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5G empowering
vertical industries

5G VERTICAL SECTORS

With 5G, networks will be transformed into intelligent orchestration platforms.

By cementing strong relationships between vendors, operators and verticals, 5G will open the field to new business value propositions.

Use-cases originating from verticals should be considered as drivers of 5G requirements from the onset with high priority and covered in the early phases of the standardisation process.
EXECUTIVE SUMMARY

Europe is faced with economic and societal challenges such as ageing of populations, societal cohesion, sustainable development. The introduction of digital technologies in economic and societal processes is key to address these challenges. 5G network infrastructures will be a key asset to support this societal transformation, leading to the fourth industrial revolution impacting multiple sectors. In the next decade, it is expected that the manufacturing industry will evolve towards a distributed organisation of production, with connected goods, low energy processes, collaborative robots, integrated manufacturing and logistics. These concepts are notably embodied under the industry 4.0 paradigm. The automotive and transportation sector will bring to market autonomous and cooperative vehicles by 2020 with significantly improved safety and security standards, as well as new multimodal transportation solutions. Due to the ongoing development of renewables, the traditional power grid will evolve into a smart grid, supporting a much more distributed generation and storage of power with real-time dynamic routing of electricity flows using smart meters in houses. Entertainment and digital media sectors are working on the integration of broadcast TV and digital media, including an ever-increasing amount of user generated content, high-quality media and innovative real-time interfaces such as haptics. E-health and M-health will optimise new, revolutionary concepts such as European “Personalised or Individualised Healthcare,” and the transition from hospital and specialist-centred care models towards distributed, patient-centred models.

As a result of these transformations, vertical industries will have enhanced technical capacity available to trigger the development of new products and services. Identifying key vertical sectors’ requirements, anticipating relevant trends early and mapping them into the 5G design will be key to ensure quality, security and safety. Deploying 5G for vertical sectors in Europe by the earliest date possible is a fundamental element for the 5G success. Therefore, a close collaboration of vertical sectors’ requirements, anticipating relevant trends early and mapping them into the 5G design is a fundamental element for the 5G success.

This paper presents innovative digital use cases from five investigated sectors.

EXECUTIVE SUMMARY

5G - A DRIVER FOR INDUSTRIAL AND SOCIETAL CHANGES

FOR EUROPE, 5G IS BUSINESS DRIVEN

TECHNICAL REQUIREMENTS

5G ARCHITECTURE FOR DISTRIBUTED AND FLEXIBLE ALLOCATION OF VERTICAL-SPECIFIC NETWORK FUNCTIONS

NEXT STEPS IN STANDARDISATION AND SPECTRUM CONSIDERATIONS
While many technical activities around 5G are scaling up globally, requirements analysis of key vertical sectors is rapidly progressing. The emergence and deployment of 5G technology is likely to trigger innovation in this industry, thus leveraging sustainable societal change. There is a vision for 5G to become a stakeholder-driven, holistic ecosystem for technical and business innovation integrating networking, computing and storage resources into one programmable and unified infrastructure. In addition, thanks to real-time and large traffic volume capabilities, 5G is expected to enable the transport of software to the data\(^1\) rather than the other way round, i.e. executing software on the device where the data is produced instead of sending all data to a centralized data centre; therefore paving the way for new opportunities in the cloud computing market, where European companies may gain significant market share\(^2\).

In the long run, it will not be sufficient to explore the requirements of the vertical industries but also conduct a proper analysis of market trends in order to sense new, upcoming technology especially through companies outside the industrial mainstream. Potentially disruptive technologies typically grow widely undetected by the established industry but certainly have a large potential to become drivers for significant technical change and innovation\(^3\). Unanticipated 5G features are likely to emerge for significant technical change and innovation\(^4\). The digitization of factories will be a key stake for the 2020s. New scenarios are emerging, that aim at increasing the efficiency of globally distributed production sites and new actors expected to ensure connectivity between different globally distributed production sites and new actors in the value chain (e.g. suppliers, logistics) seamlessly, in real time and in a secure way.

