5G:

PREPARATIONS AND OPPORTUNITIES

5G'S INFLUENCE ON ARCHITECTURES

JANUARY 2020

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Overview

5G, the fifth generation of mobile telephone standards, is replacing 4G, which is still being rolled out in France as of 2019 in addition to the existing 2G and 3G mobile networks. 2G allowed telephones to slip into people's pockets, 3G added the Internet, and 4G offered greater speed. 5G has been designed to satisfy the growing needs for ever-faster communications between individuals, but also to serve society's major economic sectors from the start. 5G allows us to connect cars, cities, and factories to the network.

5G offers several new characteristics, such as **guaranteed very-high speeds** and **low latency** that will revolutionise use cases and markets. Therefore, 5G is a technological breakthrough over previous generations. For some, this breakthrough is seen as an industrial revolution: 5G **connects several technologies** (cloud computing, artificial intelligence, IoT -Internet of things- and virtual/augmented reality) that will feed into each other to better meet customers' new expectations and future market challenges.

For the first time, there is an international standard on which everyone on every continent agrees. It will allow us to **offer seamless products and services** on a global scale by harmonising frequency bands at the international level.

5G's main objective is to **make companies more competitive** by allowing for incremental and breakthrough innovations through the development of new business models. Therefore, companies must think strategically to identify the value that 5G can bring to their business. The purpose of this report is to help employees better understand what 5G is and what its potential is so they can contribute to this strategy's development.

To get a better understanding of 5G's opportunities, companies and their ecosystems are working with carriers, co-building use cases and testing them with proofs of concept (PoCs) and proofs of value (PoVs). Businesses are building up their technical know-how so they can maximise the gains 5G offers their business. Better understanding 5G's possibilities for their businesses and identifying use cases allow businesses to guide operators and OEMs in their strategic choices (by implementing certain features in their equipment, for example) and weigh in on the standards chosen to harmonise the features they need.

IT departments have several roles to play in 5G. First, researching and testing use cases with a view to their industrialisation but also anticipating a modular architecture that will make it easier to implement them. Depending on the importance of connectivity to their businesses, companies must rethink their network strategy and decide whether to make or buy. Companies can choose to co-build new use cases with telecoms operators or to operate them themselves, either becoming a mobile virtual network operator or a mobile network operator themselves, subject to frequency ability or attribution directly to industry.

Finally, to make the most of 5G, talent in-house or in the ecosystem will make all the difference in implementing 5G and supporting its rollout.

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Introduction

The media coverage surrounding 5G remains dominated by security and geopolitical concerns (for example, the tensions between the US and China between Huawei). To a lesser extent, the media is relaying the first use cases of the 5G rollout and the experiments that major telecoms operators are conducting.

As its acronym suggests, 5G is the fifth generation of mobile telephony standards. For the first time, there is an international standard on which everyone, on every continent, agrees. It succeeds 4G, which, in 2019, was still being deployed in France and which will complement the existing 2G and 3G mobile networks. 2G allowed telephones to slip into people's pockets, 3G added the Internet, and 4G offered greater speed. Not only does 5G offer all this at a large scale, but it also allows cars, cities, and factories to connect to the network. 5G offers several new characteristics, such as **guaranteed very high speeds** and **low latency** that will revolutionise use cases and markets. (Latency refers to the time needed for the data to go from the source to the destination over the mobile network.) Therefore, 5G is a technological breakthrough over previous generations.

Some consider 5G to be a component in the 4th industrial revolution: the **cyberphysical** era. This revolution is the result of the **combination of five technological changes**: cloud computing, artificial intelligence (AI), the Internet of Things (IoT), virtual/augmented reality[1] and 5G. Today, cloud computing, AI, IoT, and virtual/augmented reality are experiencing exponential growth. **5G** will help **connect these technologies so that they can all feed into each other.**

The first industrial revolution resulted from the use of **hydraulic energy and steam**: work was no longer limited by the peoples' physical strength or endurance. The second industrial revolution began with **electricity and the division of labour**: electricity allowed people to work almost anywhere, and mass production became possible. **Electronics and information technology** made up the third industrial revolution: it became possible to offload mental labour to machines.

5G, in the same way as cloud computing, is a key issue for major corporations. Therefore, employees must understand 5G and the opportunities it offers to be able to take advantage of it, both internally and within their ecosystem (suppliers, clients, sellers, etc.). They will then have a basis to improve use cases and processes or co-build new business models to meet customer needs more fully. The intrinsic qualities of this new technology will also help reduce businesses' operating costs.

[1] Virtual reality refers to any technology that immerses its user in a computer-generated environment. The environment can be a reproduction of something real or imagined.
Augmented (or mixed) reality is a combination of real-world and virtual objects.
Source: Immersion

Introduction

The goal of this report, a summary Cigref's working group "Influence of 5G on architecture", is to explain 5G to all employees. First, this report defines what the 5G network is, then studies how this network is key for major corporations. It identifies 5G's breakthroughs and opportunities. Finally, this report studies how IT departments are preparing to implement 5G and anticipating its impact on companies' architectures to be able to implement use cases and new business models within the allotted time.

1 · What is 5G?

1.1 Characteristics and use cases

5G is a new mobile telephony network that is separate from those already deployed such as 2G, 3G, or the 4G currently being rolled out. Whatever the generation, a mobile telephony network breaks down into two parts: the **radio part**, also called **radio access**, and the **core network part**. The radio part allows smartphones, connected objects, and such to connect to the mobile network by radio using radio waves transmitted over the air on a frequency within the band of frequencies allocated to this use.

The new 5G standard brings greater **speeds** than 4G, speeds which can be **guaranteed** (4G only guarantees a maximum possible speed), as well as a **latency that is much lower** than what is currently possible. 5G also brings other gains in performance. Eight performance indicators listed in the IMT-2020[2] were established by the International Telecommunication Union[3] (ITU) to specify, quantify, and measure the characteristics of a 5G network. Below, you will find the table with this information, comparing it to the performances of 4G. You can see that the speeds experienced by users are 10 times greater in 5G than in 4G. Maximum speeds reach 1 Gbit/s for 5G, but 20 Gbit/s for 5G. Communications are supported for movement at speeds of up to 350 km/h for 4G and up to 500 km/h for 5G. 5G also allows up to 10 times more objects to be connected than 4G.

Performance/Generation	4G	5G
Maximal throughput (Gbit/s)	1	20
User previewed throughput	10	100
Spectrum efficiency	1x	3x
Speed (km/h)	350	500
Latency (ms)	10	1
Number of objects connected to a zone (quantity of objects per km2)	10^5	10^6
Network energy efficiency	1x	100x
Throughput on a zone (Mbits/s/m2)	0,1	10

Figure 1: The eight 5G performance indicators established by the ITU - IMT-2020

5G was designed to meet a certain number of companies' and the wider public's needs, which were divided into the use cases listed below:

- ***Broadband access everywhere***: (>50 Mbit/s everywhere);
- ***Broadband access in dense areas***;

[2] IMT-2020 are requirements published by the ITU radiocommunication sector for 5G networks, devices, and services.

[3] ITU: International Telecommunication Union - https://www.itu.int/en/about/Pages/default.aspx. The ITU is the United Nations specialist institution for information and communication technologies (ICT). Founded in 1865 to facilitate international connectivity among communication networks, ITU assigns radioelectric frequencies and satellite orbits around the world, drafts technical standards that provide for a harmonious interconnection of networks and technologies, and seeks to improve access to ICTs for underserved communities worldwide.

- ***Higher user mobility***: broadband access when moving at high speeds (in trains, for example),
- ***Massive internet of things***: able to manage a large number of connected objects;
- ***Extreme real-time communications***: real-time communications that require low latency to ensure a quick response;
- ***Lifeline communications***: survival communications during natural disasters;
- ***Ultra-reliable communications***: applications that require very high reliability such as medical or industrial applications;
- ***Broadcast-like services***: a network for broadcast services.

