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D2.1 – IDENTIFY USE CASES FROM VERTICALS

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List of Acronyms & Abbreviations

Acronym/Abbreviation	Description
5G PPP	5G Infrastructure Public Private Partnership
5G AP	5G for Europe Action Plan
5G IA	5G Infrastructure Association representing the private side of the 5G PPP.
3GPP	3rd Generation Partnership Project, providing complete system specifications for cellular telecommunications network technologies, leading 5G standardisation, currently in Phase 1 of the 3GPP 5G effort for Release 15. Full compliance with the ITU's IMT-2020 requirements is anticipated with the completion of 3GPP Release 16 at the end of 2019 - In Phase 2 of the 3GPP 5G effort.
ACG	???
AMI	Advanced Metering Infrastructure
BEREC	Body of European Regulators for Electronic Communications
BRIC	Brazil, Russia, India and China
Capex	Capital expenditure
CEN	European Committee for Standardisation, one of the three officially recognised European Standardisation Organisations (ESOs) with a mission to develop standards applicable across the whole EU single market.
CENELEC	European Committee for Electrotechnical Standardisation, one of the three officially recognised European Standardisation Organisations (ESOs) with a mission to develop standards applicable across the whole EU single market.
CIM	Common Information Model
CoCom WG5	EC Communications Committee Working Group NBP/5G
COPD	chronic obstructive pulmonary disease
COSEM	Companion Specification for Energy Metering
DA	Distributed Automation
DER	Distributed/Decentralised Energy Resources
DMLS	Distribution Line Message Specification
DMS	Distributed Management System
DR	Demand Response
EHR	Electronic Health Record
eMBB	Enhanced mobile broadband (use cases mostly associated with rollout phase 1 of 5G)
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ETSI	European Telecommunications Standards Institute, one of the three officially recognised European Standardisation Organisations (ESOs) with a mission to develop standards applicable across the whole EU single market. ETSI standards are also recognised globally.
FAD	Fully Autonomous Driving
FoF	Factories of the Future
HAD	Highly Autonomous Driving
IEC	International Electrotechnical Commission, an international standards

	organisation for electrical, electronic and related technologies.
IEEE	Institute of Electrical and Electronic Engineers, dealing mostly with electrical and electronic issues and more broadly engineering challenges.
ITU-T	International Telecommunication Union, Telecom Sector, the standards setting body within the United Nations.
ITU-R	ITU Radio-communication Sector, EXPLAIN
mIoT	Massive Internet of Things (use cases mostly associated with rollout phase 2 of 5G)
IS	International Standard
LPWA	Low-power, wide-area wireless technology
MCS	Mission critical services (use cases mostly associated with rollout phase 2 of 5G)
MEC	Mobile Edge Computing
NFV	Network Function Virtualisation
OpEx	Operating expenditure
SA	Substation Automation
SDN	Software-Defined Networks
TR	Technical Report
TS	Technical Specification
URLLC	ultra-reliable low-latency communications
VOIP	Voice over Internet Protocol
WBAN	Wireless Body Area Network
WLAN	Wireless Local Area Network

Executive Summary

The purpose of this document is to provide an analysis of 5G use cases across four vertical industries: automotive, energy, health and factories of the future.

An overview of the 5G proposition, capabilities, rollout phases and key technology enablers is taken as the starting point to provide the context in which the use case analysis takes place. This initial analysis also looks at the socio-economic benefits and the vast array of stakeholders that will drive or just consume 5G services and solutions.

The analysis starts with a look at three 5G use case categorisations: enhanced mobile broadband, massive Internet of Things and mission critical services, for which global market forecasts exist. On top of this, we provide a mapping of current use cases across diverse verticals based on a review of the literature and within the 5G PPP, mostly in phase 2. This mapping helps identify current coverage of use cases and verticals, identifying gaps for potential future funding of research and innovation to realise the full potential of 5G.

This provides the backdrop for a detailed analysis of each vertical, covering both high-level and specific requirements, including on-going pilots. This approach enables Global5G.org to determine expected impacts from current coverage and identify concrete actions to take forward, including events and webinars that can help explore issues and requirements to map them to the most appropriate groups, within the 5G PPP, standardisation organisations or policy makers.

The document also includes an overview of the current 5G standardisation landscape, indicating relevant work related to verticals and Global5G.org activities, with an in-depth analysis of standardisation within each vertical. This is the basis for the project's support in mapping use case requirements with on-going standardisation, as well as its online tracking tool to ensure timely and informative updates to the project's various stakeholders.

Finally, the document provides a concise analysis of cross-cutting issues spanning security, privacy, trust, policy and regulation to help identify and act on potential barriers to wide deployments across Europe, including unfavourable policy frameworks, lack of acceptance and confidence in 5G.

The document concludes with future steps to be taken by Global5G.org, turning findings into concrete actions.

1 Introduction

1.1 Scope and Purpose

Having identified health, automotive, energy and factories of the future, as the four representative vertical industries Global5G.org is focusing on, this document reports on the analysis and categorisation of a set of relevant use cases based on their priority requirements, laying the ground for strengthening the link between research and Industry and standardisation. It acts as a bridge between the activities of WP2 (Market Watch) and WP3 (Global 5G ecosystem: standards and support to consensus building).

This document also provides input for the “From Research to Standardisation and Vertical Industry Involvement” activity (Task 3.1), delivering a starting point for the set-up and implementation of the online Standardisation Timelines and Progress Tracker (Milestone 3.3).

1.2 Terms of Reference and Methodology

Verticals and use cases analysed here are framed in the 5G context: understanding the specificities of each vertical and its use cases spanning very different combinations of requirements is an activity that will feed directly into the Global5G.org standardisation support activities.

The setting of this analysis focuses on the four verticals and it outlines a methodology which is replicable for further verticals (e.g. the media and entertainment sector).

The results presented in this document are based on desk research, and leverage on input from 5G PPP collaborative activities, meetings, calls as well as third party events, reflecting the context within which 5G innovations are being sketched and covering multi-faceted perspectives, sector specific needs and approaches, as well as major cross-cutting issues, such as the overarching themes of security, data protection, privacy and trust.

Use cases and experience from 5G PPP projects of phase 1 and 2 are considered and will lead to future direct engagement.

For all identified use cases both high-level and specific requirements are considered, in terms of:

- Latency, reliability and bandwidth (wireless).
- Ubiquitous availability (coverage).
- Security, privacy and trust.
- Support of heterogeneous devices and technologies (infrastructure).

Other key requirements are also considered, including autonomy (e.g. for Factories of the Future), miniaturisation and ease of use (for health), based on key findings from the research conducted.

1.3 Structure of the Document

The document is divided into the following chapters, each corresponding to a major item as specified below:

- **Section 2** – gives a high-level view of the context under investigation in Global5G.org. It presents the 5G proposition, listing the main 5G capabilities, describing them also in terms of the applications from the end user perspective, and showing the expected rollout phases. It also analyses the main socio-economic drivers for the four vertical industries analysed: automotive, health, energy and factories of the future, and how 5G might impact on current stakeholders and possible new entrants in the market.

- **Section 3** is dedicated to an analysis of the 5G use case families, with a mapping of 5G PPP phase 2 projects and their relation to vertical industries.
- **Sections 4, 5, 6 and 7** – focus on the four verticals, from automotive and health to energy and factories of the future. Each section looks at technology and sector perspectives, with descriptions of use cases and application scenarios highlighting the main 5G requirements.
- **Section 8** – deals with the 5G standardisation landscape and its relation to vertical industries and work in Global5G.org. It then provides an analysis of standardisation in each of the four verticals. It thus anticipates work centred on the Global5G.org standardisation tracker while serving as the basis for on-going stakeholder engagement and analysis.
- **Section 9** – is dedicated to the main cross-cutting issues fundamental for the successful deployment of 5G and its rollout across vertical markets, looking at key findings on security, privacy, trust as well as policy and regulation.
- **Section 10** provides a summary plan to turn findings into concrete plan for engagement, further analysis and consensus building.

2 The 5G Proposition

2.1 Capabilities and Rollout Phases of 5G

5G represents a revolution with respect to its predecessors (3G and 4G) as an end-to-end system that shifts the role of the network from being merely a form of communication to becoming an actual platform in its self.

The 5G Proposition is best defined in the use cases, around which there is considerable consensus across the industry. The figure below shows the use case families from the alliance for the Next Generation Mobile Network (NGMN) and the International Telecommunications Union (ITU).

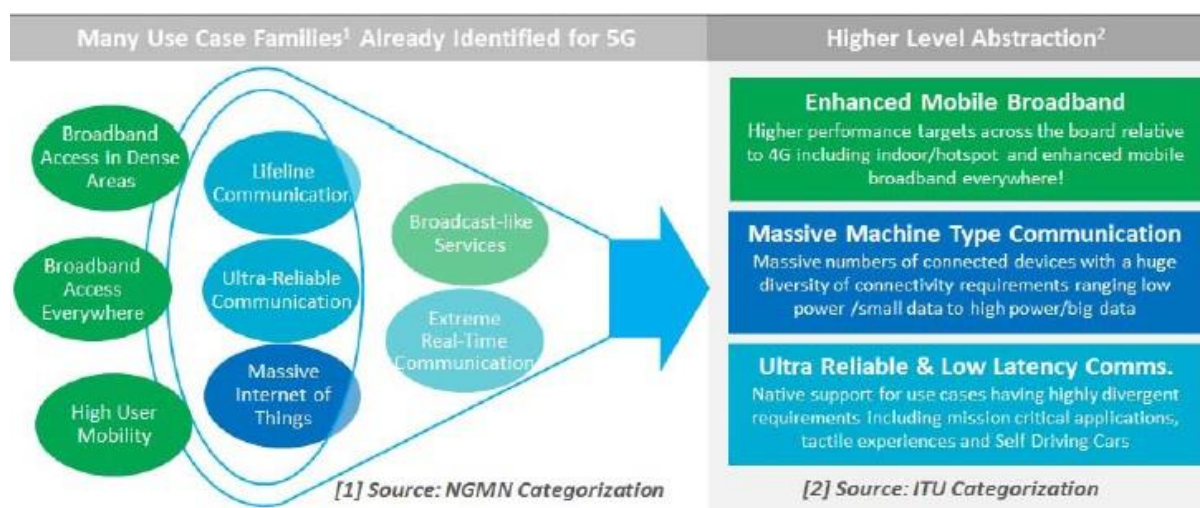


Figure 1 Use Case Families [Sources: NGMN & ITU]

5G sets out with the fundamental goal of delivering enormous socio-economic value as a priority, above and beyond the value created by previous generations of wireless networks [Glossary 1]. In

this respect 5G will be quite different - the first generation to explicitly target socio-economic benefits by rolling out many new 5G capabilities, as outlined in the table below¹.

5G Capability	Explanation
5G aims to enable a truly Pervasive Video experience	Virtual environments, ubiquitous telepresence, Augmented reality, holograms and other immersive technologies will allow you to be virtually present anywhere, or interact in real time with people all around the world as if you were in the same location. The experience is so immersive that it will come close to equalling a real human experience.
5G will enable a revolution in the Smart Office	Everything in your office and home will now be wirelessly connected. Everything is plug and play including HD screens, cameras and monitors. Everything is integrated and your office can literally be anywhere that you can access a screen and user interface.
5G goal is to deliver 50Mbit/s Everywhere	This simple but challenging capability goal is to realise a universal minimum data rate to enable high-level quality of service everywhere.
5G will allow you to create your own network if that is what you want to do	Think of this as like having your own spectrum or the ability to spin up your own network to your requirements without the hassles of ownership. Innovation in 5G, especially in the core network (e.g. network slicing) will make this possibility much easier to realise in a highly flexible manner.
5G will support dynamic increase of capacity on the fly	Resources costs to maintain very high speeds for many users everywhere will likely be very high. However, 5G will be architected to allow very flexible reallocation of resources to dynamically increase the perceived capacity of the network to serve large numbers of users when they need it (e.g. traffic jams, stadiums, disasters).
5G will enable a working solution on planes, faster trains and cars	Today, most connectivity is directed at the ground to where most users are. 5G will expand this focus to the skies. More than this 5G will support the natural evolution of transport systems to the higher speeds that are being forecast.
5G will deliver a single scalable solution for sensor networks and the IoT	Imagine connectivity technology for all vertical market needs provided at such scale that it will meet with all of the cost points of today's systems. 5G is designing its entire system to support very large scale M2M/IoT networks.
5G will enable an ultrareliable network for mission critical applications	5G will include operational modes that aim to exceed the so called five nines reliability and availability. This category of capability is seen as essential for the support of mission critical requirements found in current and anticipated future vertical industry applications.
5G will make the realisation of the Tactile Internet possible	Think of this as whole new way of interfacing with technology. A revolution many times more profound than your touchscreen has been. This encompasses all forms of new user interface technology (e.g. augmented reality, remote robotics) where an almost instant access to content or control function is required to make the service possible and user acceptable.
5G will deliver a meaningful and efficient	Generic broadcasting is moving towards more personalised and targeted services. For instance, news and information can be

¹ "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe", study carried out for the European Commission by Tech4i2, Real Wireless, CONNECT, Trinity College Dublin and InterDigital. SMART number 2014/0008, published in June 2016, hereafter SMART 2014/0008.

Broadcast service	broadcasted for a specific group of people at local, regional or national level. You could have your own broadcast services for your company, your office and your work place.
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Table 1 5G Capability Explanations [Source: SMART 2014/0008]

5G is expected to have two rollout phases though deployments are likely to be varied among operators and countries complemented with 4G and other alternative networks to provide connectivity for people and things.

