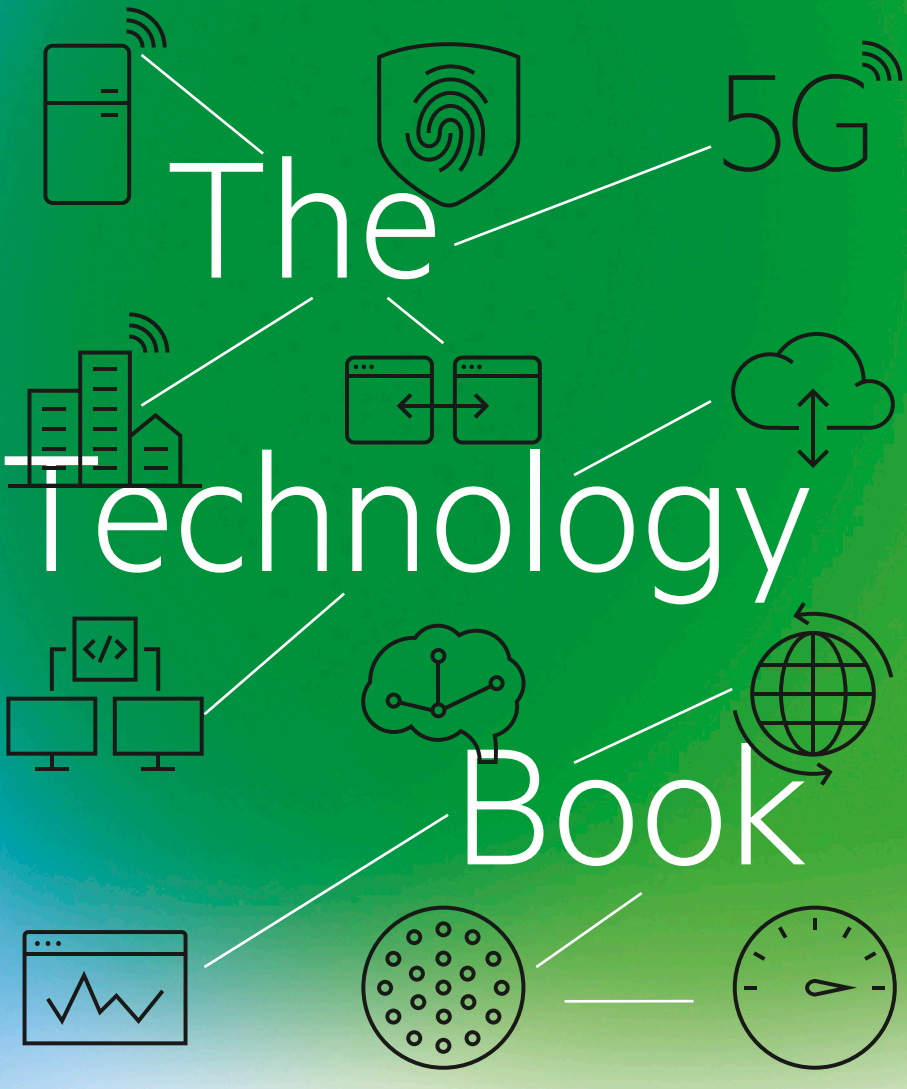

The Technology Book

The Technology trends
KPN has on its radar.

V 1.0 KPN CTO office

kpn

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Contents

Foreword

Telecom operators are in the business of long-term investments. Investing in mobile frequencies and local loop, for example, requires a decades-long investment outlook. In order to be able to advise their boards on long-term investment decisions, operators must effectively scan the technological landscape that are or could be of material impact in future.

The Technology Book, prepared by my office within KPN, is the centrepiece of KPN's technology scanning. It represents the final phase of a three-phase process:

The process consists of three main phases:

1. **Create a vision for KPN: "Operator of the Future"**
2. **Organize selected technologies graphically on a radar screen: the "Technology Radar"**
3. **Select technology topics: *The Technology Book***

The world around us is changing so fast that any frozen picture of the future is by definition wrong or incomplete. Our "Operator of the Future" project, however – whose working title is "The day has 48 hours" – has helped us to picture a very plausible future in which people's physical lives will be constantly intertwined with their digital lives. A crucial role for telecom operators in this world will be to provide instant, reliable and safe access to individual users on an always-connected basis.

In this version of the future, certain technologies such as artificial intelligence and virtualization will potentially play a very important role, but this is just the beginning. During the scanning, as we assessed which technologies will be important to the future of telecoms operators, we considered more than 500 technology trends, selected about 200 for our "Technology Radar", and finally chose 13 that we believe will have a potentially high strategic impact – 13 technology "topics" that, in our view, will define the roadmap of the Operator of the Future.

In this book these 13 technology topics are summarized and described in a manner that presents the potential impact and value not only to operators, but also to society.

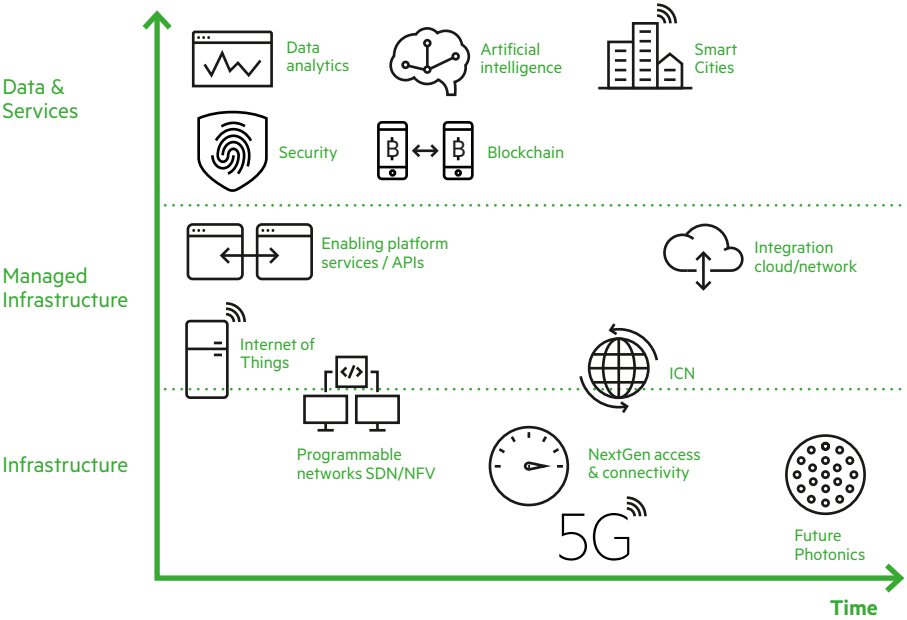
During the war Roosevelt once wrote a letter of multiple pages to Churchill, and he ended the letter with the famous words, "Sorry I did not have the time to write you a shorter letter". We *did* have the time, and so we have summarized each topic on three short pages.

Erik Hoving
Chief Technology Officer, KPN

Introduction

The 13 technology "topics" discussed in this book are in fact generic trends that incorporate many different technologies. We chose to concentrate on topics rather than on individual technologies because focusing on a single technology is a tactical choice that is only possible once one understands the generic trend enabled by such technology.

The 13 topics can be presented along a timeline, as follows:



The topics are also interrelated; for example, Smart Cities are enabled by the Internet of Things (IoT), and security is integral to almost every topic.

For this first edition of the *Technology Book*, we left some topics to one side: 3D printing, quantum computing, the future of search, HTML 5, NextGen IT, virtual reality and WebRTC. These topics may be addressed in the next edition of this book.