The network's performance needs depend on the use cases: a single solution will not satisfy the most extreme needs at the same time. Nonetheless, several use cases can be active simultaneously. 5G stands out in that it seeks to integrate an unprecedented **number of use cases** by design.

5G's performances offer the perspective of new uses in many domains, which constitute breakthroughs in themselves. They are summarised in the image below according to their needs in latency and speed. 360-degree video, also called immersive video, is a video recording of a real-world scene where the image is recorded in all directions at the same time. These video recordings are created with a device commonly referred to as a 360° camera. 360° video and 4K TV require very high speeds. Virtual/augmented reality requires not only very high speeds, but low latency as well to be able to respond in real time. Smart cities use connected objects that sometimes require fast response times. Autonomous driving also requires low latency. Obtaining data stored in the cloud requires a fast response time. Robotics, and connected factories more generally, require low latency with speeds that adapt to the use case. However, sensors used in agriculture and the environment do not require either high speeds or low latency.

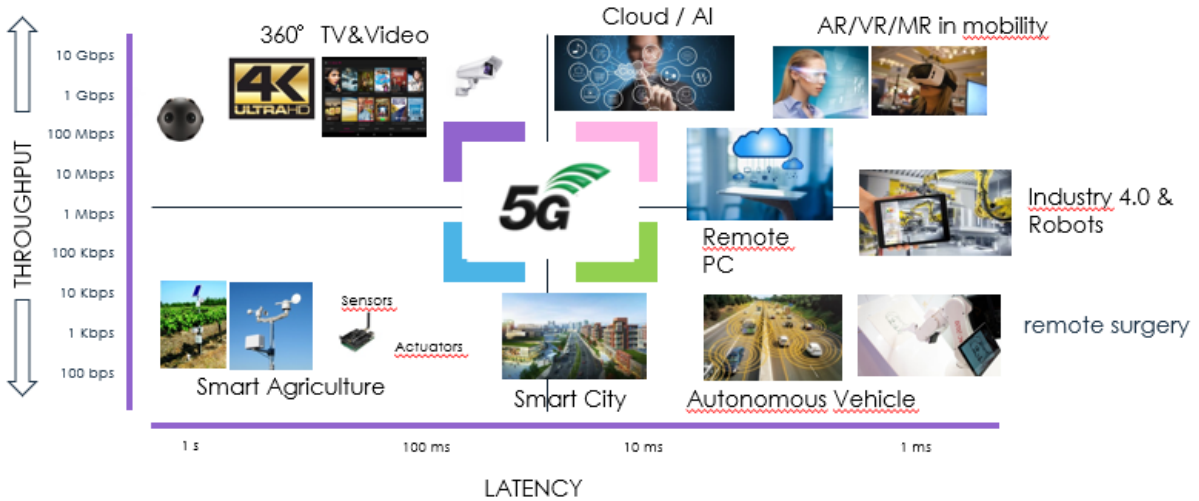
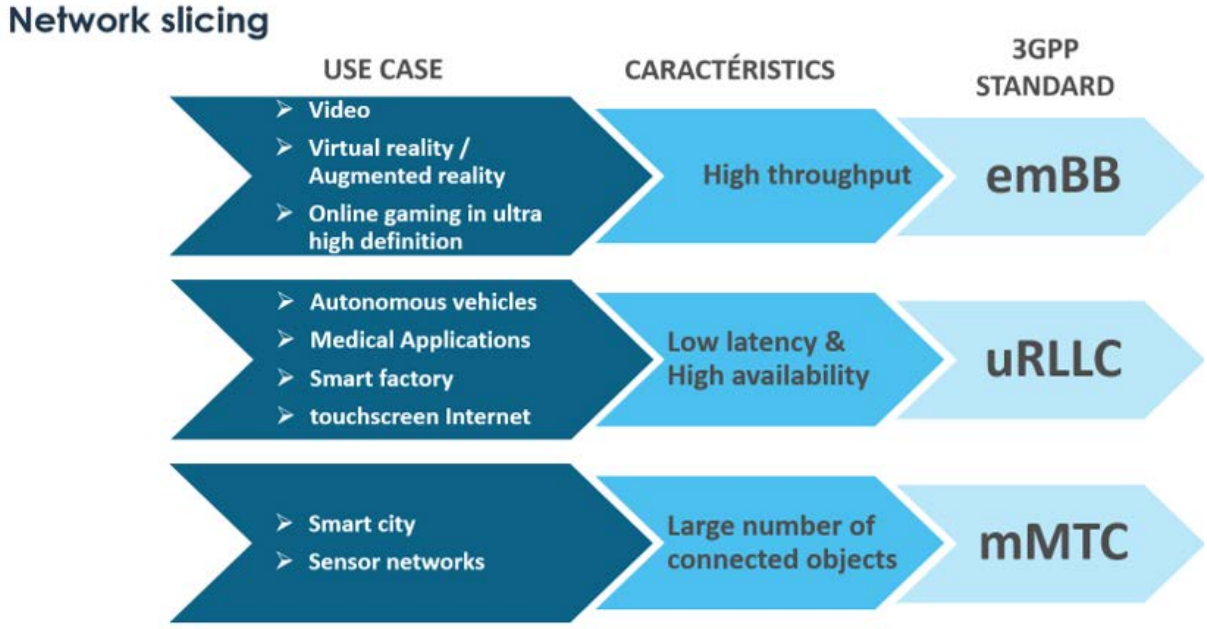


Figure 2: Perspectives for new use cases in 5G

The cornerstone of 5G is called *network slicing*, which is a mechanism that defines a performance envelope, called a *slice*. Thanks to the *network slicing* mechanism, **multiple service networks** can be configured **on the same infrastructure** to each meet a particular set of needs with specific communications characteristics. ITU has defined **three categories of use cases** which have been

standardised into the 3GPP standards[4]. These three categories are specified by 5G's three generic slices (performance envelopes):

- Enhanced Mobile Broadband (eMBB);
- Ultra-Reliable Low Latency Communications (uRLLC);
- The ability to serve a large number of objects at the same time with Massive Machine Type Communications (mMTC).



Source: Cigref

Figure 3: 5G's standardised slices, characteristics, and use cases

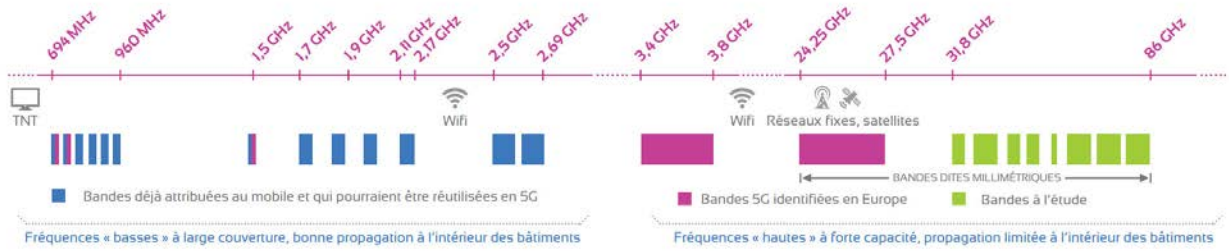
1.2 The radio part

The radio connection of the device (smartphone, connected object, etc.) to the mobile telephony network is made by radio waves that are emitted into the air at one of the frequencies in the 5G frequency band. The radio part includes everything that is needed to establish this connection.

1.2.1 Band of frequencies

5G will be rolled out over the same frequencies as 4G as well as at higher bands than 4G, i.e. 3.4-3.8 GHz and 26 GHz. The diagram below shows the frequencies already assigned in blue and those that will be assigned in pink on the radioelectric spectrum.

