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futureagenda

# The Future of Connectivity

## The Global Challenge

The telecoms industry not only faces a massive increase in data demand, it also needs to boost profitability and personalized experience at the same time. To meet this challenge by 2025 mobile networks need to support up to 1000 times more capacity, reduce latency to milliseconds, reinvent Telcos for the cloud and flatten the total energy consumption.

One gigabyte per day equates to a 60-fold increase, or roughly a doubling of traffic per user every 18 months, compared to the average 500MB per user per month some mobile networks in mature markets are seeing today. This demand will be driven by hundreds of thousands of data apps sharing the same network, each with its own requirements towards the network. Every user, human as well as machine, will expect the optimal experience from the network for its personalized set of applications.

Why do we believe demand for mobile broadband will grow to these dimensions? What will it mean for operators and their networks? And even more importantly, what are the vital capabilities and technologies we need to explore and develop in the next decade to make this happen?

**Giga Growth**
By 2025 mobile networks need to support up to 1000 times more capacity, reduce latency to milliseconds, reinvent Telcos for the cloud and flatten the total energy consumption.

**Optimal Experience**
Demand will be driven by hundreds of thousands of data apps sharing the same network, each with its own requirements towards the network. Every user, human as well as machine, will expect the optimal experience from the network for its personalized set of applications.

**More Than The Eye Can See**
Ultimately only the human eye will set the limits for the amount of digital content that will be consumed by a mobile device.

## Options and Possibilites

Demand will continue to grow exponentially in the next decade: Demand for mobile broadband is closely related to the evolution of device and screen technologies, one of the fastest evolving areas in the Information and Communication Technology (ICT) industry. In 2011, the Retina display of an iPad already had nearly twice as many pixels to fill with content compared to a Full-HD television. New device form factors such as Google's glasses, another hot topic introduced in 2012, continue to drive this evolution and ultimately only the human eye will set the limits for the amount of digital content that will be consumed by a mobile device. And these devices will not only consume content – ubiquitous integrated cameras with high resolution and frame rate are producing Exabytes of digital content to be distributed via networks.

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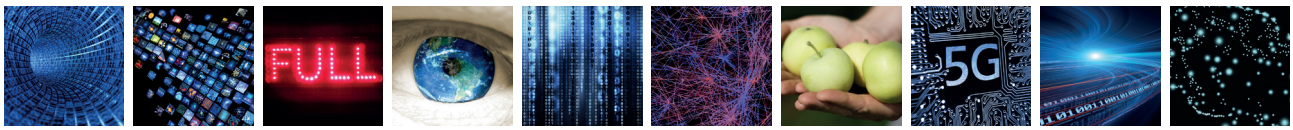


**Everything Connected**
By 2020, people might demand mobile networks that allow them to broadcast live video feeds from their glasses to thousands of other users in real time.

Enabled by these powerful new devices, the app ecosystem continues to fuel demand for mobile data by continuously inventing new categories of applications that test the limits of the network. It started with mobile web browsing in 2007 and accounted for more than 50% of video traffic in 2012. And by 2020, people might demand mobile networks that allow them to broadcast live video feeds from their glasses to thousands of other users in real time.

Many of the apps will be cloud based or rely on content stored in the cloud. IDC estimates in their digital universe study that by 2020 30% of all digital information will be stored in the cloud – and thus be accessed through networks.

An even broader range of use cases for networks will develop as communication technologies and applications proliferate into all industries and billions of machines and objects get connected. They will go far beyond the classical examples of the smart grid or home automation. Just imagine the potential – but also the requirements – that remotely controlled unmanned vehicles would bring to mobile broadband networks.

In summary, we believe that device evolution, cloud based application innovation and proliferation of communication technologies into all industries will ensure that the exponential growth in demand for mobile broadband we have seen in the last few years will continue in the next decade.

# Proposed Way Forward

**Testing the Limits**
We need to find ways to radically push the capacity and data rates of mobile networks into new dimensions to handle this amount of data traffic. live video feeds from their glasses to thousands of other users in real time.

**Intelligent Networks**
Self-aware and intelligent networks will be able to understand their user's needs and automatically act to deliver the best personalized experience.