5G

1

1 What is 5G and why does it make sense?

5G is the next generation mobile network technology that is planned to become available around 2020. As described in a recent industry white paper.

> "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models."[1]

The previous generational changes in mobile were focused on improving radio access technology, first to enable mass-market mobile personal communication (2G) and then to increase mobile data speeds (3G and 4G). The aim with 5G is not only to improve radio access technology, but also to build an infrastructure that is much more flexible, programmable, and cost- and energy-efficient. The following table puts 5G in the context of previous mobile network generations.

Generation	Year	Radio technology	Generational change (main new functionality)
1G	1980	NMT	Automatic cellular voice and data communication (analog)
2G	1990	GSM	Digital voice & data with higher quality & capacity
3G	2000	UMTS	High speed data for mobile internet
4G	2010	LTE	Mobile broadband with consistent high speeds and capacity (video)
5G	2020	To be decided	Ubiquitous connectivity & control for a fully mobile and connected society

1 Next Generation Mobile Network (NGMN) Alliance, *5G White Paper* (Frankfurt, Germany: NGMN), February 2016. See http://www.ngmn.org/5g-white-paper.html

5G is important because the future mobile network will need to support many different use cases that cannot be adequately served by 4G (LTE), which was primarily optimized for mobile broadband (video content). Two important examples of such new use cases are the Internet of Things (IoT) and the Tactile Internet:

– The Internet of Things requires that millions of objects (sensors etc.) per square kilometre can be connected to the network at low cost and with very long battery life.
– Tactile Internet applications (augmented reality, robotics, road traffic, smart grid, and so on) require precise human-to-machine and machine-to-machine interaction and network latencies below 1 millisecond.

The 5G network will not deliver all of these stringent requirements to all end-users and applications at the same time; this would be impossible and far too expensive. Instead, the 5G network should be flexible and programmable so as to adapt to the needs of individual end-users and applications and deliver exactly the performance that is needed. Also, other existing and new wireless technologies and networks, such as WiFi, will continue to co-exist with 5G.

2 What are the current status and anticipated future developments of 5G?

In February 2015 the NGMN Alliance published a 5G whitepaper setting forth the vision of the leading mobile operators on the requirements for 5G.[2] Standardization work on 5G is expected to start in 2016, leading to pre-standard deployment in 2018 (Winter Olympics in South Korea) and first-standard-based deployments in 2020 (Summer Olympics in Japan).

2 Ibid.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

It is best to start with the NGMN Alliance's *5G White Paper* and equipment vendors such as Ericsson, Huawei, Nokia, ZTE and Cisco.

4 Why is 5G relevant to KPN?

5G provides a blueprint of how KPN's infrastructure should evolve, including fixed-mobile integration, integration of information technology (IT) with technical infrastructure (TI) (for instance, datacentres as an integral part of the network and vice versa), NFV and SDN (programmable infrastructure) and operations and maintenance (highly automated). With our investment and architecture decisions, we need to anticipate and build towards 5G, starting right now in 2016.

5 What are the key technologies behind 5G, the expected timing and the main technology hurdles?

5G will deploy many technologies that are developed outside future 5G standardization work, such as software-defined networking (SDN) and network functions virtualization (NFV) (see Section 6). Other specific technologies for 5G include:

- "New waveforms" for transmitting data, allowing for a more flexible radio interface (e.g. for IoT);
- New antenna technology to increase system performance (beam forming, massive multiple-input/multiple-output [MiMO]); and
- "Millimetre technology" for ultra-high speeds in high frequency bands.

In The Netherlands we expect the next spectrum auction to take place in 2018 or 2019 and the first 5G deployment to occur in the 2020–22 timeframe. The main hurdles are worldwide spectrum harmonization for 5G and how to cost and energy-efficiently deploy small cells.

Next Generation
Access & Connectivity

2

1 What is Next Generation Access and why does it make sense?

Next Generation Access (NGA) can be loosely defined as telecommunication access networks that deliver better performance than today's networks. The most important criterion for access network performance is connection speed, which must be provided at the lowest possible cost and energy consumption. In terms of speed, NGA access should be able to deliver 1 Gbit/s.

Because most end-user devices in an NGA network will be wirelessly connected, the NGA network in a typical household will consist of a combination of (a) *wireless* technology (for example, to connect devices directly to a mobile network or a home gateway) and (b) *wired access*, such as fiber-optic cabling, to connect the home gateway. In the case of wireless networks, the medium used is the air – that is, the spectrum – and there are many different wireless access technologies that can be used in the different spectrum bands. The most commonly used wireless technologies today are mobile (UMTS, LTE) and WiFi. In the case of wired access, the three most commonly used mediums are twisted-pair copper wires, coaxial cables and fiber.

Because access networks are the most capital-intensive part of the telecommunications infrastructure, higher-performance next-generation networks are a crucial foundation for ICT-based innovations across all sectors of society.

2 What are the current status and anticipated future developments of NGA?

There is continuous evolution and improvement in telecommunication access networks. In The Netherlands most households can already enjoy broadband speeds in excess of 100 Mbit/s and KPN has almost 30 percent of homes fitted with fiber-to-the-home (FttH), which can deliver speeds of 1 Gbit/s and beyond. In its mobile network, KPN delivers

nationwide coverage at consistent speeds of 50 Mbit/s and more with LTE Advanced (maximum speeds are above 100 Mbit/s). And the latest WiFi 802.11ac chipsets enable maximum speeds of more than 1 Gbit/s.

In the very long run KPN expects that all buildings and houses will be connected with fiber for the following reasons:

- Fiber is by far the best technology for wired access in terms of speed, operational cost and energy efficiency.
- Because further digitalization of society will increase the importance of high-quality ICT infrastructure, there will be strong demand for the best possible access networks. If the 21st Century is the century in which we enter the information age, then putting a dense fiber-based access network in place seems like a relatively small effort and investment in the grand scheme of things – especially when compared with infrastructure for electricity, gas distribution, sewers, and the like.
- All copper cables have an economical and physical end of life (whichever comes first), after which they will be replaced by fiber. Note that the moment of end of life is not in sight yet.

Next to fiber, copper wires and coaxial cables ("coax") will co-exist for a long time. Coax especially is a very high-performance cable that can also be upgraded (to DOCSIS 3.1) to deliver speeds in excess of 1 Gbit/s in a very cost-effective manner. Telecom operators have driven the very successful further development of copper technologies (bonding, vectoring, Vplus, G.fast) to dramatically increase the speeds of DSL (Digital Subscriber Lines) over copper lines to 1 Gbit/s. Wireless will be the dominant means of connecting devices and all kind of objects in the Internet of Things (IoT). Therefor most future access technology developments will be in the wireless domain (5G, WiFi and other technologies).

3 What are important world-leading companies, institutes, experts and readings to invest time in?

The leading companies are Nokia, Ericsson, Huawei and many others.

4 Why is NGA relevant to KPN?

Providing access is KPN's bread-and-butter business – its main *raison d'être*. To add value for all its stakeholders it is crucial that KPN provide the best possible access network in terms of speed, cost, and energy.

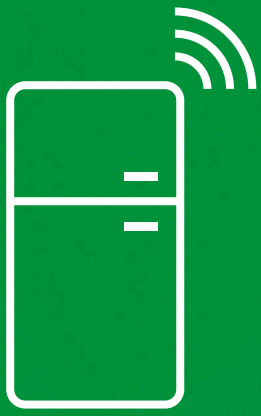
5 What are the key technologies behind NGA, the expected timing and the main technology hurdles?

