Februari 2020, 3rd edition

# THE TECHNOLOGY BOOK

The technology trends
KPN has on its radar

kpn

# Foreword

I'm extremely proud to introduce the third edition of the KPN Technology Book to you.

At KPN, we have been introducing new technology for many years. We were the first lines of communication in the Netherlands. We introduced mobile phones and mobility to the Netherlands on 2G, 3G and 4G technology. For any innovation or technology we incorporated, we have always made sure that we enable the society to use it. The connectivity we provide is what connects people, business and society.

We need to maintain our platforms of today, and also build future proof infrastructure and technology. Ten years from now, things will be very different. But what we know for sure is that the world will be digital. And data will still be expanding exponentially. We want to keep making sure that new ideas, business, and functionalities are going to come to our business and families. In order to do that we have to introduce new technologies, like 5G, XGS-PON and fiber. We must continue to modernize our network to be able to not only build for today, but for tomorrow as well.

We must think digital! Digital is not only about the way we work, but also how we communicate, and collaborate. It is also that we interact with our customers in a digital manner. Data will be very important, security will be paramount. The maintenance of our network will be automated via artificial intelligence, to bring great quality and personalized services to our customers. We have to be able to multiply our network capacity with technologies like photonics.

As a technology and digital organization, all of this is for us to build. And it is simply fantastic to be with KPN at the center of delivering this future.

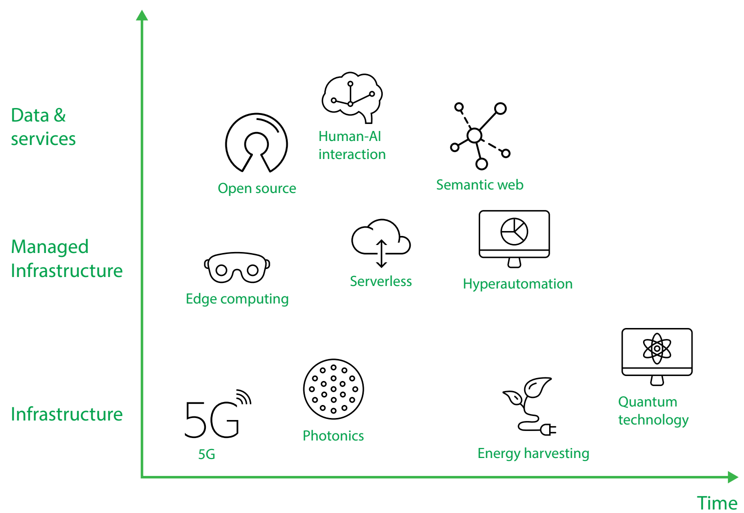
Babak Fouladi,
Chief Technology and Digital Office
Member of board of management

# Contents

# Introduction

In this third edition of our Technology Book, we present relevant technology topics for 2020 and beyond. These technology developments impact society, businesses, and KPN. For us, it is crucial to identify and monitor new developments at the earliest possible stage. We use this information to determine our innovation roadmaps. We believe it is important to share our vision on technology internally and externally, as new products and services can best be developed in partnerships. By sharing information with clients, peers and stakeholders, we can reach the full potential of these technologies and address the challenges we face.

Hence, we selected these topics for you, and we provide an overview in this book. For each topic we give more information about the current status and developments, why it is relevant for KPN, what are the key technologies and barriers and what applications are enabled by it. The topics of this technology book can be presented along this timeline:




We positioned all topics relative to each other, based on how closely they are related to infrastructure and physical layers or whether they are more related to applications for data and services. Not all topics are as close to execution as others. For some topics, implementation can still take a few years. The total timeline presents the coming decade. Nevertheless, we believe that presenting technology topics both closer and further on the horizon, provides you a good overview of what is to come.

Some of the topics are updated from the previous edition. They are still relevant and updated with the latest insights. We added the following new topics: serverless, open source, human-AI interaction, hyperautomation, edge computing, semantic web, energy harvesting.

KPN continues to monitor a wide range of technology trends. Whenever appropriate, we will update you in a new edition of this technology book.


# 5G

## What is 5G and why does it matter?

5G is the latest generation of mobile networks. Standardization of the first part of 5G has finished and in a few countries 5G has been launched. Most nationwide deployments of 5G networks will first appear in 2020. However, most functionalities will be added in the coming years. Making 5G the technology which will connect everything and enables a truly connected society.

A major game-changer is that 5G allows differentiation of use cases by virtually partitioning the network. This concept, called network slicing, has been newly introduced with 5G. 5G is expected to support a large variety of use cases, with each having their own requirements. Slicing will make the 5G infrastructure more customer-centric, instead of a one-size-fits-all network.

## What is the current status of 5G and what are the anticipated future developments?

The first deployments of 5G are focusing on Enhanced Mobile Broadband (eMBB). As a progression of 4G, it will further increase network capacity, average throughput, and peak throughput. The evolution of radio standards called New Radio (NR) as well as the use of new frequencies enables this increase. However, 5G is not complete after its initial deployment. Massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC) will add more functionality. These are currently in the process of standardization, whereby URLLC will become available the second half of 2021 and mMTC is expected around 2023 in commercial networks.

URLLC will enable new use cases that require low latency (1-10 ms) and high reliability. The introduction of the NR standard for radio technology and moving computing towards the edge of the network makes this possible.

mMTC is designed to support a much larger number of connected devices than possible in 4G, to support the growing Internet of Things (IoT). It enables a much longer battery lifetime, which is crucial for small sensors. This less feature-rich part of 5G allows further development of cost-effective, low-complexity devices. Also, higher precision location services are specified aiming for accuracies around 10-20 cm, allowing for more accurate low power location services.

## Why is 5G relevant to KPN?

Data transported by mobile networks shows exponential growth. 5G is needed for KPN to handle this growth efficiently. A new radio and antenna network is deployed nationally. This network uses the latest antenna technologies such as massive MIMO, which are hosting multiple transmitters and receivers. With a new technique for 5G radio - beamforming - a signal can be directed towards a device by steering the transmission beam in direction and power. This feature creates an improved reception and reduction of interference.

A new mobile core network based on the latest virtualization techniques enables the slicing concept and easy scale-up, as continuous data growth is anticipated. This new mobile core (5GC) is needed to enable URLLC and mMTC functions in years to come. By supporting a wider variety of use cases, 5G makes it possible for KPN to support the digitalization of businesses and society.

To advance the research and development of 5G, KPN is participating in standardization bodies e.g. GSMA, NGMN and currently is chair of the architecture workgroup of 3GPP.



## What are the key technologies and barriers?

The first 5G deployments classify as non-standalone (NSA) networks. Non-standalone means that existing 4G infrastructure supports the devices for signaling and voice, while 5G frequencies are used to achieve higher data throughput.

5G frequencies in Europe will primarily consist of 700MHz, 3,5GHz, and 26GHz. 5G can also use 4G frequency bands. Each frequency band has specific characteristics concerning capacity and coverage. Carrier aggregation is a known technique already used in 4G, which combines frequencies to enable higher throughput, allowing new applications. As first deployments of 5G are focusing on Enhanced Mobile Broadband (eMBB) the 3,5GHz band is seen as crucial to further increase network capacity. The 26GHz spectrum, also known as millimeter wave (mmWave), is most applicable for local implementations which require very high throughput, like stadiums or railway stations.