As a conclusion, innovative strategies such as Industry 4.0 and their design principles are gaining more and more acceptance and will influence present and future 5G requirements. The main use cases identified on the Factory of the Future\(^4\) are: Time-critical process control, Non-time-critical factory automation, Remote control, Intral/Inter-enterprise communication and connected goods. Energy efficient communication schemes as well as scalable data analytics will support these diverse data collection scenarios. With augmented reality, new remote services are arising that facilitate effective knowledge sharing in the factory. More generally, future communication solutions are expected to ensure connectivity between different globally distributed production sites and new actors in the value chain (e.g. suppliers, logistics) seamlessly, in real time and in a secure way. As a conclusion, innovative strategies such as Industry 4.0 and their design principles\(^4\) are gaining more and more acceptance and will influence present and future 5G requirements. The main use cases identified on the Factory of the Future\(^4\) are: Time-critical process control, Non-time-critical factory automation, Remote control, Intral/Inter-enterprise communication and connected goods.

**5G - A DRIVER FOR INDUSTRIAL AND SOCIETAL CHANGES**

**FACTORY OF THE FUTURE**

The digitization of factories will be a key stake for the 2020s. New scenarios are emerging, that aim at increasing the efficiency of globally distributed production sites and new actors expected to ensure connectivity between different globally distributed production sites and new actors in the value chain (e.g. suppliers, logistics) seamlessly, in real time and in a secure way. As a conclusion, innovative strategies such as Industry 4.0 and their design principles\(^4\) are gaining more and more acceptance and will influence present and future 5G requirements. The main use cases identified on the Factory of the Future\(^4\) are: Time-critical process control, Non-time-critical factory automation, Remote control, Intral/Inter-enterprise communication and connected goods.

**ENERGY**

- Grid access
- Grid backup
- Grid backbones

**AUTOGRAPHY**

- Automated driving
- Share My View

**AUTOMOTIVE AND MOBILITY**

The vision of advanced driver assistance systems and, in an even longer perspective, complete autonomous driving cars promise not only less fatal accidents, less traffic congestions and less congested cities, but also a wide range of new business opportunities for a broad range of industries and benefits for the environment. 5G will realise this vision by improving the cooperative automatic driving in such a way that sensor information will be exchanged in real-time between thousands of cars connected in the same area. As an example, cooperative collision avoidance sets the pre-requisite that communications be operational even in areas without network coverage, e.g., due to shadowing or other obstructions, for example thanks to relaying signals between vehicles. Most foreseen applications cannot be implemented with today’s communication technologies. This is why there are high expectations on 5G. With the introduction of technologies allowing improved performances there can be a myriad of new applications. For example, one can envision tele-operated driving – where a disabled individual could be driven with the help of a remote driver in areas where highly automatic driving is not possible. This would generate a new mobility dimension for disabled people and would enhance safety for frail and elderly people during complex traffic situations. The main use cases identified on automotive industry\(^4\) are: Automated driving, Share My View, Bird’s Eye View, Digitalization of Transport and Logistics, and Information Security on the road.
THE BIG PICTURE

1. The everywhere computing services industry is large and growing rapidly.
2. The industry is experiencing rapid changes in technology.
3. The industry is facing increasing competition.
4. The industry is facing increasing regulatory challenges.
5. The industry is facing increasing environmental challenges.

THE CONCEPTUAL FRAMEWORK

1. The conceptual framework is based on the idea of an "ecosystem".
2. The ecosystem model recognizes the interdependence of different components.
3. The ecosystem model recognizes the dynamic nature of the industry.

THEORETICAL BACKGROUND

1. The theoretical background is based on the work of K. Arrow and C. Christensen.
2. The theoretical background recognizes the importance of innovation.
3. The theoretical background recognizes the importance of competition.

METHODS AND RESULTS

1. The methods used in this study were qualitative and quantitative.
2. The results of the study showed that...
While the per-bit value of IoT is rather low, the value generated by holistic orchestration and big data analytics is enormous. For example, General Motors (GM) reports a €722 revenue per car from telematics information. Multi-sector data hubs nurturing cross-sector cooperation can create even more opportunities. By 2020, operators will have a world-wide IP infrastructure consolidated through roaming and interconnection agreements for Voice over Long Term Evolution networks. This infrastructure can be leveraged for 5G to support a global IoT control engine with unified authentication, security, billing and Service Level Agreement engines, as an umbrella layer on top of underlying heterogeneous networks. This will enhance privacy and security and will enable xAAx providers to extend their offerings using “critical infrastructures”.

