Networks business

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Our Networks business in 2016 was conducted through its four business groups: Mobile Networks, Fixed Networks, IP/Optical Networks, and Applications & Analytics.

Market overview

Through our comprehensive end-to-end portfolio of products and services, we are addressing a market that encompasses mobile and fixed network access infrastructure, IP routing and optical networks as well as software platforms and applications.

We define our primary market as a network and IP infrastructure, software and related services market for CSPs. We estimate that our primary market was EUR 113 billion in 2016. In addition, we have an adjacent market, including a vertical market that includes our Networks businesses expansion areas in both a customer and product dimension. The adjacent market includes customer segments such as Webscales, energy, transport, public sector and TXLEs. In the product dimension, this includes solutions like Nuage Networks, SDN, Analytics, IoT and Security. The adjacent market was estimated at EUR 18 billion in 2016.

Demand for our portfolio is driven by exponentially increasing growth in data traffic as people's lives and enterprises become ever more digitized. This drives the demand for highly reliable networks for massive connectivity.

Competition

The competitors in our primary market are Huawei and Ericsson. We also compete with technology experts in some of our other market segments, such as Juniper and Cisco in the routing segment, and Ciena, Adtran, and Calix in the optical networks and fixed access segments. Both the optical networks and the applications and analytics market segments are still highly fragmented markets.

Mobile Networks

Market overview

The primary market for our Mobile Networks business group includes technologies for mobile access, converged core and microwave transport as well as related services. This encompasses access and core technologies ranging from 2G to 5G licensed spectrum for both macro and small cell deployments. The services market includes implementation, care and professional services for mobile networks in addition to managed services for both mobile and fixed networks. The primary market for Mobile Networks was estimated at EUR 64 billion in 2016.

The vertical market for Mobile Networks includes solutions for the public sector, TXLEs and Webscales, and drives expansion into domains such as IoT connectivity, LTE for public safety, private LTE and unlicensed radio access. The adjacent market, including verticals, was estimated at EUR 2 billion in 2016.

Business overview and organization

Our aim is to lead with traditional telecommunications operators, as well as expand into select attractive, vertical segments. This is accomplished by delivering a comprehensive end-to-end portfolio of mobile products and services across Radio Networks, Converged Core, Advanced Mobile Networks Solutions and Global Services businesses.

Radio Networks has the task of driving leadership in radio access and specifically has end-to-end responsibility for one of the most important areas for Nokia's future: 5G. We believe that 5G will change the way in which mobile technology is used in virtually every sphere of life. As we move along the path towards making 5G a commercial reality, we aim to extend our leadership in LTE with a smooth evolution path comprising successive generations of 4.5G, 4.5G Pro and 4.9G offerings. Mobile Networks' rationalized portfolio, featuring the 5G-ready AirScale radio access, is setting the standard for scalability, openness, energy efficiency and multitechnology support ("Single RAN"). AirScale is the platform to enable 4.5G Pro/4.9G, Cloud and IoT connectivity.

The further evolution of 4G, and ultimately 5G, requires a continuous transformation of the core network. Mobile Networks' Converged Core is designing a radically simplified, robust and scalable core network based on its concept of a Cloud Native Core. Mobile Networks is already executing on this path and distinguishing its offer through its superior Shared Data Layer and AirFrame data center infrastructure solutions, which enable a Telco Cloud architecture that combines the best of both a centralized and a distributed approach. Using truly open interfaces and open source software building blocks, Mobile Networks can provide excellent performance for its customers in and beyond traditional telecommunications operators. Mobile Networks aims for a leading market position in end-to-end IP multimedia subsystem ("IMS")/voice over LTE ("VoLTE"), subscriber data management and other virtualized software infrastructure solutions, putting together the key building blocks which will enable new digital business models.

Advanced Mobile Networks Solutions spearheads Mobile Networks' expansion beyond traditional telecommunications operators to vertical markets in public safety; connectivity for IoT and connected automotive; and private LTE networks for, for example, transportation and energy companies. With a leading small cells portfolio and strong positions in unlicensed LTE and fixed wireless access—as well as innovative backhaul solutions, including a strong microwave offering—Mobile Networks aims to meet the need for increasingly dense networks to supply the capacity demands of our changing world.

