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Networking solutions for the new age of industry

White paper

We are at the beginning of an era of profound transformation and human progress — a new industrial revolution. This “Automation of Everything” era will be brought about by digital interfaces, data analysis and control of the physical world through networks employing the Nokia Bell Labs Future X for industries architecture. These networks will support the digitalization and connection of everything and everyone with the goal of automating much of life.

This major industrial revolution promises to unlock trillions of dollars of economic value in the next decade by driving massive improvements in productivity in physical and digital industries alike, enhancing quality of life in safer, healthier and more sustainable communities.

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Introduction

Industry is driven by a constant quest for productivity. They seek all means to most efficiently produce and deliver their goods and services. Growth in productivity is among the leading indicators of economic value and a strong measure of progress in the industrial age.

Yet, in the last few decades, productivity growth has slowed dramatically. That is surprising to many, given the unprecedented advancements in information and communications technology (ICT). After all, we have witnessed massive innovation in the Internet era and the digital transformation of enterprises is well underway.

A closer look[1] at US economic data reveals that it is just 30 percent of industries who are benefiting most from digitalization and automation. Information economy segments and IT-centric verticals such as financial services have made the lion's share — 70 percent — of total investment in ICT. As a result, they are benefitting from a nearly 4x faster productivity growth rate.

These gains are just the low-hanging fruit harvested by segments that drive the information economy. The gap is set to widen further, as it is the top 5 percent of these heavy investors in ICT — largely within the manufacturing and services sectors — that are seeing a majority of the productivity gains[2].

In contrast, traditional asset-intensive industries have lagged in the transition to the digital economy and thus have not yielded their share of benefits from the transformation. Even as the companies in this "physical economy" collectively represent 70 percent of US GDP and employ three-quarters of the US workforce, these industries have experienced a productivity rut over the past two decades.

Now things are changing. Industries in the "physical economy" have begun their digital transformation and the opportunity for realizing a much bigger productivity boom is before us. As the Internet of Things (IoT), edge computing, deep analytics based on artificial intelligence/machine learning (AI/ML), augmented reality (AR), robotics, remote control and digital twinning technologies mature and reach a critical mass of adoption, the opportunities to energize traditional industries are countless and within reach. Advances in robotics have begun to dramatically simplify the interface between digital systems and physical tasks. Technologies that can bring the physical and digital economies together will drive commercial and social value like never before. Augmented intelligence and automation will drive productivity while dramatically reducing risks.

Today we stand at the cusp of the next major industrial revolution, one that promises to unlock trillions of dollars of economic value in the next decade[3] by driving massive improvements in productivity in physical and digital industries alike, enhancing quality of life in safer, healthier and more sustainable communities.

The quest for value

In the first wave of digital transformation, IT-centric industries paved the way. They leveraged cloud and analytics technologies to achieve a new level of agility. Today the cloud offers all enterprises — including smaller ones and those with less IT expertise — a variety of options to achieve similar benefits in their IT environments.

1 Michael Mandel, Brett Swanson, The coming productivity boom, The Technology CEO Council

2 Jason Douglas, Jon Sindreu, Georgi Kantchev, "The problem with innovation: The biggest companies are hogging all the gains," Wall Street Journal, July 15 2018

3 Source: McKinsey - The Internet of Things: Mapping the value beyond the hype June 2015 ($3.8-$11T of economic value by 2025)

That first wave largely focused on replacing physical aspects of IT with digital and virtual means, thereby creating efficiencies and reducing waste. For the next wave, that will not be sufficient. Physical industries have substantially more to consider. For example, in an operational environment you are likely to have machinery, tools and systems that must be monitored, controlled and optimized. The key to creating efficiencies is by controlling these physical assets using digital technologies. This requires a complete, accurate and continuous understanding of the state of anything that must be monitored, controlled and optimized, encompassing physical assets, personnel, processes, workflows and even customer interactions with products and services when possible.

This is the promise of combining advances in information technology (IT) and operations technology (OT) to enable industries to drive closed-loop automation in their physical environments. It allows companies to leverage the wealth of state information to sense, analyze, optimize, and control their complex systems. In doing so, they will ensure that they are making most efficient use of their assets and resources, minimizing the occurrence and impact of failures, and maximizing their productivity.