5G: CEMENTING STRONG RELATIONSHIPS BETWEEN VENDORS, OPERATORS AND VERTICALS, 5G WILL OPEN THE FIELD TO NEW BUSINESS VALUE PROPOSITIONS.

All sectors are now transforming into multi-polar decentralised value chains that are constantly reorganising themselves around a multitude of players. The mobile ecosystem itself has evolved from being an environment of bilateral relationships between cellular operators and their customers, to a universe of specialised companies providing services at different positions of the value chain. The IoT offers clear illustrations that business relationships are no longer bilateral: consumers do not subscribe for a smart meter; it is their utility company that will choose to implement a smart meter and contract the related connectivity access on behalf of their clients. In addition, vendors play a key role in deployments of industrial IoT with long-lasting contracts with specific verticals. This will be complemented by the offerings of the operators building on their infrastructure as well as their experience in providing connectivity on a broad scale.

Virtualization will contribute to accelerate this trend. Some vertical industries will offer services on top of telco infrastructure, which is delivered in a Network as a Service (naaS) mode. Some operators will completely new services and business models, such as for example “Data and Knowledge as a Service” thanks to on demand applications deployment at the edge of the network or even in the end user devices. This will enhance privacy and security and will enable xAAx providers to extend their offerings using “critical infrastructures”.

NEW VALUE CHAINS FOR NEW BUSINESS MODELS

By cementing strong relationships between vendors, operators and verticals, 5G will open the field to new business value propositions.

SMEs—including start-ups—play a substantial role in the value chain as suppliers, service providers as well as original knowledge providers, but are often restricted by sector structures they operate in. Policies towards innovation-friendly digital business ecosystems can help SMEs to break out of their traditional sector boundaries: the development of cross-sector industrial partnerships built within the framework of the 5G infrastructure may bring SMEs new opportunities for original products and services or for business development into other sectors. Combinations of 5G infrastructure capabilities, Big Data assets and the IoT development, may help them create more value, more sector knowledge, and ultimately more ground for new sector applications and services.

5G will be instrumental for the digitalization of the traditional industry in its race for better productivity and competitiveness, especially if it can create synergies across verticals, lowering individual costs thanks to economies of scale, and enabling critical and emergency services operations. As a matter of fact, while options to improve capacity — especially for media and entertainment services in dense areas— can be found thanks to Ultra Dense Network scenarios (an architecture which is envisioned for 5G), there are still several cost challenges like site acquisition, energy provisioning as well as backhaul/fronthaul connectivity of antenna sites: for such issues, infrastructure sharing is a good approach to reduce infrastructure costs and redirect financial investments toward improved geographical coverage, as well as product and service innovation. This is why building a high capacity network through third parties (e.g. diverse infrastructure owners such as city council services, broadcasting towers owners, subscribers…) in a win-win relationship could be a game changer in this field. Compared to the traditional ecosystem, 5G can create new grounds for cost sharing with innovative partnership models built on synergies between network operators and vertical industries, e.g. use of a node carried by cars, of fibre optics deployed for connecting trains, or energy grid cabinets. Another positive side effect is that investors will be able to hedge investments into smaller opportunities and therefore diversify the telecoms investment portfolio.

5G will enable new ways for charging and pricing; throughput, data volume, latency, device movement, processing, storage, functions… or event based charging in real time.

BY CEMENTING STRONG RELATIONSHIPS BETWEEN VENDORS, OPERATORS AND VERTICALS, 5G WILL OPEN THE FIELD TO NEW BUSINESS VALUE PROPOSITIONS.
The following chapter reviews the target performance parameters for 5G, currently being assessed globally and discusses the key performance parameters derived from a comprehensive analysis of the use cases introduced in Chapter 1, as well as presents a mapping of the most plausible vertical scenarios onto the new fundamental capabilities of 5G.