- **Rollout profile for 5G phase 1: dense urban networks, 3GPP Release 15 as the main industry standard (expected December 2017 and June 2018)**

5G deployments are expected to initially centre on eMBB (enhanced mobile broadband). Initially operators are expected to selectively upgrade macro cell sites to 5G in key locations and where network capacity is under pressure, using 4G infrastructure as a fall-back option. As a result, capEx will remain relatively flat over this period, as operators aim to maximise cash flow. GSMA estimates that 5G coverage will reach 2.6 billion people (34% of the global population) by 2025. By this time, 5G mobile broadband connections will reach 1.1 billion globally.

For operators, 5G in its initial phase will be primarily an opportunity to deliver a transformed mobile broadband experience to its customers. The main target will be customers, while looking to the business segment to unlock the incremental opportunity of 5G.

- **Rollout profile for 5G phase 2: based on small cell deployments, 3GPP Release 16 as the main industry standard (expected 2019 and 2020)**

Mission critical services (MCS) is expected to lead to significant growth as it represents a new market opportunity, supporting applications, e.g. autonomous vehicles, industrial automation, and healthcare, which require high reliability, low latency connectivity and stringent security and privacy requirements.

As the focus shifts in the second phase with massive IoT and critical communications services, 5G will provide an opportunity for operators to go beyond connectivity and partner with other service providers across industry verticals to deliver new services. 5G will evolve as a technology and leverage not only a variety of spectrum ranges but also robust security as existing services evolve and new services emerge. The security of networks and services will also be critical given the current and expected future cyber security landscape.

A substantive IoT business case for 5G will become clearer later in the 5G lifecycle, supporting the massive Internet of Things (mIoT), network slices using virtualised network functions, common enablers and APIs. Operators will need to focus on B2B and B2C business, with the 5G Automotive Association also identifying B2B2C and C2C business models.

Industry and governments will be chief drivers of 5G deployments. Many industries and municipalities will also deploy mIoT with applications spanning asset tracking, smart cities, monitoring of utilities and vital infrastructure.

4G has taught us that providing good-quality mobile broadband with the right business model is profitable. However, the investment required for 5G networks, particularly in terms of dense small cell deployments and the requisite backhaul, plus the provision of reliable connectivity globally, is huge. Beyond considerable amounts of capex required for rolling out a dense small cell network in urban areas, it will also add to current network opex burdens. This will increase the importance of access to – or ownership of – dense urban fibre networks.

The challenge for the industry is to identify new services, new market segments (especially enterprise) and the right business models to unlock the incremental 5G opportunity. The industry will need to address the underlying economic assumptions for cellular networks and embrace new

business models that can achieve a healthy balance between network competition and sustainable investment in infrastructure.

2.2 Socio-economic Drivers

As the expansion of capabilities is implemented as one unified design with the same 5G infrastructure supporting a variety of use cases, mobile technologies are expected to have a deep and sustained impact across a broad range of sectors, where the greatest growth opportunities are expected to come from the automotive sector, manufacturing, healthcare, entertainment and financial services.

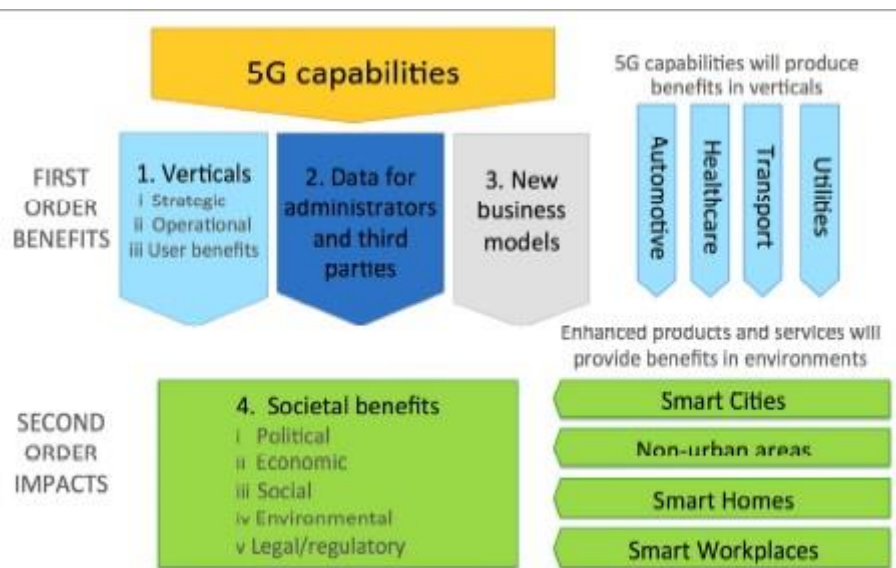


Figure 2: Socio-economic Benefits derived from 5G Capabilities [Source: SMART 2014/0008]

The figure below provides a sample of economic forecasts across vertical industries, including the four verticals studied by Global5G.org. The first figure (left) comes from Telecom TV based on the forecasts provided by SMART 2014/0008 (published in June 2016)², where the automotive sector is expected to gain the highest socio-economic benefits from 5G out of the four verticals analysed.

The figure on the right comes from IHS Economics (The 5G economy: how 5G technology will contribute to the global economy, January 2017). Forecasts for 2035 are based on positive scenarios for the standards process, regulatory environment and industry adoption. The forecast of \$12.3 trillion in 2035 represents about 4.6% of all global real output. According to IHS, manufacturing will see the biggest gains and includes complementary spending on equipment (e.g. drones in the transportation sector; medical equipment). It is important to also consider how many industries will be affected by each use case, e.g. use of autonomous vehicles also in agricultural and mining applications, transportation, delivery of consumer goods, municipality transit systems, intra-plant stocking and retrieval systems (manufacturing) while having impacts on the insurance industry.

² <https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds>.

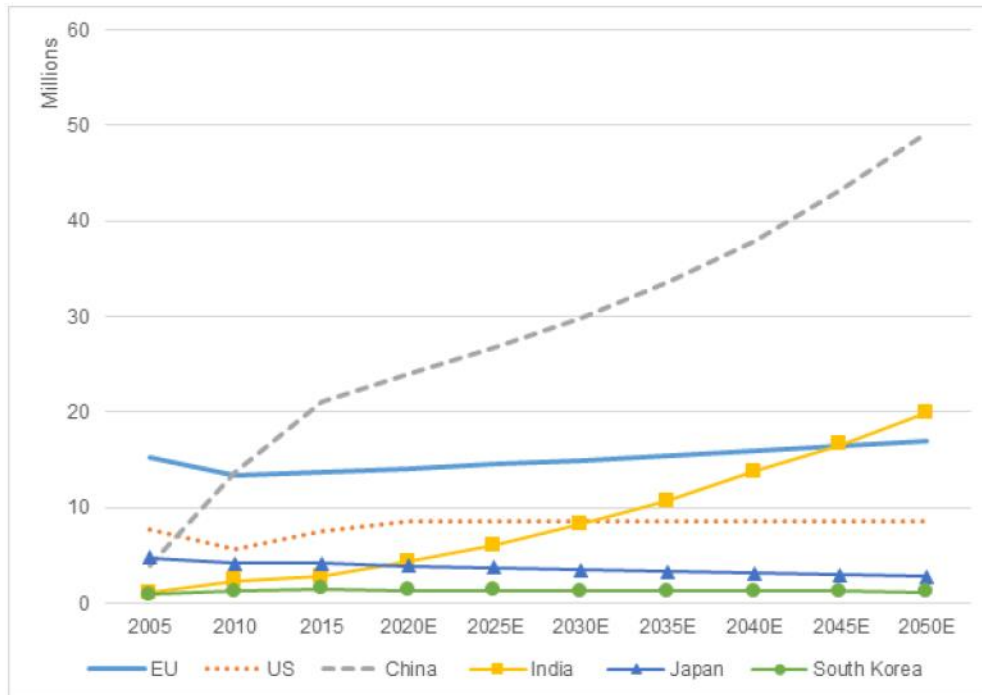


Figure 3: Forecasts for 5G Vertical Industries

2.2.1 Automotive Industry

The automotive sector is a major part of Europe's industrial landscape, contributing 4% of EU's GDP. Around 12 million Europeans have jobs in the automotive and mobility sector. The sector generates a substantial positive trade balance with the rest of the world of around **€90 billion** (2016). It also invests around **€50 billion** in R&D (2015). The EU is among the world's largest producers of passenger, with the region contributing 16 million (28%) out of the total 57 million passenger cars produced in 2015 in the six major geographical markets (EU, US, China, India, South Korea and Japan)³.

³ High Level Group GEAR 2030 report on automotive competitiveness and sustainability, October 2017, https://ec.europa.eu/growth/content/high-level-group-gear-2030-report-on-automotive-competitiveness-and-sustainability_en.



Source: GEAR 2030 Strategy 2015-2017 – Comparative analysis of the competitive position of the EU automotive industry and the impact of the introduction of autonomous vehicles

Figure 4: Sales of passenger cars 2005-2050 in six key geographical markets

As the **largest private investment in research and development (R&D)**, four out of the top five companies invest most in R&D being from the automotive sectors [GEAR 2030]. In the period 2014-2020 the EC has more than doubled the available funding for collaborative research and innovation activities for the automotive sector⁴, with a focus on green vehicles, decarbonisation of conventional engines, safety, and ICT. This substantial R&D investment and support for global technical harmonisation by Europe's automotive industry aims to maintain Europe's global technological leadership in the sector and strengthen its competitive position.

A recent report by the by High Level Group (established by the EC) on the **Competitiveness and Sustainable Growth of the Automotive Industry in the European Union (GEAR 2030)** noted that "[the] European automotive sector is expected to undergo structural changes in its value chain due to the development of digital technologies and the shift towards low and zero emission mobility." In particular, the focus of the study was on the following emerging innovation tracks: (i) decarbonisation and zero emissions vehicles (ZEVs), and (ii) connected and automated driving (CAD). The drivers, developments and trends under each of these tracks are discussed briefly below.

Decarbonisation and Zero Emissions Vehicles (ZEVs)

A quarter of the EU's greenhouse gas (GHG) emissions are attributed to transport, making it the second-largest source of emissions after the energy sector.⁵ Furthermore, two-thirds of the transport-related emissions are attributed to emissions from road transport. Therefore, the decarbonisation of transport (including road transport) is a key requirement for EU commitment to reduce GHG

⁴ EC Transport, https://ec.europa.eu/clima/policies/international/paris_protocol/transport_en.

⁵ Eurostat: Europe 2020 indicators - climate change and energy: http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_climate_change_and_energy

emissions by 80-95% by 2050 compared to 1990-levels with an intermediate target for 2030 of 40%. To that end, the EC in 2016 produced a Communication outlining "A European Strategy for Low-Emission Mobility"⁶ which includes proposals for the following actions:

- Optimising transport system and improving its efficiency.
- Scaling up the use of low-emission energy for transport.
- Moving towards low-emission and zero-emission vehicles (ZEVs).

Digital technologies are noted (in the EC strategy document) to be among the key enablers for this transition towards low-emission mobility, particularly due to the enormous potential of these technologies for optimisation of transport systems and integration of transport with other systems.

Connected and automated driving (CAD)

Providing vehicles with connectivity (regardless of whether the vehicles are automated or not) enables the communication within and outside their operational environments. Connected vehicles on the move tend to be more proactive, coordinated, cooperative and better informed of their own status and that of the surrounding environment [LU2014, UHLEM2015]. These capabilities create an environment for supporting a wide range of digital mobility services and applications that address most of the major challenges facing today's road transport systems. These include digital services and applications for road safety (e.g., collision detection, lane change warning, cooperative merging etc.), traffic congestion (e.g., traffic signal control, intelligent traffic scheduling), energy savings (e.g. route optimization) and reduction of air pollution. Moreover, in-vehicle high-speed Internet access provides opportunity enhance the quality of experience (QoE) for in-vehicle entertainment/infotainment services to the same level experienced in off-road broadband hotspots.

Although legacy connectivity solutions (WiFi, pre-5G cellular etc.) are still unable to fully support most these services, Statista already values the connected car market at 25 billion USD in year 2017, with penetration of connected cars projected to quadruple in the four-year period from 2017 to 2021. The drivers for this markets growth include factors such as, government mandated additions (e.g. the "eCall" automatic emergency call system⁷), increasing uptake of usage-based insurance (UBI) and projection of smartphone apps to vehicle built-in displays (e.g. Apple's iOS CarPlay,⁸ ETSI MirrorLink specifications,⁹ etc.).