[4] 3GPP, *3rd Generation Partnership Project,* is a partnership between telecommunication standards organisations such as ITU (International Telecommunication Union), ETSI (Europe), ARIB/TTC (Japan), CCSA (China), ATIS (North America) and TTA (South Korea). It produces and publishes the technical specifications for the various generations of mobile networks.



Source: ANFR

Figure 4: 5G frequency bands

In the first half of 2020, the French government will assign the frequencies in the **3.4 - 3.8 GHz band**. Identified in Europe as the "**core band**" for 5G, its physical properties and amount of available frequencies offer a compromise between coverage and speed. This core band will be supplemented by other bands with other properties that will all contribute to realising 5G's full potential. The 700 MHz band, already assigned to carriers in metropolitan France at the end of 2015, has been identified, as has the **26 GHz band**, also called the **millimetre frequency band** and which will be assigned later. The latter range will allow for very high speeds for small cells (with a small radio coverage size as the radio range is short).

The diagram below shows some of the physical properties of the various frequencies.

	Indoor wave penetration	Range	Throughput
700 MHz bandwidth	++	++	
3400-3800 MHz bandwith	-	+	+
26 GHz bandwidth	--	--	++

Source: Arcep

Figure 5: Some of the physical properties of 5G frequency bands

One of the innovations of 5G consists in using wider frequency bands (spectrum widths well above 20 MHz), as these frequencies are available in bands higher than 4G.

For the first time, 5G is an **international standard** on which **everyone, on every continent, agrees**. For example, an aircraft manufacturer that offers downloads of flight data via 5G upon arrival wants to be able to use the same frequencies wherever the airport might be in the world. It is an undeniable advantage in **offering a seamless product or service on a global scale or for new use cases**. The radioelectric spectrum frequency bands allocated to 5G are quite consistent and similar around the world. However, the use conditions of certain frequency bands may differ from one country to another, which may increase complexity for manufacturers who choose to become their own mobile network operator on a global scale.

1.2.2 Radio technology reminders

While the standardisation of the radio part in the previous 3GPP[5] standards was fully rehauled every ten years for 2G, 3G, and 4G, this is not the case for 5G. 5G radio access can be considered as a significant evolution of the 4G radio access based on OFDM (*Orthogonal Frequency-Division Multiplexing*), beamforming, and MIMO (*Multiple-Input Multiple-Output*) that takes advantage of 10 years of additional technological change. Here is a reminder of a few concepts of radio:

OFDM

OFDM (*Orthogonal Frequency-Division Multiplexing*) is a process for encoding digital data by dividing it into orthogonal frequency in the form of multiple sub-carriers. This technology has been widely adopted in most very-high-speed applications.

Beamforming

Beamforming is used to create very focused beams that are directed towards the devices which use the energy more efficiently. More specifically, focusing the beam during transmission concentrates the energy emitted by the radio channel towards a specific receiver. By adjusting the phase and amplitude of the transmitted signals, you can obtain a constructive addition of the corresponding signals at the device or smartphone's receiver, which increases the power of the signal received and, thus, the speed for the final user. In the same way, during reception, beamforming allows the energy of a specific emitter's signal to be collected.

***Massive* MIMO**

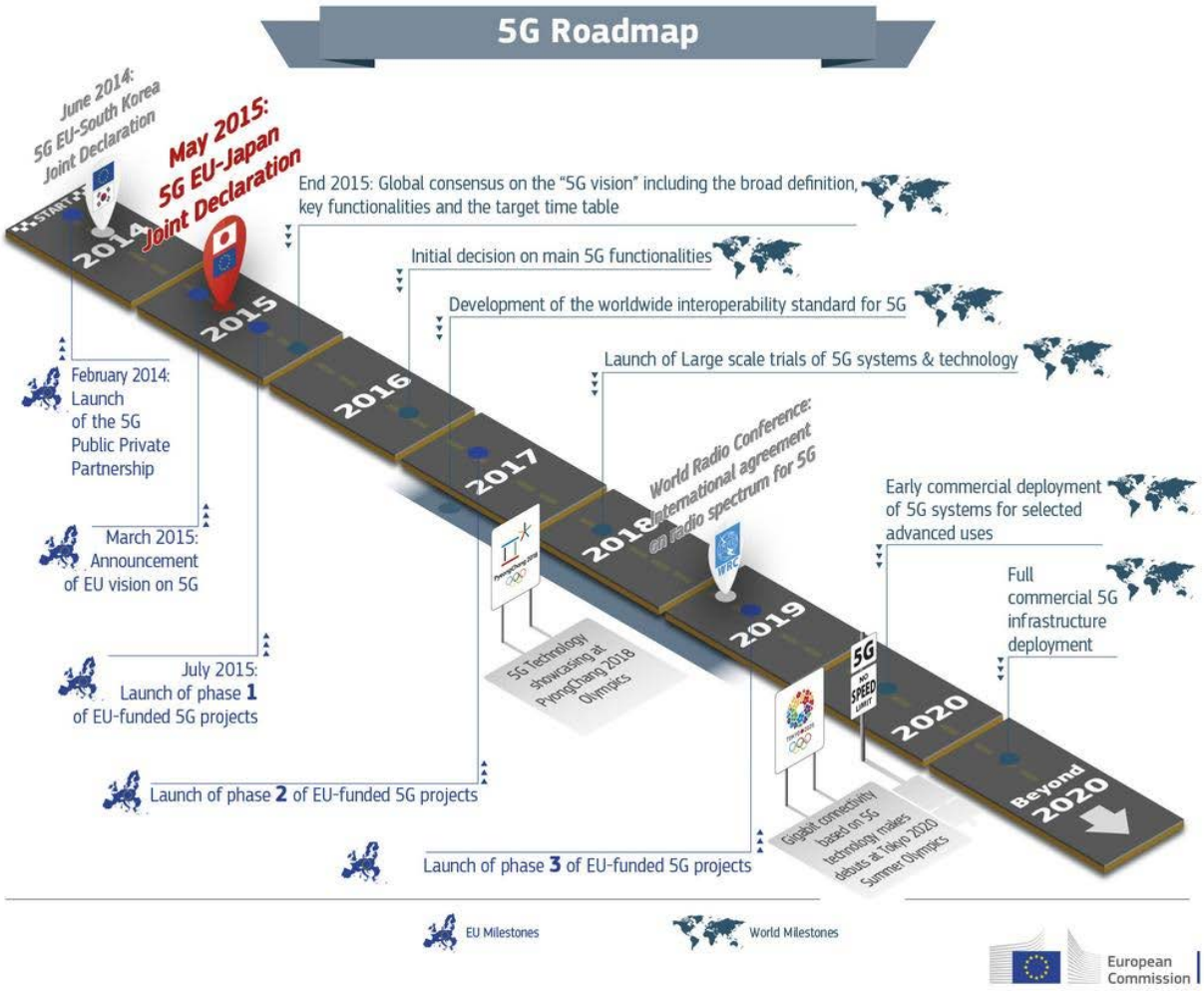
MIMO technology is already present in 3G and 4G. In 5G, this technology has evolved (massive MIMO technology) and consists in deploying new types of antennae made up of hundreds of miniaturised emitter-receivers that are able to reach high speeds with a large transmission capacity by creating, orienting, and controlling focused beams of radio waves (beamforming). The various channels or connections that use several bands of frequencies conjointly allow more data to be sent and received simultaneously, which optimises radio transmission between the various antennae emitters and their respective targets (the device, smartphone, etc.) and limits interference.