Finally, through our Global Services offering, we aim to be the most innovative and complete service provider for the connected world. Our services, solutions and multivendor capabilities help our customers navigate through the evolving technology landscape, network complexity and data growth as well as improve personalized end user experience while supporting them in day-to-day network planning, implementation, operations and maintenance. We differentiate strategically through our service delivery by driving speed, quality and efficiency with the right combination of local expertise and globalized delivery centers, as well as advanced analytics, virtualization and automation using the Nokia AVA platform.

Competition

The mobile networks market is a highly consolidated market and our main competitors are Huawei and Ericsson. Additionally, there are two regional vendors, ZTE and Samsung, that operate with a below 10% market share. As network infrastructure gets virtualized and cloudified, we expect IT companies to emerge, such as HP Enterprise.

Fixed Networks

Market overview

The primary market for our Fixed Network business group includes technologies for fixed access and related services in addition to fixed network transformation services with focus on transformation of legacy fixed switching networks. The primary market for Fixed Networks was estimated at EUR 9 billion in 2016. In this market, we see a shift from copper to fiber technologies. The copper market is currently stable partially due to Nokia-driven innovations that improve the performance of the existing copper networks.

The adjacent market, including verticals, for Fixed Networks includes virtualization solutions for cable access platforms, Digital Home (IoT) and passive optical LAN. The adjacent market, including verticals, was estimated at EUR 3 billion in 2016, including related services.

Business overview and organization

The Fixed Networks business group provides copper, fiber and coax access products, solutions and services to deliver more bandwidth to more people, faster and in a cost-efficient way. The portfolio allows for a customized combination of technologies that brings fiber to the most economical point for our customers. It consists of advanced copper-based solutions to boost capacity on existing copper infrastructure, such as VDSL2 Vectoring, Vplus and G.fast.

The Fixed Networks business group is also a leader in fiber-to-the-home solutions, such as Ethernet point-to-point, and all versions of Passive Optical Networks ("PON"), including EPON and GPON, as well as 10 gigabit next generation fiber technologies (XGS-PON and TWDM-PON). Together with Nokia Bell Labs, we continue innovation and development of even higher-capacity technologies like XG-Fast, which allows 10 Gb/s over copper, and XLG-PON enabling 40 Gb/s symmetrical bandwidth over fiber.

With our acquisition of Gainspeed, a California-based start-up specializing in DAA solutions for the cable industry via its Virtual Converged Cable Access Platform ("Virtual CCAP") product line, we have complemented our fiber access technologies for cable multiple-system operators. With this enhanced product portfolio, we provide cable operators with the end-to-end technology capabilities needed to support growing capacity requirements today and into the future. With this acquisition, we are able to offer a turnkey solution for the cable industry that includes products for routing, transport, wireless and analytics.

Additionally, our smart home solution supports digital home devices that enable communication providers to provide enriched customer experiences and diversify their offering.

The Fixed Networks services portfolio is based on our unparalleled expertise and experience and is comprised of deployment, maintenance and professional services such as copper and fiber broadband evolution, public switched telephone network transformation, ultra-broadband network design, deployment and operation, site implementation and outside plant, as well as multivendor maintenance.

Competition

The competitive landscape in fixed access has similar characteristics to the mobile access where the market is dominated by three main vendors, Huawei, Nokia and ZTE and a handful of other vendors with less than 10% market share.

IP/Optical Networks

Market overview

The primary market for our IP/Optical Networks business group includes routing and optical technologies and related services sold to CSPs. This market includes technologies such as IP edge and core routing, mobile packet core and Wave Division Multiplex and Optical Multi-Service Network solutions. The primary market for IP/Optical Networks was estimated at EUR 28 billion in 2016.

A significant portion of IP/Optical Networks revenue is derived from its vertical market, which includes customer segments like Webscales, energy, transport, public sector and TXLEs. We have also included technologies like SDN controllers, addressed with our Nuage portfolio, in this market. The vertical market was estimated at EUR 6 billion in 2016.

Business overview and organization

The IP/Optical Networks business group provides the high-performance and massively scalable networks that underpin the digital world's dynamic interconnectivity. IP/Optical Networks portfolio of carrier-grade software, systems and services play across multiple domains, from programmable IP and optical transport networks for the smart fabric to software-defined capabilities for the programmable network operating system and more.