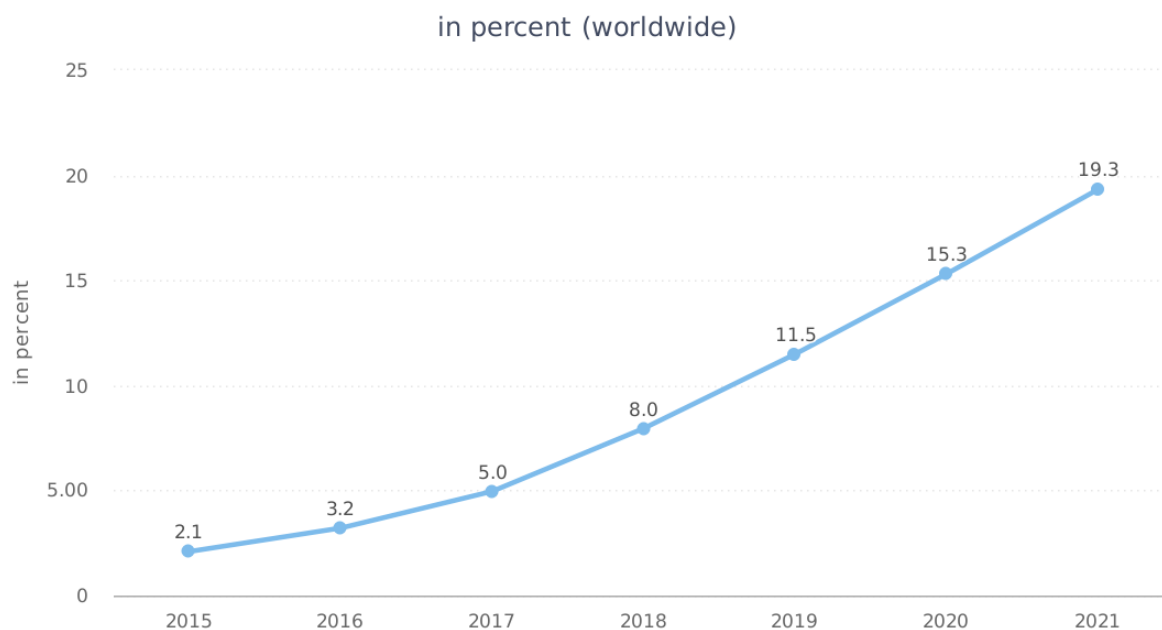
⁶ EC, "A European Strategy for Low-Emission Mobility," COM(2016) 501 final: <http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52016DC0501>

⁷ In April 2015 European Parliament voted in favour of eCall regulation which requires all new cars be equipped with eCall technology from April 2018. <https://ec.europa.eu/digital-single-market/en/news/ecall-all-new-cars-april-2018>

⁸ <https://www.apple.com/ios/carplay/>.

⁹ ETSI TS 103 544 series are adopted the MirrorLink specifications from the Car Connectivity Consortium (CCC), that were developed is an open standard for smartphone-car connectivity that allows smartphone apps to be projected on car In-Vehicle Infotainment (IVI) systems. <https://carconnectivity.org/>.

Penetration Rate in the Connected Car market



Source: Statista, March 2017; Selected region only includes countries listed in the Digital Market Outlook

statista

Figure 5 Projected penetration rate in the worldwide connected car market, 2017-2021 [Source: Statista]

As the future vehicle models attain higher-levels of automation and vehicular connectivity solutions improve (in terms of capacity, latency, reliability etc.), the development of vehicle automation and connectivity could actually reinforce each other [GEAR 2030]. For instance, the improved ultra-reliability and low-latency performance targeted by 5G systems could provide the level of vehicle-to-vehicle connectivity performance required for cooperation of autonomous vehicles (e.g. for platooning). Automated vehicles should increase the use of the cellular network through the large amount of data they will share (big data) and because they will allow the driver to perform secondary tasks (e.g. internet surfing) during driving time.

The emerging consensus is that the evolution path from LTE-V2X to 5G-V2X, will ultimately pave the way to the future vision of fully connected and automated driving (Level 4/5) that was outlined in the previous section. From a **technological perspective**¹⁰, this consensus is driven by fact that 5G enhancements (delivered through 5G-V2X) provide significant improvements in relevant KPIs (capacity, latency, etc.) and support for heterogeneous services (with varying requirements) as envisioned in future automotive use cases.

There are several **socio-economic drivers** that further promote the use of 5G in the automotive sector. A white paper on “5G Automotive Vision” by the 5G-PPP¹¹, which noted that the use of C-V2X

¹⁰ 5GAA, “The Case for Cellular V2X for Safety and Cooperative Driving” November 2016.

¹¹ 5G-PPP, “5G Automotive Vision” October 2015.

(including 5G-V2X) brought with it the benefit of economies of scale from the 3GPP technologies ecosystem. Moreover, the relatively wide coverage of existing cellular infrastructure would require significantly less costs to support automotive use cases compared to Greenfield V2X network rollouts¹² using wide area network technologies specified solely for automotive sector. With 5G widely expected to be the dominant connectivity technology for the automotive sector in the next decade, there are several projections already by various analysts. For instance, a study by ABI Research¹³ projected that by 2025 there will be 67 million automotive 5G vehicle subscriptions active, with the accuracy of these timelines dependent on the availability of very-low latency capabilities in 5G.

2.2.2 Healthcare

The digital revolution already apparent in other industries has yet to become mainstream in the health sector, with disruptions coming from improved patient engagement, connected care, unobtrusive monitoring, assisted living for people with chronic conditions, independent and active ageing, and robotic/remote surgery.

The current health model will soon be unsustainable due to a rapidly ageing population with longer life expectancy and lower birth rates. Delivering care as we know it today will not be affordable for any society 20 years from now. According to Eurostat, Germany will reach an old age dependency ratio (the ratio between older dependents—people older than 64—and the working-age population—those 15–64 years of age) of 50% by 2035. Furthermore, studies report that monthly health care expenditures for elderly people increase substantially with age¹⁴. All in all, to put it simple, people are getting older with fewer people to look after them and to pay for their care.

Virtualisation of care

Industrial and emerging economies are undergoing significant demographic and socio-economic changes. We are witnessing a shift from previous healthcare systems with hospitals, specialists and local general practitioners to treatment in day clients, day surgery units, doctor's surgeries, at home and over the internet. The delivery of care in the future will be distributed and patient centred rather than predominantly hospital based and practitioner focused¹⁵, with growing evidence for a significant shift towards **virtualisation** and **individualisation of care**¹⁶.

The same principles underpinning Industry 4.0 (interoperability, virtualisation decentralisation, real-time capability and service orientation) also apply to the healthcare sector, to deliver Health 4.0:

- Supporting the collection of data in the real world and their transformation and aggregation into more complex services (virtual world): **interoperability**.
- Delivery of care close to the patient's domain (hospital to home): **virtualisation and decentralisation**.
- The delivery of (virtualised) care will be in real time and based on (next to) real time data collection: **real-time capability**.
- Strong trend to organise care services that can be delivered anywhere, and anytime, avoiding the need for surgery waiting times or home visits, replaced by tasks that can be performed by

¹² For instance, the *5G Automotive Vision* white paper notes that the cost of rolling out a new IEEE 802.11-based infrastructure could be unacceptably high (in the order of 4000 EUR/km²).

¹³ ABI Research, "5G to be Unifying Connectivity Technology for Future Cars; To Enable V2X Communication" June 2016 <https://www.abiresearch.com/press/5g-be-unifying-connectivity-technology-future-cars/>.

¹⁴ Yang Z, Norton EC, Stearns SC (2003) Longevity and health care expenditures: the real reasons older people spend more. *J Gerontol B Psychol Sci Soc Sci.* 58(1): S2–10. doi:10. 1093/geronb/58.1.S2.

¹⁵ For evidence on such trends, see SA. Fricker, C. Thuemmler, A. Gavros (eds.), *Requirements Engineering for Digital Health*, Springer, 2015.

¹⁶ ER. Dorsay, EJ. Topol, State of Telehealth, *New England J Med* 2016; 375: 154-161.

the patient's social network: **service orientation.**

Health 4.0 has the potential to trigger changes also in pharmaceutical companies and manufacturers of devices, such as taking on new responsibilities and roles, such as a service provider.

The health care industry is the biggest and fastest growing industry in the world. In the European Union, the cost of providing health care is projected to rise by 15% by 2060, accounting for 8.5% of the GDP, when 1 in 8 people in Europe will be 80+ years old¹⁷.

Connected health, with a variety of use cases opens a whole new landscape of business opportunities for industry, new jobs and prosperity. The potential improvement enabled by 5G for patients, doctors, care givers, and society is huge. A 2015 report by PwC, commissioned by the GSMA, estimates that digital health could save €99 billion in healthcare costs to the EU GDP if its adoption is encouraged¹⁸. The same report indicates that digital health could enable:

- 11.2 million people with chronic diseases.
- 6.9 million people at risk of developing chronic conditions.

Extending their professional lives and improving productivity would add €93 billion to the EU GDP.

Additional socio-economic benefits can be accrued from interoperability, particularly at the semantic level.

Extensive, reliable and continuous data capture through health devices, collecting data such as bio-information, will be the bedrock of significant change in strategic and operational activities in the sector. Regular monitoring can increase adherence to prescribed therapies and reduce costs of non-adherence estimated to be at €140bn-420bn/year¹⁹.

Healthy living and disease preventative initiatives could reduce healthcare costs by 2.6-3.7% according to a McKinsey study²⁰. 2.6% represents a saving in public sector health care costs in European member states of €21.5bn/year. 5G is expected to contribute 5% of these savings.

5G data capabilities could provide preventative strategic benefits of approximately €1.1 billion per annum in public healthcare costs.

Remote monitoring and telemedicine will lower the average hospital stay as it will enable improved post-operative treatment of patients at home, reducing also the impact of nosocomial diseases and related costs for public healthcare.

The shift towards a decentralised model of care will also create new jobs for less qualified carers enabled to carry out routinely tasks and assist patients at home or in care centres relying on the intervention of experts on a by-need basis.

For remote treatment and surgery to become mainstream, however, these must become integral part of the national health service and insurance companies need to cover such treatments.

Operational benefits for chronic health care provision

The transformation of care moving closer to home and data moving from patients to hospitals is going to be driven by the needs of patients with chronic ailments, and it is likely to benefit these patients the most²¹.

¹⁷ A New Generation of e-Health Systems powered by 5G, part of series "Outlook: visions and research directions for the Wireless World", Wireless World Research Forum, November 2016, No 17.

¹⁸ <https://www.gsma.com/iot/pwc-report-realising-the-benefits-of-mobile-iot-solutions/>.

¹⁹ SMART 2014, 0008, p. 55 in reference to McKinsey 2013, The big data revolution in healthcare. Centre for US Health System Reform Business Technology Office.

²⁰ SMART 2014/0008, p. 56.

IoT-based health sensors will be used to monitor and treat illnesses. Based on current usage patterns, McKinsey estimates that the use of such sensors could lead to savings of 10% in health care costs in developed economies by 2025²² leading European member states to achieve savings of up to €83bn/year in public sector health care costs. The assumption is that 5G would contribute 5% of these savings.

Value comes from:

- Cost savings in treatment.
- Longer lives and improved quality of life that patients with chronic conditions could enjoy assuming that IoT monitoring helps them avoid disease complications.

5G data capabilities will provide operational benefits of approximately €4.15 billion per annum in public healthcare costs.

According to Ericsson ConsumerLab studies²³, consumers are demanding greater control over when, where, how and whom to engage for their healthcare needs.

The growing market offer of a wide range of **sophisticated wearables to monitor health and wellness** plays an important role in this trend and as the prices of such devices lowers, more and more people rely on technology for losing weight, tracing calories and keeping fit with daily regular exercise and a healthy lifestyle.

As of today, the widest employment of wearables is for fitness and wellness, addressing the consumers' desire to stay healthy through preventative measures such as regular health check-ups, daily exercises and a healthy diet. Over 60% of surveyed consumers²⁴ are ready to **use wearables as a preventive measure** for checking abnormalities and countering chronic ailments, including heart diseases, cancer and diabetes. In addition, consumers say wearables will lead to healthier lifestyles, and personalized care.

Although consumer-grade wearables are being widely used for preventative measures, 55% of healthcare decision makers from regulatory bodies say these devices are not sufficiently accurate or reliable for diagnosis.

Consumers seem readier to accept digital products than just a few years ago²⁵. The field includes mobile apps, telemedicine—health care provided using electronic communications—and predictive analytics (using statistical methods to sift data on outcomes for patients). Other areas of use include automated diagnoses and wearable sensors to measure parameters like blood pressure.

The huge quantity of health data collected by billions of sensors, coupled with the computational power of high performance computing will represent an unprecedented opportunity for medical

²¹ Ericsson, "From Healthcare to Homecare - The critical role of 5G in healthcare transformation" <https://www.ericsson.com/en/networked-society/trends-and-insights/consumerlab/consumer-insights/reports/transforming-healthcare-homecare>

²² SMART 2014/0008, p. 57.

²³ www.ericsson.com/consumerlab

²⁴ Ericsson, "From Healthcare to Homecare - The critical role of 5G in healthcare transformation" <https://www.ericsson.com/en/networked-society/trends-and-insights/consumerlab/consumer-insights/reports/transforming-healthcare-homecare>

²⁵ The Economist, 2nd March 2017, "A digital revolution in health care is speeding up", Article appeared in the Business section of the print edition under the headline "The wonder drug" <https://www.economist.com/news/business/21717990-telemedicine-predictive-diagnostics-wearable-sensors-and-host-new-apps-will-transform-how>.

research advances. In this case, **big data analytics** will facilitate identifying causes of a physical condition before it is manifest, allowing early diagnosis and preventative cure.

In the future healthcare system, patients will have all of their health data and records available within seconds, highlighting allergies, current medications, historical data etc. and therefore improving dramatically emergency interventions by saving precious time.

On-line consultation for health issues has increased over the last years. With 5G this will be taken one step further, with **remote focused patient-doctor interaction taking place in real-time**, allowing expert's advice to be delivered in a timely and affordable way. Cutting the waiting-list time and costs for consultation are among the principal benefits valued by patients.

Engaging patients (and a wide part of the healthy population for health scanning) in health data harvesting is important in particular in the early stages of the shift to e-health when there is still a cultural opposition to sharing health data.

According to the Ericsson study "From Healthcare to Homecare - The critical role of 5G in healthcare transformation"²⁶, 60% of patients are open to sharing their data with healthcare providers and making it available in a central repository – if it improves the healthcare services they receive, helps monitor chronic ailments, improves the quality of diagnosis and reduces wait times. However, 61% of patients with chronic ailments feel concerned about data from health patches being used without their permission.

As healthcare becomes more dependent on wearables and connectivity, consumers express concern about reliability. In fact, 59 % of consumers say that they are concerned about poor connectivity affecting data transmission. Battery charging is another issue – 56% of consumers with chronic ailments worry about their health patches suddenly running out of battery.