**Shared Business Models**
To further reduce costs per GB, we need to share network resources through both within a single operator

Having understood what drives demand we can define the requirements for future mobile networks: As stated earlier, one gigabyte of data traffic per user per day is about 60 times the average data traffic seen in mature mobile operator networks today. On top of this, the growth in mobile broadband penetration and the surge of connected objects will lead to around ten times more endpoints attached to mobile operator networks than today. To prepare for this, we need to find ways to radically push the capacity and data rates of mobile networks into new dimensions to handle this amount of data traffic.

Yet, being able to deal with this traffic growth is just one aspect. An increasing number of real-time apps will test the performance of the networks. To support them with a good user experience we need to find ways to reduce the end-to-end latency imposed by the network to milliseconds. Tactile (touch/response) and machine-to-machine interactions in particular have low latency demands that can be as low as in the single digit milliseconds range.

To ensure mobile broadband remains affordable even while supporting the capacity and real-time requirements described previously, we also need to radically reduce the network Total Cost of Ownership (TCO) per Gigabyte of traffic. We believe one important lever to address this will be to automate all tasks of network and service operation by teaching networks to be self-aware, self-adapting and intelligent. This will help to reduce CAPEX/IMPEX for network installation as well as OPEX for network and service management. In addition to lower TCO, self-aware and intelligent networks will be able to understand their user's needs and automatically act to deliver the best personalized experience.

To further reduce costs per GB, we need to share network resources both within a single operator network, as well as between operators. It will include physical infrastructure, software platforms, sites, spectrum assets or even the network as a whole. We must also find ways to increase the energy efficiency. In addition to their environmental impact the energy costs account today for up to 10% (in mature markets) and up to 50% (in emerging markets) of an operator's network OPEX and they have been growing constantly in the last years.

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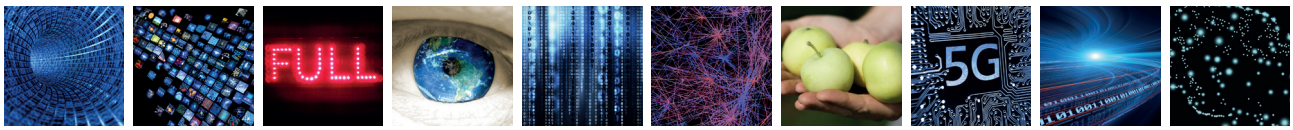


The most powerful way to deal with industry cost pressures will be to identify new revenue streams. Are end customers and termination fees really the sole revenue source for operators, or will technologies enable new business models that allow operators to better monetize all their assets?

Ultimately we of course need to admit that due to the fast pace of change in the industry it is simply not possible to predict all requirements future networks will face. There will be many use cases that are simply not known today. To cope with this uncertainty, flexibility must be a key requirement as well.

# Impacts and Implications

More spectrum, high spectral efficiency and small cells will provide up to 1000 times more capacity in wireless access. In the world of wireless, Shannon's law is the one fundamental rule that defines the physical limits for the amount of data that can be transferred across a single wireless link. It says that the capacity is determined by the available bandwidth and the signal to noise ratio – which in a cellular system typically is constrained by the interference.

Therefore the first lever to increase the capacity will be to simply utilize more spectrum for mobile broadband. In total the entire spectrum demanded for mobile broadband amounts to more than 1,100 MHz and a large amount (about 500 MHz) of unlicensed spectrum at 2.4 GHz and 5 GHz can provide additional capacities for mobile data. Of course reaching an agreement on spectrum usage requires significant alignment efforts by the industry and is a rather time consuming process. Therefore it is also necessary to look at complementary approaches such as the Authorized Shared Access (ASA) licensing model, which allows fast and flexible sharing of underutilized spectrum that is currently assigned to other spectrum-holders such as broadcasters, public safety, defence or aeronautical.

A key challenge associated with more spectrum is to enable base stations and devices to utilize this larger and a potentially fragmented spectrum. Here technologies such as intra- and inter-band Carrier Aggregation will be essential to make efficient use of a fragmented spectrum.

The second lever for more capacity will be to address the interference part of Shannon's equation. This can be achieved for example through beam forming techniques, which concentrate the transmit power into smaller spatial regions. A combination of multiple spatial paths through Coordinated Multipoint Transmissions (CoMP) can further increase the capacities available to individual users. We believe that with the sum of these techniques the spectral efficiency of the system can be increased by up to 10 times compared to HSPA today.