The continuous development in the access technologies is driven by "Moore's Law," which predicts the exponential growth of computing power for signal processing on small and cheap chips. The main NGA technologies per medium are as follows:

Fiber	NG-PON (Next Generation Passive Optical Networks for lower cost and energy consumption)
Copper	VDSL Vectoring and G.fast (speeds up to 1 Gbit/s for up- and downlink combined)
Cable	DOCSIS 3.1 (speeds above 1 Gbit/s)
Wireless	LTE-A, 5G, Wifi 802.11ac, millimetre wave (very high frequencies), antenna beamforming

The main technical hurdle for access networks is the quality of the medium transporting the information. Optical fiber is by far the best medium to achieve high network speeds and capacity. For wireless transmission a large amount of spectrum is needed to deliver high speeds.

The Internet of Things



3

1 What is IoT and why does it make sense?

The Internet of Things (IoT) describes the notion that everything can be connected, thereby providing new information that enables individuals and organizations to take better decisions. The "things" can be either physical – humans, animals, plants – or virtual, such as data. In practice, IoT is driven by a combination of sensors, actuators, connectivity (fixed and mobile networks), people and processes.

Sensors can range from GPS sensors to cameras and microphones. Data inputs from sensors are digitized and placed onto cellular, WiFi, Bluetooth, ZigBee and other networks. Using data analytics, the resulting data are then processed into relevant information that can inform decisions and actions.

The potential benefits of IoT are almost limitless, and IoT applications are changing the way we work and live by saving time and resources. As a result, IoT can contribute to a better life for all. However, there are also threats such as breach of privacy.

2 What are the current status and anticipated future developments of IoT?

The number of connected devices surpassed the number of human beings in 2011. The installed base of IoT devices connected to one another is expected to grow to 21 billion by 2020[3]. Also by 2020, less than 5 percent of IoT connections will be SIM-based. It is also expected that in 2015–19, no company or approach will offer an IoT-dominant ecosystem platform. Many alliances and partnerships are being set up, however, including AllSeenAlliance, AllJoyn, and OpenIoT.

3 Gartner Symposium/ITxpo, November 2015, Barcelona, Spain (http://www.gartner.com/newsroom/id/3165317)

The expectation is that many firms will target early deployments to maximize impact. The European Research Cluster on the Internet of Things (IERC) provides the roadmap for coordinating research and development (R&D) efforts in the field of IoT. It is aligned with the findings of the most recent Gartner Hype Cycle for the IoT.[4]

European operators such as Orange, KPN and Proximus are currently introducing LoRa technology for low-power, wide-area (LPWA) services. Meanwhile the GSMA recently launched its own Mobile IoT project, designed to address the use of low-power solutions in the licensed spectrum (like 5G). Other solutions include Sigfox, Telensa and Weightless.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

The ecosystem is very large, ranging from professional services firms to Original Equipment Manufacturers (OEMs) and telecom and infrastructure providers. Among ICT players, Cisco, Ericsson, Microsoft and IBM have been at the forefront of developments. Associations like GSMA have a Connected Living theme. Research specialists including Gartner, ABI research, IDC and TNO have all produced valuable insights. It is helpful to learn about the basic experiences of Telefonica, AT&T, DT and Vodafone. It is worthwhile to stay connected to OEMs like Samsung and semiconductor firm Qualcomm. Finally, start-ups also play a very important role in innovation and growth.

4 Why is IoT relevant to KPN?

IoT enables KPN to fulfil its potential future role of bringing supply and demand together in the digital world. At the same time, KPN is also able to address potential threats and risks: security and privacy are critical to IoT and part of KPN's core expertise.

4 http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

In the short term, KPN's core asset – connectivity – is very relevant because the first building block of any IoT ecosystem is connectivity. By 2020, Gartner expects the IoT market will amount to US$328 billion, of which US$65 billion will be for connectivity/computing/hardware and US$262 billion for services/analytics[5]. KPN could definitely play a role in both connectivity and services such as (a) providing connectivity, (b) creating and enabling smart systems, (c) delivering solutions and (d) running data analytics platforms and insights.

5 What are the key technologies behind IoT, the expected timing and the main technology hurdles?

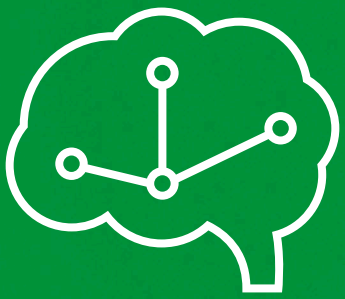
The technologies behind IoT can be organized into four categories:

- Enabling things to acquire contextual information – by using sensors, such accelerometers or pressure meters;
- Enabling things to process information – via embedded processing, such a network processors or hybrid MCU/MPUs;
- Improving security and privacy; and
- Connectivity.

The main hurdles to the swift development of IoT ecosystems include lack of standardization, lack of energy efficiency, lack of spectrum efficiency, low number of sessions/devices, lack of security, and lack of clarity on business models and roles in the value chain.

5 Gartner Predicts 2015, *The internet of things*, 30.12.2014

Artificial Intelligence



4

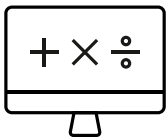
1 What is artificial intelligence and why does it make sense?

Artificial intelligence (AI) is the intelligence exhibited by machines or software. AI also refers to the science of engineering and using intelligent machines and software that are able to perceive their environment, take deliberate actions to achieve certain objectives, and learn in order to improve and increase their chances of success.

AI will transform the way in which humans and machines interact with each other, potentially transforming many human activities. AI technologies also enable the scaling and acceleration of human expertise, leading to the discovery of solutions to complex problems in knowledge driven areas such as healthcare and in fact all other sectors. This new generation of expert systems are especially valuable when dealing with quantities of unstructured information such as text and literature, audio or video that would otherwise overwhelm the time and space constraints of our human brains. Using sophisticated algorithms, these expert systems can translate huge amounts of information into knowledge and insight in order to take autonomous action or to give advice.

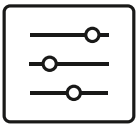
Computer vision

Speech recognition



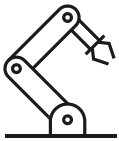
Machine learning

Natural Language Processing

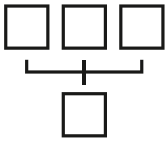


Optimization

Planning & Scheduling



Robotics



Rules Based Systems

2 What are the current status and anticipated future developments of Artificial Intelligence?

All the necessary ingredients are now in place to start exploitation of AI in a mature state[6]. The exponential increase in computing power and miniaturization make it possible to run advanced AI applications on a smartphone, using all kinds of readily available supporting (sensor) technologies to enable AI applications to "hear, see, and sense" the environment and to commercially leverage the vast and exponentially increasing quantity of structured and unstructured data.

Many advanced companies – both in the public and private sector including healthcare, law, R&D, finance, education and pharmaceuticals – already use or are investigating AI technology to work with large quantities of unstructured data. Furthermore, as the costs of processing power and storage capacity further decrease, AI solutions are becoming attractive and feasible for a wide range of smaller or less technologically advanced organizations as well. An example is the use of AI in helpdesks to assist call agents in solving customer problems. Future developments may include the training of AI systems in local languages, for example.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

AT&T, Verizon and Softbank for references and IBM for Watson[7]. OpenAI project by Musk/Altman, as well as Google and Facebook open programs, focus on deep learning. Start-ups offering innovative complementing services are also worth investing time in, as are companies like Apigee for developing API-centric frameworks as a means of "asking" AI systems to perform certain tasks and enabling AI systems to retrieve information and work together.