<p>Security, reliability and battery life are the top concerns of consumers moving towards 5G health</p>

Hopefully the model of delivery in the health care sector may shift from a "volume-based" to a "value-based" one: as highlighted by The World Economic Forum and Boston Consulting Group in their "Value in Healthcare - Laying the Foundation for Health System Transformation"²⁷ insight report, traditional delivery of health-care has rewarded vendors (e.g., physicians and specialists) based primarily on measures of volume. Paradoxically the traditional "fee-for-service" compensation model provides incentives for over-treatment. What is required, they argue, is to move to a world of "value-based health care" or (alternatively) "outcome-based health care." The essence of this new approach is to base the health care system on the delivery of the outcomes that matter the most to consumers, at the lowest possible cost. Goldman Sachs²⁸ estimates that the transition to value-based care could generate upwards of \$650 billion in savings²⁸ by 2025 through shifting care to lower-cost settings, moderating price inflation and reducing the estimated \$1.4T in annual health care waste in the US.

5G is also expected to impact positively on life insurance premiums. The EU insurance market is the largest globally with a 35% share of the total global market. Life insurance is the largest segment (in 2014, €714bn was paid in life insurance premiums in the EU, an average of €1900 per capita²⁹).

²⁶ Ericsson, "From Healthcare to Homecare, op cit.

²⁷ World Economic Forum and Boston Consulting Group Insight Report, "Value in Healthcare: Laying the Foundation for Health System Transformation", April 2017
http://www3.weforum.org/docs/WEF_Insight_Report_Value_Healthcare_Laying_Foundation.pdf

²⁸ Goldman Sachs Global Investment Research, "Healthcare's Holy Grail: Better Outcomes at Lower Costs", February 2017.

²⁹ SMART 2014/0008, p. 58.

Some functionality of sharing data from wearables with life insurance businesses already exists but the ubiquitous nature of 5G will enhance real-time capabilities and connectivity to the cloud, enabling the enhanced monitoring of more people. 5% of projected savings are attributable to 5G.

5G IoT capabilities will provide consumer benefits of approximately €207m/year in the European market in reduced life insurance premiums.

5G capabilities could radically extend the reach and reliability of various wearable and portable health monitors that would provide rich bio-data information from volunteer patients living anywhere. SMART 2014-0008³⁰ estimates that if 5G capabilities comprised 5% of savings (of 15%), savings could amount to approximately €72m/year for the European pharmaceutical sector.

5G IoT capabilities will provide third party benefits of approximately €72m/year to the European pharmaceutical research and development sector.

2.2.3 Energy

The business potential of 5G in the energy vertical is expected to be very high through the support of critical machine type communication (MTC) applications of energy grid protection and control and the massive volume of MTC type applications coming from smart metering. The performance and flexibility promised by 5G will enable a communication infrastructure capable of supporting emerging energy use cases for 2020 and beyond. Examples include increasingly distributed generation and storage of power and micro-grids.

Forecasts for the energy vertical usually include all utilities. The 2016 SMART Study reports several forecasts for 2020, when the utilities could account for two-thirds of the 30 billion smart, wirelessly connected devices in homes and industry worldwide³¹. EIT Digital has predicted a global market worth almost €400 billion for smart grid technology in 2020 while Pike Research predicts that investment in smart grid technologies in Europe will total \$80.3 billion between 2010 and 2020³². The more recent analysis from IHS Economics shows the highest economic impacts coming from mission critical services such as smart grid deployments with stringent security requirements.

Realising the full potential for the energy vertical will require many challenges and changes within the industry, including critical concerns like trust, control and liability, as well as a favourable policy and regulatory environment, as highlighted in the SMART 2014/0008 optimistic and pessimistic scenarios. Today's communications, control and data frameworks were not conceived for the multiple applications that are emerging with new requirements in the energy vertical. Challenges include coping with increasing numbers of outstations, data volumes and service requirements, as well as the on-going evolution of the power grid, where the industry needs to rethink current power systems based on a centralised architecture that is centred on the control centres of Transmission Network Operators (TNOs) and Distribution Network Operators (DNOs).

There are other changes important to note in the context of 5G. On the supply side, we are seeing more and more small, distributed generation embedded close to communities offering power alongside large centralised generation networks. The advent of affordable storage solutions and demand side response mechanisms now means that demand is flexing to meet available generation.

³⁰ SMART 2014/0008, op cit., pp. 58-59.

³¹ Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe (SMART 2014/0008), <https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds>.

³² SMART 2014/0008, p. 66.

These technical changes in societal usage require highly secure and available communications such as for sensing and control.

The European energy industry needs to adapt to evolving requirements on both the supply and demand sides and embrace a new social, commercial, technical and market landscape. While the physical infrastructure is unlikely to undergo substantial changes, the way we use it and new market structures will unleash new possibilities. IoT, home automation, social media and smart users will help bring about the shift from centralised functions to a hybrid of central and distributed intelligence that must work seamlessly together.

Whole systems perspective. It is essential that future 5G solutions prioritise all direct and indirect socio-economic costs, spanning market structure, technical, commercial, environment, health and safety, social costs, as well as integration costs, including any hidden or unforeseen costs that could make the business case less compelling. Key advantages of a whole systems perspective include coverage of all cost considerations and testing by use cases to help address unforeseen inter-related issues while offering an opportunity to test against a range of scenarios beyond the central scenario.

Overall, this vertical can draw on the following priority actions. SMART 2014/0008 stakeholder discussions pinpointed the international harmonisation on spectrum as one of the major drivers in the utility IoT environment, giving manufacturers confidence in the market and allowing the industry to take advantage of economies of scale. This would subsequently foster innovation, integration and interoperability. Another important driver is a clear direction and strategy at the EU level covering all the different regulatory policies needed in this sector, enabling investment, innovation and development in the utility vertical.

Control is the utility providers' concern of using a network that they cannot control and manage. Here there is a fundamental "trust" issue. Discussions within 5G PPP work groups have also highlighted the importance of having a trust model as a general benefit for phase 2 projects. Projects like NRG5 with energy vertical use cases that also deal with security and trust can benefit from phase 1 outputs, such as the 5G-ENSURE Trust Model³³, taking its relationship to risk mitigation fully into account, especially when formulating vertical applications. This is something that could be promoted through the 5G-PPP Security WG as it is a key issue across most vertical industries.

2.2.4 Factories of the Future

Factories of the future (also known as Industry 4.0 and smart factories) leverage the technical integration of Cyber-Physical-Systems (CPS) in production and logistics as well as the application of Industrial "Internet of Things in industrial processes.

Industrial production represents 16% of Europe's GDP and is a key driver for innovation, productivity, growth and job creation. Manufacturing employs around 30 million persons and twice as many in support activities such as logistics. In such context, the manufacturing industry sector is the second most important sector in Europe, with a total of 23.8% of GDP (including support activities), behind the services sector.

This sector has gone through various evolution cycles over the past centuries, and the Factory of the Future is the next development of the industrial sector. Historically, at its beginning, during the 18th century, the industrial sector was characterized by mechanized production using coal and the development of the steam engine. At the end of the 18th century, the arrival of electric power allowed

³³ 5G-ENSURE Trust Model (Final), Conclusions, http://5gensure.eu/sites/default/files/5G-ENSURE_D2.5%20Trust%20model%20%28final%29%20v2.2%20inc%20history.pdf.

for mass production and finally, in the middle of the 20th century, machine control and robots allowed the automated production.

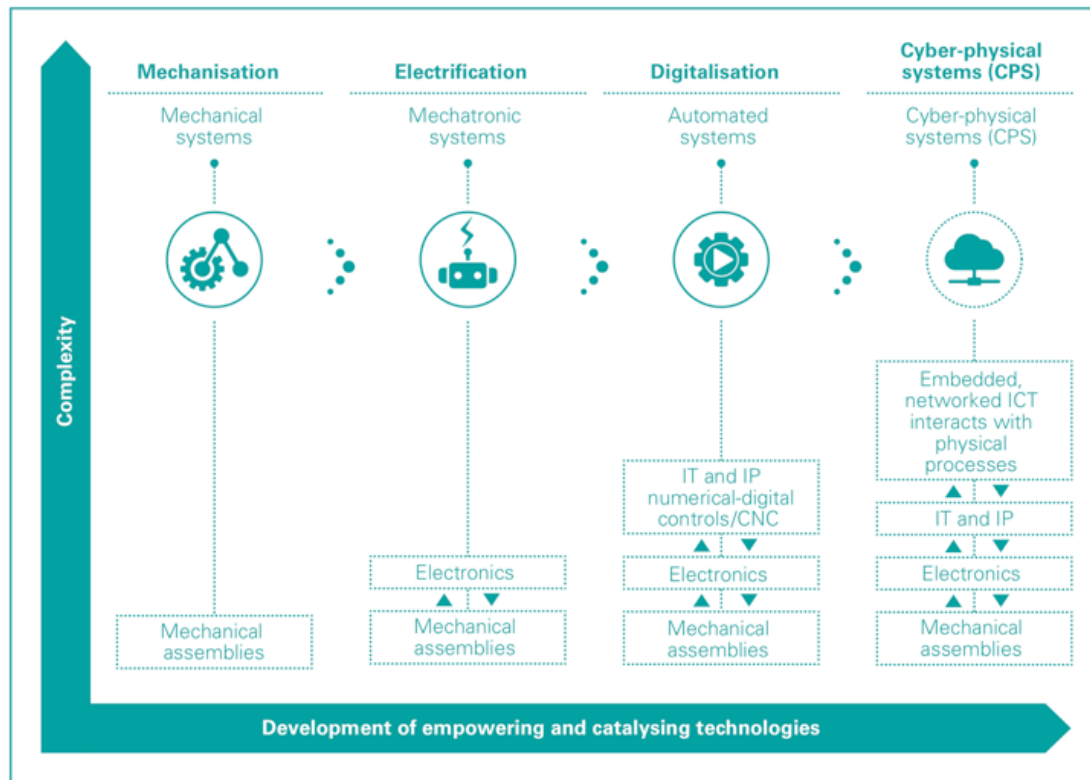


Figure 6: Industry Lifecycle [Source: KPMG³⁴]

Factory of the Future is the next evolution of the manufacturing industry. Basically, it is a merge of two distinct areas: factories and the Internet. Factories, as highlighted previously, have automated production mechanisms to operate equipment without human interventions. However, staff are still required to monitor, maintain, repairs robots and tools. On the other hand, a new area has emerged on top of the Internet of Things (IoT) paradigm: the CPS, Cyber Physical Systems, also called IIoT (Industrial Internet of Things) which provides factories with IoT solutions. Here comes the Factory of the Future, the connected factory, and it represents the upcoming transformation of the manufacturing industry: processes based on new and Internet-related technologies and innovative concepts. For the big picture, in the production and supply chains, tools and workstations communicate constantly. Machines, systems, and products exchange information both among themselves and with the outside.

³⁴ <https://assets.kpmg.com/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf>.

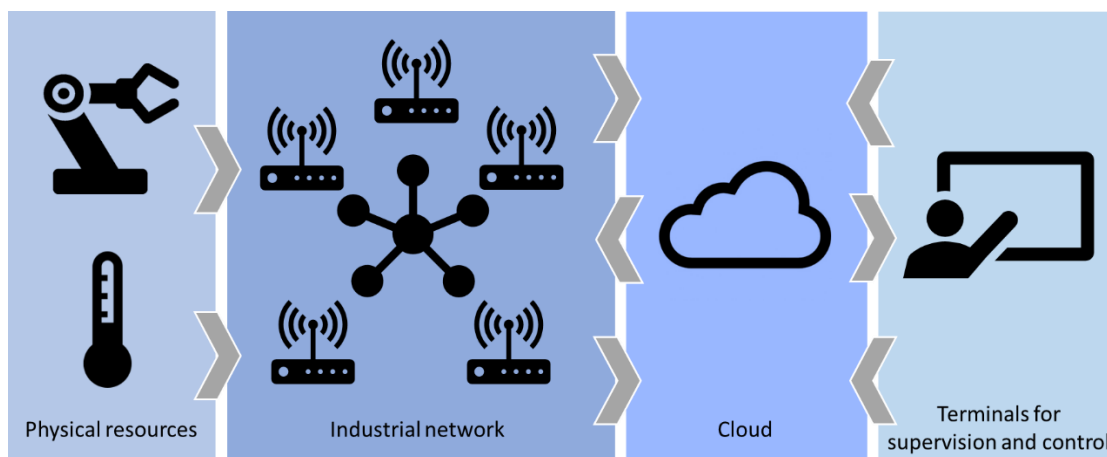


Figure 7: Smart Factory Basics [Source: S.Wang 2016]

Compared with previous evolutions, it is here important to note that all components needed for this step already exist: the Internet of Things, big data solutions, cloud applications with paradigms such as Software as a Service (SaaS), Platform as a Service (PaaS) (and next models could be Machines as a Service or Equipment as a service). This evolution is therefore more an integration of new technics in modes of production. And these new technics all rely strongly on the network, being wired or wireless.

Technology innovations involved in Factories of the Future span robotics, 3D-printing, advanced materials, novel sensors, autonomous vehicles, which all contribute individually to increased efficiency and flexibility. Part of the increased efficiency and flexibility, can be achieved by connecting and integrating these technologies in a smart and manageable manner and extracting actionable insights. Digitisation relies on IoT technology, cloud solutions, big data crunchers, and cyber security components. 5G technologies can play a key enabling role in integrating them and offer a ubiquitous platform to interconnect machines, robots, processes, auto guided vehicles, goods, remote workers, etc., where the infrastructure is supported by robust wireless telecom infrastructure – thus allowing all “things” to communicate and exchange information.