The next phase of 5G will deliver a standalone (SA) network. In this situation, devices no longer need to be supported by 4G infrastructure but fully function using only 5G technology. It will enable use cases in the category of URLLC, due to its simple and more efficient radio and core interactions. SA requires different devices than NSA, which are currently still under development.

Society and businesses rely more and more on communication technologies, and especially mobile networking. Therefore, awareness of reliability and security increases. More sensitive data is shared digitally, which formerly was only shared on paper or verbally. Therefore, continuously additional measures need to be in place to guarantee privacy and security. KPN further advances its security policies to stay at the forefront of worldwide developments. From a standardization perspective, 5G is developed to be more secure and robust. On national levels, additional measures are enforced to further secure the 5G networks of the future.

### Which applications are enabled by 5G?

5G enables the digitalization of various sectors, such as transport, agriculture, manufacturing, and entertainment.

Vehicle-to-infrastructure communication supports assisted driving. With functionality as low latency the next step, connected autonomous vehicles, become a reality. 5G enables real-time upload of huge images files, for example allowing agriculture to use drones to inspect crops while working in the fields. More accurate location information will be available to support on-premises tracking of assets which can be used for example in the manufacturing sector.

Furthermore, the high throughput of 5G enables a proper augmented or virtual reality experience. For instance, for remote employee support or the entertainment sector.

Imagine harvesting your entire field of crops, just before breakfast, using your automated drone. That is the power of 5G.

# Edge computing

**What is edge computing and why does it matter?**

Edge computing is a computing topology where processing is performed closer to the end-user. It reduces the amount of data that needs to be transferred to the cloud for processing and storage while offloading the resource-limited device from compute-intensive applications. Most intensive computations (such as for information processing, content collection and delivery) can be processed and analyzed by compute nodes at the network edge. Keeping the traffic and processing local will result in smaller latency, less network congestion and less dependency on device capabilities, creating a better customer experience.

Traditionally, computing is done in a datacenter on-premise or in the cloud, where centralized servers or computing clusters process and store data. With edge computing, distributed processing can take place on the border of the network.

We differentiate three types of locations where edge computing can take place in the order of declining capacity: Telco edge, on-premise edge, and the end-device. The telco edge is the computing location at the far end of the network of a telecommunication operator. Generally, there are decentralized compute clusters at a service provider point of presence where generic services like CDN caches or analytics for image processing are hosted. The on-premise edge is closer to the end-user, being computing resources on-site of an industrial plant or in-home where services run that process or store data that shouldn't leave the premise. The last type is the end-device itself, which can process and store data, but generally has limited resources to do so.

Edge computing plays a critical role in 5G. As most mobile devices have limited storage capabilities and rely on battery power, compute-intensive applications do not run well on the mobile end-devices. Edge computing is a powerful building block of the 5G architecture. It can optimize mobile resources by hosting compute-intensive applications at the mobile network edge, both relieving the mobile device and the backhaul as data is processed on edge before uploading it further towards the Internet.

### What is the current status of edge computing and what are the anticipated future developments?

Current edge implementations mainly focus on the Internet of Things (IoT). On-premise edge computing delivers functions like image processing or data normalization for industries such as manufacturing or retail IoT solutions. It is expected that edge computing will become more dominant across all sectors, with increasingly more sophisticated and specialized compute resources and more data storage. The introduction of advanced end-devices such as robots, drones, and autonomous vehicles will accelerate this shift.

Today's edge-oriented IoT architectures have a hierarchical structure with information being processed on edge or centralized cloud. In the future, the distinction where data is processed will become less prominent, due to the evolution of IoT solutions. A wide range of ‘things' and services will dynamically connect to distributed cloud services on demand.

The dominance of edge computing is expected to materialize in conjunction with 5G. Since 2014 technical standards have been developed in the ETSI MEC group by both operators and vendors. They aim to define a network architecture concept that enables cloud computing capabilities at the edge of a network. Initially, it was focused mainly on mobile networking only, but the scope has been expanded beyond cellular. This has resulted in the term Multi-access Edge Computing (MEC). MEC has been deployed in LTE networks, but as low latency and bandwidth efficiency requirements of 5G can be fulfilled with edge computing, significant edge implementation uptake is expected with 5G deployments.

### Why is edge computing relevant to KPN?

KPN is continuously balancing transport costs versus compute costs by hosting workloads in the most efficient place in the infrastructure. Content caching takes place on the edge of the network and less traffic-intensive applications like voice are hosted in central datacenters.

For KPN, the multi-access aspect of edge computing is especially of interest. We foresee that we can create additional value by combining fixed and mobile access on the network edge, creating a similar experience over wireline and wireless technologies. Given our strong position in fixed and mobile connectivity, KPN is well-positioned to become the top provider of edge computing. We already have physical locations suitable for hosting edge systems. Moreover, by integrating edge computing into our network edge, we can achieve both cost advantages and better user experience.

### What are the key technologies and barriers?

How to leverage edge computing possibilities depends per application. Factors like the type of application, scalability, latency and throughput requirements and security constraints need to be considered. Placement decisions depend on the required sizing. The closer one moves to the core network; the more computational capacity is available. Besides this, deciding not to centrally store your data, using a lower concentration of data at the edge, makes the solution less susceptible to attacks.

Implementation of edge computing also depends on developments in cloud computing and virtualization. As an example, edge and cloud computing can be combined, distributing a solution over different parts of the networks. It is essential to pursue a service-oriented architecture and develop a proper communication protocol used over the network to let the various services of an application work together in a distributed solution.

**Which applications are enabled by edge computing?**

Besides the possibilities in IoT that we are already seeing, a relevant new field enabled by edge computing is immersive experience. This is the feeling of truly being part of an event in virtual reality or augmented reality. VR puts strong requirements on image processing and rendering while being throughput heavy and latency sensitive.

Edge computing can also improve online gaming experiences. By moving the first computations towards the nearer edge servers, the strict real-time requirement of highspeed responses can be satisfied.

True Fixed Mobile Convergence starts with Edge Computing.

# Hyperautomation

### What is hyperautomation and why does it matter?

Hyperautomation is the next step beyond automation as we know it. Technologies like Artificial Intelligence, Machine Learning and Robotic Process Automation are applied to automate processes or augment tasks. It helps people perform the same jobs more efficiently, and sometimes even more creatively to improve the performance of a company.

Hyperautomation will change the nature of human work. Jobs will change and require new skills. As not only simple tasks are automated, but also complex components are automated or augmented. The development of AI itself will require highly skilled people. We need to enable/ stimulate work redistribution. By setting up digitally-focused feature teams to allow people to gain new skills and competences.

### What is the current status of hyperautomation and what are the anticipated future developments?

We are now in the era of implementation of hyperautomation. The fundamentals are clear, and the underlying algorithms have been published. The availability of enormous computing power and large datasets enabled an explosion of applications. Over the years, AI progressed from brute force calculation of decision trees to pattern recognition on large datasets, forming a model using advanced statistical methods on which analytics could take place.

Now a lot of practical problems (varying from optimizing websites to diagnosing medical illnesses) can be solved using AI. The AI's result is a prediction, which may be the basis for a decision or an action. However, this requires you to judge the prediction. After that, actions can be automated. This enables machines (self-driving cars, robots, drones) to make their own decisions.