5G KEY CAPABILITIES AND Kpis

As described in the 5G Infrastructure PPP Vision (March 2016), the 5G capabilities will provide ubiquitous access to a wide range of applications and services with increased resilience, continuity, and much higher resource efficiency, while protecting security and privacy. In addition, 5G will provide enormous improvements in capacity and boost user data rates. The highly demanding capabilities of 5G require an outstanding research and innovation effort to reach orders of magnitude of improvement over the current technology and infrastructure. The following 5G targets, which are under further discussion worldwide, in bodies such as International Telecommunication Union–Radiocommunication Sector (ITU–R), 3rd Generation Partnership Project (3GPP), and Next Generation Mobile Networks (NGMN) Alliance, indicate the advances of the 5G systems compared to previous generation:

- 1,000 x in mobile data volume per geographical area reaching a target of 0.75 Tbps for a stadium
- 1,000 x number of connected devices reaching a density ≥ 1 M terminals/km²
- 300 x in user data rate reaching a peak terminal data rate ≥ 1 Gbps for cloud applications inside offices.
- 1/10 x in energy consumption compared to 2010 while traffic is increasing dramatically at the same time.
- 1.5 x in end-to-end latency reaching delays ≤ 5 ms.
- 1.5 x in network Management Operational Expenditure (OPEX).
- 1/1,000 x in service deployment time reaching a complete deployment in ≤ 90 minutes.
- Guaranteed user data rate ≥ 50 MBytes/s.
- Capable of IoT terminals ≥ 1 trillion.
- Service reliability ≥ 99.99999% for specific mission critical services.
- Mobility support at speed ≥ 500 km/h for ground transportation.
- Accuracy of outdoor terminal location ≤ 1 m.

IDENTIFYING 5G VERTICAL SECTORS USE CASES AND REQUIREMENTS

There is a worldwide effort on the further characterization of 5G use cases and related requirements (e.g. ITU, 3GPP SMARTER, NGMN...). The 5G Infrastructure Public Private Partnership (PPP) is progressing on the identification of use cases with a clear effort on vertical markets, e.g. the five white papers addressing Factories, Automotive, eHealth, Energy, as well as Media and Entertainment.

Considering the 5G Infrastructure Association vertical use cases introduced in Chapter 1, the three ITU–R usage scenarios6 (Enhanced Mobile Broadband, Ultra-reliable and Low Latency Communications and Massive Machine Type Communications and the related spider diagram capabilities), the eight NGMN use case families15 and the four 3GPP use cases groups16 (Enhanced Mobile Broadband (eMBB), Massive IoT (mIoT), Critical Communications (C2C) and Network Operations (NEC)) covering more than seventy distinct use cases, this section presents the 5G Infrastructure PPP vertical use cases capabilities spiders, considering the major relevant capabilities of each vertical sector.

Several ITU–like capabilities can be considered as critical parameters for the different vertical sectors:

- Data Rate: Required bit rate for the application to function correctly. It corresponds to the user experienced data rate as defined by ITU. The most demanding vertical use cases are related to Media & Entertainment with maximum values in the order of Gbps.
- Mobility (speed): Maximum relative speed under which the specified reliability should be achieved. The most demanding vertical use cases are related to Automotive and eHealth with maximum value in the order of 500 km/h.
- E2E Latency: Maximum tolerable elapsed time from the instant a data packet is generated at the source application to the instant it is received by the destination application. If direct mode is used, this is essentially the maximum tolerable air interface latency. If infrastructure mode is used, this includes the time needed for uplink, any necessary routing in the infrastructure, and downlink. The most demanding vertical use cases are related to Factories with minimum values of 100 µs to 1 ms.
- Density (number of devices): Maximum number of devices (vehicles in the case of Automotive) per unit area that are 5G capable, although they might not all be generating traffic simultaneously for the specified application. The most demanding vertical use cases are related to Factories with up to 1000 m².
- Reliability: Maximum tolerable packet loss rate at the application layer within the maximum tolerable end-to-end latency for that application. The most demanding vertical use cases are related to eHealth with values up to 9.9999999%.
- Position Accuracy (Location): Maximum positioning error tolerated by the application. The most demanding vertical use cases are related to Automotive with minimum values in the order of 1 m.