The term Factory of the Future (FoF) refers to the vision on how manufacturing processes will be operated in the future. This evolution is needed to increase industry’s share of GDP to 20% by 2020 in Europe. Historically, the FoF initiative has been started as a Public Private Partnership (PPP) by the European Commission in 2012 to help the industry sector fighting against the financial crisis and competition from BRIC countries.

2.3 Stakeholders in the 5G Ecosystem

2.3.1 Stakeholder benefits for Automotive

The **automotive sector** encompasses a diverse range of stakeholders, including the automotive value chain, authorities responsible for providing and managing the road transport network, and the vehicle owners/passengers, as well as the other non-vehicular users of the road infrastructure (e.g. pedestrians). As noted in the EC GEAR 2030 report³⁵, the European automotive sector is braced for a

³⁵ GEAR 2030 High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union Final Report:

period of profound structural change due to several factors, including: increased consumer demands/expectations, adoption of innovative technologies (including 5G-V2X), new production processes, evolving regulatory requirements and, more significantly, the increased competitive pressures from emerging vehicle-manufacturing regions.

The table below summarises the expected impacts of new 5G capabilities on different stakeholders within the automotive sector.

Automotive Stakeholder	Expected Impacts ³⁶
<p>Vehicle manufacturers and component suppliers in the value chain.</p> <p>Key statistics:</p> <p>Manufacturers/suppliers contribute up to 80% of the total vehicle's added value.</p> <p>The EC GEAR 2030 report notes that the highly-diversified automotive component supply business involves over 3,000 companies (both SMEs and multinational suppliers) spread across all EU member states.</p>	<p>Drivers: the need to decarbonise, increase competitiveness and to consolidate EU leadership position in vehicle production.</p> <p>Roles: Major player in making the shift from just purely mechanical engineering towards electrochemistry, electronics and software, as vehicles become increasingly connected and automated.</p> <p>Benefits: 5G will enhance the capability of vehicle manufacturers to gather data on real-time status of their vehicles in use, thus enabling them to better anticipate demands on required components and reduced observed faults out of future models of their model designs. The rich real-time data on vehicle will provide manufacturers with additional capabilities for remotely improving and/or personalising the driving experience and vehicle performance.</p> <p>5G will improve the vehicle relationship management (VRM) and maintenance related services through sharing of the rich vehicular diagnostic data with car dealerships. This will enable them to better anticipate faults and optimally schedule vehicle servicing thus minimising downtime experienced by vehicle owners.</p> <p>The 5G increased data capabilities will provide both economies of scale and scope in vehicle production. Enhanced data exchange capabilities for assembly operations and throughout the automotive supply chain will enable vehicle manufacturers to mass produce customised variants of the vehicles within models and/or between models using data-enhanced production systems that are able to operate efficiently in response to predicted variations in production demand.</p>
<p>Consumers/vehicle users</p>	<p>5G will provide several benefits for consumers (drivers, vehicle/fleet owners, passengers etc.). The LTE-V2X is already expected to provide some of the functionalities envisioned for consumers in the future. However, 5G will enable further enhanced real-time capabilities and high-speed cloud connectivity, which in turn provide several knock-on benefits including:</p> <p>Enhanced vehicle data sharing capability for vehicle</p>

<https://ec.europa.eu/docsroom/documents/26081/attachments/1/translations/en/renditions/native>

³⁶ SMART 2014/0008, op cit.

	<p>manufacturers and dealerships to provide improvements in driving experience, vehicle personalisation, VRM and quality of servicing (as noted above).</p> <p>Improved navigation services including access to higher quality traffic information that goes beyond current traffic information delivered to the car over low bandwidth connections.</p> <p>Improved access to entertainment and other relevant consumer content provided in seamless continuity allowing the user to access the content regardless of its context (in or outside the vehicle). To that end, the trend is shifting from limited content provided to vehicle occupants from in-vehicle infotainment systems (or smartphone integrations) towards connectivity of the car to the cloud enabling access to larger amount of content.</p>
Administrators	<p>5G capabilities and resulting enhancements in both vehicle and road information can also benefit entities responsible for administering/managing road transport systems. The sensing and sharing of real-time and high-quality information between vehicles and roadside infrastructure will enable administrators to enhance traffic management, increase speed of response to various road events (e.g. accidents) and improve long-term road safety measures.</p>
Stakeholder benefiting from new business models	<p>The generation and sharing of substantial amounts of vehicular data will catalyse many new business actors providing data-driven services and applications. This could create new revenue streams for vehicle manufacturers and any other owners of data generated by vehicles, as well as, purchase or recurring usage fees for the data-driven automotive applications and services. An emerging disruption in landscape of connected and automated cars which will also be further enhanced by 5G is the "mobility as a service" (MaaS) paradigm, which aims to put users at the core of transport services, offering them tailor-made mobility solutions based on their individual needs³⁷.</p>
Smart services opportunities for drivers, passengers, car makers, telecom operators/service providers and many other new actors in this new market identified by the 5GAA.	<p>Automated Driver Assistant Services (ADAS): driver assistant, parking assistant, self-parking and automated/unmanned driving.</p> <p>Telematics: traffic alerts and road weather condition alerts.</p> <p>Infotainment services: music streaming, video streaming to passengers.</p> <p>Tourism: tourist visit to passengers with augmented reality (AR) and virtual reality (VR).</p> <p>Remote and automated management for smart vehicles such as software/firmware updates.</p>

Table 2: Automotive Stakeholder Benefits

³⁷ On Mobility-as-a-Service, see for example <https://maas-alliance.eu/> and <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/consumer-business/deloitte-nl-cb-ths-rise-of-mobility-as-a-service.pdf>.

Other stakeholders include industry bodies, alliances and other organisations relevant for adoption of 5G in the automotive sector. This includes both actors from the ICT sector and traditional verticals from the automotive sector, as outlined in the table below.

Organisation Name	Description
ERTICO	A partnership of around 100 companies and institutions involved in the production of Intelligent Transport Systems (ITS). Together, ERTICO Partners conduct a range of activities to develop and deploy ITS to save lives, protect the environment and sustain mobility in the most cost-effective way
5G Automotive Association (5GAA)	A global, cross-industry organisation of companies from the automotive, technology, and telecommunications industries, working together to develop end-to-end solutions for future mobility and transportation services. The 5GAA supports the idea that 5G will be the ultimate platform to enable C-ITS and the provision of V2X.
European Automobile Manufacturers' Association (ACEA)	Association representing 15 Europe-based car, van, truck and bus manufacturers: BMW Group, DAF Trucks, Daimler, Fiat Chrysler Automobiles, Ford of Europe, Hyundai Motor Europe, Iveco, Jaguar Land Rover, Opel Group, PSA Group, Renault Group, Toyota Motor Europe, Volkswagen Group, Volvo Cars, and Volvo Group.
European Association of Automotive Suppliers (CLEPA)	Association including 119 of the world's most prominent suppliers for car parts, systems and modules and 23 National trade associations and European sector associations representing more than 3000 companies and covering all products and services within the automotive supply chain.
European Telecommunication Network Operations Association (ETNO)	ETNO, founded in 1992, is the principal policy group for European network operators and aims at supporting a positive policy environment to deliver the best quality services to consumers and businesses.
European Competitive Telecommunications Association (ECTA)	A pan-European pro-competitive trade association that represents over 100 of the leading challenger telecoms operators across Europe. ECTA supports the regulatory and commercial interests of telecoms operators, ISPs & equipment manufacturers in pursuit of a fair regulatory environment that allows all electronic communications providers to compete on level terms.
GSMA	Represents the interests of mobile operators worldwide, the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events, such as, Mobile World Congress. The development of C-V2X is one of the main areas of interest ³⁸ .
Global mobile Suppliers Association (GSA)	Association representing worldwide mobile supplier ecosystem who are engaged in the delivery of infrastructure, semiconductors, test equipment, mobile devices, applications and mobile support services.

³⁸ <https://www.gsma.com/iot/automotive/>.

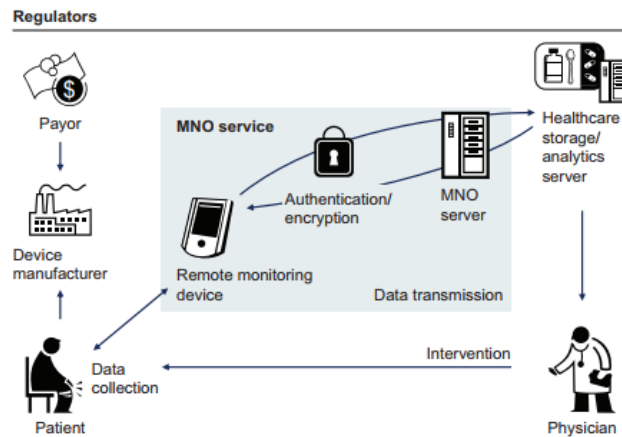
European Automotive-Telecom Alliance (EATA)	An Alliance includes six leading sectorial associations (GSA, GSMA, ECTA, ETNO, CLEPA, ACEA) and 37 companies, including telecom operators, vendors, automobile manufacturers and suppliers for both cars and trucks. The main goal of this Alliance is to promote the wider deployment of connected and automated driving in Europe.
Next Generation Mobile Networks (NGMN) Alliance	Association of mobile operators, vendors, manufacturers and research institutes. It was founded by major mobile operators in 2006 as an open forum to evaluate candidate technologies to develop a common view of solutions for the next evolution of wireless networks. Its objective is to ensure the successful commercial launch of future mobile broadband networks through a roadmap for technology and friendly user trials. NGMN includes a V2X task force to provide essential guidance in terms of end-to-end requirements for automotive use-cases. ³⁹

Table 3: Industry Associations and Influencers for 5G Automotive

2.3.2 Stakeholder Benefits for Healthcare

The health care industry is complex, with multiple stakeholders, principally health care providers, medical devices/services providers, and consumers, but also the pharmaceutical industry and insurers. Each stakeholder has different incentives to adopt 5G-related technologies and change their practices⁴⁰.

The mHealth ecosystem is complex, with multiple stakeholders playing critical roles



SOURCE: Expert interviews; McKinsey

Figure 8: mHealth Stakeholders [Source: GSMA]

³⁹ <https://www.ngmn.org/news/ngmn-news-and-press-releases/ngmn-news-and-press-releases-details/ngmn-alliance-and-5gaa-sign-co-operation-agreement.html>

⁴⁰ GSMA mHealth: A new vision for healthcare, March 29, 2012, <https://www.gsma.com/iot/mhealth-a-new-vision-for-healthcare/>

Health Stakeholder	Expected Impacts ⁴¹
Health care facilities	In hospital and health care facilities health management systems combine the Internet of things (IoT) with cloud computing and big data technology. Medical equipment and drugs can be better managed (automatic alert when supply is low or expiry date near, easy tracing of equipment in large hospitals. Patient information is updated in real time and available for medical consultation in all departments allowing consultation between the most expert practitioners regardless of their physical location.
Patients	5G is considered an important opportunity for patients to take charge of their health and act upon it. Increased access to data enables greater transparency, empowers patients and improves overall patient engagement with their health care providers. Continual monitoring by means of unobtrusive connected wearable sensors could drastically reduce fatalities by shortening the time for intervention (e.g. patients suffering from heart failure could be localised in real time and assistance could be triggered almost instantaneously).
Manufacturers of medical devices	Manufacturers of devices like infusion pumps, monitors, ventilators, and hospital beds are looking for strategies to hyper-connect these machines to integrate patients and professionals. Overall, manufacturers in the medical domain are seeking to transform their products into real time services, which can be integrated and aggregated based on individual requirements and preferences underpinned by new business models.
Pharmaceutical Companies	Pharmaceutical companies are conducting research into smart pharmaceuticals aiming to collect real-time information from patients to massively enhance the effectiveness and efficiency of their products. Examples include smart asthma inhalers, insulin pens and smart wound dressing.
Informal carers	Mobile technologies will enable and empower less qualified carers to adopt routine tasks that would otherwise be conducted by professionals, thus making use of individual social capital.

⁴¹ "A New Generation of e-Health Systems Powered by 5G" Chief Editor: Christos Politis, v1.1

Health insurance companies	(Authorised) access to data from wearables for enhanced monitoring of more people will allow insurances to better calibrate the premium for life insurance.
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Table 4: Health care Stakeholder Benefits

2.3.2 Stakeholders Benefits for Energy

The following benefits have been identified for stakeholders in the energy vertical in relation to the potential of 5G.

Stakeholder	Benefits
Energy producers and distributors	Mobile networks offer clear benefits as a means of IoT connectivity. Compared with private networks they obviate the need for spending money on building and maintaining data infrastructure. Compared with fixed-line public networks, they offer advantages in terms of geographic reach, and provisioning/maintenance costs.
Energy suppliers	Access to, and sharing of, better information about customers' use of energy, both real-time and historical. This will support more efficient energy generation, enabling savings in generation capacity especially in periods of high demand. Operational benefits from reduced needs for site visits, to read meters and carry out safety inspections. Automated maintenance and feedback procedures, and more accurate and up-to-date billing could also reduce customer inquiries and complaints.
Mobile network operators	Smart energy applications increase the number of devices connected to mobile networks and generate data traffic. Opportunity to move further up the value chain by developing and operating other parts of the overall solution, such as application hosting and data analytics.
Consumers	Smart meters will help consumers better understand their energy consumption by providing access to historical data and localised best practices on energy use and consumption. This will enable them to identify areas where they can save money by optimising usage. They can also benefit from more accurate and up-to-date billing.
Benefits across core activities in the energy industry: extraction, harvesting, generation, storage, distribution, service, consumption.	As an enabler of IoT, 5G can further boost the potential for energy companies to save costs, operate more efficiently and improve customer service by connecting plant and devices to data processing facilities, and to each other. Tasks

	such as metering, monitoring and automation can benefit greatly from IoT connectivity in all seven of the core activities by using public networks. Internet connectivity can be used by field service engineers for task scheduling, inventory querying, parts ordering and job administration.
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Table 5: Energy Stakeholder Benefits

2.3.4 Stakeholder Benefits for Factories of the Future

Mapping benefits on stakeholders is a complicated task as stakeholders may vary a lot according to the concerned industry. For this document, stakeholders will be limited to the: employees, factory management staff, shareholders and policy-makers.