6 https://hbr.org/2015/03/artificial-intelligence-is-almost-ready-for-business

7 http://www.ibm.com/smarterplanet/us/en/ibmwatson/what-is-watson.html

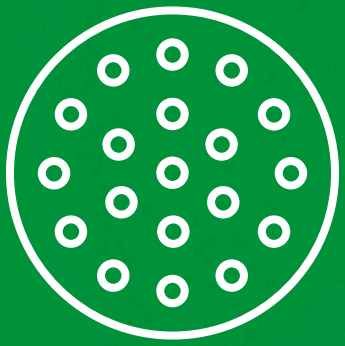
4 Why is artificial intelligence relevant to KPN?

Both the management of data and information and reliable networks and infrastructure stand as central enabling factors in AI. Because these are core KPN competencies, KPN is well positioned to be one of the key players in an AI ecosystem. KPN is working to differentiate itself as a trustworthy provider of safe and secure AI services to users and companies, also using the Dutch language, and as a custodian of data. In addition, KPN can use AI to create value internally in such areas as call centres, field services, and online sales.

5 What are the key technologies behind AI, the expected timing and the main technology hurdles?

The main technology elements for AI are readily available and do already provide significant value in connecting, aggregating and visualizing data, including some levels of local language support. To make a quantum leap in the cognitive domain in The Netherlands, though, support for the Dutch language in the real cognitive area – meaning really understanding the Dutch language, not just keyword-picking – would make a big difference. A cognitive engagement involves both the exploration and connection of data as well as cognitive learning.

The Future of **Photonics**



5

1 What is photonics and why does it make sense?

The term photonics is derived from the word photon, which is a fundamental unit of light. The science of photonics includes the generation, emission, transmission, modulation, processing, switching, amplification, detection and sensing of light and optical signals. It covers all technical applications of light over the entire spectrum, from ultraviolet to visible to near-, mid- and far-infrared. Most applications, however, are in the range of the visible and near-infrared light. In telecom, the wavelength of the light in the fibers ranges from about 1300 to 1650 nanometers.

Applications cover not only the telecom sector but can be found in many other sectors such as healthcare and manufacturing; here, however, we restrict ourselves to telecom. Roughly, we can then say that photonics can be split into fiber optics (FO) and integrated optics (IO). Obviously, FO is fundamental for the transmission of light and the information that the light carries from A to B. IO, meanwhile, is fundamental for the manipulation of light and can be regarded as the counterpart domain of the manipulation of electrical signals. IO uses photonic integrated circuits (PICs), which are the counterparts of electrical integrated circuits (EICs). The relevance of photonics increases with the exponential growth of bandwidth demand. This impacts both (a) the emergence of IO and research for innovation in the fibers themselves and (b) the applications of PICs – in datacentres, for example.

2 What are the current status and anticipated future developments of photonics?

The status quo is that single-mode fiber cables have been and are being deployed globally, including in The Netherlands. Obviously, fiber was first rolled out in the core network, later in the metro networks, and from 2000 onwards gradually in the access network to connect business and residential customers. Given the exponential increase in data and data transport, the capacity in (core) telecommunication networks has to increase exponentially too. That is why a part of photonic research is successfully investigating new generations of optical fibers to address such increase. However there is a more urgent issue: the exponential increase in energy usage by telecommunication networks, especially in datacenters. Photonics, more specifically the Photonic Integrated Circuit, solves this issue effectively as it only requires a fraction of the space and energy needed (a factor of at least minus 10.000 is achievable). The future data center can be exponentially smaller - as small as a street cabinet (compared to a whole building today) – and use exponentially less energy. Regarding IO, almost no PICs are used today in our networks. But from now on, this will change. Applications will emerge increasingly in the core and access networks as well as in datacentres. This has already begun, with passive optical components such as FiberClick[8] allowing for increased flexibility in access networks. Photonics will grow towards a multi-billion industry and will, according to reports of the EU, belong to one of the top 5 key industries[9]; in the Netherlands alone it will create some 7000 jobs in the brainport region (Eindhoven)[10].

8 FiberClick: innovative and unique network concept allowing fiber cables to be connected in one simple click (www.fiber4all.eu/fiberclick)

9 Heiko Jessayan, "Zonder Fotonica loopt het Internet vast" (Het Financiële dagblad, 29 April 2016)

10 Photonic Institute conference (Technisch Universiteit Eindhoven, 25 April 2016)

3 Which world-leading companies, institutes, experts, publications should readers invest time in?

There are four leading centres, plus two starting up in China:

- The Cobra Group at the Technical University in Eindhoven (including world experts Prof. Ton Koonen, Prof. Meint Smits, Prof. Kevin Williams and Dr. Hugo de Waardt; a new centre called "The Photonic Institute" will be opened on April 25, 2016);
- Bell Labs and NEC Labs in the United States;
- Southampton in the UK, which specializes in optical amplifiers;
- NTT-Labs and KDDI in Japan; and
- Chinese centres ZTE and Huawei, which are currently just beginning their research.

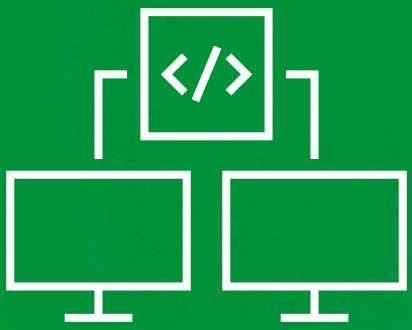
4 Why is photonics relevant to KPN?

As the incumbent telecom operator in the Netherlands, KPN owns the country's largest fiber-optic network and is known as a forerunner in technology. As such it will become a necessity to embark on the use of photonics – or, more precisely, to determine when to introduce a new generation of fiber-optic cabling in KPN's core networks and where to apply PICs. In addition to enable increasing bandwidth and decreasing latency demands, space, energy and sustainability requirements come within reach.

5 What are key technologies behind photonics, the expected timing, and the main technology hurdles?

A combined knowledge of optics, electronics and telecom networks are the basis for IO. KPN can play a role in the steering and dissemination of knowledge through cooperation with the aforementioned groups at the Technical University in Eindhoven (TU\e). Applications of PICs can start now. A new generation of fibers in the core will probably emerge after 2025.

Programmable Networks
SDN and NFV



6

1 What are programmable networks (SDN and NFV) and why do they make sense?

Software-defined networking (SDN) and network function virtualization (NFV) are two technology trends that are crucial for the future of any telecom operator. Indeed, they enable the vision that a telecom operator should be allowing users to fulfil their digital life needs with the best user experience for all services on all devices and across any access network, all at the lowest possible cost.

Programmable networks are more flexible and adaptable to the demands of markets and customers. The configuration is no longer fixed by the network elements in use, but can be changed (programmed) using open interfaces. Within KPN, the Network Personal Video Recorder in the iTV platform (where users make recordings) is an example of network function virtualization: the functionality to record TV programs is migrated from the hard disk in the set-top box to a generic cloud platform.