Advanced technologies and more spectrum will help to grow capacity by upgrading existing macro sites for still some time. However, a point will be reached when macro upgrades reach their limits. By 2020 we believe mobile networks will consist of up to 10…100x more cells, forming a heterogeneous network of Macro, Micro, Pico and Femto cells. Part of this will also be non-cellular technologies such as Wi-Fi, which need to be seamlessly integrated with cellular technologies for an optimal user experience.

Although the industry today has not defined what 5G will look like and the discussions about this are just starting, we believe that flexible spectrum usage, more base stations and high spectral efficiency will be key cornerstones.

The capacity demand and multitude of deployment scenarios for heterogeneous radio access networks will make the mobile backhaul key to network evolution in the next decade. The backhaul requirements for future base stations will easily exceed the practical

**5G**
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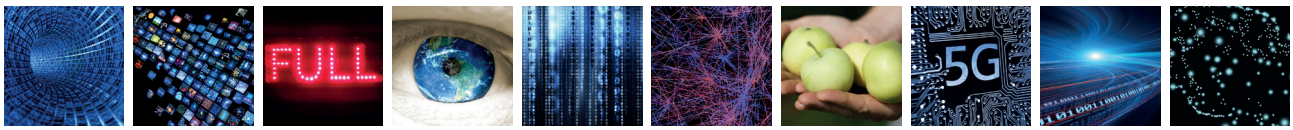


**Less Distance, More Speed**
One physical constraint for latency remains: Distance and the speed of light… As the speed of light is constant, the only way to improve this will be to reduce the distance between devices and the content and applications they are accessing.

limits of copper lines. Therefore from a pure technology perspective, fiber seems to be the solution of choice. It provides virtually unlimited bandwidth and can be used to connect macro cells in rural areas and some of the small cells in urban areas. However the high deployment costs will prevent dedicated fiber deployments just to connect base stations in many cases. Due to the number of deployment scenarios for small cells, from outdoor lamp post type installations to indoor, we believe a wide range of wireless backhaul options will coexist including microwave links and point to multipoint link, millimetre wave backhaul technologies. For many small cell deployment scenarios (e.g. for installations below rooftop level) a non-line-of-sight backhaul will be needed. The main options here are to either utilize wireless technologies in the spectrum below 7 GHz or to establish meshed topologies.

Besides pure network capacity, the user experience for many data applications depends heavily on the end-to-end network latency. For example, users expect a full web page to be loaded in less than 1000ms. As loading web pages typically involves multiple requests to multiple servers, this can translate to network latency requirements lower than 50ms. Real-time voice and video communication requires network latencies below 100ms and advanced apps like cloud gaming, tactile touch/response applications or remotely controlled vehicles can push latency requirements down to even single digit milliseconds.

The majority of mobile networks today show end-to-end latencies in the range of 200ms-500ms , mainly determined by slow and capacity limited radio access networks. Therefore the high bandwidth provided by future radio access technologies and the use of fast data processing and transmission will provide a major contribution to reduce the network latency. Due to the amount of data being transferred the user perceived latency can be much higher than the plain round-trip-time. Thinking of future ultra high resolution (UHD) real time video applications this clearly motivates the need for further technology evolution.

Equally important is the real traffic load along the end-to-end path in the network. A high traffic load leads to queuing of packets, which significantly delays their delivery. When attempting to solve this, it is not efficient to just overprovision bandwidth in all network domains. Instead latency sensitive media traffic might take a different path through the network or receive preferred treatment over plain data transfers. This needs to be supported by continuously managing latency as a network quality parameter to identify and improve the bottlenecks. In return, low latency traffic could be charged at a premium, providing network operators with new monetization opportunities.

One physical constraint for latency remainins: Distance and the speed of light. A user located in Europe accessing a server in the US will face a 50ms round-trip time due simply to the physical distance involved, no matter how fast and efficient the network is. As the speed of light is constant, the only way to improve this will be to reduce the distance between devices and the content and applications they are accessing. Many future applications such as cloud gaming depend on dynamically generated content that cannot be cached. Therefore the processing and storage for time critical services also needs to be moved closer to the edge of the network.