Benefits for factory management staff

One of the main enablers of smart factory innovation is the factory owner. As explained by the concept of intelligence of usage,⁴² the customer, as the final smart factory user needs to interact with the process. Also, in a changing landscape, factory owners need to move constantly, always questioning the way they do business. By reducing secondary tasks, smart factories allow operators to focus on their main activity and adopt new processes quickly and efficiently.

Benefits for employees

The array of potential benefits introduced through 5G-powered Factory of the Future is humongous. As for example through the monitoring and management of alerts.

Alert management processes are usually managed and controlled by **specific resources (HR) supported by dedicated systems of varying degrees of complexity**. Security control centres equipped with screens, cameras and permanent on-call duties are expensive and not always efficient, introducing a certain level of risk, notably human error, into the process. With the deployment of new and smarter technologies with a smart factory environment, such centres can be replaced by **automated and tailor-made systems**.

Today a completely automatic detection system can perform all such alert management duties in real-time. For example, the uses of sensors and signal detectors throughout the production process can help detect alerts and trigger the **appropriate response** to fix the problem. Thus, these smart factory set-ups do not just detect simple malfunctions such as power surges or elevator breakdowns, they also provide actionable prescriptions to facilities managers, which help to ensure smooth operations and avoid production bottlenecks and delays.

⁴²Research concept by the Lirmm, <https://www.lirmm.fr/le-lirmm/>.

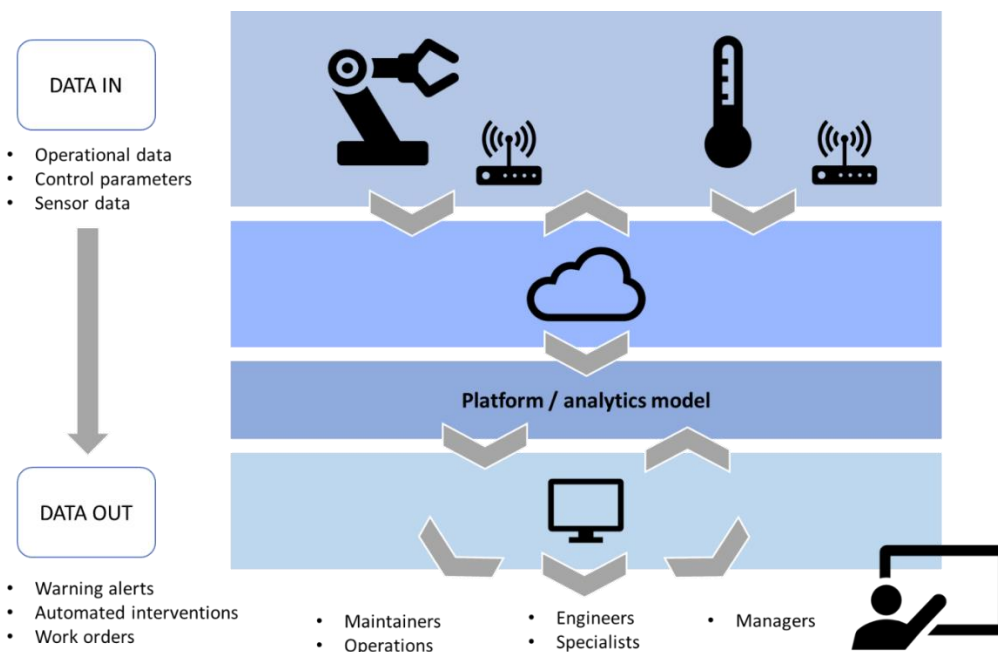


Figure 9: Smart alert management system [Source: inno TSD, 2017]

The figure above illustrates how a wireless notification system can be used to alert managers and / or technicians that they are needed on the line, reducing the need for technicians and managers to constantly check each production line and for workers to leave their workstations when they need assistance. Such an alert management system **efficiently dispatches alert outputs**, indicating which production line needs a manager’s attention, a maintenance technician or the intervention from an engineer.

The applications for employees go beyond alert management, benefits of Factory of the Future could outweigh the concerns for many production facilities⁴³. In very dangerous working environments, the health and safety of human workers could be better protected.

Mapping benefits across stakeholders is more complicated for factories of the future because of the variety of groups potentially affected and diversity of interpretations possible. Given the complexity reported in the literature in terms, the following table provides a **forward-looking perspective** associated with new business models that leverage data collection within the manufacturing context⁴⁴. The growth potential of new data-driven business models, either by service providers or manufacturers, will come from connecting suppliers, the supply chain, engineering and manufacturing services and other manufacturers. Manufacturers can play a key role in terms of product improvement and product-oriented models. Other service providers can bring efficiency to data oriented business models due to their expertise in IT solutions.

New roles or Services	Overview
Unified network manager: the party managing the communication network	Involvement of many different wireless network infrastructures deployed in a manufacturing context either

⁴³ <https://www.forbes.com/sites/bernardmarr/2016/06/20/what-everyone-must-know-about-industry-4-0>.

⁴⁴ 5G PPP White Paper: 5G and the Factories of the Future, 5G Infrastructure Association, 2015, p. 26.

infrastructure	in private or public areas. Key questions include: who owns the infrastructure? How is co-ownership of the network and managing infrastructure managed? Who is liable in the event of a failure along the communication/production chain?
Remote factory manager	The availability of highly reliable networks could become a key driver for new business models and new actors taking responsibility for remote SW upgrades, remote operations monitoring, remote maintenance and other relevant activities.
Machines-as-a-service/equipment-as-a-service	Outsourcing of operations and maintenance of machines or equipment. Rather than buying production machines, the manufacturer rents or leases them, with the machine vendor taking care of operations and maintenance (akin to the Rolls Royce business model for its airplane engines).
Providers of smart clothing	The integration of electronics in textile and wearable devices presents new business opportunities for existing or new actors in the value chain. Providers could also deploy very specific research activities in industrial environments that are not friendly to devices (e.g. noise, vibration, temperature etc.).
Provider of flexible robotic services	The increased autonomy of robots could lead to the introduction of new services that apply robots to execute dangerous, dull and dirty tasks.

Table 6: Forward-looking Perspectives on FoF Stakeholders

New actors could enter the market of optimising the connected factory by adding data analysis to sensing and communicating. Moreover, new data-driven business services could support manufacturers in improving product design based on product-related data that generates knowledge about the behaviour of products along the entire lifecycle. Services focused on product performance are a new business topic, where product productivity and performance data are a key aspect and the goal is to improve product behaviour on site, thereby reducing maintenance etc.

There are many industrial internet and Industrie 4.0 taking place around Europe and globally as potential implementers of 5G-enabled innovations by 2020 and beyond.

<p>Industrie 4.0⁴⁵ Initiated by government and academia. Focused on production. Covering the entire life cycle. RAMI 4.0 reference architecture⁴⁶.</p>
<p>Industrial Internet Consortium⁴⁷ Driven by large corporations with stakeholders from business, academia and industry. Focused on connectivity, IT integration, security. Covering several industrial domains.</p>

⁴⁵ www.plattform-i40.de.

⁴⁶ <https://www.zvei.org/en/subjects/industry-4-0/the-reference-architectural-model-rami-4-0-and-the-industrie-4-0-component/>.

⁴⁷ <http://www.iiconsortium.org/>.

EU Public private partnership – Factories of the Future⁴⁸

The FoF multi-annual roadmap (2014-2020) sets a vision and outlines routes towards high added value manufacturing technologies for the factories of the future, which will be clean, high performing, environmentally friendly and socially sustainable. The European Factories of the Future Research Association (EFFRA) represents the private side of the PPP⁴⁹. Its key objective is to promote pre-competitive research on production technologies. EFFRA was established jointly by the MANUFUTURE technology platform and key industrial associations to shape, promote and support the implementation of the 'Factories of the Future' public-private partnership.

The partnership aims to bring together private and public resources to create an industry-led programme in research and innovation with the aim of launching hundreds of market-oriented cross-border projects throughout the European Union. Such projects will produce demonstrators and models to be applied in a wide range of manufacturing sectors.

Made in China 2025 Strategy: aims to lift the country into a higher value-added economy in the drive to move away from a largely low-tech based approach; boost R&D capacity, increase cost efficiencies.

The table below provides a snapshot of current Industry 4.0 initiatives in EU member states, where funded initiatives could be a source of future use cases for 5G and mIoT.

Country & Initiative/Policy	Main objectives
Austria Industrie 4.0 Oesterreich ⁵⁰ Digital Roadmap Austria ⁵¹	Drive innovation around the concept of the smart factory within a value network: advancements in product development and manufacturing processing; virtualisation; intelligent and self-optimised products and systems; opportunities enabled by human-machine interactions ⁵² .
Belgium MADE DIFFERENT – Factories of the Future ⁵³	7 key changes to achieve the factory of the future: end-to-end engineering, digital factory, eco production, smart production systems, human centred production, world-class manufacturing technologies ⁵⁴ . Flanders Make is the strategic research centre for the Belgium manufacturing industry (operational sites in Lommel and Leuven, 10 research facilities at Flemish universities to stimulate open innovation).
Czech Republic Průmysl 4.0 ⁵⁵	Improve competitiveness of Czech industry through investments, standardisation and applied research while addressing issues like cyber security ⁵⁶ .
Denmark	8 key actions geared towards national leadership: rapid product development, modular production platforms, 3D print

⁴⁸ http://ec.europa.eu/research/industrial_technologies/factories-of-the-future_en.html.

⁴⁹ <http://www.effra.eu/>.

⁵⁰ <http://plattformindustrie40.at/>.

⁵¹ <https://www.digitalroadmap.gv.at/>.

⁵² <http://plattformindustrie40.at/was-ist-industrie-4-0/?lang=en#vision>.

⁵³ <http://www.madedifferent.be/>.

⁵⁴ <http://www.madedifferent.be/en>.

⁵⁵ <http://www.mpo.cz/en/industry/industry-four/>.

⁵⁶ <https://www.mpo.cz/en/industry/industry-4-0/initiative-industry-4-0-approved-by-the-czech-government--177195/>; full documentation (Czech) <https://www.mpo.cz/assets/dokumenty/53723/64494/659339/priloha001.pdf>.

<p>MADE – Manufacturing Academy of Denmark</p>	<p>and new production processes, model-based development of supply chains, digitisation of supply chains, lifelong production customisation, future production paradigm, hyper flexible automation, sensors and quality control⁵⁷. Dedicated support for SMEs⁵⁸.</p>
<p>France Alliance Industrie du Futur</p>	<p>The 'Alliance Industrie du Futur⁵⁹', a French non-profit organisation, brings together stakeholders involved in the deployment of the Industrie du Futur plan, e.g. scientists, academics, private companies, local authorities (and specifically regions). It take care of coordinating and managing projects and initiatives aiming to modernise the French manufacturing sector, and especially ICT-related projects.</p> <p>The 'Commissariat Général à l'Investissement⁶⁰' (CGI) is responsible for the implementation of the 'Investissements d'avenir' programme, a large investment program started in 2010 by the French government with a total budget of €47 billions. The funds are supporting research and innovation projects through co-financing schemes.</p> <p>The 'Transition Numérique⁶¹' is an initiative launched and supported by the French Government in 2012 to support SMEs in their digital transformation, and to accelerate their growth through digital skills and offers. It makes available to SMEs advisors and consultants from both public and private sectors.</p>
<p>Germany Industrie 4.0 (Industrie 4.0 by design – Made in Germany)</p> <p>Mittelstand 4.0</p>	<p>Main action areas of Industrie 4.0⁶²: encompass Work 4.0 (redesign of working conditions, training and education)⁶³, trust and security (incl. at design phase)⁶⁴; standardisation⁶⁵; data protection and legal framework⁶⁶; interdisciplinary co-operation⁶⁷. The platform also provides a map of practical implementations and test-beds.</p> <p>Industry 4.0 for SMEs (Mittelstand 4.0⁶⁸) is a dedicated support programme for awareness/educational and</p>

⁵⁷ <http://made.dk/>.

⁵⁸ <http://www.made.dk/saerligt-for-smv/>.

⁵⁹ <http://allianceindustrie.wixsite.com/industrie-dufutur>.

⁶⁰ <http://www.gouvernement.fr/investissements-d-avenir-cgi>.

⁶¹ <http://www.transition-numerique.fr/>

⁶² <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/areas-of-action.html>.

⁶³ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/Work40/work-40.html>.

⁶⁴ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/Security/security.html>.

⁶⁵ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/NormsAndStandards/norms-and-standards.html>.

⁶⁶ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/LegalFramework/legal-framework.html>.

⁶⁷ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/ResearchAndInnovation/research-and-innovation.html>.

⁶⁸ <http://www.mittelstand-digital.de/DE/Foerderinitiativen/mittelstand-4-0.html>.