The networks of CSPs are under tremendous pressure from Cloud-based applications, ultra-broadband evolution and the IoT. IP/Optical Networks solutions reduce CSPs time-to-market and risk in launching new services, enabling rapid scaling to meet surging demands in the most optimized configurations. The solutions further assure that network services are delivered with consistent quality, reliability and security and that restorative actions are automatically initiated when any parameter varies beyond set limits. These carrier-grade attributes also benefit—and are valued by—the needs of vertical markets including internet content providers, public sector and verticals, and TXLEs.

The IP/Optical Networks product portfolio includes:

- comprehensive IP and optical Wide Area Networking ("WAN") solutions that dynamically, reliably and securely connect people and things from any technology modality to any Cloud at the lowest cost-per-bit;

- advanced, Cloud-optimized IP service gateways for residential, business, mobile and IoT services and unique hybrid solutions enabling a converged services future;

- carrier SDN solutions for network management that dynamically provision, optimize and assure network services and resources end-to-end, from access to the Cloud, and spanning IP and optical technology layers;
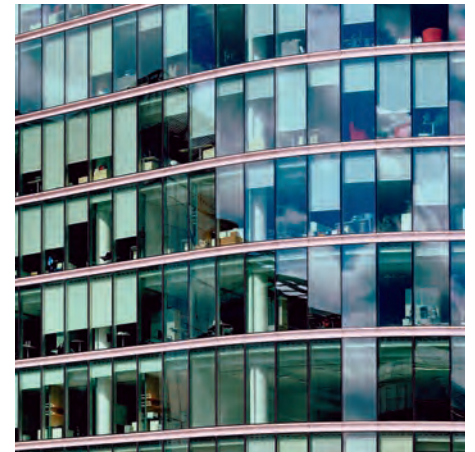
- advanced datacenter automation and software-defined WAN solutions that configure network connectivity among Clouds and to any enterprise branch office with the ease and efficiency of Cloud compute using products from our Nuage portfolio;

- advanced IP video services offering the utmost user experience streamed efficiently and flawlessly from the Cloud; and

- an extensive portfolio of professional services to accelerate the benefits of integrating new technologies to transform networks and leverage the latest innovations in SDN, virtualization, video and programmable all-IP networks.

Competition

The competitive landscape is dominated by Cisco, Juniper, Huawei and Nokia in addition to various specialized players in optics such as Ciena.

Applications & Analytics

Market overview

The Applications & Analytics market is focused on software platforms and applications that help CSPs to optimize their operations, monetize services and improve customer experiences. Applications & Analytics' primary businesses include Business Support Systems ("BSS"), Operational Support Systems ("OSS") and Service Delivery Platforms ("SDP"). The primary market for Applications & Analytics and associated professional services was estimated at EUR 12 billion in 2016.

The adjacent market, including verticals, for Applications & Analytics includes emerging software and services for Self-Organizing Networks ("SON"), Cloud, Analytics, Security and IoT. From a customer perspective this market also includes Webscales, digital enterprises and IoT verticals. The adjacent market, including verticals, was estimated at EUR 6 billion in 2016.

Business overview and organization

The Applications & Analytics business group is our dedicated software business. We have long-standing positions in its primary markets: our BSS solutions support hundreds of millions of subscribers and manage over 1.5 billion devices each day; we lead in LTE network management; we have thousands of OSS deployments with differentiated capabilities in service assurance, automation, analytics and Cloud; and our Session Border Controller, a SDP that secures network borders and connects an exploding number of devices, stands out for its virtualization capabilities.

These markets are being reshaped by four trends: the transition to the Cloud, the growth of the IoT, the increased need for security and privacy, and the impact of augmented intelligence and machine learning. These trends impact the way networks will operate, how new services and business models will be monetized, how customer expectations will evolve and the speed at which CSPs and TXLEs will need to innovate.