1.3 5G rollout schedule in Europe

In September 2016, the European Commission had presented the 5G action plan: the common European schedule plans for a coordinated market launch of 5G services in 2020 with 5G coverage in one large city per Member State in 2020 and all urban areas and key traffic routes in 2025. The action plan also lays out collaboration between the Member States and players in the sector to harmonise the frequencies on the radioelectric spectrum for 5G, organise pan-European 5G trials starting in 2018,

[5] 3GPP produces and publishes the technical specifications for mobile networks.

promote common 5G standards worldwide, and incentivise the adoption of national roadmaps for deploying 5G in all EU countries.



Source: Arcep

Figure 6: The European Commission's 5G action plan

2 · Why is 5G key for companies?

From the start, 5G was designed with the idea of serving the major economic sectors in society in addition to meeting individuals' communication needs in voice and data services. First, this chapter presents how the 5G standard stimulates innovation. The various breakthroughs of 5G are then listed with a focus on two technological breakthroughs in tailor-made connectivity, which is of major interest to businesses. The new connectivity services can be co-built with operators or internalised by transforming the company into an internal MNO[6]. It is strategic for companies to actively participate in the 3GPP standardisation of 5G to obtain the full benefits of it.

2.1 Stimulating innovation and co-innovation

Companies are reviewing the entire value chain of their data considering the new possibilities offered by 5G to improve or even create new business models. The 5G standard's main objective is to **make companies more competitive** by stimulating **incremental and breakthrough innovations** through the **development of new business models** and **reducing operating costs**. 5G has the potential to improve processes, customer relationships, and the user experience as well as enhance existing business products or services. 5G offers even more possibilities for incremental or breakthrough innovations when combined with various technologies such as cloud computing, virtual, augmented and mixed reality, artificial intelligence, IoT, etc.

Companies need to think strategically to identify the value this new network will have for their business and processes.

In 2012, France Télévisions closely followed the initial studies into the definition of the future generation of the mobile network, which was already called 5G. France Télévisions has public service missions to inform, educate, and entertain. Its ambition is to reach all audiences in all circumstances of consumption. The growth in mobile devices, and tablets and smartphones in particular, has led to new ways of consuming audiovisual content for which France Télévisions has a duty to provide an appropriate response. France Télévisions takes care to ensure a quality experience for all viewers and is working to reach each user of the public service directly, without intermediaries. That is why the company began its reflections on 5G very early, so that this new generation of the mobile network can meet the challenges of public service. In partnership with Syradel, France Télévisions tried to imagine what the networks in the future could be, much more than an evolution of current mobile networks. This video[7] is an illustration of the fruits of this study; it presents the various use cases that it imagined.

Véronique Demilly, France Télévisions

[6] An MNO (Mobile Network Operator) is an operator that owns a mobile network.
[7] "*A day in 2025 - Smart Networks for better services*": https://www.youtube.com/watch?v=4oRpGRPhomk

To take advantage of the perspectives opened up by 5G, the participants in the Cigref working group "Influence of 5G on architecture" invite companies **to join forces with partners within or outside their ecosystem to study together the scope of possible incremental innovations or disruptions in their direct or adjacent businesses**. Co-innovation also occurs through partnerships between businesses and public organisations with needs that are not addressed or satisfied by operators.

2.2 Breakthroughs made by 5G

2.2.1 Instant exchanges

5G offers **real-time connectivity**. Digital technology allows data to be directly and massively collected, processed, transformed, and stored to have complete, coherent, relevant, consolidated, real-time information about customers or users and their transactions. Today, manufacturers are joining forces with partners in their ecosystem (suppliers, clients, vendors, etc.) to work and co-innovate on the real-time aspect and the massification of connected objects to create the interactions in their respective factories.

> 5G has considerable potential in the aviation sector and will profoundly change professions and working methods. For example, 5G will allow various types of airport vehicles to be autonomous in the medium term: runway vehicles, passenger transport buses, even the planes themselves during the driving phases. They will also allow surveillance drones to be used, devices to be maintained using augmented reality, and even behavioural analyses of crowds to be performed. 5G will optimise airport management processes, whether in operational security, aircraft turnover, or visitor capacity. In an environment of ever-increasing competition between airports around the world, the potential for innovation that 5G brings will represent sizeable strengths for the players that adopt this technology.
>
> **Eric Barnier, Groupe ADP**

2.2.2 Respect for the environment

5G uses ten times less energy than 4G for the same amount of data transported.[8] More globally, the 5G network addresses **environmental concerns** with a strong potential to save energy and better control the spread of waves. The various 5G radio technologies help reduce the **energy consumption of the network and devices** (high energy efficiency). The fact that 5G is a focusing, not diffusing, technology avoids inundating the surrounding space with electromagnetic waves, helping to better control their effects on individuals.

[8] Franck Bouétard, CEO of Ericsson. Source: Le Figaro article of 3/10/2019 (in French) https://www.lefigaro.fr/secteur/high-tech/l-attribution-des-frequences-5g-prend-encore-du-retard-en-france-20191003

Source: Orange

Figure 7: Radio transmission of 4G antennae and 5G antennae: a focusing vs diffusing radio solution

However, we must make sure that beamforming's concentration of waves does not subject an individual located at the concentration point to an unacceptable SAR.[9]

2.2.3 Network convergence

First, 5G will supplement the various 2G, 3G, and 4G networks, not replace them. It improves the offer to the wider public as 2G, 3G, and 4G did before it. Once the features are available on the market, 5G will allow the radio-mobile, wired, long-range for IoT and Wi-Fi **networks to converge** by offering a standard to all kinds of use cases. Nevertheless, the existing networks are evolving (for example, the arrival of Wi-Fi 6 in 2019), and replacing them with 5G will only happen if the company finds real value in it.

2.2.4 A breakthrough in IT architectures

5G also offers another major breakthrough in **architecture**. 5G is revolutionising the mobile world just as cloud computing revolutionised company networks. Remember, cloud computing decorrelated data storage and application processing by making them available to everyone everywhere, with no limits to location, means, or storage. The 5G infrastructure will become extremely malleable once the core network switches to Stand Alone mode (specified in release 15 already published): the infrastructure can be configured on the bases of the needs of the service put on the market and to offer connected, customisable products and services. This flexibility will be possible using two new key services for businesses: **network virtualisation** and **slicing** (performance envelope).

5G also meets needs for **occasional connectivity**. This is the case when a company wants to create pop-up stores or temporary events that last a short period of time. For example, 5G's modular connectivity will be beneficial to factories where several assembly lines could possibly be used, depending on their orders.

[9] SAR, or Specific Absorption Rate, is an index that indicates the power of a flow of energy carried by radio waves that is absorbed by the user of a radioelectric device (a mobile telephone, for example) when it is operating at full power and in the worst operating conditions. Source: Wikipedia.