In addition to these ITU–like capabilities, the Coverage capability is also assessed as critical for the different vertical sectors:

- Coverage: Area within which or population for which the application should function correctly, i.e. the specified requirements (latency, reliability and data rate) are achieved. Most of the vertical sectors have strong requirements on geographic and/or population coverage. The analysis of the key requirements from the different vertical sectors on this critical baseline lead to the spider charts captured in Figure 2. The quantification is based on the following ranking: (0) No requirement, (1) Low level of requirement or no specific constraint, (2) Medium level of requirement, which could be satisfied with existing legacy systems (3) High level of requirement, which may be at the limit or not satisfied with the existing legacy systems and (4) Very high level of requirement, corresponding to the 5G Infrastructure PPP targets and Key Performance Indicators (KPIs). No single vertical use case requires the full set of 5G capabilities to be met at the same time. The 5G system will be relying on a dynamic and flexible function allocation and configuration and 5G networks will highly rely on software networking, virtualization and slicing techniques. It is expected that the softwarisation of infrastructure composition and usage will allow addressing various use cases from the vertical sectors, as detailed in Chapter 4.

The following additional capabilities are also assessed as key from the vertical sectors perspectives:

- Service Deployment Time: Duration required for setting up end-to-end logical network slices characterized by network capability level guarantees (such as bandwidth guarantees, End-to-End (E2E) latency, reliability...). Required for supporting services of that particular vertical sector. Programmable networks and multi-tenant capability in 5G will ensure speedy service deployment of services (e.g. 5G Infrastructure PPP targets 90 minutes for service deployment).
- Data Volume: Quantity of information transferred (downlink and uplink) per time interval over a dedicated area (e.g. 5G Infrastructure PPP targets a maximum of 10 Tbit/km²).
- Autonomy: Time duration for a component to be operational without power being supplied. It relates to battery lifetime, battery load capacity and energy efficiency.
- Security: System characteristic ensuring globally the protection of resources and encompassing several dimensions such as authentication, data confidentiality, data integrity, access control, non-repudiation...
- Identity: Characteristic to identify sources of content and recognise entities in the system. One key parameter to guarantee the fast adoption of 5G is the possibility to access low cost solutions in several use cases of the vertical sectors.

5G VERTICAL SECTORS: BEYOND TODAY’S NETWORK CAPABILITIES

Through an integration of various radio access technologies and Device-to-Device (D2D) communication, 5G is expected to provide the coverage needed to support road safety applications everywhere. Additionally, by targeting an end-to-end latency of 5 ms (down to 1 ms for direct mode) with extreme network reliability and enabling scalability of solutions by providing deterministic performance also at high load, 5G is envisioned to be a key enabler for automated driving and related critical applications for which the stringent requirements could not yet be met by existing technologies. Manufacturing is one of the most demanding industry in terms of 5G networking support (mobility and wireless broadband), requiring ultra-high reliability, latencies down to 1 ms (for real time process control), and densities of more than 10 to 100 machine sensor streams per square meter. Existing legacy technologies however do not handle mobility, especially in terms of handovers. In addition, the bandwidth per user is very limited and the latency is high (full second may need to be transmitted to a message), thus not allowing the deployment of real time applications. Also, due to the utilization of unlicensed bands, these technologies lack dedicated quality-of-service guarantees.

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6 http://www.3gpp.org/ftp/SpecsMultiple/201501/3gpp-brochure-1g.pdf
9 https://www.3gpp.org/uploads/media/NGMN_5G_White_Paper_V1.0.pdf
It is envisioned that billions of heterogeneous devices and terminals for advanced mobile broadband services and IoT services from different verticals will be connected to the Internet. The vast amount of connected devices will generate an aggregated huge volume of data, which poses a tremendous challenge to processing and information transport.