## Why is hyperautomation relevant to KPN?

We believe that becoming digital is the means of providing greater customer service and increase service revenue while reducing costs. With digitalization comes hyperautomation. Digitalization of KPN happens on three levels: digital inside, digital outside and digital services.

Digital inside is related to simplifying and digitalizing operations. Making sure we all work digitally together from collaboration tools to simple one-click processes. Digital outside focusses on digital customer experience. It defines how we digitally interact with customers. Customers can perform self-service online without any need for offline interaction and are thus in charge of their services and data. Lastly, digital services revolve around digital business models. How we continuously bring digital services and digital products based on customer analytics to deliver great services to our customers.

## What are the key technologies and barriers?

The key technologies for hyperautomation are artificial intelligence (AI), machine learning (ML), and robotic process automation (RPA).

AI is about 'making predictions' (in a broad sense of the word): the creation of missing information based on available data. Machine learning is a specific part of AI where algorithms and statistical models are used to identify patterns in structured data. Pattern recognition is a fundamental component of nearly all AI implementations. It structures input data in such a way that further analysis is possible.



Machine learning applications can perform a specific task without using explicit instructions, relying on recognizing patterns instead. There are three different types of machine learning: supervised learning, unsupervised learning and reinforcement learning. Supervised learning focuses on the exploitation of current knowledge by learning from structured data. Unsupervised learning builds up a model from scratch, without having any previous knowledge creating new insights by recognizing patterns in large data sets. Reinforcement learning is balancing both approaches.

Robotic process automation is divided into the fields of attended, unattended, and cognitive RPA. Attended RPA automates routine tasks through standard user interfaces. It automates only part of the work and often needs human supervision to start or stop the robot, for example, replacing manual clicks on a screen when UI testing. With unattended RPA, robots can work 24/7 on automated tasks, their logic is mostly rule-based and therefore need to be configured or adjusted by people. Cognitive RPA uses the intelligence of AI or ML to automate more complex tasks and can handle exceptions. It is mainly applied for improving data and making automated decisions.

Challenges for hyperautomation are mostly related to data. In today's connected world, data often exists in multiple unaligned sources. Keeping it secure and compliant is challenging as the stakes for losing critical data are high. Understanding and translating data into actionable business insights is hard.

The data is often there but is not clean, not being used, and regularly exists in multiple forms across multiple platforms. You need to build the right infra, a single version of the truth, and be able to get the correct information in real-time to your entire organization. It is impossible to become a digital organization and use hyperautomation without a proper data strategy to handle big data.

The GDPR legislation specifies that you are only allowed to gather and store data for a predetermined goal. You are not allowed to use the data that you have collected for a specific purpose, for another, new purpose.

Finally, you need to be aware that the dataset you have access to may be biased and may not be a good representation of the whole market that you operate in. Understanding and translating data into business insights requires both data skills as well as industry domain expertise. To achieve this, data scientists and business leaders need to learn to understand each other.

### Which applications are enabled by hyperautomation?

Hyperautomation enables new advanced use cases like intelligent transportation including automated driving, road safety and traffic efficiency services. Industrial automation with automatic inspection or remote healthcare with remote treatment and response or surgery. This calls for an intelligent approach to network planning and optimization to be able to fulfill the ultra-reliability requirements needed to accommodate these use cases.

With the rise of Artificial Intelligence (AI) techniques, networks become self-optimizing. With the use of intelligent antennas with AI-powered radio-frequency (RF) front end and intelligent chipsets. These radio networks enable higher levels of uptime by analyzing multiple process parameters simultaneously and identifying when and where critical maintenance needs occur.



Machines are looking for more than just dull and repetitive jobs.

# Serverless

## What is serverless and why does it matter?

Computer architectures have evolved over the years. It started with mainframes in the 50s, big computers running code to process bulk data. This later evolved into distributed computing with client-server architectures, where multiple physical servers were interconnected. Applications were distributed asymmetrically over clients and the central server, like web browser to web server.

In the last decade, cloud computing gained popularity. In the cloud, computing resources are provided as a service, and you run your application in a virtual machine or container. The most recent step in this evolution is serverless. This is a platform which dynamically allocates and provisions resources. It provides abstraction from hardware and operating system, so application developers don't need to be concerned anymore about the servers running their code. The serverless platform provider runs the required infrastructure for them.

A serverless architecture enables a new style of programming for cloud platforms which changes the way applications are built and deployed. As it creates another layer of abstraction between the cloud platform and applications, it simplifies cloud programming. Serverless fosters the adoption of microservices. Such small deployable units result in faster delivery of features to the market. It reduces the number of manual actions involved in testing and deploying code. This makes serverless a very lean way to develop applications.

Also, it has a different business model compared to the cloud. The pricing is based on the number of executions rather than compute capacity. Accounting is defined by the size of memory space used by the function for the execution duration. In this way, you don't pay for the resources when they are idle, as happens when you are charged for reserved VMs even if they are unused.

Serverless technology splits complex applications into smaller pieces of code. Some of these units of code will be provided by third parties and are known as Function-as-a-Service (FaaS). These code snippets are self-contained, stateless, event-triggered, and managed by a service provider.

### What is the current status of serverless and what are the anticipated future developments?

There is a multitude of serverless platforms, FaaS providers, and serverless frameworks available today. The term serverless was largely introduced in 2014 when Amazon started with its Lambda platform, where functions are provided as a service. All the large cloud providers stepped into the serverless and FaaS business by 2017, like Google, Microsoft, Alibaba, and Tencent. Also, opensource projects have been initiated, like OpenFaaS, Iron.io and OpenWhisk with which you can create your own on-premise serverless platform.

Serverless frameworks are used by programmers to develop applications that could span multiple FaaS providers. Serverless frameworks provide an agnostic way to define and deploy serverless code on various platforms. Examples are Serverless Framework, Apex, ClaudiaJS, and Zappa.

As opposed to traditional cloud platforms, serverless platforms need to support specific programming languages, as serverless takes place on application level. The runtime environments support multiple higher-level languages, like Python, Go(lang), Ruby, Node.js, Java, C#, and PHP.



Serverless and FaaS are considered by Gartner to climb the peak of the hype cycle quickly [1]. There have been a lot of trials, but also, more and more production environments are implemented. Serverless technology still needs to mature before becoming the leading cloud technology.

The future of serverless promises us truly cloud-native applications, that can be distributed on several locations. They could even run at the edge instead of in large datacenters, where platforms have limited resource capabilities. The enormous amount of data produced at the edge can be processed locally, therefore avoiding the need to transfer this data to the cloud, thus being more efficient.

### Why is serverless relevant to KPN?

Serverless technology will enable KPN to take the next step towards becoming a digital operator, embracing cloud technology and support agile service development. KPN started this journey with network virtualization (NFV and SDN) to decouple software from hardware. Serverless decouples code from underlying infrastructure even more than virtualization. This helps to achieve full network-independent services, where every service can be delivered via all network technologies.

A serverless platform handles all system administration operations related to running servers such as load distribution, resource allocation, monitoring, and security patching. It causes a shift of responsibility for resource management from the software developer to the cloud provider. This facilitates the programmer to focus on their core task: application development.

