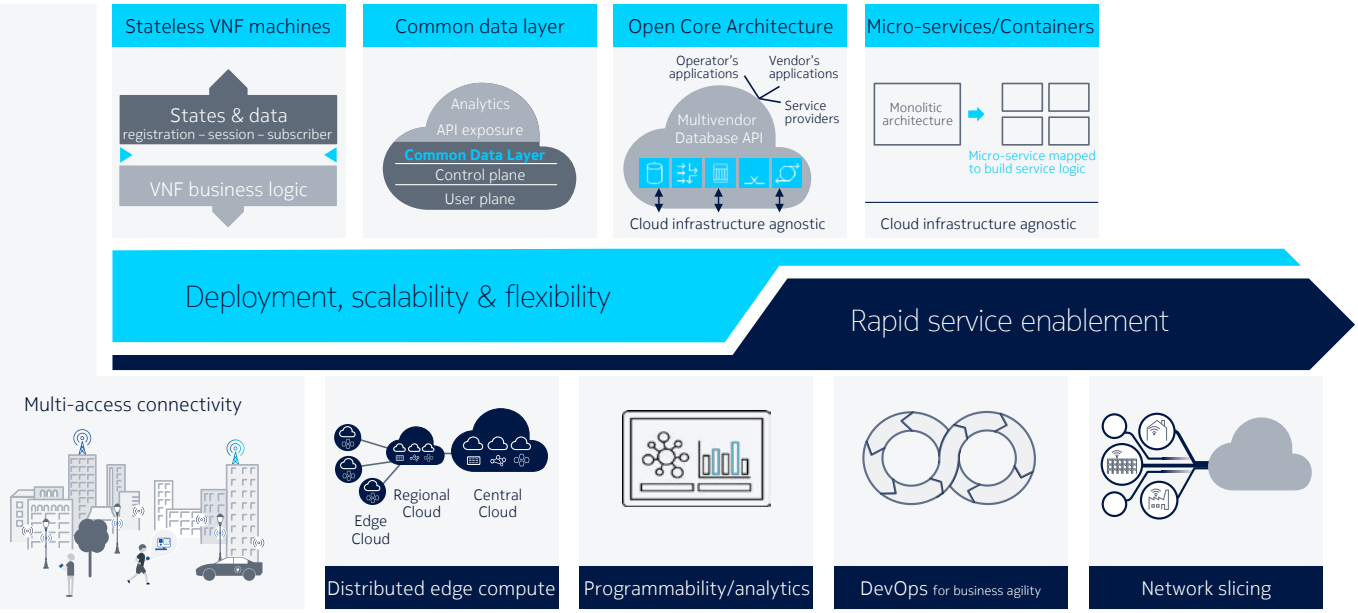
Supporting programmability and analytics, a distributed cloud-native core network also enables CSPs to benefit from ML and AI to dynamically adjust network resources in real-time according to changes in service demands.

Nokia AirGile cloud-native packet core network supports seamless network evolution

The Nokia 5G cloud-native packet core supports both Non-Stand-Alone (NSA) and Stand-Alone (SA) deployment options in the same core network, with many of the existing Nokia Core functions adding new 5G capabilities. This provides CSPs with seamless network evolution from their existing 2G/3G/4G networks to 5G.

The Nokia 5G cloud-native core supports multi-access connectivity that enables CSPs to converge their fixed and wireless services over a common core. It can be deployed as either virtual network functions or physical network functions. Both options support network slicing, programmability, service orchestration and automation to meet the stringent operational requirements of 5G.

Figure 4. Nokia 5G cloud-native core network offers flexible centralized and distributed deployment as well as minimum time-to-market for services



Decomposition: separating network functions for a more agile business

CSPs cannot economically, or technically, support the many devices connecting to the network and meet 5G services requirements by upgrading an existing non-cloud packet core network. The required scalability, flexibility and performance demands a cloud-native, 5G Services-Based Architecture (SBA) that separates the user and control planes.

This enables the control and user plane functions to be scaled separately and placed in different locations to save infrastructure costs. It also enables new, highly reliable and low latency services to be launched rapidly.

This decomposition allows the use of a common data layer to store all user and service data and act as an open repository for third parties to develop services and contribute new revenue streams. It also supports stateless VNF machines for simplified operations with plug-and-play installation and high resilience.

Thirdly, decomposition enables micro service architecture, with small components that allow services to be created, developed, scaled up and managed much more quickly and readily.

Nokia AirGile cloud-native core network supports

The Nokia 5G cloud-native core network is part of the Nokia Bell Labs Future X network architecture, which is defined as a Universal Adaptive Core that supports multi-access connectivity to converge fixed and wireless services on a common core.