The introduction of additional radio access technologies, multiple cell layers and diverse backhaul options will increase complexity and bears the risk that network OPEX will rise substantially. This is why the Self- Optimizing-Network (SON) is so important. SON not only increases operational efficiency, but also improves the network experience through higher network quality, better coverage, capacity and reliability. Extending the SON principles now to a heterogeneous network environment is a challenge and opportunity at the same time.

Fortunately, big data analytics and artificial intelligence (AI) technologies have matured in recent years, mainly driven by the need to interpret the rapidly growing amount of digital data in the Internet. Applied to communication networks, they are a great foundation for analyzing Terabytes of raw network data

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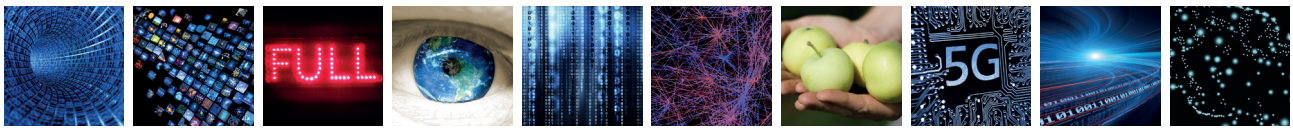


and to propose meaningful actions. In combination with AI technologies, actionable insights can be derived even in the case of incomplete data; for example machine-learning techniques can find patterns in large and noisy data sets. Knowledge representation schemes provide techniques for describing and storing the network's knowledge base and reasoning techniques utilize this to propose decisions even with uncertain and incomplete information. Ultimately we believe that both, big data analytics and AI technologies will help to evolve SON into what we call a "Cognitive Network", one that is able to handle complex end-to-end optimization tasks autonomously and in real time.

Customer Experience Management (CEM) can provide insights that will enable operators to optimize the balance of customer experience, revenues and network utilization. Cognitive Networks will help to increase the automation of CEM enabling network performance metrics to be used to govern the insight/action control loop, as well as experience and business metrics. This again increases the operational efficiency and at the same will be the prerequisite to deliver a truly personalized network experience for every single user.

The big data analytics and AI technologies introduced with the Cognitive Networks will be the foundation for advanced customer experience metrics. The ability to deal with arbitrary amounts of data in real time will allow a much more detailed sensing of network conditions and the resulting user experience in real time.

It also will be the foundation for large-scale correlations with other data sources such as demographics, location data, social network data, weather conditions and more. This will add a completely new dimension to user experience insights.

Cloud technologies and being able to provide computing and storage resource on-demand have transformed the IT industry in the last years. Virtualization of computing and storage resources has enabled the sharing of resources and thus their overall efficiency. Virtual cloud resources can also be scaled up and down almost instantly in response to changing demand. This flexibility has created completely new business models. Instead of owning infrastructure or applications it is possible to obtain them on-demand from cloud service providers. So far this approach has mainly revolutionized IT datacenters. We believe that similar gains in efficiency and flexibility can be achieved when applying cloud technologies to Telco networks. Virtualization will allow decoupling of traditional vertically integrated network elements into hardware and software, creating network elements that consist just of applications on top of virtualized IT resources. The hardware will be standard IT hardware, hosted in datacentres and either owned by the network operator or sourced on-demand from third party cloud service providers. The network applications will run on top of these datacentres, leveraging the benefits of shared resources and flexible scaling.

Also user plane network elements such as base stations will be subject to this paradigm shift. Over time, the migration of network elements in combination with software defined networking will transform today's networks into a fully software defined infrastructure that is highly efficient and flexible at the same time.

Efficient radio technologies, high utilization and network modernization will reduce the network energy consumption, another important cost factor for operators. Having the forecasted traffic growth in mind, reducing the network energy consumption must be a major objective. The focal point for improving network energy efficiency will be the radio access, which accounts for around 80% of all mobile network energy consumption. Ultimately the energy efficiency that can be achieved depends on the pace of network modernization. Efficiency gains materialize only when the new technologies are introduced into the live network. Determining the right pace for modernization requires careful balancing of CAPEX and OPEX. We believe that energy efficiency can beat the traffic growth - which makes keeping the network energy consumption at least flat a challenging - but achievable goal.

**Cognitive Network**
Ultimately we believe that both, big data analytics and AI technologies will help to evolve SON into what we call a "Cognitive Network", one that is able to handle complex end-to-end optimization tasks autonomously and in real time.