## What are the key technologies and barriers?

It is important to match the needs of your application against the benefits and drawbacks of the technology. Serverless applications only exist during runtime. Functions are event-based; every execution is triggered via an API. The code is stateless and intended to run ephemeral, which means so much as that it may only last for one invocation. This works well for event-driven and unpredictable workloads that don't need continuous access to data and don't have outside dependencies.

There are a few risks with serverless, which are expected to be mitigated when the technology matures. First of all, there is possible vendor lock-in, when the application relies on specific platform functions. Migrating workloads to different serverless platforms can be difficult, which is a concern for all developers that consider using serverless.

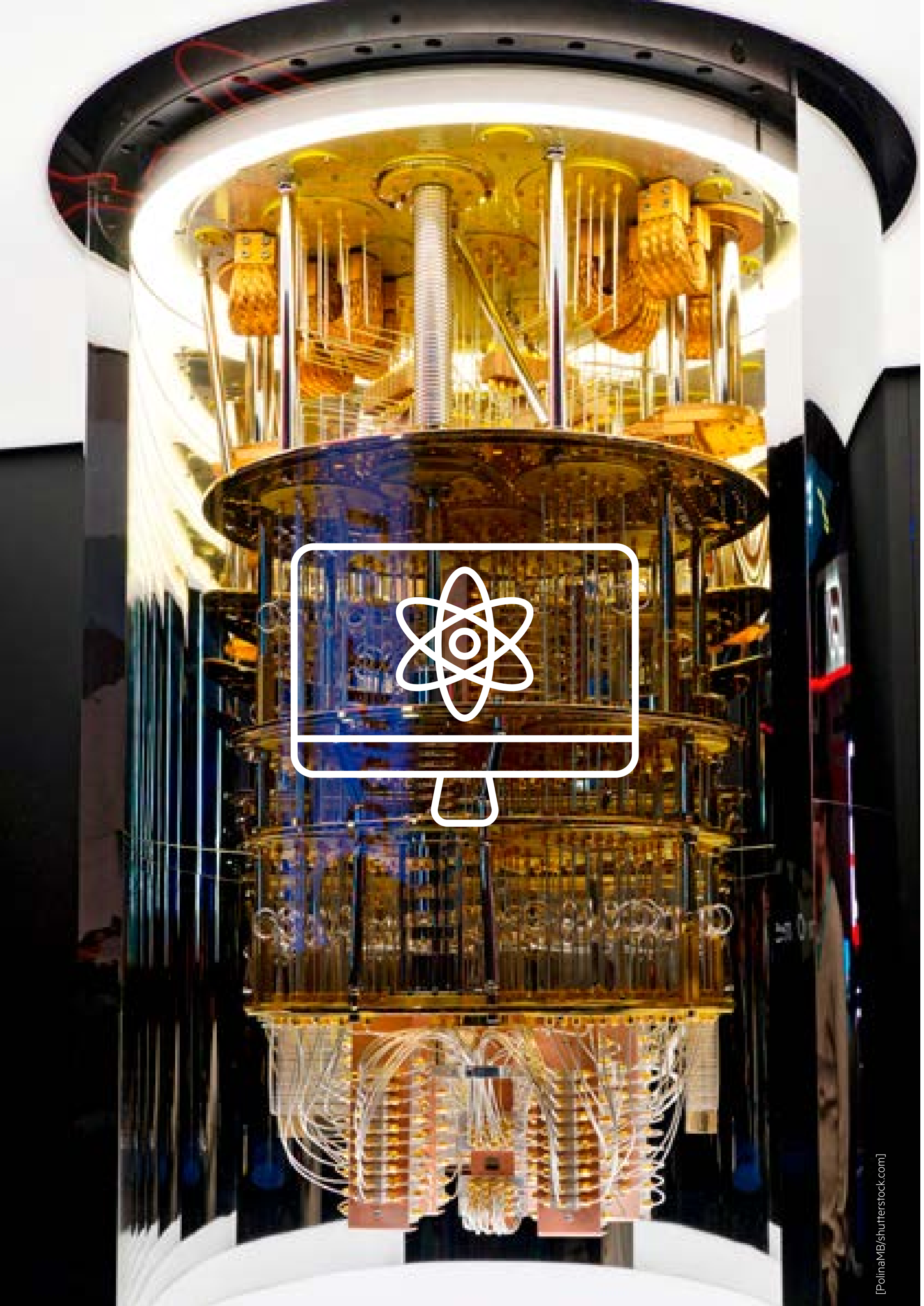
Storage in serverless settings is one area of ongoing research. The stateless nature of serverless platforms makes it difficult to provide storage solutions with low latency and high speed (input/output per second) at reasonable costs. As functions are removed when idle, function startup after a period of inactivity may result in performance declines if the number of instances of the function has dropped down to zero.

## Which appilcations are enabled by serverless?

The flexibility of serverless technology means it can be used in a wide variety of applications. The most popular is website-scaling. A website can be deployed faster and instantly scale to handle each incoming request.

Also, data processing intense applications, like image processing, ETL (extract, transform, load) software, and analytics are easier to deploy. Furthermore, automation of scheduled computing tasks, when tasks need to be performed at certain intervals or times, automation can be done with serverless functions.

[1] https://www.gartner.com/en/documents/3956097/hype-cycle-for-cloud-computing-2019



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# Quantum technology

### What is quantum technology and why does it matter?

Quantum technology is an overarching term that encompasses concepts like quantum computing and quantum internet. It may sound like technology for the far future, but the first results could be seen in the coming years. Quantum technology has its roots in physics. Luckily you don't need to fully understand quantum mechanics to get a grasp on quantum technology.

Quantum technology is considered one of the most disruptive technologies in the near future. Quantum computing will unleash a vast amount of computing power, solving problems classical computers cannot handle. Quantum internet provides us with more secure communication, and in due time creates a network of quantum computers. The combination of quantum computing and quantum internet can enable applications that we currently cannot even imagine.

In the future, increasing computing power will break currently used security techniques. All encrypted messages ever sent and stored could be decoded in the future, according to the concept of 'capture now, decrypt later.'. As more and more information is shared digitally, secure communication is of increasing vital importance.

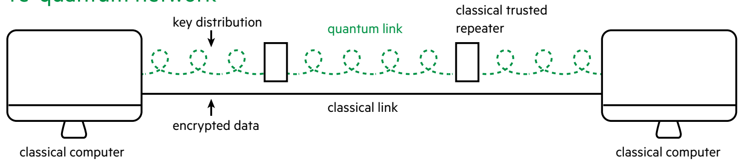
New encryption techniques that should be unbreakable by quantum computers are qualified as post-quantum. When an encryption key is created over the quantum internet, this is called quantum key distribution. Either post-quantum cryptography or quantum key distribution can keep our data safe in the future. The classical internet still transports the encrypted data. The quantum internet transmits only the key.