At the processing level, 5G requires massive distributed computing and storage infrastructures in order to process all this information (e.g., temperature monitoring, distance measurement, energy consumption measurement, big data analytics, etc.). Additionally, emerging technologies such as Network Functions Virtualization (NFV), Software Defined Networking (SDN), Mobile Edge Computing (MEC), and Cloud Radio Access Network (C-RAN) require high performance computing capabilities for the deployment of network functions such as mobile Evolved Packet Core (EPC), Firewalls, local cache, virtual base station, etc. Up to now such functions were typically deployed in specialised and dedicated hardware. Thus, 5G is required to dynamically allocate computing and storage resources wherever needed, and at the transport level, to embed the required performance computing capabilities for the deployment of network functions (e.g., temperature monitoring, distance measurement, energy consumption measurement, etc.). These processes typically combine sets of vertical-specific activities.

The activities can be carried out as application-related sequences of services, defined by orchestration of functions provided by the Business Function Layer. Each of the activities is characterised by application-related constraints, such as due dates, energy consumption, accuracy, quality requirements, security and safety requirements, and other KPIs. These constraints set the Quality of Service (QoS) requirements for the underlying layers. For example, different resources implementing a drilling function may offer a drilling service required for a product manufacturing activity. For a given material and a given surface roughness, only those services fulfilling the requirements can be selected.

The Business Service Layer defines and implements the business processes of the verticals along specific value chains. Thus, it makes possible to support more business applications, e.g., manufacturing of a product, autonomous driving, energy production and delivery. These processes typically combine sets of vertical-specific activities.

The Business Service Layer defines the QoS requirements for the underlying communications infrastructure, involving an end-to-end heterogeneous network. Each function requires different QoS levels according to contractual service level agreements.

The Business Service Layer defines rules and policies for its invoking, operating, and its orchestration process in the Business Service Level. Each function contains a set of vertical-independent functions, like persisting data, logging, etc. The functions are typically defined on an abstract and implementation-independent level. They may expose a service interface to the orchestration process in the Business Service Level. Each function defines rules and policies for its invoking, operating, and its results. It also defines capabilities that can be used for matching of requirements of the Business Service Layer.

The Business Service Layer decomposes them into physical and virtual network functions, and decides on the placement of the network functions within the existing infrastructure. Subsequently, the dedicated network service can be instantiated and lifecycle management as well as runtime optimization are performed. Since the fragmentation of administrative domains considerably increases, tenant isolation management and shared function control constitute key enablers for native multi-tenancy support. They guarantee the required level of isolation and enforce QoS level according to contractual service level agreements.

MULTI-SERVICE CONTROL LAYER

The overall purpose of the Multi-service Control layer is to enable the creation, operation, and control of multiple dedicated communication networks running on top of a common infrastructure. Each of these networks is configured in a way that it exhibits specific functionality and capabilities addressing the requirements as defined by the respective network tenant. The Multi-service Control Layer acts as an intermediary between the vertical-centric service layers and the network-centric service layers. Efficient control frameworks allow for an abstraction of controllable resources and functions and expose uniform control APIs on different architectural levels. Northbound APIs are used by business-centric layers. In southbound direction, the layer makes use of the interfaces provided by the network-centric function layers. For the commissioning of a network service, the Multi-service Control Layer performs mapping between business service requirements and network service topology and configuration. It selects appropriate service function chains, decomposes them into physical and virtual network functions, and decides on the placement of the network functions within the existing infrastructure. Subsequently, the dedicated network service can be instantiated and lifecycle management as well as runtime optimization are performed. Since the fragmentation of administrative domains considerably increases, tenant isolation management and shared function control constitute key enablers for native multi-tenancy support. They guarantee the required level of isolation and enforce QoS level according to contractual service level agreements.

NETWORK FUNCTION LAYER

The Network Function layer implements the abstractions provided by Software Networks technologies (essentially SDN and NFV) to support an abstracted model for any 5G network function, independent of its nature (network, computational, storage) and the implied resources (optical, wireless, satellite, cloud...). Based on these abstractions, this layer allows the network functionalities to be offered as services to the users/verticals.

The core elements of this layer incorporate the management and orchestration mechanisms required to assemble the supported virtual resources running network functions and making them available to the upper layer during their lifetime.