Digital transformation: Three imperatives

Connect everything

All businesses invest in some form of assets — physical, digital or human — to create their products and services. Today, enterprises in most industries operate with broadly distributed assets, workforce and geographic footprints. They serve customers near and far and spread their supply chains and facilities across the globe. Further, a portion of their workforce and assets are often on the move. As a business grows, so does the number, diversity and distribution of its assets.

Therefore, optimizing utilization of those assets should improve productivity and business performance. To achieve this, a business must be able to do two things: know the state of all relevant assets in time to facilitate a business decision and orchestrate or control the allocation or behavior of the assets regardless of location.

This requires a network that connects everything: workforce, devices, machines and tools, supply chain elements, partners, customers and even the products and services sold when possible. This network will play a central role in the future productivity boom. The ability to sense, analyze, optimize and control what matters will unlock business value that would otherwise never have been possible.

Compute, wherever you need it

The cloud has been embraced by enterprises because it enables a level of agility and efficiency that had been elusive in classic IT environments. The ability to dynamically turn up and adapt compute and application workloads in a company's own data centers or the public cloud provides undeniable resource efficiency. Today, private or hybrid cloud implementations are a part of almost every enterprise's digital transformation reality.

While well suited to many of the current enterprise productivity applications, centralized hybrid clouds simply will not meet the stringent performance envelopes imposed by future scenarios. Applications for which performance and ultra-low latency are paramount will require proximity. Other applications will require the ability to run uninterrupted. For instance, robots in an automotive factory, remotely operated tools or autonomous vehicles in a mine, and some telemedicine applications such as remote surgery will never become broadly deployed unless compute resources are immediately nearby.

Compute should be available wherever it is needed, which fuels the need for edge clouds. Edge clouds push applications closer to distributed assets and users, even placing the compute capabilities on premises in local clouds where stringent requirements demand it.

This gives enterprises the means to analyze information about the state of their assets and operations in the most efficient way. To ensure that happens, networks must seamlessly and reliably connect users and applications to the clouds — be they edge, local or hybrid — and adapt swiftly to changes in workload placement. As the cloud provides agility and compute elasticity, so must the underlying network provide its own level of resource elasticity and uninterrupted availability.

Apply insights and execute with precision

Historically, data collection has often proven elusive. We were able to leverage IT for those aspects of business where data was easy to collect, and the processes that generated the data were well understood so that we could develop algorithms to manage these processes. With the rapid proliferation of sensors and connected systems, the data collection concern is going away. We now face a data deluge — including for far-less understood processes — which will create new problems and opportunities.

The first problem is that data alone is not sufficient. It needs to be timely, relevant, and contextually comprehensive. (Indeed, it is estimated that more than 90 percent of the data collected on a factory floor is simply discarded — neither stored nor transmitted — as no one knows what to do with it.) This drives the need for advanced analytics platforms that can operationalize data to drive human decisions or machine actions. As local compute capabilities soar and the sophistication of analytics improves, there are unprecedented opportunities to collect and draw on a variety of real-time, state-driven information, in addition to contextual and historical data. Furthermore, advances in machine learning can help us improve our grasp of complex processes.

Understanding of state across complex operational systems is critical to success in automating physical industries and achieving productivity gains. As we gather and process state information from the multitude of devices, sensors and machines, big data will shift to big insights.

Reactive approaches with automated corrections that are commonplace to date will initially yield to predictive open-loop automation alternatives that are parsed by humans. Ultimately, the goal is to achieve closed loop automation with predictive approaches that are fully automated.

We must drive to operationalize data about the state of systems in each industrial environment in order to generate timely and actionable insights. These insights are most often driven by real-time information that is correlated with contextual and historical datapoints to uncover optimal paths and guide human decision making.

Once these requirements are met, the right networking infrastructure is in place to achieve the following capabilities:

- Richer human-machine interfaces (HMI) leveraging AR/VR
- Precise control of autonomous systems
- More efficient digital operations (e.g. learning and optimization with AI/ML)

For key industries, ranging from transportation to global logistics, this yields tremendous benefits. Trains can be proactively re-routed based on the probability of flooded tracks. Logistics hubs that handle unthinkable volumes of goods daily will see massive efficiency gains. Scene analytics will help first responders optimize their approach, saving lives while protecting their own. Each scenario depends on making sense out of data quickly and effectively.