## What is the current status of quantum technology and what are the anticipated future developments?

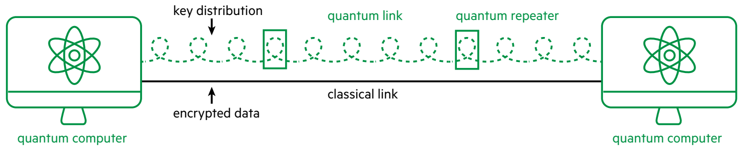
The first 'pre-quantum networks' are operational in Japan and China. Here quantum key distribution has been performed over longer distances. But covering long-range requires elements that repeat the signal. These repeaters must know the key and therefore, break end-to-end confidentiality and put security at risk.

Secure end-to-end delivery of data is possible when using quantum repeaters. These quantum nodes do not need to know the key while refreshing the signal. This technique has not been shown yet but is expected in 2020, when hopefully the first quantum internet arises. Four cities in the Netherlands are going to be linked with optical fiber transporting quantum bits. This initial setup will primarily serve applications like quantum key exchange, synchronization, and secure identification. Over time, this network of small quantum computers needs to evolve into a pan-European and world-wide internet.

Pre-quantum network




Quantum computing network




Quantum computers today have a limited capacity. They are prone to errors and suffer from scalability issues. Different types of implementations are still in the running to be used to store data.

One approach is to develop the so-called fault-tolerant quantum computing. The errors that occur during the computations are corrected fast enough to enable a stable fault-tolerant computation. Another method is the Noisy Intermediate-Scale Quantum (NISQ) technology. With this technique a quantum computer with relatively low amount of qubits and tolerant to noise can still outperform classical computers in certain tasks.

Eventually, the scaling-up of the quantum internet and increasing capacity of quantum computers will lead to the quantum cloud. Distributed computing can take place when the quantum network connects quantum computers in several locations. The quantum cloud unleashes vast amounts of computing power which can solve problems that are currently out of range — for example enabling DNA sequencing, advanced material design, chemical development for medicine and Monte Carlo simulations for complex mathematical problems.

## Why is quantum technology relevant to KPN?

Quantum technology will have a profound impact on future communication. KPN values security and privacy of connectivity highly and invests in secure transmission in a post-quantum era.

KPN is participating in research to make the quantum internet reality together with QuTech, a collaboration between TU Delft and TNO. KPN will be providing the fiber infrastructure to connect four cities in the Netherlands. This network aims to be the first implementation of quantum internet in the world, evolving into a European quantum internet in the coming years.

## What are the key technologies and barriers?

Internet and computers use standard bits consisting of 0 or 1. Quantum internet and quantum computing use qubits, which can have a value of 0 and 1 at the same time. This ambiguity causes an exponential capacity for computing power.

The most relevant aspect of quantum physics is entanglement. Entanglement causes qubits to act like twins. Both qubits will have the exact same value at the exact same time, even if they are far apart. Furthermore, qubits are inherently private. This means that no third party can listen in on these twins to copy their value since observing their value disrupts the entanglement between qubits.

Current challenges for quantum technology are the stability of qubits and distance of transportation. Keeping the state of a qubit for more than a few seconds is impossible at the moment. Incorporating large amounts of interacting qubits in quantum computers is therefore not feasible yet. Research is ongoing on how to achieve high-quality qubits suitable for large scale quantum computers by looking into different materials. When photons transport qubits, they are absorbed by the atmosphere or by optical fiber. This attenuation limits the distance currently to around tens of kilometers.

## Which applications are enabled by quantum technology?

The first applications of quantum technology focus on security and synchronization. Quantum key distribution can ensure secure identification. Instead of sharing credentials, entanglement is used to validate identities. Or Physical Unclonable Keys (PUK) can be created for asymmetric cryptography. Applications in the area of digital signatures, elections, or auctions can make sure that this can securely take place online.

Synchronizing clocks with entanglement improves the efficiency of GPS and other systems like radio telescopes, which rely on high-precision timing. Higher accuracy of GPS results in a more precise location. A lot of IoT solutions can benefit from a higher location precision.

# Semantic web

**What is semantic web and why does it matter?**

The Internet, as founded in the 90s, has been evolving since its inception. Initially the Internet was focused on information sharing and linking websites. Early this century it changed to the social web, where interaction and connecting people was the web's main use. Now the world wide web is developing into the Internet of Value, connecting context, people, knowledge and 'things' in real-time.

The Internet of Value or Web 3.0 is data-driven. Everyone is in control over their data and can access data at any time and from anywhere because it is stored in the cloud. The increased awareness of security and privacy causes the power to gradually shift back from the big tech players to the people, taking control over their own data.

Two key technologies enabling the Internet of Value are Semantic Web and Artificial Intelligence. Semantic web techniques make the websites meaningful for machines, not just humans. It teaches the computer how to interpret the data, by adding semantics (meaning) to web pages. Artificial intelligence can utilize this machine-readable information for various applications. Therefore semantics are often a precondition for AI.

Semantic web techniques create a common language for describing meaning. It enables linking data between multiple websites and does not require programs to be engineered to talk to each other. Semantic metadata describes the meaning of regular web pages by adding semantic tags. A basic example is rich snippets of Google, where data is labeled to have it recognized by search engines.

## What is the current status of semantic web and what are the anticipated future developments?

The concept of semantic web was introduced by Tim Berners-Lee as early as 2001. In his vision, the semantic web or web 3.0 was an evolution of the Internet focused on linked data, which was machine-readable, instead of linked websites sharing information between people. In the meantime, the semantic web technology went through the full Gartner hype-cycle. Finally, we see the first actual implementations and applications appearing, but there is still a long road ahead to completely fulfill the vision of Berners-Lee. [1]

Currently, there are digital assistants like Google Assistant, that can make an appointment at the hairdresser. But Google Assistant only supports web services that have been selected and integrated by Google. The next step is to combine semantic metadata with Linked Open Data. Linked Data is structured data interlinked with other open data, so that the Internet becomes a global database. Linked open data is already used with government, public institutes and universities, for people to use data for a variety of use cases and applications. In this way, digital assistants can interact with any service published on the internet.

Secondly, we see an increased use of context. Search engines include people's behavior and preference in the search results, which makes them personalized and more meaningful.

Several projects are ongoing to materialize the semantic web vision further. Tim Berners-Lee initiated the Solid project at MIT in 2018 as a response to the big social platforms. Solid contains conventions and tools for building decentralized social applications offering true data ownership and improved privacy. [2]



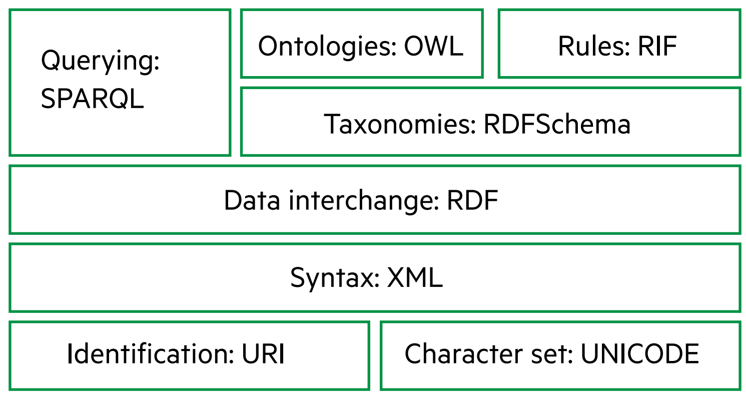
## Why is semantic web relevant to KPN?