INFRASTRUCTURE LAYER

The lowest layer of the integrated 5G architecture is the infrastructure, involving an end-to-end heterogeneous network and distributed cloud platform. This infrastructure consists of i) a data communications network spanning all network segments to provide end-to-end connectivity services, covering large scale heterogeneous access systems (cellular, fixed, satellite, WiFi, personal area networks), optical/wireless backhaul/fronthaul, metro aggregation packet networks and high-capacity optical core transport networks; ii) massive distributed cloud computing and storage centres, including core data centres for high-computational capability and long-term response time, edge data centres with

**FIG. 3. INTEGRATED 5G ARCHITECTURE FOR MOBILE BROADBAND AND VERTICAL SERVICES**
lower capabilities but fast response time, and network nodes or base stations with small capabilities for ultra-low latency, and billions of heterogeneous smart devices and terminals for traditional mobile broadband services (e.g., smartphones, tablets, etc.). IoT services (e.g., sensors, actuators, etc.) and autonomous IoT devices (e.g., robots, cars, drones, etc.). The 5G infrastructure may belong to different infrastructure providers (mobile, cloud, transport, etc.). The 5G infrastructure may belong to different infrastructure providers (mobile, cloud, transport, etc.). The 5G infrastructure may belong to different infrastructure providers (mobile, cloud, transport, etc.).

The business services are handled based on business functions. A drilling function assigns a set of operating data, e.g., diameter, material, quality, throughput. The capabilities of a specific drilling machine are characterised by maximum diameter, maximum drilling speed, level of roughness, etc. These capabilities need to be considered for orchestration and for deployment of the services to specific resources. Business function “drilling” itself combines activities like tool mounting, positioning, drilling at a certain speed, countersinking, or in-line quality inspection. Each of these functions is deployed or implemented by networked resources (sensors, actuators, controllers). The requirements for the communication services of the network vary depending on the specific functions. For example, controlling the position of the drilling head requires data transfer of coordinates in milliseconds. Changing set points for position may be requested within minutes or seconds. Logging of quality data results in bulk data transfer of camera images and logs. At the same time the network needs to guarantee cyclic, low latency services with low jitter for the control loops. Since communication is more and more provided by one network instead of dedicated, specialised ones, this single network is expected to be capable of fulfilling the specific requirements of all communication relations. This calls for network slicing and flexible network operation.

EXAMPLE FOR THE VERTICAL “FACTORY OF THE FUTURE”

This scenario describes the production of metal workpieces. Customer orders are processed at Enterprise Resource Planning (ERP) level. They define requirements like delivery dates, shipping details, etc. At Manufacturing Operations Management (MOM) level, customer orders are combined into production orders, e.g., as production lots with due dates, material assignments (e.g., a specific alloy of metal), and quality requirements. The production process itself represents a sequence of services, e.g., for retrieving raw material from stock, transportation, processing on several machines, quality testing etc. The processing service may again be a sequence of other business services, e.g., cutting, milling, and drilling services. Each service defines requirements, e.g., for machining speed, material roughness, etc. The business services are handled based on business functions. A drilling function assigns a set of operating data, e.g., diameter, material, quality, throughput. The capabilities of a specific drilling machine are characterised by maximum diameter, maximum drilling speed, level of roughness, etc. These capabilities need to be considered for orchestration and for deployment of the services to specific resources. Business function “drilling” itself combines activities like tool mounting, positioning, drilling at a certain speed, countersinking, or in-line quality inspection. Each of these functions is deployed or implemented by networked resources (sensors, actuators, controllers). The requirements for the communication services of the network vary depending on the specific functions. For example, controlling the position of the drilling head requires data transfer of coordinates in milliseconds. Changing set points for position may be requested within minutes or seconds. Logging of quality data results in bulk data transfer of camera images and logs. At the same time the network needs to guarantee cyclic, low latency services with low jitter for the control loops. Since communication is more and more provided by one network instead of dedicated, specialised ones, this single network is expected to be capable of fulfilling the specific requirements of all communication relations. This calls for network slicing and flexible network operation.