The Nokia 5G cloud-native core supports the full range of 5G services and provides substantial performance and scalability with fast time to market. It introduces an open core architecture that runs on cloud infrastructure with open Application Programming Interfaces (APIs) that expose its capabilities for the development of innovative services. It also reduces costs by increasing network resource utilization and supporting both wired and wireless access (licensed, unlicensed, shared, Wi-Fi) for fixed/mobile convergence.

Transport: programmability to connect mobile functions and network slices

CSPs will not be able to take advantage of 5G's business and technological opportunities without preparing their transport infrastructure to handle new requirements. Transport networks for 5G must provide very high throughput, ultra-low latency links that are essential for 5G services and as RAN and core networks migrate to centralized and distributed cloud architectures.

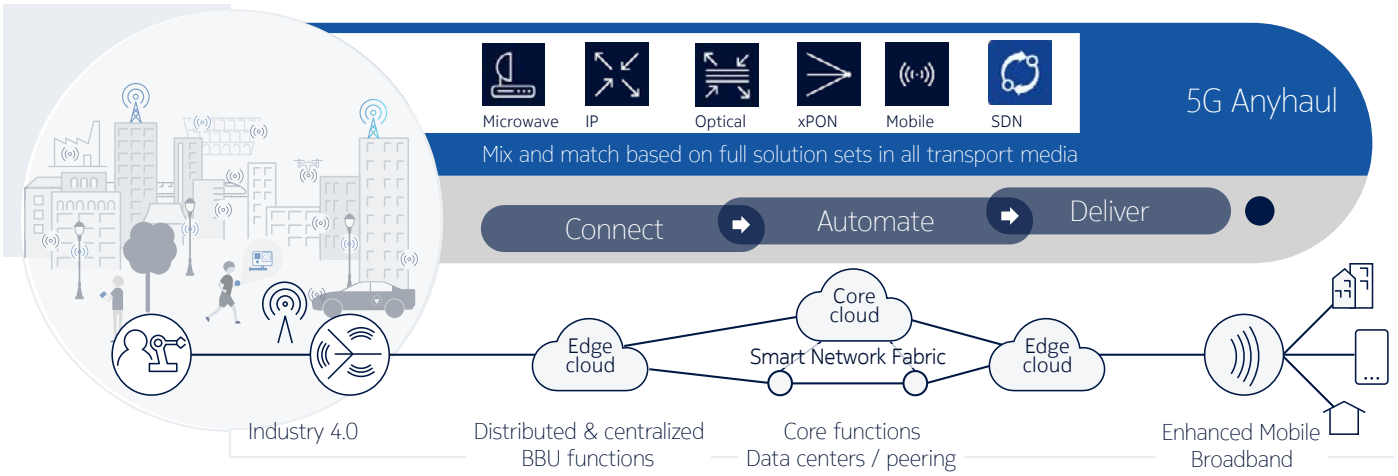
This can only be achieved by a programmable end-to-end transport network that includes Software Defined Networking (SDN) to flexibly connect, radio access and packet core functions deployed on a distributed data center infrastructure.

Nokia Anyhaul unites all transport technologies for 5G

The Nokia Anyhaul transport portfolio spans optical, IP, microwave and broadband technologies, unified into a carrier SDN transport architecture that integrates with cloud-based radio access and core networks and supports automated end-to-end network slicing and service provisioning. Programmability and automation dynamically create transport network slices to match diverse application and user needs with end-to-end service delivery guarantees, quickly and cost-effectively.

Anyhaul is a fully programmable transport fabric that encompasses current and new technologies. CSPs can protect their existing network investments as well as introduce new capabilities such as mmWave links to meet the high-performance demands of 5G.

Figure 5. Nokia 5G Anyhaul is a software-driven transport fabric that connects mobile functions and network slices with the required performance



End-to-end automation and orchestration: powered by Artificial intelligence

5G introduces a substantial increase in network and operational complexity that demands advanced management and orchestration capabilities to use the installed infrastructure efficiently, while supporting multiple use cases and business models in parallel. Advanced automation powered by AI and ML provide those capabilities.

As well as ensuring the network delivers the best possible service, whether that requires ultra-high bandwidth or ultra-low latency, AI/ML reduces Operational Expenses (OPEX). In the RAN, AI/ML ensures the effective use of radio resources for demanding services. For example, AI-based Quality of Service (QoS) management can produce near 100 percent successful video delivery by anticipating problems and predicting problematic network situations. AI/ML is also critical for enabling zero touch network slicing.