<p>Autonomik fuer Industrie 4.0</p>	<p>competence-building activities to build a strategy for manufacturing SMEs⁶⁹. Autonomics for Industry 4.0⁷⁰ provides pre-competitive funding to drive innovation around smart data⁷¹, smart homes⁷² and smart services⁷³ and includes energy efficiency in manufacturing processes and eco-sustainability⁷⁴ alongside educational material on the Trusted Cloud.</p>
<p>Hungary IPAR 4.0 Technology</p>	<p>Alliance between industry and research forming a national technology platform to help drive digital transformation⁷⁵. Objectives are currently pursued through 7 working groups: Strategic Planning⁷⁶, Employment, Education and Training⁷⁷, Production and Logistics⁷⁸, ICT Technologies (safety, reference architectures, standards)⁷⁹, Industry 4.0 Cyber-Physical Pilot Systems⁸⁰, Innovation and Business Model⁸¹, Legal Framework⁸².</p>
<p>Ireland National Digital Strategy</p>	<p>Broad initiative for a digitally enabled society with practical actions and steps to assist citizens and small businesses in getting online⁸³. Phase one focuses on business and enterprise, citizen training and schools and education.</p>
<p>Italy Industria 4.0 Cluster Fabbrica Intelligente CFI</p>	<p>The Industry 4.0 initiative targets multiple industries that can benefit from digitisation with incentives for innovation, investments and accelerator programmes for start-ups and tech-savvy SMEs⁸⁴. The Italian Technology Cluster (Intelligent Factories) is a strategy for research and innovation that builds national competitive advantage by transforming the Italian manufacturing sector with new products, processes and systems⁸⁵.</p>

⁶⁹ VDMA, the German engineering federation, has over 3000 representatives, mostly from SMEs,

<https://www.vdma.org/>.

⁷⁰ [http://www.digitale-](http://www.digitale-technologien.de/DT/Navigation/EN/Home/home.html;jsessionid=09E07A4DAF2840EC6C9518E5DC51C9BB)

[technologien.de/DT/Navigation/EN/Home/home.html;jsessionid=09E07A4DAF2840EC6C9518E5DC51C9BB](http://www.digitale-technologien.de/DT/Navigation/EN/Home/home.html;jsessionid=09E07A4DAF2840EC6C9518E5DC51C9BB).

⁷¹ http://www.digitale-technologien.de/DT/Navigation/EN/Foerderprogramme/Smart_Data/smart_data.html.

⁷² http://www.digitale-technologien.de/DT/Navigation/EN/Foerderprogramme/Smart_Home/smart-home.html.

⁷³ <http://www.digitale-technologien.de/DT/Navigation/EN/Foerderprogramme/Smart-Service-Welt-2/smart-service-welt-2.html>.

⁷⁴ [http://www.digitale-](http://www.digitale-technologien.de/DT/Navigation/EN/Foerderprogramme/Autonomik_fuer_Industrie/autonomik_fuer_industrie.html)

[technologien.de/DT/Navigation/EN/Foerderprogramme/Autonomik_fuer_Industrie/autonomik_fuer_industrie.html](http://www.digitale-technologien.de/DT/Navigation/EN/Foerderprogramme/Autonomik_fuer_Industrie/autonomik_fuer_industrie.html).

⁷⁵ <https://www.i40platform.hu>.

⁷⁶ https://www.i40platform.hu/en/working_groups/strategiai_tervezes.

⁷⁷ https://www.i40platform.hu/en/working_groups/foglalkozatas_oktatas_trening.

⁷⁸ https://www.i40platform.hu/en/working_groups/gyartas_es_logisztika.

⁷⁹ https://www.i40platform.hu/en/working_groups/infokommunikacios_techologiak.

⁸⁰ https://www.i40platform.hu/en/working_groups/kiserleti_mintarendszerek.

⁸¹ https://www.i40platform.hu/en/working_groups/innovacio_es_uzleti_modell.

⁸² https://www.i40platform.hu/en/working_groups/jogi_keretek_meghatarozasa.

⁸³ <http://www.dccae.gov.ie/en-ie/communications/topics/Digital-Strategy/Pages/default.aspx>.

⁸⁴ <http://www.sviluppoeconomico.gov.it/index.php/it/industria40>.

⁸⁵ <http://www.fabbricaintelligente.it/en/>.

Luxembourg Digital4Industry	Supports businesses of all sizes (large, SMEs) driving digitisation of production processes and new economic models based on big data, IoT and cloud ⁸⁶ .
Netherlands Smart Industry – Dutch Industry fit for the Future	Programme to create the rights conditions for smart industry to thrive with dedicated support structures for entrepreneurs, the development of new skills and knowledge and fieldlabs as practical environments to develop, test and implement goal-oriented smart industry solutions ⁸⁷ .
Portugal Indústria 4.0 PRODUTECH – Production Technologies Cluster	Industry 4.0 PT is a government-led initiative to accelerate the adoption of Industry 4.0 by the business community with the support of over 120 companies and organisations ⁸⁸ . It is based on 64 measures, both private and public, expected to impact on 50,000 Portuguese companies. Training on digital competences. Network of manufacturing technology providers aimed at boosting competitiveness while addressing sustainability challenges by responding to the manufacturing industry's requirements ⁸⁹ .
Romania Manifesto for Digital Romania	Foster innovation in private sector, with a focus on start-ups, SMEs, encouraging innovation to support the emergence of new entrants ⁹⁰ .
Slovenia Digital Coalition	Broad strategy aimed at modernising the national economy and society through cross-sector co-operation involving trade and industry, science, education, public sector and public administration, local government and civil society ⁹¹ .
Spain Industria Conectada 4.0	Strategy aimed at digitising and enhancing the competitiveness of Spain's industrial sector with investments of €97.5m in 2016. The strategy includes loans and incentives for industrial innovation ⁹² .
Sweden Smart Industry Produktion 2030	Smart Industry is a strategy for new industrialisation for Sweden, aimed at strengthening capacities for digital transformation and competitiveness, boost leadership, foster sustainable development (production, resource efficiency etc.), value creation, jobs and skills development. Test Bed Sweden underpinning research and innovation ⁹³ . Produktion 2030 is a strategic innovation programme designed to increase the competitiveness of Swedish manufacturing industry through co-operation between industry, academia and research institutes based on

⁸⁶ <https://www.fedil.lu/en/topics/industry-4-0/>.

⁸⁷ <https://smartindustry.nl/>.

⁸⁸ www.i40.pt.

⁸⁹ www.produtech.org.

⁹⁰ <http://gov.ro/en/news/address-by-prime-minister-dacian-ciolos-at-the-international-digital-romania-4-0-industry-forum>.

⁹¹ <http://www.digitalna.si/si/>.

⁹² <http://www.industriaconectada40.gob.es>.

⁹³ <http://www.government.se/information-material/2016/04/smart-industry---a-strategy-for-new-industrialisation-for-sweden/>.

	advanced products and services, customised, high-end industrial services ⁹⁴ .
<p>UK Industrial Strategy</p> <p>High Value Manufacturing Catapult</p> <p>Innovate UK – Future manufacturing & infrastructure systems</p>	<p>The Green Paper on Industrial Strategy (Jan 2017) sets out 10 pillars to drive growth, increase investments in R&D, develop new skills, improve infrastructure, ensure more affordable energy and boost productivity⁹⁵.</p> <p>HVM Catapult supports 7 centres with world-class equipment, expertise and collaborative opportunities. The programme supports manufacturing companies of all sizes from all sectors, including commercialisation of new products and services⁹⁶.</p> <p>Competitive programme with £19m to be allocated for innovation in manufacturing and materials and £16m for business-graduate partnerships to boost industrial competitiveness⁹⁷.</p> <p>Other programmes include EPSRC Manufacturing the Future⁹⁸. Policy goals are documented through National Industrial Policy Guidelines 2014-2020⁹⁹.</p>

3 5G Use Case Families, Overview and Mapping

3.1 Sample of eMBB, mIoT and MCS Use Cases

In this section, we provide an overview of foreseeable and broadly defined 5G use cases for enhanced mobile broadband (eMBB), massive Internet of Things (mIoT) and mission critical services (MCS) (see definition in Glossary) as a representative sample of the innovations that 5G will make possible¹⁰⁰. Use cases in bold indicate relevance for the four vertical industries analysed by Global5G.org.

3.1.1 **Enhanced mobile broadband (eMBB)**

Two key facets of enhanced mobile broadband will drive adoption and value creation in the 5G economy.

1. Extending cellular coverage into a broader range of structures including office buildings, industrial parks, shopping malls, and large venues.
2. Improved capacity to handle a significantly greater number of devices using high volumes of data, especially in localised areas.

These improvements to the network will enable more efficient data transmission, resulting in lower cost-per-bit for data transmission, which will be an important driver for increased use of broadband applications on mobile networks. The net result for end-users will be an improved, more consistent

⁹⁴ <http://www.produktion2030.se/>.

⁹⁵ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/586626/building-our-industrial-strategy-green-paper.pdf.

⁹⁶ <https://hvm.catapult.org.uk/>.

⁹⁷ <https://www.gov.uk/government/news/future-manufacturing-and-infrastructure-systems-apply-for-funds>.

⁹⁸ <https://www.epsrc.ac.uk/research/ourportfolio/themes/manufacturingthefuture/>.

⁹⁹ https://em.gov.lv/files/uznemejdarbiba/finl_en.pdf.

¹⁰⁰ IHS Economics and IHS Technology | The 5G Economy: How 5G technology will contribute to the global economy, IHS Markit, Jan. 2017. <https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf>

experience using mobile broadband applications regardless of location.

Use cases for eMBB include:

- Enhanced indoor wireless broadband coverage: addressing challenges many buildings face in providing consistent coverage, even with complex and sometimes expensive small cell and commercial WLAN deployments. Improved cellular coverage in structures of any size, allowing for wireless broadband coverage for a range of devices and applications. Far-reaching industry impact.
- Enhanced outdoor wireless broadband. Applications like streaming high-definition (HD) infotainment to cars, improved capacity for outdoor events and highly populated urban centres. Improved internet access on mass transit systems, allowing more users to work online during transit time. Improved coverage and capacity for densely populated urban areas, reducing traffic congestion and improved coverage and capacity for live events. Positive general impacts, including diverse industries.
- Fixed wireless broadband deployments. Beyond today's LTE networks to offer a better consumer experience. Allowing carriers to offer more services without costly Capex investments. Impacts include underserved rural areas and emerging markets with little or no fixed infrastructure but high wireless penetration. Addressing last mile deployments (lower cost alternative to fibre), and dense urban areas where it is costly and/or impractical to use a wired solution.
- Enterprise teamwork/collaboration. Benefits will come from combining streaming ultra-high definition (UHD), AR/VR, video telepresence, and tactile internet. Enhancing existing enterprise communications solutions and facilitating more dynamic interaction in global business scenarios (teams, clients/end-users). Positive impacts on broad range of professionals and ICT industry.
- Training/education. Enterprise users (training) and traditional education, including remote and underserved areas. Benefits to society include the ability to expand the number of students accessing general and specialised education and training.
- **Augmented and virtual reality (AR/VR).** Supporting dynamic AR content at scale requires a 5G interface. Reduced latency and multiple Gb/second speeds will enable computationally heavy AR/VR user interactions. Specific cases include field support and telehealth. Mobilised AR/VR will benefit users by providing a virtual display in any environment or surface, eliminating the need for additional hardware or display. Reduced costs for field support workers, creating the ability to have a core team of highly trained and experienced workers centrally located to support a much larger field support team. Industries benefitting include industrial, manufacturing, construction, service firms and social services.
- Extending mobile computing. Combined with significantly larger wireless data pipes and easily accessible cloud computing, 5G smartphones will be able to take on productivity tasks that have been the province of laptop/desktop computers. 5G benefits are being able to deliver a robust mobile computing experience regardless of device form factor.
- Enhanced digital signage. Combining UHD and AR, 5G will support various applications such as improving retail experience and smart city applications, significantly increasing the number of use cases supported. This could be a key differentiator in retail environments struggling to compete with online shopping. Other applications include real estate and home improvement, hospitality and service industries, transportation, smart cities, which rely on digital signage.

The eMBB use cases are most likely to have a near-term impact. These are largely an extension of the existing 4G value proposition, and should see relatively quick uptake in the market as 5G networks become commercially available. Uptake will lead to significant impacts to global economic activity but the net economic impact of 5G will be less transformative than with mIoT and MCS cases as we are largely dealing with enhancements to existing technologies.

3.1.2 **Massive Internet of Things (mIoT)**

5G builds on earlier investments in machine-to-machine (M2M) and traditional IoT applications to enable significant increases in economies of scale that drive adoption and utilisation across all sectors. Improved low-power requirements, the ability to operate in licensed and unlicensed spectrum, and improved coverage will all drive significantly lower costs within the mIoT. This will in turn enable the scale of mIoT, and will drive much greater uptake of mobile technologies to address mIoT applications.