2 What are the current status and anticipated future developments of Programmable networks (SDN/NFV)?

The development of the SDN and NFV concepts has been very rapid. Where last year the hype cycle was at its peak, we now see concrete solutions appearing on the market. Currently KPN Network Infrastructure and Operations department (NIO) is working together with several suppliers to build proofs-of-concept for several SDN/NFV use cases, including a content delivery network to cope with the growth of video traffic, virtual customer premises equipment (CPE), Infrastructure as a Service (IAAS) and integration of network, datacentre housing, and cloud platforms as a basis for all IT applications of both KPN and its customers. Although the standardization of the functional building blocks and used interfaces is underway, is far from ready. Nonetheless, all big suppliers are offering solutions. The expectation is that eventually parts of KPN's portfolio will be based on SDN/NFV solutions.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

The big telecom suppliers (Huawei, Ericsson, Cisco, Nokia, HPE) are all actively building portfolios of SDN- and NFV-based solutions. Standardization is the focus of Opennetworking.org and the European Telecommunications Standards Institute (ETSI). Bell Labs is an important research institution that focuses on SDN and NFV. Several large telecom operators across the world are implementing SDN and NFV; AT&T and Telefonica are two examples.

4 Why are programmable networks (SDN/NFV) relevant to KPN?

KPN will become a software-defined operator within a few years. We believe it is the best way to improve the customer experience while driving down costs. The transition towards this end goal may be quite difficult, as it implies a merging of IT and TI in both development and operations. Processes need to be changed fundamentally, as management will become more holistic while configuration work will become automated.

5 What are the key technologies behind programmable networks, the expected timing and the main technology hurdles?

There are two key technologies. SDN controls traffic flows, whereas NFV governs how network functions are implemented, as follows:

- NFV leverages cloud technology for network functions, using standard hardware solutions instead of specialized equipment. Network functions (such as a router or base station) run as a software package on standard hardware. Applications of NFV focus on the borders of the network (datacentres and CPE).
- SDN is an architecture in which the network control function is decoupled from the data transport. It offers a holistic, abstracted image of the network and IT resources. With SDN, traffic flows can be adjusted dynamically via a programmable interface to meet changing (application/customer) needs in real time. Most applications of SDN will be in core networks.

There are three main hurdles:

- Standardization is not finalized.
- Transition will take several years. This is not only about some network equipment. To obtain the full potential from SDN and NFV, a transition of all portfolios, customer interactions and processes is necessary. After that, the customers need to be guided towards the “new world”.
- There is still a great deal of legacy IT and (non-IP) TI that cannot be migrated to the new architecture. Those applications/networks will need to be rationalized.

Edge Computing
Integration of Cloud and Network

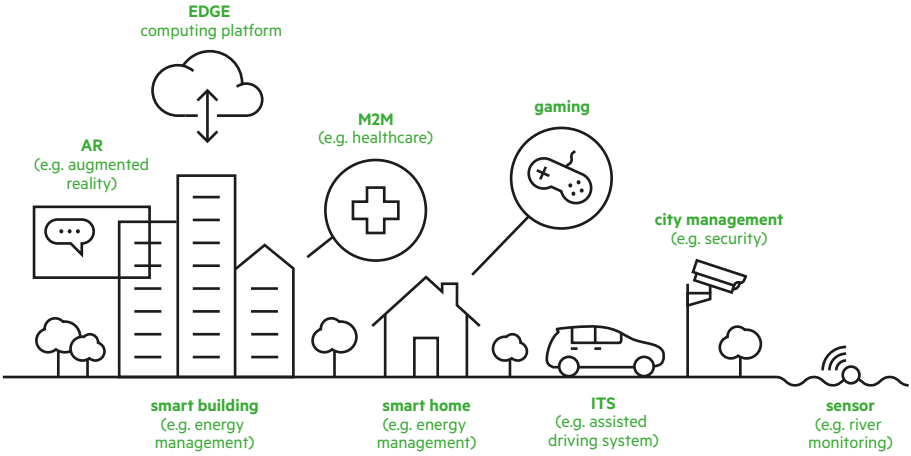
7

1 What is “edge computing” and why is it important?

Current cloud services face problems of poor scalability and slow response time because they depend on remote servers that may be located far away. For example, it takes several hundred milliseconds to interact over the Pacific Ocean because of the finite speed of light. These problems hinder promising latency-sensitive applications that will likely be widely deployed, such as intelligent transport control systems (ITS) and games that necessitate real-time response time.

Edge computing solves these problems simply locating small “edge servers” close to the end-users and devices, then passing some of the load of central servers and/or user’s devices to these edge servers. Potential benefits are:

- Execution of real-time applications that require high-speed response at the nearer edge-servers to satisfy the severe real-time requirement (the communication delay is shortened to a few milliseconds);
- Confinement of regional data processing of machine-to-machine (M2M) and big data applications that incur large amounts of data traffic to local edge servers, thus reducing network bandwidth; and
- Offloading of some of the computation-intensive processing on the user’s device to edge servers, which makes application processing less dependent on the device’s capability (it is possible to run applications faster and improve the user’s experience).



Edge computing is a natural development in the evolution of digital services and the convergence of IT and telecommunications networking. It will enable new vertical business segments and services for consumers and enterprise customers, such as:

- Video analytics
- Location services
- Internet of Things (IoT)
- Augmented reality
- Optimized local content distribution
- Data caching

2 What are the status and anticipated future development of edge computing?

Edge computing is a hot topic, especially in the context of mobile networks and 5G. The business case for isolated, application-specific platforms for edge computing seems rather difficult. It is most likely that edge computing will piggyback on (mobile) network developments where virtualised network functions are decentralised. The computer and storage platforms for these network functions (including content delivery networks, or CDNs) can then also be used for edge computing use cases. A new business model option for operators will be to offer IaaS (Infrastructure as a Service), combining network and cloud. Although NTT has already developed an edge computing platform, widespread edge computing is still a few years away.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

World leaders in this arena include Nokia, Ericsson, Huawei and many others.

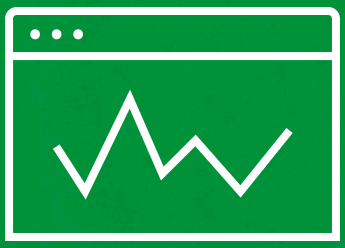
4 Why is cloud and network integration relevant to KPN?

Given its strong position in fixed and mobile connectivity, KPN is well positioned to become the top provider of edge computing. We already have the physical locations. Moreover, by integrating Edge Cloud (decentralized data centers that are closer to end-users than the current centralized data centers) into our network we can achieve both cost advantages and a better user experience.

5 What are the key technologies behind edge computing, timing and main technology hurdles?

Edge computing itself builds on existing technology and there are no major technology hurdles. However, large deployments are expected to happen only when piggybacking on the implementation of NFV/SDN in the context of 5G.

Data **Analytics**



8

1 What is data analytics and why does it make sense?

The analysis of data is the process of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions, and supporting decision-making. It makes sense because better decisions can lead to greater operational efficiency, reduced cost and risk, and increased business growth. Thus, raw data is transformed into information, knowledge and, in the end, wisdom.

Although data analytics is not a new concept, it is gaining in importance thanks to the Internet of Things and the increasing computing power of devices. Data today are high-volume and high-velocity, and they come from highly varied information sources. Data analytics uses inductive statistics and concepts to infer laws from large sets of data with low information density to reveal relationships, dependencies and predict outcomes and behaviours.

In 2014, every single minute the world generated 1.7 million billion (quadrillion) bytes of data, equivalent to 360,000 DVDs or over 6 megabytes of data for each person every day. The data sector is growing by 40 percent per year, seven times quicker than the overall information and communications market. Data analytics has already helped us speed up the diagnosis of brain injuries, find the ideal locations for wind farms, prevent traffic congestion, and forecast crop yields in developing countries.