2.3 Connectivity that dynamically adapts to the use case

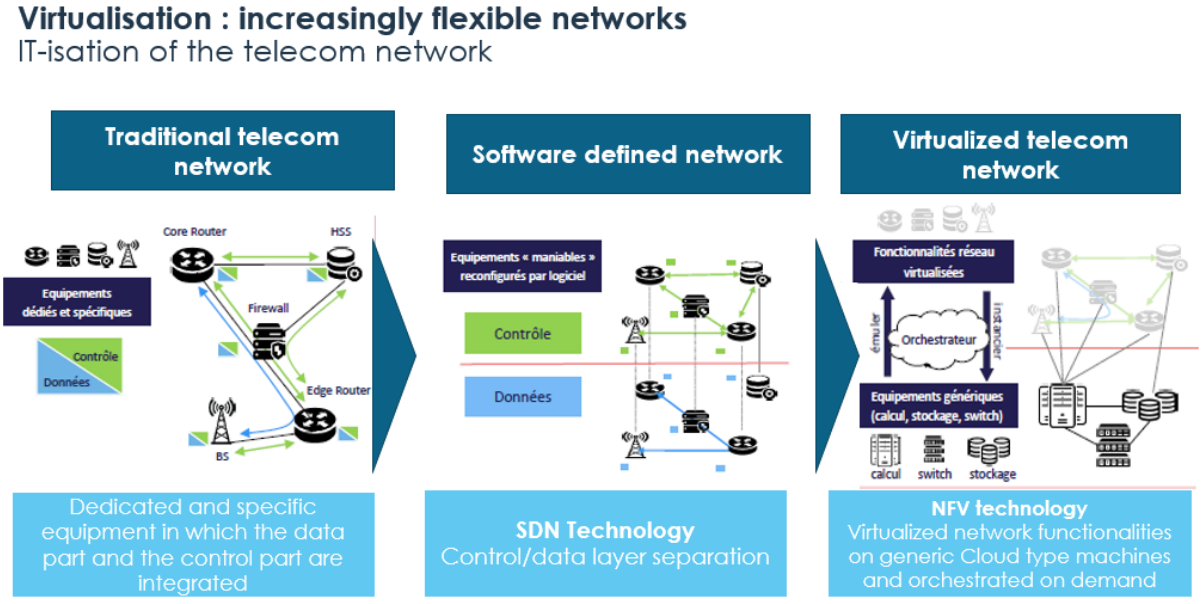
2.3.1 Core network virtualisation

Enterprise networks are already experiencing several major technological evolutions that are well underway to which 5G will add a new telecommunication dimension. The first evolution is the **reconfiguration of the telecom network by software**. This consists in separating the control layer (programmed by software) from the data layer that allows for automation thanks to SDN (Software-Defined Network) technology. This technology centralises the network's intelligence in a controller to simplify the equipment deployed by offloading "smart" functions that were historically distributed and replicated on each of them. SDN technology allows resources to be used optimally, maximise performance, and simplify network administration by automating them.

A second technological evolution is NFV technology (Network Function Virtualization) on generic cloud-computing machines (calculators, switches, storage, etc.) configured on demand.

Starting in 2021, this type of equipment can be used to separate the 5G infrastructure from the logical network (the software function), unlike the 4G network which is always monolithic. Virtualisation ensures that the network is flexible and adjusts to the function of the request. This generates Capex[10] and Opex[11] savings for operators and facilitates the service's lifecycle management (a service-on-demand offer), interoperability between players, and a reduction in time to market.

The diagram below illustrates these two evolutions of the telecom network.



Source: Arcep

Figure 8: Switching from a traditional telecom network to a network reconfigured by software then virtualised

[10] CAPEX, or capital expenditure, refers to capital assets, i.e. expenses that have a positive value over the long term.

[11] OPEX, or operational expenditure, is the current expense of operating a product, business, or system.

In early 2019, Rakuten, Inc., a global leader in internet services and soon to be a mobile network operator in Japan, jointly announced the creation of the first virtualised small cell in the world with Sercomm, the leader in manufacturing and distributing telecommunication equipment. This 5G micro-network, which has the size of a cell, improves the user experience by leveraging the first end-to-end cloud-native technology.

Being able to deploy a totally virtualised mobile network allows the network to be optimised and avoids oversizing the network to handle peak usage. Virtualisation allows you to match the installed capacity to its effective use as closely as possible (for example, the backbone usage rate at Google vs. traditional, standard non-virtualised telecoms operators). With virtualisation, a certain number of operations will be administered from a control centre, and the model of the operator who sends technicians to the site will be less and less necessary.

2.3.2 Network slicing

One of 5G's greatest breakthroughs is slicing the network to adjust the size of mobile connectivity to the needs of a use case or a type of application. Network slicing consists in slicing the network into several **logical networks custom-made for different services**, called virtual slices. Each of these slices can be configured to the use case that it supports to deliver a suitable level of performance in terms of reliability, latency, bandwidth capacity, coverage, etc. For example, one slice can control robots in the mining industry, another for autonomous vehicles. The operator must ensure that it respects all the commitments made for each slice of its network. Slices share common resources: network transport capacity, calculation capacity, storage capacity, the antennae and radio spectrum that the operator uses.

The network slice segmentation can be:

- **Vertical** focused on the type of industry or field of activity;
- **Horizontal** focused on the user, device, or application and intended to serve a variety of use cases (mass market).

Static slices consist of fixed and stable slices (scope and parameters), generally for machine-to-machine and IoT use cases. **Dynamic slices** offer a scalable approach to create and manage the slice in real time. This type of slice can be used in a factory when manufacturing a product. The manufacturing process can require a variable speed throughout its completion. Finally, **isolated slices** and **joined/overlapping slices** allow network features to be used in a dedicated or shared way. How these different types of slices are made available depends on the willingness of the mobile operators allocating the frequencies and/or the architects of the future network infrastructure. It would be desirable for the regulations to specify the conditions of accessing these slices.

The standards propose three generic slices—eMBB, URLLC, and mMTC—seen previously. Whether the generic slices or custom ones are made available depends on the one hand on the capacities of the

devices and the core network equipment, and whether operators choose to implement them, on the other. Private enterprise networks could enjoy a secondary slice market configured according to clients' needs by resellers as long as Arcep[12] allows such a market and the operator makes it possible. This market, linked to network slicing, would make it easier for verticals, MVNOs[13] (Mobile Virtual Network Operators), and other service providers to enter it, which would stimulate the ecosystem.

The evolution of telecom operators' business function

With the standardisation of hardware, telecom operators became IT suppliers. The possibilities offered by network slicing and virtualisation will contribute to changing the value chain, calling into question the telecom operators' business function. According to Stéphane Richard, CEO of Orange, 5G introduces a change to the business model with the development of partnerships where each partner contributes its expertise. Therefore, operators and/or OEMs are considering switching from a supplier mode to a partner mode. During its presentation to Cigref, Verizon insisted on the fact that they were looking for partners to co-innovate, not consultants.

> Convinced of the importance of working together to innovate, Verizon has created the "ALLEY" community to build the 5G ecosystem. This community is made up of start-up incubators, entrepreneurs, universities, strategic R&D partners, and clients who can help them as partners. This way, they can benefit from the talent and expertise of local industries who, by connecting with each other, can amplify the results. These communities are spread over four sites in the USA, and one site in Europe in Cambridge, each covering themes related to the local ecosystem. These sites' objective is to develop ideas locally, implement them, and use the ecosystem's lever effect.
>
> **Toby Redshaw, Verizon**

Thanks to experiments and co-innovation, operators have advantages in anticipating large companies' needs and of sizing the network in consequence.

2.4 Private enterprise network

To implement 5G's use cases, companies can choose to make or buy their mobile connectivity. In other words, companies have the possibility of either collaborating with operators or internalising the private enterprise network.

[12] Created in 1997, French telecom regulator ARCEP (*Autorité de Régulation des Communications Electroniques et des Postes*) acts on behalf of the government while remaining an independent administrative authority. With around 160 people, ARCEP was created to support opening the telecommunications sector to competition, and it regulates electronic and postal communications.

[13] An MVNO (Mobile Virtual Network Operator) is a mobile telephony operator that does not own a license for a frequency spectrum nor its own network infrastructure, instead contracting with mobile operators with a mobile network (known as an MNO, Mobile Network Operator) to buy a usage package of their radio network to resell it to clients under their own brand. Source Wikipedia.

Network slicing features are key to the success of 5G as a private enterprise network: in an airport context, they will allow critical use cases (police, fire brigade, snow ploughing, security, passenger inspections, etc.) to cohabit with standard use cases. However, to prepare for slicing's availability, it is essential to **develop private mobile networks right now** that are able to respond to real needs in normal and crisis management situations: runway vehicle crash prevention, downloading of plane data upon landing for immediate maintenance, forwarding video to various control centres, etc. In this context, private 4G LTE technology can already be used to replace and expand the scope of ageing (for example, Tetra, DECT) or unsuitable (Wi-Fi) technology. These professional 4G networks must be operated by trusted third parties in line with the criticality of their mission. In this context, Groupe ADP, through its subsidiary Hub One, decided to speed up the development of the 'Smart Airport' by deploying a private 4G LTE network at Paris's airports to provide efficient and secure coverage to the 1,000 companies and 120,000 professionals who are based there.