The Applications & Analytics business group is driving an aggressive innovation agenda that includes an Emerging Business unit that is developing software for IoT, security, Cloud, SON, and analytics. These advances are helping our customers:

- modernize BSS systems to rapidly launch and monetize new IoT and Cloud services;

- improve customer experiences with rich analytics and machine learning;

- operate larger networks and more services with fewer staff through virtualization and automation;

- predict issues before they happen with augmented intelligence;
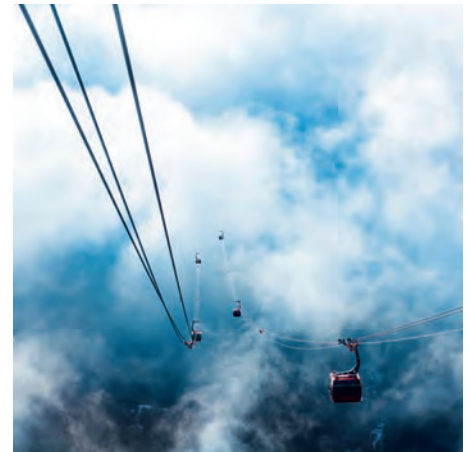
- scale IoT services with a platform that handles data collection, event processing, device management, data contextualization, data analytics, and end-to-end security;

- increase the success of digital transformations with improved processes, collaboration and profitability; and

- secure services and data with confidence.

Growing this business into a standalone software business at scale is a key tenet of our strategy. Please refer to "—Our strategy" for more information on our strategy.

Competition

The Applications & Analytics business group operates in a highly fragmented market in which very few players have a market share above 10%. Our main competitors are Ericsson, Huawei, Amdocs, Oracle, HPE, Cisco and Netcracker.

Within our Networks business

Services

Our Services are focused on developing innovative services, solutions and multivendor capabilities around the mobile, fixed and IP networks and beyond. With our full service portfolio we address the current and future needs of our customers, including network operators, public sector, TXLEs and transportation. Customer satisfaction, quality and efficiency are key in service delivery. To achieve that, we leverage a combination of local engagement with the customers, the network of Global Delivery Centers, and Nokia AVA, the next-generation delivery platform. Altogether, our service portfolio and delivery are powered by 38 000 services experts around the globe.

Sales and marketing

The Customer Operations ("CO") organization is responsible for sales and account management across the four network-oriented business groups. The CO teams are active in approximately 130 countries to ensure that we are close to our customers, both physically and in terms of understanding the local markets, thus helping us build and maintain our customer relationships. Refer to "General facts on Nokia—Production of infrastructure equipment and products" for more information on our manufacturing facilities globally.

The CO organization is divided into seven markets:

- **Asia-Pacific and Japan** spans a varied geographical scope, ranging from advanced telecommunications markets, such as Japan and the Republic of Korea, to developing markets including Bangladesh, Myanmar and Vietnam. We work with leading operators in the market, including Indosat, KDDI, KT, LG Uplus, NBN Australia, NTT DoCoMo, Singtel, SK Broadband, SK Telecom, Smartfren, SoftBank, Spark, StarHub, Telekom Malaysia, Telkom Indonesia, Telkomsel, VNPT and Vodafone.

We have close technology cooperation with leading operators in Korea and Japan as well as two Service Delivery Hubs located in Japan and Indonesia.

- In **Europe**, we are engaged with all the major operators, including Deutsche Telekom, MegaFon, MTS Sistema, Orange, Telefónica, Telia Company and Vodafone Group, serving millions of customers. We have extensive R&D expertise in Europe, and some of our largest Technology Centers, which are developing future mobile broadband technologies, are based in this market. We also have a Global Delivery Center and four regional Service Delivery Hubs in Europe.

- In **Greater China**, we are the number one player with headquarters outside China, and we are working with all the operators including China Mobile, China Telecom, China Tower and China Unicom. We have also extended our market presence to the public and enterprise sectors, including railways and public security. In Taiwan, we work with all major operators, including Chunghwa Telecom and Taiwan Mobile. In China, we have six Technology Centers, one regional Service Delivery Hub and more than 80 offices spread over megacities and provinces.

- In **India**, we are a strong supplier and service provider to the leading public and private operators, including Bharti Airtel, Vodafone, Reliance Jio, Idea, BSNL, MTNL, Aircel and Uninor. Collectively, our networks for these operators carry over 280 million subscribers across over 230 000 sites, and these figures are growing every day. In addition, we are a key telecom infrastructure supplier to non-operator segments, including large enterprises, utilities companies such as Tata Power and GAIL, Indian defense sector through L&T and BEL, and we are a strategic telecommunication partner for GSM-Railways technology to Indian Railways, including Kolkata Metro Railways and DMRC (Delhi Metro Rail Corporation). We have a Global Delivery Center, a Service Delivery Hub and a Global Technology Center in India.