Networks are at the intersection

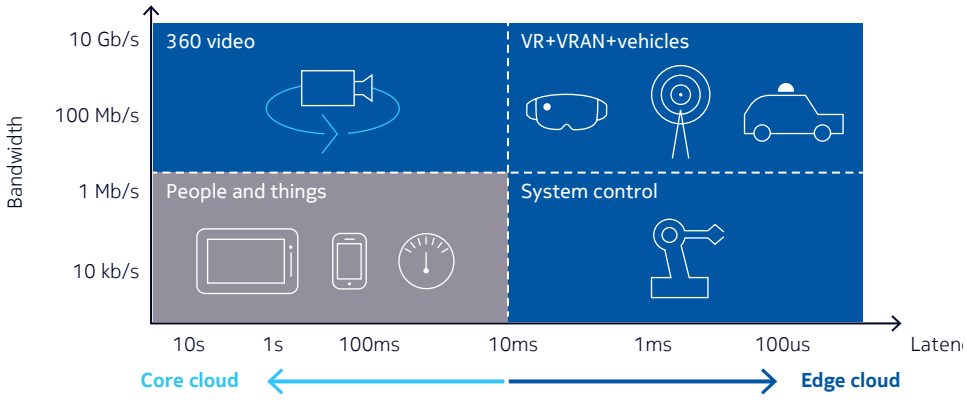
Digital transformation drives a set of new requirements that have the network at their center.

As we have discussed, it is of fundamental importance that we connect everything, provide compute wherever it is needed, and apply insights to execute with precision. Each of these requirements places new demands on the networking infrastructure. In many cases, this extends far beyond what has traditionally been acceptable for even the largest enterprise networks. In other cases, it greatly expands the capabilities required of today's mission-critical network infrastructures.

In addition, as smart devices and systems proliferate, and business applications evolve, they will require dramatically more bandwidth to deliver richer information about the state of systems and the operating environment.

Further, as business-critical applications rely on tele-operation, fine control of systems and autonomous vehicles, they will demand latency that is orders of magnitude lower than required for today's simpler applications.

Figure 1. New applications force new bandwidth and latency requirements in the network



To support these requirements and truly drive productivity gains, networks must be fundamentally more:

- **Accessible:** Networks must provide deeper reach and extend everywhere the business is. Regardless of access medium, dedicated network connectivity is a must. Various wireless, fixed, IP, optical and microwave technologies must work together to ensure that no site, sensor, worker or customer is left behind.
- **Elastic:** Networks must be dynamic and programmable. As compute workloads move, as new sites are added, as demands fluctuate, the network should adjust in an automated fashion to optimize resource utilization and meet application needs in accordance with policies. Dynamically optimized connectivity is established wherever it is needed. Programmatic handling of changes in the connections to (and between) local, edge and hybrid clouds will be essential to the performance of the applications and the viability of key use cases.
- **High-performance:** The network should deliver seamless, deterministic performance across all the applications it supports. While the requirements of each set of applications may vary, performance against stringent guidelines must be independently guaranteed for each.

- **Resilient:** For business-critical applications, downtime can have catastrophic consequences. Networks must ensure availability at all costs to meet business objectives. Ultra-reliable operation at five and six 9s of reliability (99.9999 percent) is a requirement. In some cases, human lives and safety are at stake.
- **Secure:** As business perimeter expands and devices proliferate, so does threat radius. Networks should be a part of the enterprise security solution, rather than the problem. A smart network fabric can play a role in minimizing certain threats and ensure that changes are in strict accordance with enterprise policy.
- **Scalable:** Richer data provides deeper context and higher value. A simple move to video for surveillance or scene analytics necessitates higher bandwidth at each site. Video streams, for example, will be used for multiple purposes — to detect anomalies, to measure properties of the physical environment. Each additional use will require the deployment of additional computational power. Control of automated vehicles, for example, may ultimately require the processing and coordination of data from a wide spectrum of sources, including roadside surveillance cameras, in-vehicle sensors, and other devices. The use of high-fidelity state information from a full spectrum of sensors will improve automation decisions made across a wide spectrum of industrials. As a result, networks must cost effectively scale in place, as business-critical infrastructure must operate and grow for periods of a decade or longer. Networks should be designed in a manner that anticipates and adapts to expansion of bandwidth, processing and other capabilities. Within the duration of the next investment cycle, we will undoubtedly encounter many compelling new applications that are unheard of today, and those will need to be gracefully accommodated by infrastructure that is put in place.