Grégoire de La Crouée – Hub One, Groupe ADP

The decision to work with operators or internalise the private enterprise network will depend on the methods with which frequencies are allocated: they are decided at the national level and differ from one country to another. Frequencies can be:

- **licensed**, similar to what is done for 2G, 3G, and 4G network frequencies;
- **Licensed Shared Access** (LSA). LSA allows them to use a band that has already been allocated 'under an exclusive license regime' to one or more initial users (*incumbents*). In short, new users are given a permission on frequencies that remain allocated to another with the explicit condition to not disturb it: the new arrival must respect specific rules that guarantee that the incumbent's services will not be degraded. In Europe, the 2.3 GHz band quickly became the first candidate band for LSA experimentation;
- **Unlicensed,** like Wi-fi.

The table below illustrates the types of frequency band allocations chosen by a few countries.

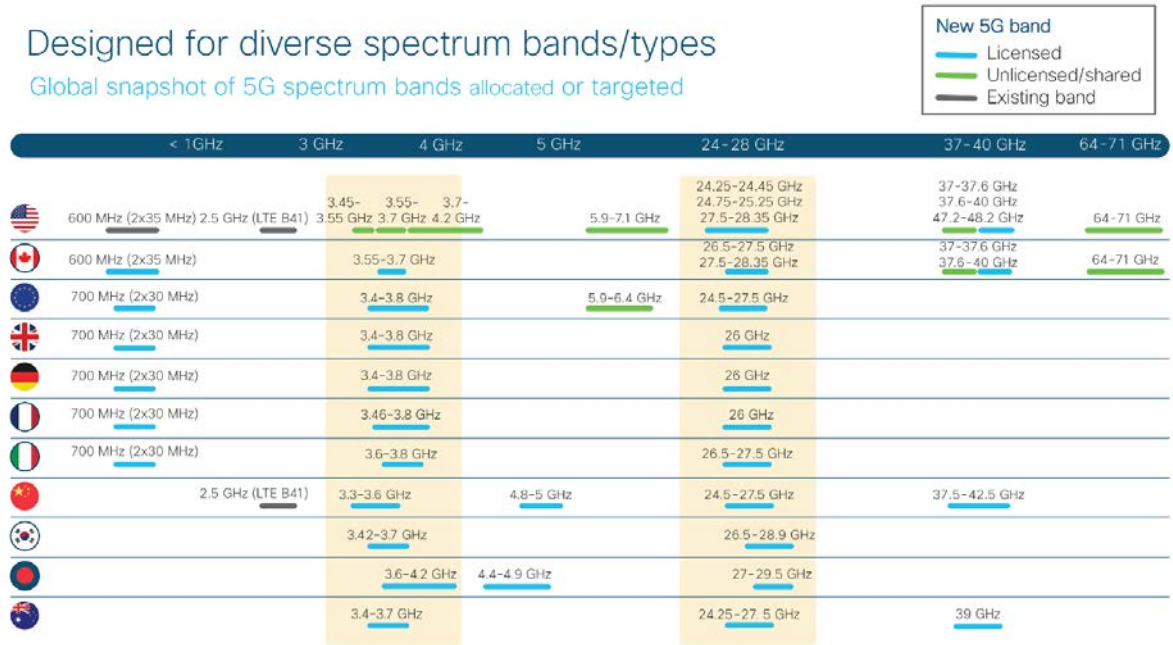


Figure 9: A sample of spectrum allocation in 2019 by country

Companies and government institutions are working together in associations to study the desirability of operating their own private network if operators do not fulfil or insufficiently cover their needs.

By undertaking to listen to and analyse business units' needs very early, Air France KLM identified needs similar to other verticals and worked with them to create AGURRE and defend their interests. AGURRE influenced, and continues to influence, Arcep as well as device suppliers, integrators, etc. This foresight allowed them to take into account 3GPP's standardisation, regulation, and decision-making cycles. PoCs (Proofs of Concept) in real situations were experimented.

Christian Régnier – Air France KLM

AGURRE (*Association des Grands Utilisateurs de Réseaux Radio d'Exploitation*, Association of Heavy Users of Operational Radio Networks), founded in 2012, currently brings together 13 key economic players in the transport, energy, and industrial sectors as well as a federation of local authorities impacted by the evolution of professional use cases toward mobile broadband. It coordinates the presentation of its members' needs and positions to public authorities in terms of the evolution toward mobile broadband.

AGURRE's missions are as follows:

- Federate users' needs regarding the evolution of professional mobile networks (often called PMR for Private Mobile Telecommunication);
- Encourages pooling expertise and sharing evolution strategies;
- Encourage conducting complementary experiments related to radio technologies and frequencies for critical communications and sharing feedback;
- Promote the needs for frequency to public authorities in a coordinated way. For example, AGURRE regularly contributes to public consultations conducted by ARCEP, ANFR, and companies' general management and presents the consolidated needs and positions of its members;
- Monitor technology news and guide manufacturers in developing solutions (infrastructure and devices).

AGURRE

To meet professionals' needs for very-high-speed coverage, ARCEP opened an office to **allocate the frequencies** 2575 - 2615 MHz of the 2.6 GHz RDD band, subject to availability, in the limited areas of metropolitan France where specific mobile coverage is required. These frequencies were considered to be very useful for revealing new use cases with equipment that was already available and proven.

Then, during its public consultation in late 2018, ARCEP noticed a demand from companies for spectrum in the 3.4 -3.8 GHz band. It submitted a draft decision proposing the methods for allocating this band in France, which was completed in September 2019. The interested companies and stakeholders were invited to submit their comments on these documents and to reply to several questions. This underscores the **importance** for companies who wish to operate their own 5G network of **preparing their request for frequencies from ARCEP very far in advance**.

2.5 Companies' participation in standardisation

5G services are defined using the scale of the 3GPP standards on which telecom operators and OEMs weigh as active members. The 3GPP standard is steered by their needs in speeds, capacity, mobility, roaming (from one operator to another or one country to another), protocols, and interoperable interfaces. In the same way, companies must participate actively in the standardisation of 5G to take full advantage of the possibilities that 5G offers them.

3GPP's release (version) 15, currently being rolled out, is the first to specify 5G. It responds to the public's expectations, i.e. a faster connection with high bandwidth: it will support the use cases expected for the enhanced Mobile BroadBand (eMBB) slice.

Releases are published every 18 months or so. Today, the standardisation of release 16 is expected for mid-to-late 2020. This will be the first release version to cover the three main use cases (eMBB, uRLLC, mMTC). This release, and release 17, will cover enterprise services such as smart factories, smart cities, smart homes, etc. Therefore, it is very important that businesses consolidate their use case needs and share them during standardisation to be able to put their business models into place in an efficient manner. However, for requests to be considered, **companies must participate regularly over the long term in standardisation by becoming an active member**. Therefore, in certain sectors, players (verticals or ecosystems) are organising into associations to give an exhaustive view of their prerequisites to weigh on standardisation. For example, this is the case of the 5G Alliance for Connected Industries and Automation[14] and the 5G – Media Action Group[15] presented briefly in the annex. There are other types of associations as well, for example the 5G -Infrastructure Association[16] whose objectives are to speak up for Europe on various continents and to provide leadership in 5G's development and evolution by facilitating the convergence of telecommunications and vertical industrial sectors to create a 5G ecosystem at a European scale with the support of the European Union.

Nevertheless, standardisation does not guarantee the availability of equipment and/or devices. Just because features are standardised does not guarantee that OEMs and/or device manufacturers will implement them. **Only the business model's benefits encourage OEMs to implement features**.