2 What are the current status and anticipated future developments of data analytics?

Data analytics drives higher expectations from our current systems because of three characteristics that all start with the letter V: the *volume* of data (we want bigger datasets, from terabytes (10) to petabytes (10), the *velocity* of the data (we want it now, not tomorrow), and the *variety* of the data (we want to combine all datasets, not some of them). One third of globally stored information is in the form of alphanumeric text

and still-image data, which is the best format for most big-data applications. This shows the potential of as-yet-unused data – for example, video and audio content.

Some of the major trends currently in the telecommunication industry have a direct or indirect relationship with the concept of data analytics; these include IoT, over-the-top (OTT), mobile commerce/payments, and mobile advertising.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

The market is moving fast and new solutions arise daily. As a start, Apache Hadoop, IBM, SAP, Oracle, Marklogic, Teradata, Informatica and Microsoft are companies to watch with regard to database management systems/data ecosystems. Open Source Software plays a big role. Hadoop as data analytics framework and including OSS projects around it is a major enabler and contributor; many independent software vendors recognise this position and enable their products to work with or on Hadoop. With regards to analytics and data visualisation, important players are Tableau, Qlickview, SAS and Datameer. Thought leaders with regards to data are Alex (Sandy) Pentland and Tom Davenport. Among peers, Swisscom is also developing relevant skills.

4 Why is data analytics relevant to KPN?

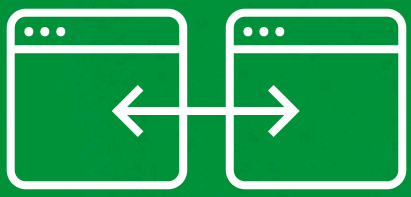
Because transporting and storing customer data is one of KPN's core businesses, KPN is in a unique position to help its customers gain insights into their data. Internally, data analytics is needed for security and capacity management perspectives, but also to support an optimal multichannel commercial strategy. Externally there is also a big commercial opportunity as new data analytics tools allow for the combination of data from different open and closed sources to generate knowledge and new insights. For example, logistical parties in harbours could share data on current inventory. But as the number of parties involved increases, agreeing on a standard becomes very difficult.

Although with new data technologies this is no longer a necessity, trust is still needed. This represents an opportunity for KPN to act as a trusted third party to collect external data and provide the relevant information to external parties.

5 What are the key technologies behind data analytics, the expected timing and the main technology hurdles?

Technology	Timing	Hurdles
Hadoop Framework	Now	– Mature but still developing rapidly – High demand on knowledge
Enterprise NoSQL	Now - 2018	– Evolving, merging traditional and new worlds – Build from a different perspective so has prompted a clash between believers and non-believers.
In-memory analytics	> 2016	Still expensive but price is expected to decrease rapidly
Machine learning	> 2017	– Clarity of goals: data analytics can only lead to the successful sequence of raw data to information to knowledge to wisdom if and only if the purpose is set clearly. This in turn requires deep business and scientific knowledge about the topics at hand – Data driven culture is necessary as machines suggest actions – Fear for vendor lock-in

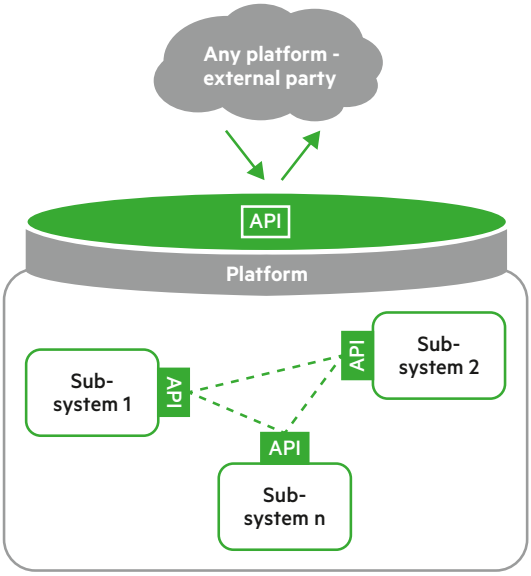
Enabling Platform Services / **APIs**



9

1 What are enabling platforms / APIs and why do they make sense?

An enabling platform is a plug-and-play business model that allows multiple participants (producers and consumers) to connect, interact with each other and create or exchange value. Producers can plug into the platform and offer their services on top of the platform. For instance, developers create apps on top of Android, writers create articles on top of Medium, hosts create room availability on top of Airbnb, producers create goods on top of Etsy, eBay, and Taobao (Alibaba). An application program interface (API) enables an organization to expose its resources and assets, including data, in a machine-readable format to internal and external developers. A typical example is Google's APIs, which allow developers to integrate YouTube videos and functionality into websites or applications. YouTube APIs include the YouTube Analytics API, YouTube Data API, YouTube Live Streaming API, and YouTube Player API. APIs can therefore act as "super catalysts" to create new markets.



APIs can be used in three settings: (a) internally to improve architecture and productivity, (b) externally with suppliers or customers to create new distribution channels or revenue streams, and (c) to create an ecosystem in which assets from service providers and other organizations are offered to a community of developers. The following graphic illustrates an ecosystem mediated by APIs.

2 What are the current status and anticipated future developments of APIs?

The overall telco API market is currently predicted to grow by 26 percent each year, with a global industry revenue base of US$167.5 billion by 2020.[11] APIs are the digital glue holding our world together, the keys to unlocking the digital economy, and the driving force behind smart cities and the Internet of Things. The business world has begun to understand this and has started to establish API-centric, enterprise-wide programs.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

- API platform providers: Companies like Apigee, Layer 7, Atmosphere, Mashery, Nokia (OAP), Intel (Expressgateway), and Vordel provide flexible, reliable, simple and cost-efficient API platforms.
- Vendors using APIs: At the other end of the spectrum are the well-known ICT suppliers – including HPE, Ericsson, and Huawei – which are offering customer solutions based on open APIs.
- Operators using APIs: One of the first movers was AT&T, using APIs for internal, partner and open developer communities. Others are now following suit. In Europe, two of the most committed telcos are Swisscom and Orange.

11 Mind Commerce, *Telecom Network API Marketplace: Strategy, Ecosystem, Players and Forecasts 2015 – 2020* (2015). http://www.mindcommerce.com/telecom_network_api_marketplace_strategy_ecosystem_players_and_forecasts_2015__2020.php

4 Why are enabling platforms and APIs relevant to KPN?

Digital technology has fundamentally changed two things: the dynamics of the market and the speed needed to remain competitive. Successful businesses today are data-driven, creating ecosystems of value that connect digital resources inside and outside the company, quickly and at low cost. Using APIs, KPN now has the opportunity to open up its networks and data using SDN/NFV technology. This will enable agile development of new products and services, thus fulfilling the needs of users in an increasingly digital world. Enabling platforms and APIs will be crucial for KPN to remain competitive and continue to be relevant and valuable to its users.

5 What are the key technologies behind APIs, the expected timing and the main technology hurdles?

Three observations:

- Robust, secure and scalable solutions are needed to protect APIs against hacking attempts while enabling business scale.
- The supporting infrastructure for APIs has to be in place, including the digital layer and SDN network management.
- Operators need to develop a new skillset and way of working to be able to develop and manage the APIs.

Information **Security**

10

1 What is information security and why does it make sense?

Information security is the set of preventive, detective, repressive and corrective measures – as well as procedures and processes – that ensure the availability, confidentiality and integrity of information within an organization. Information is an asset that represents value, which is why every organization has an obligation to its stakeholders to protect it. The development of modern communication networks, the spectacular proliferation of information technology, and changes in society's perception of privacy are the main drivers behind the enormous and growing importance of information security.

In practice, information security is an applied type of risk management in that it addresses subjects like threats, vulnerabilities, exploits and mitigation techniques.