Wireless networking options expand

As industrial customers rely more heavily on wireless connectivity to control and manage their operations, access to spectrum will continue to be one of the dominant forces that shapes ecosystems, partnerships and solutions. This presents other interesting areas of potential collaboration between industry and service providers who own and operate spectrum.

The combination of wide area coverage networks and hyper-local networks that support demanding requirements in terms of latency, reliability, capacity and security for business- and mission-critical applications will open up a rich set of new solutions for industry customers and business opportunities for communications service providers (CSPs).

Industry verticals have explicit requirements for their business-/mission-critical services that are currently provided over fixed (wired) infrastructure, carefully managed unlicensed broadband wireless infrastructure, or low capability, low data rate licensed narrowband wireless infrastructure. To increase productivity, industries are seeking to evolve their systems to be wirelessly connected at levels of performance similar to those of wired infrastructure. Such mission-critical, hyper-local broadband wireless connectivity will allow dynamic reconfiguration of manufacturing machines on factory floors and the use of untethered robots and drones, while maintaining critical protections and the need for guaranteed quality of service (QoS) and service level agreements (SLAs). These extreme requirements, the need for a high degree of support and control over the associated services and favorable economics lead some verticals to be interested in directly controlling their own network infrastructure.

A variety of spectrum solutions will be used to meet these needs. These include:

- unlicensed spectrum (with suitable management of interference)
- sub-licensing of spectrum to enterprises by service providers
- the use of dynamic shared spectrum (such as CBRS in the US or similar opportunities in EMEA in the 2.3 GHz - 2.4 GHz band).

This is in addition to vast networks that are deployed worldwide by service providers. Pervasive LTE infrastructure will soon be augmented with the introduction of 5G services and capabilities, further increasing the suitability to the needs of industries assessing business-critical infrastructure.

With the introduction of 5G, CSPs will be able to use network slicing to provide end-to-end connectivity specifically tailored to the needs of industrial customers and industrial applications. These tailored slices can be combined to create virtual private network services for targeted industries. Given their extensive reach and scale of infrastructure, CSPs will be able to offer advanced networking services with compelling economics. Partnerships will make it possible to extend the necessary services nationally and internationally.

These hyper-local islands of connectivity will create opportunities for commercial service providers and new entrants alike. Further, using nationally and internationally managed network slices, commercial service providers will be able to interconnect these islands of hyper-local connectivity — providing seamless connectivity for business-critical applications and paving the way for realizing the potential of Industry 4.0.

Applying a connected systems approach

In addition to evolving networks to support Industry 4.0, enterprises should adopt a connected systems approach for even greater benefit. This approach can unlock the full potential of insight-driven automated operations. The power of IoT to transform business outcomes is amplified when relevant data is shared and leveraged across a multiplicity of applications. In fact, up to 40 percent of the potential economic value is unlocked by integrating multiple IoT systems[4].

In a typical city, for instance, security cameras might be a compelling IoT application for public safety. In addition to the capital investment and installation, the organization needs to provision networking, compute and analytics resources for the application. If future smart city applications are also deployed in a bespoke manner, the operations quickly become unwieldy and the economics far less compelling. Efforts are duplicated rather than leveraged.

This application can be remarkably more efficient by using a connected systems approach. City departments that deliver citizen safety and services can share application resources. Video captured for monitoring public safety can be used for crowd analytics that feed traffic management optimization scenarios. Sensors on cameras or on the same light poles could feed smart lighting applications. All applications share resources from capability layers that pool compute, analytics, and networking resources. This maximizes efficiency as well as the overall viability of each IoT application.

To realize the full value, a platform-driven mindset is required. Only then can economies of scale be leveraged to optimize business outcomes for many use cases and uncover new possibilities.