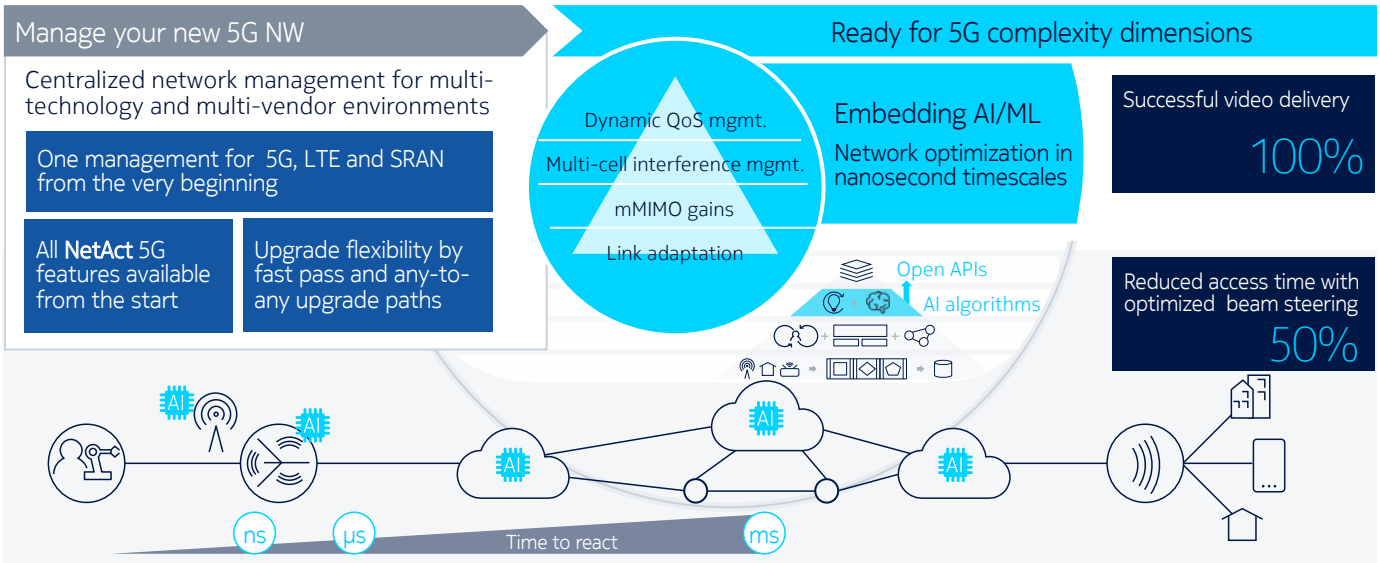
Nokia AI/ML optimizes 5G network performance at all levels

Nokia 5G Future X implements AI at every level. At the chip level, Nokia ReefShark chipset technology is founded on embedded AI-driven architecture, which provides continuous, real-time and complex cognitive processing. Continuous learning from live data and applying complex decision models in real time creates unprecedented performance in networks.

At the RAN level, the operation of 5G massive Multiple Input Multiple Output (MIMO) is simplified by the Nokia ML-based scheduler which solves the highly complex task of mMIMO scheduling in real time to provide superior 5G user experience.

At the network level, Nokia NetAct is a common network management system for all radio technologies that combines network configuration management with a high level of advanced automation. Meanwhile, Nokia EdenNet is an AI-based Self-Organizing Network (SON) solution that automates operations, eliminating complexities from multi-vendor, multi-technology and multi-layered 5G networks.

Figure 6. Nokia uses AI and ML technologies at all levels of the network to achieve the highest performance and lowest operational costs



Slicing: creating as-a-Service business models for diverse demands

One of the most exciting capabilities of 5G is network slicing in which multiple 'virtual' networks run on top of the same physical network infrastructure to provide every application with the precise quality of service and connectivity characteristics it needs, such as assured throughput, peak data rate, coverage, reliability and latency. This programmability transforms the network from a best effort consumer service engine to a predictable connectivity hub for any use case.

However, as the number of slices grows, the potential for higher operational costs increases because of the complexity of managing the multiple slices and customers. Implementing end-to-end automation effectively brings down the operational costs, enabling a CSP to address more customers profitably. With full automation, the overall costs of extreme numbers of network slices becomes acceptable.