- In **Latin America**, 16% of the population use LTE services, and high-speed fixed broadband is still in its early phase. With the aim of providing broadband services to a population of over 600 million people in the area, we supply ultra-competitive solutions to all major operators, such as América Móvil, AT&T, Oi, Telefónica, Telmex and Tim, as well as local operator groups, such as Avantel, Milicom, Nuevatel and Personal.

- In **Middle East and Africa**, we have built a position of considerable strength, working alongside leading operators such as Airtel, du, Etisalat, Maroc Telecom, Mobily, MTN, Ooredoo, Orange, OTA Djezzy, Smile, STC, Telkom, Vodacom and Zain, among our key customers in the market.

- In **North America**, we count all the major operators as our key customers. We also deliver advanced IP networking, ultra-broadband access, and Cloud technology solutions to a wide array of customers, including local service providers, cable operators, large enterprises, state and local governments, utilities, and many others. North America is also home to the company's most important and thriving innovation practices—from the renowned Nokia Bell Labs headquarters in Murray Hill, New Jersey, to the development labs of Nokia Technologies in Silicon Valley.

In addition, we have a dedicated sales organization focused on driving mission-critical communications sales to organizations outside the telecommunications operator market. This structure is targeted at allowing us to gain speed and efficiency in dealing with customer requirements and cultivating new and existing customer relationships.

The Global Enterprise and Public Sector organization focuses on four segments vertical to the telecommunications operators that require mission-critical communications networks: Public Safety, Transportation, Energy and TXLEs. This global sales organization is dedicated to serving the needs of customers such as Nedaa in Dubai, which provides telecommunication

services to all specialized governmental, semi-governmental and private institutions; the Swiss railway company SBB (Swiss BundesBahn); the Swiss electricity transmission system operator Swissgrid; Smart City initiatives e.g. 'Bristol is open', which aim at exploring solutions to make cities smarter, safer and more sustainable; and name-brand banks such as BBVA and Santander that are transforming complex legacy environments into leading-edge Clouds that improve their global customer experience.

Research and development

Our Networks business is one of the industry's largest R&D investors in information communication technology and we expect it to drive innovation across telecommunications and vertical industries to meet the needs of a digitally connected world. Product development is continually underway to meet the highly programmable, agile and efficiency requirements of the next generation software-defined networks that will accommodate the IoT, intelligent analytics, and automation used to forge new human possibilities.

Our four networks-focused business groups are responsible for product R&D within the Networks business. The Networks business has a global network of R&D centers, each with individual technology and competence specialties. The main R&D centers are located in Belgium, Canada, China, Finland, France, Germany, Greece, Hungary, India, Italy, Japan, Poland, the Philippines, Portugal, Romania, the United Kingdom and the United States. We believe that the geographical diversity of our R&D network is an important competitive advantage for us. In addition, the ecosystem around each R&D center helps us to connect with experts on a global scale and our R&D network is further complemented by cooperation with universities and other research facilities.

Innovation steering within our Networks business is carried out by the Chief Innovation and Operating Office ("CIOO"). For R&D activities of our Nokia Technologies business group refer to "Nokia Technologies— Research and development". Within the CIOO, the Chief Technology Office ("CTO") and Nokia Bell Labs organization are responsible for our research agenda and research portfolio along with group services for architecture, compliance, reliability and standards. The CIOO develops disruptive technologies, incubates these technologies into novel prototype systems and solutions and then launches them through our business groups to generate growth and differentiation across our entire portfolio. The CIOO organization also steers innovation externally with customers, partners and governments, and has new solutions tested in collaboration with customers and our business groups.