Industry examples

Mining

In a strong economy, the mining industry benefits from an insatiable demand for minerals. When economic conditions are favorable, mining productivity is primarily limited by bottlenecks in mineral production or in the supply chain. The industry is also plagued by excessive operational costs and capital expenses (e.g. as high as $1 million per worker, $6 million per haulage truck). These factors encourage the mining industry to drive ever higher efficiency. The hazardous nature of mining environments (characterized by dust, the use of high explosives, extremely high temperatures, and moving heavy equipment) drive a greater industry emphasis on worker safety.

4 Source: McKinsey - The Internet of Things: Mapping the value beyond the hype June 2015

The need for continuous improvement of safety, productivity, and efficiency has created an unprecedented demand for digitizing, automating, and optimizing all aspects of mining operations from pit-to-port, placing the mining industry at the cutting edge of industrial automation in the 21st century.

As an example, the introduction of automated haulage open-pit iron mines in Australia's Pilbara region is credited by BHP for creating a 15 percent improvement in operating efficiency.

Manufacturing

Consumer expectations are increasingly out of synch with old-style, mass production. Manufacturers and their supply chains are directly implicated, looking for a new level of agility and predictive abilities to bolster their just-in-time (JIT) manufacturing to more accurately map to rapid shifts in consumer demand. With productivity growth stalling, manufacturers are also looking for more efficient ways to manage supply chains and logistics, create more agile production facilities and empower their workers.

Fortunately, many manufacturers are already highly automated. The use of assembly line robotics and automated ground vehicles (AGVs) tends to be tied, however, to static workflows. The next-generation of industrial automation promises to optimize production for more agile workflow changes, quickly shifting constellations to match new requirements, even for small batches or fast changeovers. Connected sensors, tools and machines (IoT), digital twins, analytics, AI and ML show great promise for improving real-time intelligence and control of automated processes and augmenting the performance and decision-making of personnel.

Harbor/Seaport

Global trade has driven significant growth in maritime traffic over the last 30 years. Today 90 percent of the world's goods are transported by sea. As a result, container ports play a critical role in handling traffic surges and ensuring fast turn-around for their customers. The scope and benefits of digitalization are massive, as much of the current operation relies on manual processes. Many of these harbors have started to embrace increased automation to enhance processes, efficiency and safety of the goods they handle.

When a vessel carrying over 20,000 containers representing sometimes over $500 million worth of cargo docks at a sea port, the race is on to unload the goods rapidly and safely for further dispatch. Automation and digitalization enable the harbor to handle the massive influx of information that comes with the vessel containers and that need to be generated for the rest of the journey. Several companies are often involved in the operations, each with their own need for dedicated connectivity while in the harbor. Furthermore, these efforts must be closely coordinated. The first application most often requested is to create a real time overview of the port operation, using cameras to give dispatchers the visibility to operate the cranes and straddle carriers. These cameras are also used to verify the state of the containers on arrival and avoid theft while in harbor. Ports of the future will need to leverage remote and automated trucks, straddle carriers and cranes to further enhance efficiency and safety.

Electric grids

Pervasive, wide-scale deployment of distributed generation and storage is a major disruptive force that will shape the electric power utility of the future.

Creating a safe, reliable energy supply from what is often an unreliable source will require monitoring and control of devices installed in homes, enterprises and the distribution grid at a speed and scale far beyond today's operations. This shift is driving radical changes in utility functions and business models. Significant amounts of power will be generated on consumer premises and at stand-alone distributed generation locations, which will lead to neighborhood and community energy exchanges. Retail energy markets will emerge to support real-time energy transactions using blockchains to facilitate their execution.

Widespread automation, use of data analytics to support new utility applications, and use of augmented intelligence systems by field personnel will transform utility operations. Huge capital investments have been made to support the centralized grid of the past. Now that infrastructure — originally designed for one-way energy flow — needs to cope with two-way flow. Sweating existing assets to keep consumer energy costs low is imperative. As a result, utilities will need to deploy a host of sensors and controllers to ensure capital assets are not overloaded and power quality is maintained. The opportunities for digital efficiency in the energy grid abound.