A standardized way of exchanging data enables several use cases that are relevant to KPN and customers. With Semantic web technology we can define an enterprise data model that eases interaction between different organizations or organizational parts. A common language or schema to describe your business is helpful when merging organizations, but also when exchanging data between organizations.

Another example where the value of data stands out is the Internet of Things. Data is gathered from sensors and can be used by other parties to use in different applications. Currently, API descriptions are used to define the format of the data. But with semantic web techniques specific descriptions or definitions are no longer needed. Eventually semantic web enables the integration of different data sources and leads the way to truly converged and integrated service offerings.

## What are the key technologies and barriers?

The World Wide Web Consortium (W3C) defined several standards, which are the underlying technologies for semantic web: RDF, SPARQL, and OWL.




Semantic web stack

Resource Description Framework (RDF) is the format in which data is stored. The purpose is to provide structure to describe things by defining its properties in the form of Triples, sets of 3 words. It is merely a flexible graph data model that does not involve logic or reasoning. SPARQL is the language to query data in RDF format. This language is specifically designed to query data across various systems. Web Ontology Language (OWL) describes semantic relationships (ontology, structured data model or schema) in mathematical statements so that applications can use them as logic.

One of the barriers for full-scale adoption of semantic web is the perceived complexity and lack of experience with developers. Furthermore, there is a disconnect between the need of semantics and the effort to provide it. For each application a vocabulary needs to be selected to describe the semantics of the data. Hopefully developed tooling helps to simplify the view of datasets, while preserving the semantic richness of the data model.

### Which applications are enabled by semantic web?

Media companies like BBC, SpringerNature and many others use semantic publishing to make data integration and knowledge discovery more efficient.

In smart cities, where Internet of Things connects numerous assets, from traffic lights to recycle bins and busses, semantic web enables easy application development on data from different sources. For example, when you drive your autonomous car into a new area, another city or country, traffic lights can be recognized with semantic segmentation. This labels objects in an image that the self-driving car cameras record.

[1] https://medium.com/@schivmeister/the-semantic-web-where-is-it-now-f4773f3097e3

[2] https://medium.com/@timberners_lee/one-small-step-for-the-web-87f92217d085



Context is the challenge for artificial intelligence the coming years. Semantics can help to interpret the intended meaning of people.

# Open source

## What is open source and why does it matter?

The development of open-source (OS) software is one of the most prominent drivers of digital disruption. Open source has led to huge popularity in the field of IT, but the Telecom Industry is also experimenting a lot with open platforms.

In telecommunication, the idea of 'open' is applied to the platforms that are used by operators. Traditionally, most of these platforms are closed appliances wherein tailor-made software runs on dedicated hardware (with specialized chipsets), which are bought from well-known suppliers.

The greatest advantage of OS software is that it is free to use or adapt, and therefore flexible, but it doesn't mean it comes at no cost. OS software is crowd-sourced: Code is written and maintained by volunteers and community members. It is available and open to anyone. You can adapt it to meet your specific needs. As a result, it enables new applications without vendor or ecosystem (like Apple or Microsoft) lock-in. Furthermore, it is designed to integrate with 3rd party applications by nature.

OS can bring down operational cost, speed up innovation, and can bring a higher level of security, but only when used appropriate. The advantages mainly exist because of the community aspect; more people look at and test the code. It is more likely that a problem will be quickly noticed.

In the world of proprietary software, it can often take weeks or months for companies to release a patch for their product. Most of the time, no one outside of the producer has information on what vulnerabilities are present in the software.

True, open-source software may have more "discovered bugs" than closed sourced alternatives, but those bugs are usually fixed before they can cause serious harm.

### What is the current status of open source and what are the anticipated future developments?

First, mostly surfacing from the academic world or idealists, we have genuinely open source software, where the software has the intention to remain open to anyone and there is no revenue model involved. Secondly, we have semi open-source software, where basic functionality is open source but additional functionality or support has a revenue model attached to it. It is important to be aware of this boundary and the notion that true OS software can, at any moment, transform into software with a revenue model attached.

As an example, Open IP has been around for quite some time, e.g. WWW protocols, Linux, Wikipedia, but for years it lingered outside of the application domain because companies mainly bought off-the-shelf software solutions from big vendors like IBM and Microsoft to drive their technological initiatives. However, now we see an uprise in these vendors buying open-source companies or incorporating open-source technology in their own software stack and changing their own licensing model. It also happens the other way around; open-source initiatives transform into commercial vendors by adding revenue-models for support or extra functionality.

### Why is open source relevant to KPN?

With growing traffic demand, increasing capacity at acceptable cost is a continuous challenge for KPN. The trend of Open Source can put pressure on the incumbent vendors in the network and overall reduce the cost of infrastructure. KPN is participating in Open Source initiatives like Open Networking Foundation (ONF) in order to understand the impact of Open Source on telecommunication infrastructure.



At KPN we make or adapt a lot of software ourselves. However, for this, we have limited resources. For each application, we decide whether open source is a viable alternative to commercial software and whether we have the skills and resources to accommodate the effort of open source.

### What are the key technologies and barriers?

Two factors lower the price of networks using open software. First, generic (cheaper) chipsets have become powerful enough to be used in telecommunications. Secondly, open standards which are already used by Telecom Operators can be adapted to create open platforms. As an example, the virtualization of network functions and the implementation of software-defined networking happens with the use of open-source software.

Open-source software is built for and maintained by the open-source community. However, it is not a complete software suite created for enterprise purposes. It needs to be adapted into a custom-built application to be useful. The innovation and maintenance effort required by teams to incorporate, build and operate the OS software is often not calculated and taken into consideration when compared to commercial software. Therefore, commodity software is in some cases still preferred as it mediates the company’s risk of support (no active OS community), liability (copyright and patent infringements) and warranty (patents and proprietary code safekeeping).

It is important to note that also (free) OS software is protected by copyright. Software developers open-sourcing their software give their consent to others to use, modify and distribute the software, but also here certain conditions are set in a license. If not complied, the developer’s copyrights are infringed.

### Which applications are enabled by open source?

We can show two examples, that not new technologies (like AI) drive technological developments, but the way we collaborate with open source initiatives do.

First, Deutsche Telecom has virtualized a Broadband Network Gateway (BNG) based on open source. A BNG is an extremely complex appliance, also used throughout KPNs network, in which an immense amount of functions are brought together and all fixed Internet access connections are concentrated and controlled. They have proven that it is possible to implement a BNG on generic hardware, which is bad news for the Telco suppliers (such as Nokia, Huawei) that up until now had a monopoly on the production of such crucial equipment.

Second, we see a lot of development towards programmable network devices with the programming language P4. P4 is an open-source language maintained by the Open Networking Foundation (ONF), which has the goal to steer innovation in the area of Software Defined Networking. The introduction of P4 has accelerated the development in the field of programmable networks and introduces for custom telemetry and monitoring in the network.

The true power of open source is in the power of the many.


# Human-AI interaction

### What is human-AI interaction and why does it matter?

Artificial intelligence (AI) exists to enhance human productivity and quality of life. AI is a technology that has a lot of application areas. One domain where AI can make a difference is how we interact with computers or machines around us. We are used to typing commands, getting more accustomed to touchscreens on every system, and start to use speech to make engaging easier. AI helps to make interaction with machines more intuitive.