5G BUSINESS AND POLICY DRIVERS

Standards play a key role in providing technological, economic, and quality benefits. Standardisation solutions provide end-users with services that are safe, reliable, and of good quality. For businesses, standards create the interoperability that is necessary to save costs and provide access to global markets. When the 5G standards are in place, entirely new eco-systems are expected to emerge. In the European context, 5G networks are a key pillar to realise the wider ambitions of the Digital Single Market, see Section “A framework that incentivises the deployment of 5G”, page 9. The trend towards a digitised economy is shared globally, with many world-wide initiatives to develop digital automotive, health, factories, and many more. The next convergence wave is expected to target industrial and professional businesses with very specific communication requirements. 5G is the platform of choice to support this industrial and economic transformation. Global 5G Standardisation is at the heart of achieving this.

VERTICALS INTEGRATED FROM THE START

The integration of verticals is one of the key differentiators between 4G and 5G systems to open truly global markets for innovative digital business models. Use-cases originating from verticals have to be considered as drivers of 5G requirements from the outset with high priority and covered in the early phases of the standardisation process. The vision of 5G is driving the standards developments needed to address the entire network, including new and evolved Radio Access Technologies (RATs), new Radio Access Networks (RAN), and core network architectures based on fundamental changes to business models and eco-system.

In 5G the communication network is an integral part of the product/service, e.g., an IoT service includes the device, network, and cloud service; e.g., for remote robot-assisted surgery or care, and the liability will then include more than just the device. This leads to a set of security, privacy, identity and liability issues that have to be addressed natively in the standardisation and regulation processes according to the “Security by Design” approach to allow widespread introduction of new 5G services.

MULTIPLE STANDARDISATION BODIES

5G will integrate different telecommunication technologies (e.g., mobile, fixed, satellite and optical), spectrum-regulatory frameworks (e.g. licensed and unlicensed) and enabling capabilities (e.g. IoT) for the benefit of vertical industries. The corresponding standards organisations should work together very closely in order to optimise the 5G capabilities. The standardisation process should be inclusive of vertical industries through each vertical industry typically has its own standard body and association. This is needed to ensure a globally applicable and consistent set of 5G mobile communication standards which can benefit all industrial sectors at large. Key standardisation bodies like ITU-R and 3GPP should thus put in place the needed communication channels with the vertical industries, preferably by key actors from the vertical industries getting directly involved in 3GPP. The 5G community and each of the vertical industries must work together towards joint cost/benefit analysis of vertical industries’ requirements and how they can be best supported by 5G networks. The 5G PPP research and innovation framework should be leveraged to catalyse these partnerships.

Beyond ITU-R and 3GPP that are identified as core 5G standardisation bodies, several standardisation bodies are expected to contribute to the overall standardisation efforts. In addition to RAN and core network standardisation, also the slicing of the 5G network to serve tenants with different service requirements has to be addressed. The 5G research community has to actively contribute its requirements and findings to relevant standardisation bodies, e.g., ITU Telecommunication Standardisation Sector (ITU-T), European Telecommunications Standards Institute (ETSI), Internet Engineering Task Force (IETF), Institute of Electrical and Electronics Engineers (IEEE), Open Networking Foundation (ONF), Broadband Forum (BBF), as well as relevant open-source projects. The 5G standardisation time plan currently adopted by 3GPP, which is gradually realizing the full 5G capabilities in three consecutive releases, needs to be shared with other relevant standardisation bodies and appropriate liaison established, such that the holistic 5G perspective can be smoothly developed over the envisaged 2016–2019 time span.

SPECTRUM CONSIDERATIONS

To meet the expected growth in traffic and requirements associated with new applications, the success of 5G systems and services depends on the timely availability of spectrum bands in order to support new capabilities for which demand exists. The decisions of the World Radio Communication Conference 2015 (WRC-15) offer opportunities for 5G systems, identifying both more spectrum below 6 GHz for IMT (mobile broadband applications) and a number of spectrum bands above 6 GHz for studies which could result in new mobile primary allocations. Beyond IMT, the Radio Regulations of the International Telecommunication Union (ITU) provide the critical spectrum, as well as relevant open-source projects. The 5G standardisation time plan currently adopted by 3GPP, which is gradually realizing the full 5G capabilities in three consecutive releases, needs to be shared with other relevant standardisation bodies and appropriate liaison established, such that the holistic 5G perspective can be smoothly developed over the envisaged 2016–2019 time span.
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More information at https://5g-ppp.eu

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