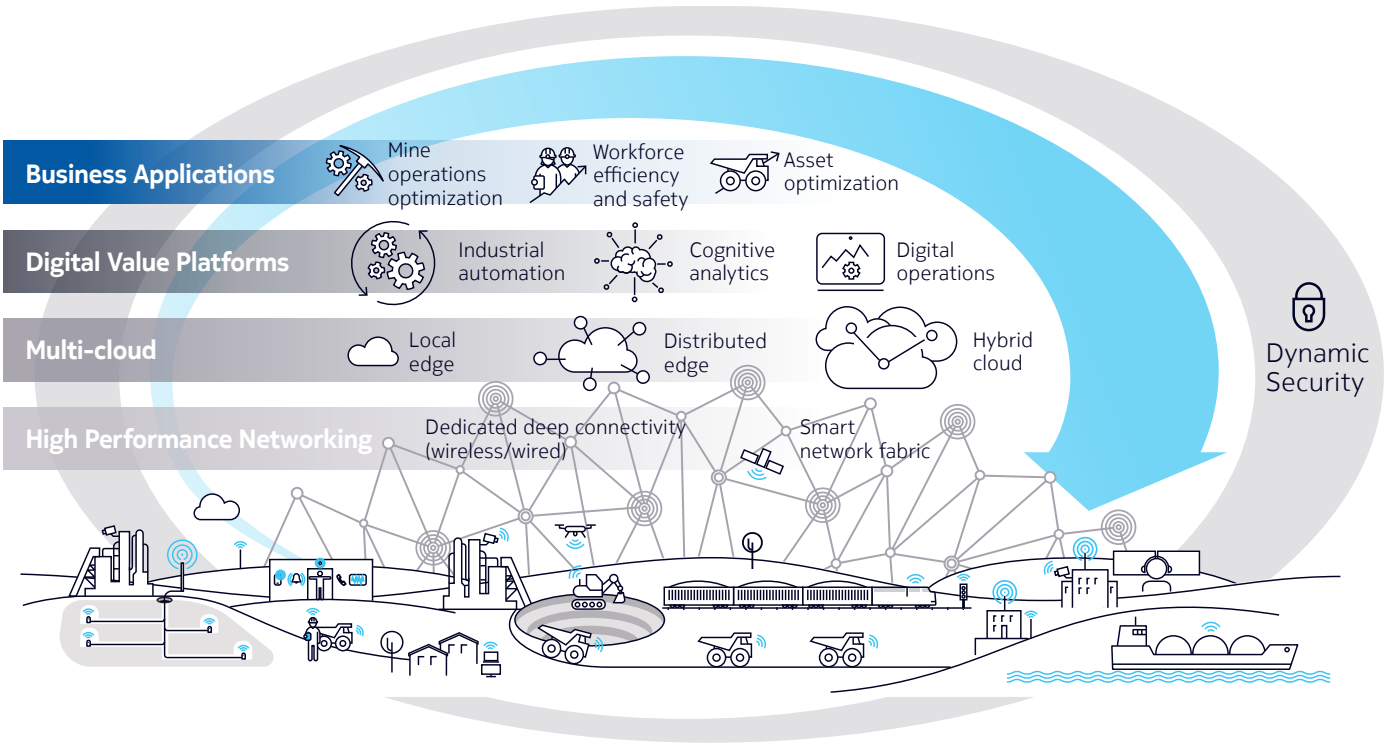
Introducing Future X for industries

A robust framework that outlines industry direction as enterprises plot a path for their future must incorporate all these elements in a meaningful way. It must accept the realities and unique considerations of each industry and adapt to accommodate them in the most economically feasible way to drive increased productivity and enhanced customer experiences.

Nokia delivers exactly that framework with Future X for industries — a connected systems approach based on Bell Labs Future X architecture with capability layers that leverage the power of digital value platforms, distributed clouds, pervasive dedicated high-performance networks, and ingrained security to bridge the gap between people and machines and the business applications they drive and rely on.

A Future X architecture is the nervous system of the new industrial reality. The network facilitates the flows of all the streams of data and sensor state. With edge clouds as part of the network infrastructure, those streams are terminated, analyzed and secured in the most timely and efficient way, with the outcomes determined and sent back over the network in real time to end systems that execute them.