We are increasingly surrounded by smart things in our daily life, from chatbots on a website to robots that take care of hospitality in hotel receptions. We require that these systems learn from us and collaborate with us in a meaningful and personalized way. This results in systems that use AI to learn, predict, adapt, and influence human behavior. Like a thermostat that knows when you are on your way home.

### What is the current status of human-AI interaction and what are the anticipated future developments?

Slowly voice assistants have entered our life, on our phone with Siri and in our home with speakers like Google Home or Amazon's Alexa. The next step is that these systems become your digital assistants that can book a hairdresser appointment. Eventually, they can provide you with a digital twin, which is a virtual copy of our behavior, goals, and preferences.

Research started in the 80s as human-computer interaction. Over time, machines have evolved to responsive systems and use more speech for communication. Most recent research areas focus on how to enhance our life even more with AI, by designing it around the user, called human-centered AI.

Big companies like Microsoft and Google are investing in research on human-centered AI. The first results are human-machine interaction guidelines from Microsoft and Google's PAIR (People and AI Research) program that performs fundamental research and technology innovation to drive human-centered artificial intelligence design.

At the moment, different technologies enable AI to learn from people, whether by looking at big data sets for object recognition or learning from experience to improve tactics for games. In the future, people will also learn from AI. Because systems can calculate so many options, new designs or strategies can emerge. For example, powerpoint recommending you a slide design for your content or the DeepMind machine coming up for new tactics for the game Go [1].

The increase of applications for AI is enabled by evolution in processing capacity. Companies like Google (Tensor Processing Unit) and Apple (Neural Engine) are building AI in a chip. These so-called AI-dedicated processing units or AI accelerators enable ultra-fast pattern recognition of speech, text, or images so that systems can listen, reason, anticipate, and speak in real-time.

**Why is human-AI interaction relevant to KPN?**

KPN can use chatbots and voice assistants for service desks to improve customer experience. Furthermore, AI can be used to recommend content on a website or tv, to personalize the service. Also, integrating voice assistants with more KPN devices like set-top-box can simplify the interaction with your tv. Simple communication highly aligns with KPN's mission to make life more free, easy, and fun.



**What are the key technologies and barriers?**

Technologies that support human-AI interaction consist of generic AI techniques like machine learning, artificial neural networks, and deep learning, but also machine vision and natural language processing. Machine vision is the technology for real-time image recognition with a camera, for example, to detect anomalies in manufacturing processes. Natural language processing is a technique that enables machines to recognize speech in real-time. Also, it allows systems to understand spoken language and to be able to generate a response in real-time. Natural language processing enables humans and robots to have real conversations.

To ensure that users have a positive experience, the use of contextualization and intent modeling is crucial. Context is information about the whereabouts or activity of the user so that the system can incorporate that in its response. For example, a virtual assistant that proposes to order an Uber when your plane lands. Understanding the intent of users, what someone is trying to do, is essential but for computers hard to interpret. Intent classification creates a model of possible responses. With this model, the AI can be trained to have a better understanding of category of responses it should consider.

Multiple ethical aspects should be considered when using AI for interaction with people. First, we must avoid bias in machine learning. AI algorithms can provide prejudiced responses due to wrong assumptions in the learning process. Secondly, users should always be in control of their own data. Parties must build a trust-relation by guaranteeing traceability of data access, explainability of the AI's decisions. And it should be possible to access this information in a way that is easy to view, edit, control and curate the data.

**Which applications are enabled by human-AI interaction?**

We try to make robots respond more humane to provide a better user experience. This results in human-robot interaction like companions for the elderly or coaching apps for autistic children.

Visual recognition supported by AI can simplify the log-on to your wifi network. Point the camera of the device you want to connect to the SSID-sticker on your gateway, and the phone automatically knows how to connect [2].

Artificial Intelligence is inspired by human intelligence, powered by human data, and only effective when it positively affects the human experience.

[1] https://deepmind.com/blog/article/alphago-zero-starting-scratch
[2] https://lens.google.com

# Photonics

### What is photonics and why does it matter?

Photonics is the science of light and includes cutting-edge technologies of optics, fiber-optics, electro-optical devices, and lasers. It is used in telecommunication for glass fiber access networks to households and is used in data centers for data transportation and can be found in wireless communication. In the last decades, photonics has been applied in optical fibers for transmission of information, creating the fundaments for the Internet.

Be aware that photonics is a next-generation underlying technique on which many more technologies build upon. Applications are therefore not limited to telecommunication but also apply to various other sectors like healthcare and transportation. Photonics is considered one of the key technologies where innovations are expected in the next decades because it makes data transportation even more efficient by reducing cost and energy consumption while increasing transmission capacity and speed.

### What is the current status of photonics and what are the anticipated future developments?

Fiber-optics are continuously under development to support higher throughputs on long haul transmission. Multiplying the number of wavelengths per fiber and innovation on modulation techniques to mix these wavelengths effectively, increases bandwidth. New speed records have been set with a throughput of 500Gbps for each wavelength, resulting in total transport capacity of over 50 Tbps. [1]

Furthermore, the development of electronic and photonic convergence, called integrated photonics, has a tremendous impact on telecommunication. Currently, for all switching activities the optical signal first must be translated to an electrical signal before packets can be processed.

Therefore, switches require a separate optical light source next to a silicon chip for electrical processing. Innovations are ongoing to produce a single semiconductor that can directly use the optical signal for switching. Such chip will remove the need to cascade optical switches and ethernet switching fabric.

Facebook & Google (hyperscalers) use co-packaged optics with switching silicon and reached 256 Terabit switch chips [2]. Integrated photonics result in massive disruption for data center networks, which become more energy and resource-efficient at low cost.

### Why is photonics relevant to KPN?

Each year the required capacity of data transport and processing is growing by a factor of 2. This increased demand applies to both long-haul transport networks, connecting homes, and mobile antennas, as short-reach data center networks, connecting switches, and servers. Therefore, having technology that enables higher throughputs efficiently is of utmost importance, making photonics very relevant to KPN.

Processing all this traffic in data centers is enabled by integrated photonic switching — resulting in faster and efficient datacenter networking. The energy efficiency of electrical/optical integration is vital to KPN to reduce energy consumption per bit. This environmental awareness helps KPN to remain one of the most sustainable operators and make every day a little greener.



In the Netherlands, we are in de midst of the transition of the copper infrastructure to fiber. Connecting houses, business parks, and mobile antennas through high speed, low latency fiber-optics is one of KPNs core strategic areas. Roll-out of glass fiber enables bandwidth growth of households and enterprises and low-latency services such as defined in 5G.

Photonics also play a significant role in the innovation of wireless data transmission. One example is the use of integrated photonics for 5G beamforming. Beamforming steers the direction of the radio signal to reach higher throughput per user. A second example is the development of LiFi complementary to WiFi. Where WiFi uses electromagnetic waves at radio frequencies, LiFi uses invisible light for data transmission. LiFi provides advantages in high-density environments due to less interference compared to WiFi. Both innovations on 5G and indoor connectivity are important to evolve the services KPN provides.

To advance the research and development of integrated photonics, KPN, and the University of Eindhoven (TU/e) have a strategic collaboration, called Flagship Telecom.