[14] The 5G-ACIA organisation promotes the use of 5G in the industrial production sector and is putting all its weight behind making this radio technology suitable for industry's needs from the start.

[15] In the media sector, the European Broadcasting Union (EBU) has worked with 3GPP for several years so that the audiovisual sector's needs are taken into account in mobile networks' specifications. However, this move to standardise is not enough to give birth to a complete ecosystem for mobile media. At EBU's initiative, 5G-MAG was created in September 2019 to bring in the work of players who are not members of the EBU.

[16] 5G-IA is an association with over 70 members: telecom companies—operators and manufacturers—universities and research institutions as well as a few vertical industrial sectors, Airbus, Thalès, etc. and, finally, European small and medium businesses.

3 · How can companies and IT prepare for 5G?

Companies are studying their network strategy in light of 5G's features and availability. Right now, they are looking into their business line, IT, and connectivity needs and testing the use cases that meet them in Proofs of Concept (PoCs) and Proofs of Value (PoVs). This is the subject of the first part of this chapter. The second part expands on how to prepare for 5G in enterprise architecture.

3.1 By shaping the network strategy with 5G's possibilities

Business units' digitalisation projects have significantly grown overall in the past few years, with connectivity resources that have not changed much in the same span of time and which are neither reliable nor homogeneous throughout the workspace, such as Wi-Fi. Radio networks, where they exist, often only concern voice communication, whereas the business units are expressing a growing need for mobile videos and photos. The IT department has a role to play in the overall thinking about the company's connectivity strategy and in the possibilities 5G can offer combined with other technologies. For this, IT departments must analyse them or co-build them with the business units and, more generally, with the company's ecosystem. The objective is to confirm the use cases' merits and value and specify their benefits and any eventual limits.

For its part, IT departments are looking to contain costs while seeking to control engineering, operations, and connectivity. IT departments are also looking to offer a flexible infrastructure to meet current and future operational needs (voice, data, video, IoT, 5G). For example, offering a single network for voice, video, and data would simplify companies' connectivity.

Whether at the end of a contract, when revising existing contracts, or planning for future needs (such as supplying a 5G-ready factory or building), 5G should be included when studying the technical impact on existing systems and evaluate new opportunities with calls for information or bids. It is also time to identify alternative operators and their business models.

3.2 By participating in experiments or PoCs

From the start, operators have followed Verizon's example in participating in the 5G marathon through experiments to learn by doing and **acquire technical know-how with a greater impact on their business.** The working group's participants insist on the **importance of the experience gained from experiments**, PoCs, or PoVs **in real-life situations** to better grasp the range of possibilities, improve use cases, and find new business models.

Additionally, companies use PoCs to build a global **communications plan**, both in-house and out. A PoC is an **opportunity to demonstrate real business line needs to the device-supplier, operator, and integrator ecosystem.**

Air France needed rugged 4G-compatible devices that had been unavailable previously. During its experiment on the new spectrum made available to companies, Air France KLM, with the help of AGURRE, made this need known and invited manufacturers to its experiments. They were able to measure the potential number of devices necessary to meet these needs. With this data in hand, they decided to alter their production chain to meet Air France KLM's needs.

Christian Régnier - Air France KLM

In-house communication on PoCs also makes sure that employees **better understand the possibilities** that 5G offers and feeds into studies on improving use cases, processes, or new business models.

Anticipating and testing use cases also help **influence 3GPP decision-making cycles, regulations, and standards**.

Arcep has opened calls for projects in the 3.4-3.8 GHz and 26 GHz bands as well as calls to create experimentation platforms in the 26 GHz band by temporarily allocating 5G frequencies. The objective is to conduct technical tests and trials, identify new use cases, and stimulate innovation around 5G **within industrial and sectoral ecosystems or ecosystems with strong business links.** The experiments allow each of the participants **to better understand this technology and to study any potential combinations with other technologies within the wider ecosystem.** On the other hand, companies, departments, and regions in a phase of strategic reflection, are asking themselves if they want to embark on 5G without going through an operator. These platforms allow this option to be tested. These tests are also an opportunity for the government to better grasp stakeholders' interests.

3.3 By anticipating 5G's impact on architecture

Even though connectivity is growing with an increase in employee mobility, companies often are looking to reduce network budgets.

5G is a veritable connectivity toolbox: mobile and fixed telephony, internal network, machine-to-machine communication. Depending on the company's strategy, IT is called upon to prepare a programme to replace existing network in waves to take advantage of 5G. This transition must be seamless for the user. That's why some recommend **designing an architecture to offer services continuously**. Other participants mention the importance of being able to plug networks into the company's architecture for occasional temporary events.

3.3.1 Modular architecture

Today, architecture is generally evolving to become modular so as to provide the agility the market requires over time. 5G **makes network management agile** by separating the physical and virtual network, and it **makes the deployment of 5G networks agile** since the core network and access network can migrate independently, allowing for several options. For example, if the launch is made

in Non Stand Alone (NSA) mode, then 5G access is associated with a 4G access, and the 4G core network is used. This case adds capacity above and beyond 4G. If migrating to a Stand Alone (SA) mode, the 5G access is separated and connected to a new 5G core network (CN) which provides for decentralised architectures using an edge computing rationale; this opens up new use cases by optimising the spectrum efficiency (more traffic in the same place for a given frequency band - the capacity to support different qualities of service to serve different fields of activity). In the longer term, flexibility will translate into 5G's promise to **converge networks**.

3.3.2 Edge computing

Today, the core networks, and often the applications, are centralised in data centre computing (i.e. cloud computing) on the current networks. To ensure low latency, 5G, in conjunction with the trend toward application containerisation, plans for decentralised, or edge, core networks with Stand Alone 5G. In Multi-access Edge Computing, previously called Mobile Edge Computing (the ETSI[17] MEC group), Nokia and Huawei define the edge datacentre resources that follow mobiles during movement. For this, APIs (ETST specification) are used. Edge computing is made possible by the 5G architecture's virtualisation. In general, the software sector is not very standardised. The need for edge computing, which is becoming increasingly urgent with the exponential increase in data, feeds into the request to be specified in the 3GPP specifications.

3.3.3 Security

Security is managed at the global company level, and not just the 5G network, which is only one link in the chain. The company must identify security mechanisms, ensure 'security by design', and anticipate how to manage user management and authentication on the company's network by Wi-Fi, 5G, or any other network, not to mention connected objects. You should note that security is integrated natively in 5G to satisfy the prerequisites of services and applications in use cases for verticals. 5G also allows end-to-end slices to be created to guarantee service quality with the quality of the resources on the core network and radio access. For this, resources are reserved, and a redundancy and security mechanism in case of a slice-specific failure is put in place if necessary.

3.3.4 Bringing enterprise and industrial IT together

The borders between enterprise and industrial IT are already beginning to disappear. (See the Cigref report 'IT-OT convergence: a fruitful convergence of IT and operational technology systems') This is due to the need for data to be transversal and shared by all the company's business units. 5G will

[17] ETSI is a standards organisation that cooperates with other organisations (such as ITU, for example) within 3GPP. Remember, 3GPP produces and publishes the technical specifications for mobile networks.

amplify this trend by making it easier to communicate and maintain security. Deciding on the governance sometimes results in a new company organisation or, at least, defining new roles.

Icade is considering a data and network architecture attached to and located within its real-estate assets that connect IT technologies with operational systems technologies to make autonomous buildings safe and secure.
This computing object could be comprised of:

- A multitude of connected objects: simple sensors (temperature, presence) connected to the building management system and to the access control systems, for example;
- A wired and mobile connectivity layer where 5G could quickly be needed to cover users' needs, since indoor coverage is becoming a growing problem;
- A data consolidation and building intelligence layer (a Building Operation System (BOS) concept is emerging).