Figure 1. The Future X for industries mining architecture



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Nokia: a partner for Industry 4.0

Global networking leadership

To pave the road to Industry 4.0, Nokia brings unmatched networking experience. Nokia holds leadership positions in key technologies — fixed, wireless and microwave access as well as IP and optical transport technologies — and is powered by continuous innovation from Nokia Bell Labs. Nokia offers the broadest portfolio of mission-critical networking infrastructure in the industry for providing ubiquitous connectivity. This provides enterprises options to leverage dedicated slices of public networks or to build private LTE, IP/MPLS and optical networks as required.

We have deployed over 1,000 mission-critical networks with leading utilities, railways, air traffic controllers, mining companies, banks and healthcare institutions around the globe. Leading enterprises across industries have already started to work with Nokia on their digital transformation journey. They are leveraging our decades of experience building some of the biggest and most advanced IP, optical, and wireless networks on the planet. We have adapted the technologies that power the infrastructure of over 700 service providers around the world to suit the specific needs of key industries.

Innovation and investment

We continue to invest in and extend our insight-driven infrastructure. We are driving more automation, better analytics and advanced cloud integration to ensure that key solutions are world-class and ready for broad deployment.

With Nokia's investment and focus in cloud networking, machine learning and analytics, digital platforms and security, enterprises benefit from:

- IoT platforms for connectivity, device management and data collection
- Analytics for operational intelligence
- SDN solutions for data center networking and SD-WAN
- Cloud infrastructure and workload lifecycle management solutions
- Scalable central and edge cloud compute platforms
- Endpoint security solutions
- Cloud network security enhancements
- Innovative approach to dedicated broadband wireless connectivity and microservices
- Insight-driven operations with Advanced Command Center & Integrated Command Center solutions

Ecosystem and partnerships

The move to Industry 4.0 and the ongoing transformation of enterprises to adopt cloud, IoT and advanced wireless networking options is a massive undertaking. It will demand strong partnerships with industry, and ecosystems that are at once more diverse and more cohesive than we have ever seen before. As such Nokia is actively engaged in catalyzing, developing and joining the ecosystems and consortia that will drive specific industries to accelerated benefits.

Nokia's longstanding position as a trusted supplier and partner to communications service providers (CSPs) will facilitate the broad range of opportunities for industry and enterprises to address their needs, through their own investments and leveraging service provider infrastructures as needed. Some CSPs are tapping

Nokia to help them transform to digital service providers to gain the benefits of Industry 4.0. They are re-tooling their networks, operational infrastructures and processes with 5G technologies, architectures and digital services to better service the evolving requirements of their enterprise customers.

Conclusion

This next industrial revolution promises to unlock massive economic and productivity gains and set us on course for a new era of tremendous transformation and progress.

Industry 4.0 technologies — IIoT, edge computing, deep analytics based on artificial intelligence and machine learning, ubiquitous networking, augmented and virtual reality, remote control and digital twinning — are maturing and promise to bring together the physical and digital economies. As they reach a critical mass of adoption, the opportunity for realizing a much bigger productivity boom is before us.

The Nokia Bell Labs Future X for industries architecture offers a framework for how companies can seize this opportunity. It hinges on investing in an architecture that can acquire a complete, accurate and continuous understanding of the state of anything that must be monitored, controlled and optimized. Valuable insights from such an understanding will make the most efficient use of assets and resources, thereby maximizing productivity. It is this marriage of physical and digital worlds that will allow industries to drive the automation of everything.

Networks will be at the intersection of the key requirements of this transformation: to connect everything, put compute wherever it is needed, and apply insights to execute with precision. Nokia has a heritage in networking built over 150 years. Together with Bell Labs, Nokia brings innovation, experience, investment and a strong, global ecosystem of partners to support its enterprise offerings. Nokia is ready and eager to make Industry 4.0 the era that transforms the productivity of enterprises, delivers dramatically richer user experiences, and helps humanity enjoy safer, healthier and more productive lives all around the world.

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About Nokia

We create the technology to connect the world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry's most complete, end-to-end portfolio of products, services and licensing.

From the enabling infrastructure for 5G and the Internet of Things, to emerging applications in digital health, we are shaping the future of technology to transform the human experience. networks.nokia.com

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