2 What are the current status and anticipated future developments of information security?

Information security ensures that products and services are designed and created with security in mind; in other words, they are "secure by design." This will be first regarded as a competitive selling point, but will eventually develop into a standard feature. Security is currently still regarded as something which is difficult. This will change over time in the same way ICT has developed: its use and deployment will become easier.

The security department in an organization sometimes act as the “owner”of risks and prohibits many things concerning the use of information. The most basic of these is to limit access to≈information. In this way, security is trying to fulfil its mission. In practice the prohibition-based approach produces resistance and frustration.

Modern security does not try to act as the “department of business prevention” but is an enabler of secure information access and, above all, gives insight into possible risks. The ownership of these risks stays where it belongs: management. In this way, the security department is able to properly assess risks.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

International standards and regulations like Common Criteria, the U.S. National Institute of Standards and Technology (NIST), and the Federal Information Processing Standards (FIPS) play an important role in vendor selections. Other procedure-driven regulations that are just as important include ISO27001/ NEN7510 (information security), ISO 9001 (quality), ISO22301 (business continuity), PCI-DSS (credit card payments), ISEA3402, and SSAE-16.

There are also many branch-specific institutions like ETSI, and the Certification Authority Browser Forum (also known as CA/Browser Forum) playing a leading role in drafting security requirements. Leading independent institution publishing security advice include SANS and, in The Netherlands, the National Cyber Security Centre (NCSC).

4 Why is information security relevant to KPN?

KPN considers security one of the main pillars of its strategic development and has maintained a credible position in the Dutch market since the mid-1980s. KPN focus is threefold:

1 KPN leads programs to *protect* itself. In addition to the activities of the Information and Security Office, KPN administer Security Information and Event Monitoring (SIEM) services from a Security Operations Centre (SOC) whose staff comprises (a) people trained by both CISO and the Nederlandse Orde van Registered Auditors (NOREA) and (b) ethical hackers. KPN constantly monitors and tests the security of all equipment and networks, and has instituted procedures to ensure KPN is in control.

2 KPN ensures its products and services are *secure* via such measures as secure networks, secure cloud services, and secure phones.

3 KPN supplies managed *security* services – namely cybersecurity, continuity, and secure communications.

5 What are the key technologies behind security, the expected timing and the main technology hurdles?

The key technologies are roughly similar to standard ICT technologies. Security itself is not limited to technology. People, processes and other parties in the supply chain need to have security built-in in order to reach the organization's security goals. Security will benefit from developments like cloud technology and analytics, which will make it possible for security measures to operate in near-real time and to predict possible security breaches.

Information Centric Networking

11

1 What is information-centric networking (ICN) and why is it important?

The current IP-based architecture uses the "named host" principle. If you want to retrieve information, you have to specify the address of the host (a computing resource) where that information can be found. For example, when you type an URL to go to a website, the URL is "translated" into an IP address by a domain name server (DNS), allowing a connection with the host to be established. The IP-based architecture is not well suited to content distribution for three reasons:

- Conversation (that is, two machines communicating) is inefficient for content dissemination.
- Support for multicast is lacking, resulting in a huge waste of resources in terms of bandwidth and power.
- There is limited mobility (the connection lost when moving), so a separate mobile overlay network is needed.

Also, security is weak because although the connection is secured (via VPN, IPSec, SSL, etc.) the transmitted content is not.

In contrast, the ICN architecture uses the "named content" principle. In an ICN architecture, retrieving information requires only a simple request to the network specifying the name of the piece of content. This makes ICN much more suitable for content distribution. The key ideas are:

- Data is referenced by name, not by location;
- Data is directly requested at the network level (not its holder), so no more DNS – meaning more security and less delay);
- Anybody with the data can answer;
- The data itself is authenticated (and secured), not the connections it traverses; and
- The system relies on close data storage (caching).

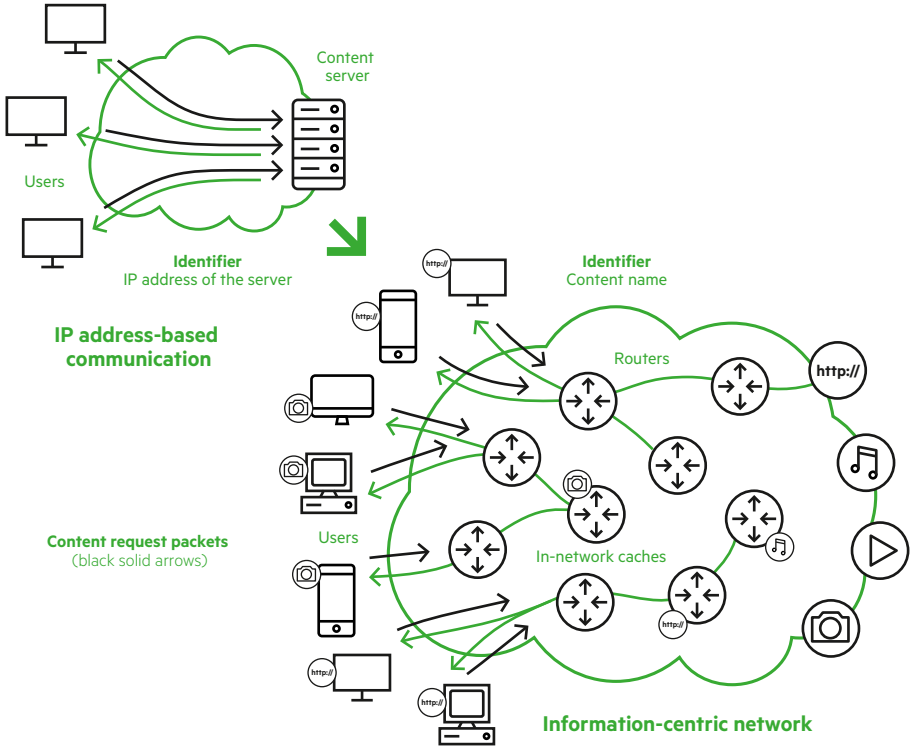


Figure 1: Interrelations of the six megatrends
(Source: Megatrends: A broad outlook on innovation", TNO December 2010)

Example: A self-driving car could ask the network for (or "subscribe to") the most recent information in the specific geographic area it is in. This information could be delivered (or "published") by a local service provider. The software in the car just needs to know the pre-defined name of the information, not the identity of the service provider. The network could cache this information very close to the specific geographic locations so that the information can be delivered with very low latency.

2 What are the current status and anticipated future developments of ICN?

ICN is still at the research stage. The idea is very elegant, and some compare it to the Copernican revelation of placing the sun, not the Earth, at the centre of our universe. But changing the Internet will be very difficult and will take a long time. There are smaller, private implementations of ICN-type infrastructure; examples are Akamai and Google.

3 Which world-leading companies, institutes, experts and publications should readers invest time in?

Cisco is actively promoting the concept of ICN and is pushing for it to be implemented as part of 5G. Apart from this, there are many other companies researching ICN, such as Interdigital.

4 Why is ICN relevant to KPN?

ICN puts information at the heart of networking. This is exactly in line with our vision of providing a smart network that can provide the connection between our physical and digital lives.

5 What are the key technologies behind ICN, the expected timing and the main technology hurdles?

There are still many challenges, such as scalability, privacy, and the business case for deployment. Timing is uncertain and implementation more than five years away.