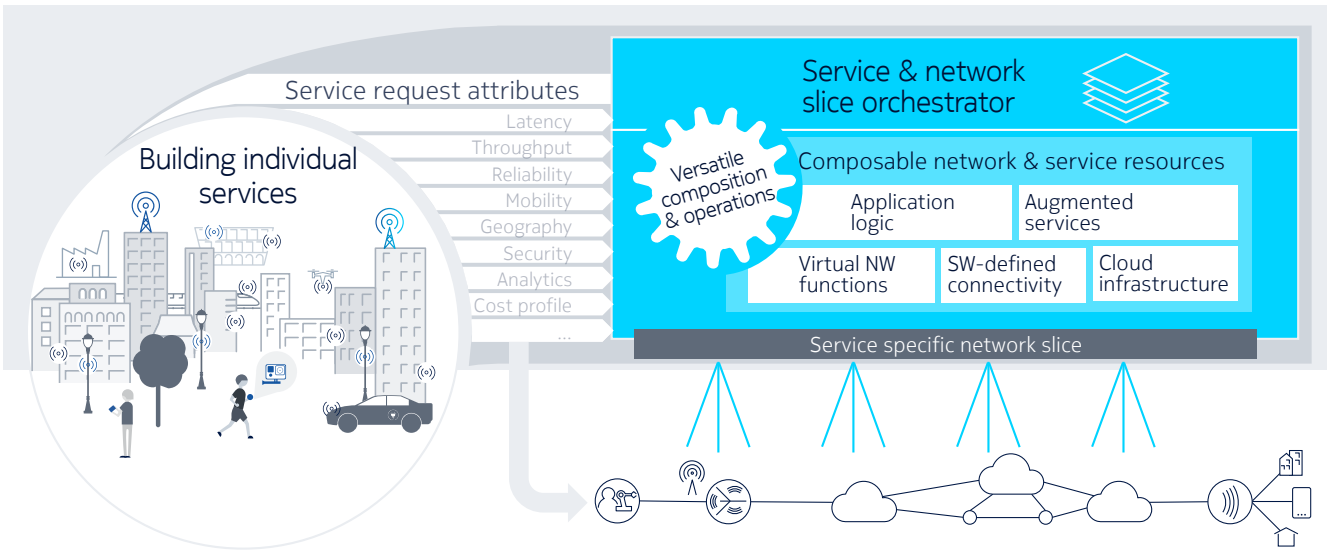
Nokia supports end-to-end dynamic network slicing

The Nokia 5G portfolio supports fully automated, end-to-end network slicing to meet the needs of diverse services, use cases and business models.

Nokia has implemented programmable network architecture across the RAN, core and transport domains with automated slice creation and operations for fast time to market. The architecture implements microservices that enable modular RAN and core network VNFs to that flexibly meet any need.

Nokia Anyhaul transport implements carrier SDN to dynamically create a path, with the specific capabilities needed for the network slice, through the transport network from the RAN to the core network or edge application servers. Carrier SDN uses open interfaces to automatically discover the network topology and use the performance characteristics of each physical link in the network to calculate an end-to-end route.

Figure 7. Nokia 5G network architecture supports automated network slicing to meet specific service requirements



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Nokia 5G Future X: faster deployment, lower cost, higher performance

Nokia has implemented the closely synchronized 5G transformation streams in its 5G Future X solution that makes the deployment of 5G simple.

By completing nearly all integration and testing of the network infrastructure before it is deployed in a live network, Nokia reduces the time and cost CSPs expend on their 5G roll outs. This helps them meet tight budgets and extreme customer performance requirements, while at the same time bringing customized services to market quickly to win a competitive advantage.

- **Pre-design:** Nokia 5G solutions take advantage of the cloud-native and open 5G Future X architecture to use the latest technology developments. It combines the benefits of tight integration of solutions from a single vendor with the confidence and choice of open architecture. Third-party VNFs can be first onboarded in less than one month, substantially faster than six months (and more) other solutions require. Furthermore, once prepared, VNF instances can be created immediately with full functionality, without the workarounds that proprietary systems need.
- **Pre-integration:** Nokia 5G products feature comprehensive pre-deployment integration for short time to market and low implementation costs. Avoiding the need for case-by-case amalgamation of network components on site delivers substantial cost and time savings such as 45 percent faster time to market, 30 percent lower total cost of ownership and 14 percent higher end-to-end service reliability.
- **Pre-validation:** Each use case for 5G is validated before deployment. Performance evaluation and TCO analysis are performed at the Nokia 5G Future X Lab. Nokia Prime Integration Service provides design and deployment of tailored multi-vendor networks that integrate third-party components. This approach addresses end-to-end performance evaluation and TCO analysis for different applications. It also helps ensure the highest automation for network slicing.