3.3.5 Indoor coverage

For buildings, the French HQE (*Haute Qualité Environnementale*) standard, which targets energy savings, encourages people to install windows with high thermal insulation. These windows degrade the radioelectric signals that penetrate building interiors.

In the absence of other, complementary transmission systems (for example, the distributed antenna system called DAS), indoor coverage of modern buildings is worse than outdoor coverage. However, the needs of mobile device users are no less demanding inside than outside. Furthermore, service continuity such as speeds and service quality when mobile must also be guaranteed when entering or leaving the building.

With the arrival of 5G, this problem risks becoming more significant given the frequencies used (higher, therefore less penetrating).

Preparing for the implementation of dedicated network solutions allowing for the eventual integration of 5G is one of the major challenges for the construction sector. For existing buildings, there are several solutions. That is why it is essential to take up the issue as early as possible to prepare, gather needs, and examine the various solutions to choose the best one, identifying what can be pooled in the network equipment, technical facilities, cabling paths, etc. The life of a real-estate development project is around fifteen years. The implementation and operations of mobile networks must therefore be scheduled for an equivalent timespan.

3.3.6 Required skills

The development of skills needed on 5G, particularly from an antenna and core-network point of view, requires strengthening or evolving skills in a way that will certainly be as deep as that required for virtualisation or cloud computing. IT departments must prepare for this and hire or train as a consequence.

Conclusion

5G has been designed to satisfy the growing needs for ever-faster communications between individuals, but also to serve society's major economic sectors from the start. 5G could be a failure if companies do not use it. 5G's main objective is to make companies more competitive by stimulating incremental and breakthrough innovations through the development of new business models and reducing operating costs. 5G makes it possible to combine and mix several technologies (cloud computing, IoT, AI, virtual/augmented/mixed reality) to better meet customers' new expectations and take up future market challenges.

To take advantage of the prospects of 5G, which is currently being rolled out, companies are working with their ecosystem, operators, and, sometimes, new partners to study use cases and test them with PoCs and PoVs. They are looking to acquire a technical know-how that will ensure more business impact.

IT departments have several roles to play in 5G. First, researching and testing use cases with a view to their industrialisation while anticipating a modular architecture that will make it easier to implement use cases or new lines of business. Depending on the strategic importance of connectivity, particularly locally (the 26 GHz band), companies must rethink their network strategy (decide whether to make or buy). Then, 5G's ambition is to bring together and progressively integrate the various radio, landline, long range for IoT, Wi-Fi, etc. networks to make connectivity easier.

Several challenges remain to be tackled, such as ensuring 5G's security by design, consolidating vertical needs (automobile, industry 4.0, healthcare, energy, public safety, etc.), ramp up experiments/pilot schemes between telecom players (suppliers, operators) and vertical players to build the 5G ecosystem, contributing actively to standardisation to be able to implement the features that will improve companies' performance on an international scale.

Finally, to make the most of 5G, it is talent in-house or in the ecosystem that will make all the difference in implementing 5G and supporting its rollout.

This study of 5G will be complemented by two new Cigref working groups:

- 'Networks: evolving strategies and architectures' to elaborate the possible changes to network strategies and examine the impact of new connectivity needs on architectures;
- 'Post-cloud and edge computing' to evaluate the perspectives for cloud computing's evolution and the emergence of edge computing and to identify the impacts on IT architectures.

Annex

5G-ACIA (Alliance for Connected Industries and Automation)

The 5G-ACIA organisation promotes the use of 5G in the industrial production sector and is putting all its weight behind making this radio technology suitable for industry's needs from the start. This organisation was officially created in April 2019 at the initiative of ZVEI, the powerful German union of the electric and electronics industries and its Industry 4.0 group. The new association, dominated by German companies for now, already counts 26 members, most of whom come from the traditional fields of automation and manufacturing, telecoms, operators and OEMs, as well as research. According to the members of the 5G-ACIA alliance, 5G will allow for a faster implementation of the precepts of Industry 4.0 and drive them to a higher level than was imagined a few years ago thanks to its flexibility, versatility, and mobility applied to the field of industrial production. The objective is to solve problems of interoperability between public and private networks and to define authentication in the private networks. For example, 5G-ACIA has published several *white papers* on the technical solutions that it suggests including in the standardisation. 5G-ACIA members are reflecting on their worksheet in release 17 whose standardisation works have already begun: identify a profile of devices and network for certain applications; how to optimise the lifespan of devices that are constrained by low-consumption batteries; drone management (they cannot be managed by a cellular network—other frequencies are needed); think about how to orchestrate and automate the various slices with AI and machine learning when their number is great; think about how to standardise the management and inspection interfaces and the standardisation of slices: needs for from-the-top and from-the-bottom operability (multi-operable by several operators).

5G-MAG (Media Action Group)

In the media sector, the European Broadcasting Union (EBU) has worked with 3GPP for several years so that the audiovisual sector's needs are taken into account in mobile networks' specifications. However, this standardisation action is not enough to give birth to a complete ecosystem for mobile media. At the EBU's initiative, 5G-MAG was created in September 2019 to bring in the work of players who are not members of the EBU.

The 5G Media Action Group (5G-MAG) seeks to create an operational framework to harmoniously implement 5G solutions on the market that can meet the requirements of content production and distribution and audiovisual media services. The 5G-MAG association is an interprofessional organisation that brings together stakeholders from the media sector, including content and service providers as well as network operators, providers of components and technological solutions, equipment manufacturers, R&D organisations, regulators, and political decision-makers.

5G-IA (Infrastructure Association)

There are other types of associations, such as 5G-IA, for example, whose objectives are to:

- Clearly speak for Europe on different continents;
- Provide European leadership in the development and evolution of 5G by facilitating the convergence of telecommunications and vertical industrial sectors to create a 5G ecosystem at a European scale with the support of the European Union;
- Steer the European 5G PPP (Public Private Partnership) research agenda, the implementation and evolution of the programme to maximise the impact, coordination, and exploitation of the results;
- Promote the availability of the radio spectrum and the global regulation roadmap to achieve a 5G communication standard that is harmonised and interoperable on a global scale.

5G-IA is an association with over 70 members who are telecom companies—operators and manufacturers—universities and research institutions as well as a few vertical industrial sectors, Airbus, Thalès, etc. and, finally, European small and medium businesses. The association refines its messages to convince verticals to become members and participate in 5G's development. 5G-IA is currently setting up partnerships with industrial sectors so that a maximum number of them can be represented.

Achieving digital success to help promote the economic growth and competitiveness of its members, who are major French corporations and public administrations, and users of digital solutions and services

Cigref is a network of major French corporations and public administrations set up in order to develop its members' ability to acquire and master digital technology. It is a unifying player in the digital society, thanks to its high-quality thinking and the extent to which it represents its members. Cigref is a not-for-profit body in accordance with the French law of 1901, created in 1970.

To achieve its mission, Cigref counts on three business units, which make it unique.

1/ Belonging:
Cigref speaks with one voice on behalf of major French corporations and public administrations on the subject of digital technology. Its members share their experiences of the use of technology in working groups in order to elicit best practices.

2/ Intelligence:
Cigref takes part in group discussions of the economic and societal issues raised by information technologies. Founded nearly 50 years ago, making it one of the oldest digital associations in France, it draws its legitimacy from both its history and its understanding of technical topics, giving it a solid platform of skills and know-how, the foundation stones of digital technology.

3/ Influence:
Cigref publicises, promotes, and champions its member organisations' collective positions on digital technology issues. As an independent organisation in which digital technology practitioners and actors can discuss and create content, Cigref is a benchmark recognised by its ecosystem.

www.cigref.fr

21 av. de Messine, 75008 Paris
+33 1 56 59 70 00
cigref@cigref.fr