Smart Cities

12

1 What are smart cities and why do they make sense?

The term *smart city* (SC) was coined a decade ago in a doctoral thesis on smart cities published in 2006 in The Netherlands[12]. A more recent definition is formulated as follows:

> "A city can be defined as 'smart' when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement."[13]

The urbanization trend (it is predicted that by 2050 about 65 percent of the developing world and 85 percent of the developed world will be urbanized) fuels interest in SCs. But the interest also derives from major technological, economic, social and environmental changes combined with the necessity to improve governance in cities (decentralization). For these reasons it seems to make sense to take a closer look at smart cities. However, the major reason could be that we need a fundamental different look at life itself to really tackle man's economic, social and ecological challenges for our planet; in other words, an integral systemic view . Indeed, although ICTs will enable savings and disruptive innovations, by no means are they a remedy for insufficient human interaction or economic, social and ecological governance. Overall ICT will enable the delivery of new disruptive city services in and across nearly all sectors such as healthcare, energy, education, transport. Such services will be offered in a secure, integral and reliable way to manage the city assets and the needs of the citizens.

12 Heleen Weening, PhD Thesis, Smart Cities 2006, Technische Universiteit Delft

13 Caragliu, Del Bo, Nijkamp, *Smart Cities in Europe* (Central European Conference in Regional Science – CERS, 2009)

2 What is the current status and anticipated future developments of smart cities?

SC technologies and programs have been implemented in Amsterdam, Barcelona, Bristol, Eindhoven, Singapore, Southampton, Stockholm and elsewhere. An overview can be found in the Intelligent Community Forum (ICF)[14]. It is estimated that the global market for smart urban services will be worth $400 billion per year by 2020.

3 Which world-leading companies, institutes, experts, publications should readers invest time in?

Many companies acknowledge the opportunities of smart cities. Key, however, is that consortia need to be formed to enable an integral systemic approach for the transition towards smart cities. Although as yet we do not see this happening, the aforementioned ICF is a start. The mayor of Eindhoven, Rob van Gijzel, plays an important role there, given that ICF selected the Eindhoven region as its "Intelligent Community of the Year" in 2011. A 2013 book[15] describes the decentralization trend and the rise of the cities as the key (inter)national factors. KPN has digested this knowledge and translated it into a white paper titled "De Verbonden Samenleving in de slimme stad"[16].

14 Fritjov Capra, *The Systems View of Life*, 2014

15 https://www.intelligentcommunity.org/

16 Benjamin R. Barber, If Mayors Ruled the World: Dysfunctional Nations, Rising Cities (New Haven: Yale University Press, 2013).

4 Why are smart cities relevant to KPN?

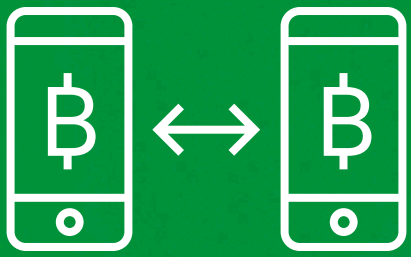
As the largest telecom operator in the Netherlands and a specialist in technology and ICT services, KPN will need to consider smart-city initiatives. More precisely, we will need to determine the right time to introduce a new generation of SC applications, and especially to learn how to play KPN's new, catalytic role bringing stakeholders (from government, science, industry, society, the arts, and the media) together to generate value inside and outside smart cities. This role could extend to that of a digital information service provider, distributor or orchestrator of future solutions for complex societal systems, perhaps including topics such as block-chain.

5 What are key technologies behind smart cities, the expected timing, main technology hurdles?

The key issues are a combined knowledge of sectors and ICT, the governance of the quintuple helix, value-cases and integral systemic thinking. Now is the time to prepare and act[17]..

17 Baken, van Gennep, October 2015, KPN

Distributed Ledger (Or Block Chain) Technology



13

1 What is distributed ledger technology and why does it make sense?

A distributed ledger is essentially an asset database that can be shared across a network of multiple sites, geographies or institutions.[18] All participants within a network can have their own identical copy of the ledger. Any changes to the ledger are reflected in all copies in minutes or, in some cases, seconds. The assets can be financial, legal, physical or electronic. The security and accuracy of the assets stored in the ledger are maintained cryptographically through the use of "keys" and signatures to control who can do what within the shared ledger. Entries can also be updated by one, some or all of the participants, according to rules agreed by the network. Underlying this technology is the "block chain", which was invented to create the peer-to-peer digital currency Bitcoin in 2008.

Distributed ledgers offer a range of benefits. They can be distributed extremely widely in a precisely controlled fashion. They are highly efficient because changes by any participant with the necessary permission to modify the ledger are immediately reflected in all copies of the ledger. They can be equally robust in rejecting unauthorised changes, so corrupting the ledger is extremely difficult. However, distributed ledgers should not be seen as an end in themselves. It is only when they have other applications – such as smart contracts[19] – layered on top on them that their full potential can be realised.

18 This section uses descriptions from the report *"Distributed ledger technology: beyond block chain"* (London: UK Government Office for Science, 2016).

19 Smart contracts are contracts whose terms are recorded in a computer language instead of legal language. Smart contracts can be automatically executed by a computing system, such as a suitable distributed ledger system. This can lower the costs of contracting, enforcement, and compliance, making it economically viable to form contracts over numerous low-value transactions.

2 What are the current status and anticipated future developments of distributed ledger technology?

The Estonian government has been experimenting in this area for a number of years using a technology known as Keyless Signature Infrastructure (KSI) developed by Guardtime, an Estonian company. The ability to assure citizens that their data are held securely and accurately has helped Estonia to launch digital services such as e-Business Register and e-Tax.

Distributed ledger technology is still at a very early stage of development. Distributed ledgers can be applied to a wide range of industries and services, such as financial services, real estate, healthcare and identity management. They can underpin other software-and hardware-based innovations such as smart contracts and the Internet of Things. Furthermore, their underlying philosophy of distributed consensus, open source, transparency and community could be highly disruptive to many of these sectors.

3 Which world-leading companies, institutes, experts, publications should readers invest time in?

There are many companies and institutes working on distributed ledger (block chain) technology. Good starting points are the report *Distributed ledger technology*: beyond block chain (London: UK Government office for Science, 2016) and the website www.guardtime.com.

4 Why is distributed ledger technology relevant to KPN?

KPN could use this technology to ensure the integrity of its networks and datacentres, especially in the era of NFV/SDN. Also, KPN could offer a range of distributed ledger services to enable different types of organisations to easily and efficiently set up and use distributed ledgers – to support smart city applications, for example.

5 What are the key technologies behind distributed ledgers, the expected timing and main technology hurdles?

The key technologies behind implementing distributed ledgers by using the blockchain concept are advanced cryptography and the synchronization of distributed databases.

The blockchain concept is already in use today and there are no fundamental technology hurdles. However, scalability is still an issue. It is difficult to support a high number of transactions per hour since there is a limit as to how fast all the distributed ledgers (databases) can be synchronized.

The main challenges for the adoption of distributed ledgers and the blockchain concept are trust, legislation and regulation, and identity management. Today people are used to trust central authorities and institutions that can be held accountable. From here it takes a big leap to put trust in a distributed ledger without a clear ownership. Therefore it may take quite some time to build trust and acceptance of distributed ledgers by the general public. The use of distributed ledgers with blockchain technology will also need to receive the explicit approval from regulators ahead of time. This might require the adaptation of certain legislation (depending on the field of application) and regulation on the territory where data may be stored e.g. to enable globally distributed ledgers. And last but not least, it will be a challenge to implement a widely accepted, easy to use and secure method to link the (often anonymous) digital identities used in the blockchain to real world identities of persons or things.


kpn