### What are the key technologies and barriers?

Photonics uses photons instead of electrons, which are the elementary particles carrying information in electrical switches and copper wires. But photons have different characteristics than electrons. Photons used to create coherent light beams can transport much more information than radio frequency and microwave signals. Photonics supports the increasing demand for bandwidth and speed, but in a more energy-efficient way than electromagnetic waves. It is characterized by having a higher processing speed and lower energy consumption per bit than microelectronics.

One of the most important technologies is the integrated photonics, also known as photonic integrated circuits (PICs). It must be possible to produce these types of semiconductors against a very low cost to use them on a large scale. As this is advanced nanotechnology, connecting the chip to other components needs to be done accurately. Currently a large portion of production costs is due to this assembly and packaging process.

### Which applications are enabled by photonics?

Photonics enables a lot of applications in different sectors, like healthcare, transportation, and public services.

With micro-spectrometers, which are very accurate lasers fully integrated on a chip, a smartphone can be used to check how clean the air is, whether food is fresh or a lump on the skin is malignant. Furthermore, photonic technology can be used to detect minimal amounts of protein in urine, which can indicate tumors. Healthcare professionals can use this technique, making healthcare more accessible at a low cost, or even enables self-use.

Photonics is also the enabling technology for LIDAR (LIght Detection And Ranging). LIDAR can detect distances of objects, which is used for autonomous and assisted driving.

Combining photonics with quantum technology improves security of identification documents or credit cards. Photonic readers and special 'paint' can validate the document instead of a pin code.

[1] https://www.technologist.eu/new-record-data-transfer-speed-in-fiber-optic-network/
[2] http://www.gazettabyte.com/home/2019/5/13/co-packaged-optics-to-debut-with-256-terabit-switch-chips.html



> "Photonics plays a major role in the success of the Dutch high-tech industry and makes an important contribution to solving social challenges."

[National Agenda Photonics]

# Energy harvesting

**What is energy harvesting and why does it matter?**

Energy harvesting makes it possible to power or recharge devices from ambient energy sources. Devices can scavenge electricity from natural sources like solar, thermal, or wind, mechanical sources like vibration or pressure, or magnetic waves like radio frequencies. This enables true wireless devices that are not dependent on a conventional power source.

Wireless power transfer has the potential to remotely charge small, low power electronic devices, like IoT devices over the air. Remote charging enables lifetime batteries, which last as long as the lifetime of the device it is powering, without the need to replace these batteries. It allows new application areas like deploying sensors in remote locations that are difficult to reach, where replacing batteries would economically impossible.

**What is the current status of energy harvesting and what are the anticipated future developments?**

There are two categories of energy harvesting through wireless power transfer: Near-field and far-field techniques. Near-field enables energy harvesting at a distance from centimeters up to a meter. Far-field technology can transfer power up to 5 km. For both of the above, the further away from the source, the less amount of energy that can be harvested.

Examples of near-field applications are charging handheld devices like phones or wearables on a Powermat, electric toothbrushes, RFID tags. Several wireless charging standards are competing for dominance, causing incompatibility across different charging solutions. Most important wireless power transfer standards are Qi set by an industry standardization body Wireless Power Consortium (WPC), and AirFuel by the AirFuel Alliance (includes Power Matter Alliance (PMA) since 2015).

Far-field power transfer techniques use radio frequencies like WiFi or 5G. There are different methods to harvest energy, for example via a separate foil or the existing antenna. An electronic sheet can charge mobile phones, laptops, and other gadgets by picking up wifi and other radio-frequency signals and turning them into power. Recent research shows that buildings could be wrapped in this type of layer, to harvest energy from ambient sources at all times.

The most significant impact of this technology is still to come. When devices can harvest energy from wireless signals, so that no battery is required, or wireless power transfer enables charging of the device throughout the day on cellular or WiFi signals, you can always use your phone or smartwatch when needed.

## Why is energy harvesting relevant to KPN?

More electronic devices are entering our daily life, phones, rechargeable headphones, and smartwatches. They have to be recharged each night or every few days. It would be valuable to take away the nuisance of having to plug in your devices time and again. Therefore, continuous charging will enable customers to enjoy their communication devices longer and allow for more use cases for low power devices.

The main advantage of energy harvesting from radio frequencies in comparison with solar, or thermal sources, is its availability in indoor environments.

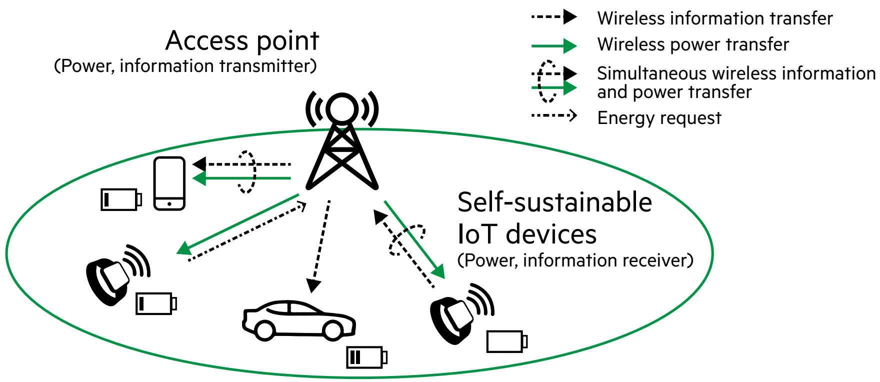
The use of edge computing can optimize wireless power transfer. Heavy computing loads can be offloaded to the edge



so that the device needs less power. When a device offloads data to edge servers, it needs to consider how much energy and time are required for transmitting the offloading of the data and receiving the computation result, compared with the required power corresponding to the local computation.

## What are the key technologies and barriers?

The concept of simultaneous wireless communication and power transfer (SWIPT) combines information transmission and power transfer via radio frequencies at the same time. The energy harvesting process may affect information transfer. Hence, the device should separate the energy harvesting and information receiving.




In general, there are three different energy harvesting architectures: (i) Harvest-Use: Energy is harvested just-in-time for use. (ii) Harvest-Store-Use: The energy is harvested when available and stored into a battery for future use. (iii) Harvest-Use-Store: Using two energy storage devices: a supercapacitor storing the harvested energy for immediate use, and a buffer saving the remaining power for later use. Research on the most optimal materials for energy storage is ongoing.

One of the key challenges is the unpredictability and uncertainty of produced electricity. In general, the level of available energy is low, variable, and unpredictable.

### Which applications are enabled by energy harvesting?

Consumers are the first to encounter energy harvesting in their life. Personal devices and wearables can already be charged via wireless charging docks, so does your voice assistant or the robotic vacuum cleaner. Also, home automation devices like smart doorbells and smart locks, which are inconvenient to power via wire, are prime areas of application. Furthermore, wirelessly charging or continuous wireless power transfer in implantable medical devices like artificial cardiac pacemakers enhance quality of life. Out of home, several solutions for wireless charging of electric vehicles are studied, so that electric car can be charged without connecting a cable to the socket.

Another application areas are sensors of various sorts and types. Sensors for environmental monitoring of indoor greenhouses for the concentration of certain gasses (pollution, agriculture). Or sensors that detect vibrations or oscillation in dikes, which are in remote locations.

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