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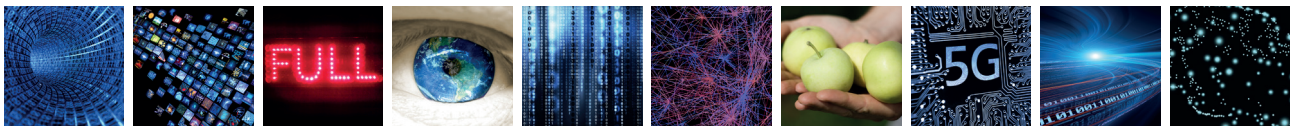


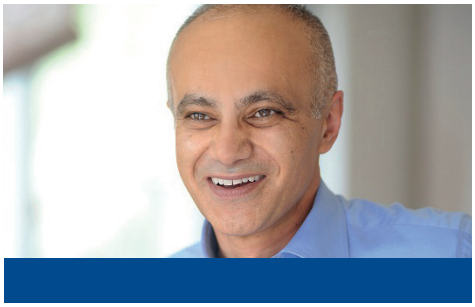

# Conclusion

We believe that device evolution and application innovation will continue to drive the exponential growth in demand for personalized mobile broadband in the next decade. This demand and the associated usage profile define the key requirements for future mobile networks in terms of capacity, latency, automation, resource utilization and energy efficiency.

For each of these requirements, we've shown an essential set of technologies that needs to be explored and developed in the next decade. This technology evolution leads to our vision of a fully software defined "liquid" network architecture - a network architecture that combines highest efficiency with flexibility and is the foundation to deliver the best experience to every mobile broadband user.

## *Lead Expert – Hossein Moiin*

**Executive Vice President and Chief Technology Officer, Nokia Networks**
*Lead expert on the Future of Connectivity.*



An inventor and technology visionary, Hossein leads long-term technology evolution and drives transformational innovations for the company. Having held several management positions in BT, T-Mobile and Sun Microsystems over the last 25 years and as an active adviser and board member of several technology start-ups, he brings in-depth technology expertise, customer focus and innovation to Networks. Hossein joined NSN in 2010.

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# About Future Agenda

## *Context – Why Foresight?*

In an increasingly interconnected, complex and uncertain world, many organisations are looking for a better understanding of how the future may unfold. To do this successfully, many companies, institutions and governments are working to improve their use of strategic foresight in order to anticipate emerging issues and prepare for new opportunities.

Experience shows that change often occurs at the intersection of different disciplines, industries or challenges. This means that views of the future that focus on one sector alone have limited relevance in today's world. In order to have real value, foresight needs to bring together multiple informed and credible views of emerging change to form a coherent picture of the world ahead. The Future Agenda programme aims to do this by providing a global platform for collective thought and innovation discussions.

### Get Involved

To discuss the future agenda programme and potential participation please contact:

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## *Future Agenda 1.0*

The Future Agenda is the world's largest open foresight initiative. It was created in 2009 to bring together views on the future from many leading organizations. Building on expert perspectives that addressed everything from the future of health to the future of money, over 1500 organizations debated the big issues and emerging challenges for the next decade. Sponsored globally by Vodafone Group, this groundbreaking programme looked out ten years to the world in 2020 and connected CEOs and mayors with academics and students across 25 countries. Additional online interaction connected over 50,000 people from more than 145 countries who added their views to the mix. All output from these discussions was shared via the futureagenda.org website.

## *Future Agenda 2.0*

The success of the first Future Agenda Programme stimulated several organizations to ask that it should be repeated. Therefore this second programme is running throughout 2015 looking at key changes in the world by 2025. Following a similar approach to the first project, Future Agenda 2.0 builds on the initial success and adds extra features, such as providing more workshops in more countries to gain an even wider input and enable regional differences to be explored. There is also a specific focus on the next generation including collaborating with educational organizations to engage future leaders. There is a more refined use of social networks to share insights and earlier link-ups with global media organizations to ensure wider engagement on the pivotal topics. In addition, rather than having a single global sponsor, this time multiple hosts are owning specific topics wither globally or in their regions of interest. Run as a not for profit project, Future Agenda 2.0 is a major collaboration involving many leading, forward-thinking organisations around the world.