In response to the six megatrends identified by Nokia as driving the Programmable World (for a more detailed description refer to "Our strategy" above), Nokia Bell Labs has defined the Future X network architecture—a massively distributed, cognitive, continuously adaptive, learning and optimizing network connecting humans, senses, things, systems, infrastructure, and processes. All of our Networks business groups—and also Nokia Technologies—are committed to this single architecture view and are developing products in their respective domains to build seamless end-to-end solutions in the future:

- Mobile Networks will enable 1 000X higher throughput, 100X lower latency, 10X peak speed, support for multiple spectrum bands and technologies by building application-aware and self-organizing networks that are ultra-secure;

- Fixed Networks will provide massive-scale, ubiquitous access, fiber-like speed over any media, and flexible software-defined access;

- IP/Optical Networks will implement terabit scale capacity, dynamic cloud-optimized smart networks and unlimited network programmability/slicing;

- Applications & Analytics will automate edge/Telco Cloud networks, and enable cognitive network operation and future enterprise interactivity, as well as provide terabit-scale automated IoT/device management contextual security; and

- Nokia Technologies will explore and innovate new digital value platforms, as well as continue to innovate professional and consumer devices and technologies, with focus on digital health and digital media.

Patents and licenses

Intellectual property assets are fundamental to Nokia, which owns a large patent portfolio of more than 26 000 patent families, originating from three distinct organizations (Nokia Technologies, Nokia Solutions and Networks and Alcatel Lucent). The Patent Business in Nokia Technologies is the primary monetization entity for patent assets. Refer to "Nokia Technologies—Patents and licenses" for a description of the patent licensing activities of Nokia Technologies.

Our Networks business, including Nokia Bell Labs, generates valuable patents from their industry leading R&D in fields, such as wireless, IP networking, ultra-broadband access and Cloud technologies and applications.

Our patent portfolio includes high-quality standard-essential patents ("SEPs") and patent applications which have been declared to the European Telecommunications Standards Institute and other Standards Developing Organizations as essential to standards including LTE, WCDMA, GSM and other standards. We continue to drive new patent generation.

Our Networks business has patent license agreements in place with a number of third parties as part of its ordinary course of business.

Nokia Bell Labs

Nokia Bell Labs is the world-renowned industrial research and innovation arm of Nokia. Over its 90-year history, Nokia Bell Labs has invented many of the foundational technologies that underpin information and communications networks and all digital devices and systems. This research has resulted in eight Nobel Prizes, two Turing Awards, three Japan Prizes, a plethora of National Medals of Science and Engineering, as well as an Oscar, two Grammys and an Emmy award for technical innovation. Nokia Bell Labs continues to conduct disruptive research focused on solving the challenges of the new digital era, defined by the contextual connection and interaction of everything and everyone.

Nokia Bell Labs searches for the fundamental limits of what is possible, rather than being constrained by the current state of the art. It looks to the future to understand essential human needs and the potential barriers to enabling this new human existence. It then uses its unique diversity of research intellects and disciplines and perspectives to solve the key complex problems by discovering or inventing disruptive innovations that have the power to enable new economic capabilities, new societal behaviors, new business models and new types of services—in other words, to drive technological revolutions.

Research at Nokia Bell Labs is focused on key scientific, technological, engineering or mathematical areas which require 10x or more improvement in one or more dimensions. It then combines these areas of research into the Future X network architecture, which brings these disruptive research elements together into industry-redefining solutions. These innovations are brought to market through our business groups or through technology and patent licensing. Nokia Bell Labs also engages directly with the market and customers through its consulting service to help define the path to the future network with business model innovation and the optimum techno-economics.

This model of defining future needs and inventing game-changing solutions to critical problems while advising the market on the path forward has been the constant mission of Nokia Bell Labs.

Nokia Bell Labs and Alcatel-Lucent Submarine Networks achieved **65 Tb/s transmission record** for transoceanic cable systems using Bell Labs' new Probabilistic Constellation Shaping ("PCS") technology, a ground-breaking new modulation technique that maximizes the distance and capacity of high-speed transmission in optical networks.

Nokia Bell Labs, Deutsche Telekom T-Labs and the Technical University of Munich achieved a **1 Tb/s transmission rate** over optical fiber using Bell Labs' Probabilistic Constellation Shaping technology to provide greater flexibility and performance enabling optical networks to operate closer to the Shannon limit to meet growing consumer and business data demands.

Nokia Bell Labs achieved the world's first **10 Gb/s symmetrical data speeds** over traditional cable access networks using XG-CABLE that is based on unique access technology innovations and applications developed by Nokia Bell Labs.