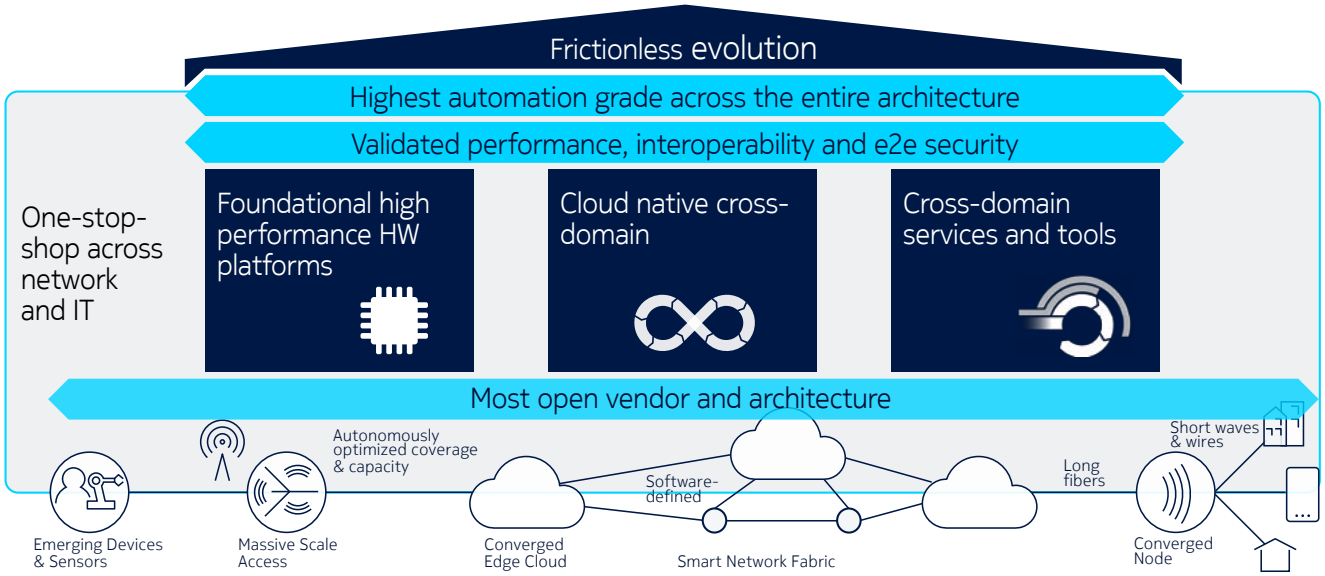
Nokia Digital Design addresses 5G complexity

The Nokia Digital Design process is dynamic and automated, uses real-time simulation and directly involves multiple stakeholders to ensure that, as the network design is optimized, the needs of the required use cases will be met.

Analyzing huge amounts of data from many sources to build up a digital twin of the use case and its environment provides the design parameters for the network. This is then fine-tuned in an iterative process to produce a final design for a 5G network or a network slice that meets the precise performance needs of the target use case.

As well as being able to handle the huge complexity of 5G deployments, the Digital Design process helps CSPs to shorten the time to implement a use case and ensure a more precise network design that requires minimal post-deployment optimization.

Figure 8. The Nokia 5G Future X solution simplifies the deployment of 5G networks. The cross-domain solution minimizes the need for the time-consuming and costly post-deployment integration of core, transport, radio infrastructure and IT systems for 5G network roll-out



Conclusion: 5G deployments de-risked

5G is built on a set of closely interwoven technologies that appear to create hugely complex networks. The seven transformational technology streams identified in this paper provide a guide to the areas of focus needed for successful 5G deployment and operation. In addition, innovative pre-design, pre-integration and pre-validation techniques, plus the application of AI-based automation, greatly simplify the task that CSPs face.

With the Nokia 5G Future X solution, the effort required to deploy the core, transport, radio infrastructure and IT systems for 5G network roll-outs is potentially much easier than that needed for previous mobile generation implementations. By completing nearly all integration and testing of the infrastructure before it is deployed in a live network, Nokia can reduce the amount of time and cost CSPs expend on their 5G roll outs. This helps them to meet tight budgets and extreme customer performance requirements, while at the same time bringing customized services to market quickly.

In effect, Nokia's approach de-risks CSPs' 5G deployments.

Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
CSP	Communications Service Provider
eMBB	enhanced Mobile Broadband
IoT	Internet of Things
MEC	Multi-Access Edge Computing
MIMO	Multiple Input Multiple Output
ML	Machine Learning
NFV	Network Functions Virtualization
NRT	Non-Real Time
NSA	Non-Stand-Alone
OPEX	Operational Expenses
QoS	Quality of Service
RAN	Radio Access Network
RoI	Return on Investment
RT	Real time
SA	Stand-Alone
SBA	Services-Based Architecture
SDN	Software Defined Networking
SLA	Service Level Agreement
TCO	Total Cost of Ownership

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