Use cases for mIoT include:

- **Asset tracking.** Monitoring the distribution of assets and people over large areas. This includes applications like people tracking, high value goods in transit (well-established in M2M markets). 5G will offer additional benefits to current solutions in terms of deep coverage, low power and low cost (economies of scale), and by being a 3GPP standard technology. 5G improvements include optimisation of logistics in a wide range of industries; improved worker safety; increased efficiency in locating and tracking assets, thereby minimising losses. 5G will also expand the ability to track a wider range of goods in transit dynamically. Asset tracking will become more important as more shopping shifts to online retailers.
- **Smart agriculture.** Increased use of connected sensor technologies for applications like basic tank monitoring and specialised sensors monitoring moisture levels and chemical composition in soil. Optimisation of watering and feeding schedules, growing and harvesting scheduling, leading to increased farm operational efficiency and less need for manual labour. Improved reporting and accountability for “farm to market” with greater transparency for consumers. It should be noted that smart agriculture will benefit from different 5G features. eMBB capabilities of 5G include drones with sophisticated camera and sensor packages used to monitor crops and herds in real time, while MCS features of 5G include autonomous agricultural equipment.
- **Smart cities.** Opportunities for many different types of applications and potential new business models. Key technology applications include lighting, security, energy/utilities, physical infrastructure environmental monitoring and transportation/mobility. Lower costs, improved quality of service and reliability, an established standard for the market. It is expected that smart city applications will be able to leverage existing carrier infrastructure as opposed to heavier Capex investments to deploy a dedicated proprietary network. Using network slicing techniques could provide a guaranteed quality of service for applications that are more essential (e.g. street lighting). It should also be noted that smart cities will also rely on eMBB and MCS capabilities, such as dynamic traffic management and control (MCS) and use of security drones and fixed cameras (eMBB). Even in 2035, smart cities will still be in the relatively early stage of development. As the market matures beyond 2035, mobile technologies and 5G are expected to play an even more important role.
- **Energy/utility monitoring.** Consolidation on a single platform for smart meters would allow for significant cost savings from economies of scale.
- **Physical infrastructure.** MIoT features and connected sensors can significantly improve the monitoring of physical infrastructures like bridges and overpasses and smaller structures like elevators. Geotagging can allow AR to be used by visitors to large cities to improve the tourism experience. Ability to deploy wireless sensors from monitoring bridges, roadways, train tracks and overpasses in real time and prioritise repairs/improvements.
- **Smart homes.** Revolutionising how smart home devices are deployed and serviced by overcoming difficulties associated with common consumer complaints such as device set-up, reliability and high latency as the smart home market becomes more DIY. Cellular connectivity via 5G will provide a more streamlined experience and more secure devices (rather than current reliance on correct WLAN and firewall configurations).
- **Remote monitoring.** Industrial automation application spanning multiple sectors using pervasive sensing for incremental performance improvements and predictive maintenance of equipment. Current solutions rely heavily on wired technologies, which are difficult to retrofit.

5G is expected to be a robust alternative that can be used to provide solutions for both new and existing equipment. Helping to prevent safety risks in often inhospitable environments.

- Beacons and connected shoppers. Enhanced brick and mortar shopping experience, including product/brand interaction with consumers in a more dynamic way. Beacons (currently using mostly Bluetooth) are also starting to gain traction in industrial applications. A more robust wireless connectivity solution is key to growth in this market including the potential for a low power variant of 5G.

MIoT use cases are characterised by a very large number of connected devices typically transmitting a relatively low-volume of non-delay-sensitive data. As a result, devices are required to be low cost and have a very long battery life.

With these mIoT use cases we will start to see the transformative impact of 5G. Many of these applications are being serviced today by a mix of older generations of cellular technologies as well as low-power wireless technologies operating in unlicensed spectrum. The current LTE roadmap includes purpose-built cellular technologies such as Cat-M1 (eMTC) and Cat-NB1 (NB-IoT), which are starting to incorporate low-power improvements to address the growing cellular IoT market. These technologies are establishing the foundations for 5G mIoT, which will continue to improve on the extended low-power operation capabilities, as well as the ability to use both licensed and unlicensed spectrum. Faster growth is expected to occur when 5G mIoT modules are widely commercially available.

5G could also have the potential to address a much larger segment of the M2M and IoT markets, as well as reducing costs because of economies of scale.

3.1.3 **Mission Critical Services (MCS)**

MCS represents a potentially huge growth area for 5G to support applications that require high reliability, ultra-low latency connectivity with strong security and availability. MCS use cases require extremely high performance.

Use cases for MCS include:

- **Autonomous vehicles.** MCS features of ultra-low latency, high reliability and high availability are vitally important for the autonomous market to succeed. However, it is important to note that eMBB features of 5G will also play an important role, e.g. in many data intensive but less mission-critical activities. Benefits span safer roadways, reduced costs associated with collisions, reduced costs and investments in infrastructure.
- **Drones.** Deployment potential in multiple industries including commercial transport, agriculture, construction, manufacturing and public safety. Potential uses by government include police reconnaissance, anti-terrorism, riot-control, patrolling, search and rescue, tracking, public safety, traffic regulation, exploration surveys, weather monitoring. Benefits include minimised time and risk, enhanced functionality and effectiveness, reduced costs compared to fees for vehicle operators. Most commercial drones in use today are in the trial phase. 5G features are important to address the breadth of use cases fully. The MCS segment of use cases calls for low latency, high reliability and high availability as essential features for the reliable and safe operation of commercial fleets of drones. However, HD cameras and sensor packages will benefit from enhanced mobile broadband capabilities as critical for handling large volumes of data generated.
- **Industrial automation.** Although the vast majority of infrastructure on the factory floor will continue to rely on wired connectivity, creating smarter factories, augmenting workers and supporting mobility of assets brings opportunities for a high bandwidth, secure wireless solution addressed through 5G. Mission-critical 5G can offer benefits such as real-time close loop communication and hands-free machine monitoring and control.
- **Remote patient monitoring/telehealth.** 5G can help eliminate current reliance on disparate connection strategies between patients, care providers and monitoring equipment. There are

a broad range of applications that fall within this use case, including ubiquitous access to imaging and medical records, advanced telemedicine (including remote surgery and treatment using robotics and AR/VR), remote clinical care. 5G would also enable health care workers to perform controlled substance management using wearables. Benefits include standardised connectivity platforms leading to greater ease of use, higher implementation and lower costs. Medical professionals would have faster, more secure access to records for patients on their devices, easier file management, and access for providers in any location. Increased use of outpatient monitoring and the ability to reduce in-hospital stays will offer both reduced costs and greater patient comfort.

- **Smart Grid.** The low latency of 5G should be attractive in this environment where uptime is heavily regulated and downtime penalised in more developed economies. If 5G can push cheaper, more ubiquitous low latency radios to the market, this would have the potential for automated real-time grid switching. This would essentially create a more reliable grid with significant economic impact.

These use cases highlight many genuinely new applications for mobile technologies. The potential to support applications with high reliability, ultra-low latency, widely available networks with strong security creates significant growth opportunities. As many of the use cases are still emerging markets (autonomous vehicles, commercial drones, remote medical treatment), growth will be dependent on market innovation and the development of appropriate regulation, as well as the deployment of 5G networks. As a result, growth may take longer to accelerate. However, given the broad implications of some of these use cases, the overall impact to society will be tremendous.

3.2 Mapping of 5G PPP Use Cases

A visual mapping of the 5G PPP use cases provides an easy, at-a-glance analysis of vertical industry coverage, where it is immediately apparent that entertainment and media is the most popular vertical. A popular vertical is automotive, where two of the 5G PPP phase 2 projects (5GCAR and 5G CORAL) focus their efforts on this sector, through industry-led R&I and convergent multi-RAT access, while 5G TRANSFORMER also covers the health care vertical and MATILDA Factories of the Future, public safety and smart cities through its focus on end-to-end services. Energy and health care are among the verticals with less coverage, where phase 1 project, VirtuWind brings early experience in terms of SDN and VFN.

5GPPP Phase 2 Grouping per vertical sector	5G ESSENCE	5GCAR	5G-CITY	5G-MEDIA	5G-MoNARch	5G-PHOS	5G-PICTURE	5GTANGO	5G-TRANSFORMER	5G-Xcast	BlueSpace	IoRL	MATILDA	METRO-HAUL	NGpaaS	NRG-5	ONE5G	Sat5G	SUCENET	Clear5G	5G-CORAL	
Automotive	x							x				x				x					x	5
Energy														x	x				x			3
Health								x											x			2
Broadcast	x								x				x									3
Public Safety	x								x			x										3
Media and entertainment	x	x	x			x	x	x	x			x						x				9
Manufacturing/Industry							x					x					x			x		4
Agriculture														x			x					2
Transport for logistics (other than automotive)				x		x												x			x	4
Public uses (smart city, shopping malls, tourism, waste management)		x		x	x	x					x	x	x				x		x		x	10

Figure 10: Visual Mapping of 5G PPP Phase 2 Use Cases

The following table provides a summary of application/use case focus across each vertical. All projects are 5G PPP phase 2 unless otherwise stated.

Coverage of Vertical Industries in 5G PPP (phases 1 and 2)		
Vertical Industry	Application/Use Case	Description
Automotive	Autonomous vehicles (lane merge; perception of manoeuvres; vulnerable road user)	5GCAR : 5G V2V use cases, building on ETSI-ITS (Intelligent Transport Systems) and the 5GAA, to cover a broad set of scenarios. Live demonstrations of Lane merge, co-operative perception for manoeuvres of connected vehicles and vulnerable road user perception.
	Connected car	5G-CORAL ¹⁰¹ : connected car test-bed to demonstrate the benefits of 5G-CORAL V2V communications supported by Fog computing devices nearby or onboard cars.
	Autonomous vehicles (autonomous cruise control; enforcement application; advanced driver assistance systems)	5G-Transformer : autonomous cruise control (ACC) enforcement application; collaborative advanced driver assistance systems (ADAS) application; Remote Vehicle Interaction (RVI) application.
	Autonomous vehicles	MATILDA ¹⁰² : Remote control and monitoring of automobile electrical systems.
Energy	Renewable energy: wind farms	VirtuWind ¹⁰³ : (phase 1). Adoption of virtualisation and softwarisation technologies for industry control network. Open, modular and secure framework showcasing a prototype for intra-domain and inter-domain scenarios in real wind parks. VirtuWind adopts the approach of application-level slicing in an industrial network, where slicing is applied in the context of multi-tenancy in operational wind parks. This approach provides access network technology independence while offering flexibility to the operators to select different IoT products to be installed at the edge.
	Energy-as-a-service	NRG-5 ¹⁰⁴ : make the deployment, operation and management of existing and new communications, and energy infrastructures, energy-as-a-service, easier, safer, more secure and resilient from an operational and financial point of view.
	Energy monitoring	NGPaaS ¹⁰⁵ : IoT for energy monitoring in the context of a telco-grade PaaS.

¹⁰¹ <http://5g-coral.eu/>.

¹⁰² <http://www.matilda-5g.eu/>.

¹⁰³ <http://www.virtuwind.eu/>.

¹⁰⁴ <http://www.nrg5.eu/>.

¹⁰⁵ <https://5g-ppp.eu/NGPAAS/>.

	Smart Grid	SLICENET ¹⁰⁶ : A 5G Smart Grid Self-Healing Use Case to increase automation in distribution with self-healing solutions towards a smarter grid. The objective is to achieve a fully softwarisation 5G infrastructure by addressing associated challenges in managing, controlling, and orchestrating new services across vertical sectors.
Entertainment and Media	Inflight connectivity and Infotainment	5G-ESSENCE ¹⁰⁷ : Next-generation, integrated, in-flight connectivity and entertainment services for passengers.
	Ultra-high definition; real-time transmission, acquisition and production	5GCity ¹⁰⁸ (3 use cases): mobile real-time transmission; UHD video distribution; real-time video acquisition and production in the edge and cloud.
	Immersive media and virtual reality	5GMEDIA ¹⁰⁹ : (3 use cases) immersive media and VR; production and user-generated content; UHD over CDN.
	Outdoor environments	5G-PICTURE ¹¹⁰ : large venues with a 5G stadium test-bed in Bristol to address scenarios with increased density and static-to-low mobility.
	Immersive media	5GTANGO ¹¹¹ : immersive media with a solution that relies on virtualisation technologies to implement a virtual content delivery network (vCDN) architecture and adaptive streaming technologies.
	Outdoor and indoor environments	5G-Transformer ¹¹² : media applications for stadiums and Olympic Games.
	Broadcasting	5GXCAST ¹¹³ : (3 use cases) hybrid broadcast services; object-based broadcast service; public warning messages.
	Media on demand	MATILDA : high resolution media on demand.
Factories of the Future	Smart manufacturing	5GTANGO : smart manufacturing with deployment and orchestration of network services to control machinery or factory-wide networking system processes, address network security issues and deal with operational verification and validation.
	Smart factory	MATILDA : Industry 4.0 smart factory.

¹⁰⁶ <https://slicenet.eu/>.

¹⁰⁷ www.5g-essence-h2020.eu.

¹⁰⁸ <http://www.5gcity.eu>.

¹⁰⁹ <http://www.5gmedia.eu/>.

¹¹⁰ <http://www.5g-picture-project.eu/>.

¹¹¹ www.5gtango.eu.

¹¹² <http://5g-transformer.eu/>.

¹¹³ 5g-xcast.eu.

	Machine communications type	CLEAR5G¹¹⁴ (EU-Taiwan): Investigate and demonstrate some of the key enablers necessary to support Machine Type Communications (MTC) traffic in 5G networks, especially Factories-of-the-Future (FoF) environment.
Health	Connected ambulance	SLICENET : The 5G eHealth Smart / Connected Ambulance Use Case will advance the emergency ambulance services using the ambulance as a connection hub (or mobile edge) for the emergency medical equipment and wearables. The use case has the support from the Irish National Ambulance Services through Irish Department of Public Expenditure and Reform.
	Emergency communication network	5G-Transformer : Improving municipal emergency communication network and developing a new technological solution for health workers and volunteers.
Public safety	Mission-critical applications	5G-ESSENCE : Mission critical applications for public safety communication providers.
	Emergency infrastructures	MATILDA : 5G emergency infrastructure and service orchestration with SLA enforcement.
Smart cities	Illegal dumping of waste	5GCity (2 use cases): dynamic end-to-end slices with virtualised edge and network resources leased to 3 rd -party operators (telecom use case – neutral hosts). Unauthorised waste dumping prevention with the deployment of multiple instances of a virtualised service processing video streams near cameras automatically to identify illegal dumping.
	Tourist city (mobile operator deployment)	5G-MONARCH¹¹⁵ : tourist city (mobile operator) with efficient use of resources through resource elasticity.
	City services	5G-PICTURE : converged fronthaul and backhaul services hosted by the City of Bristol network infrastructure.
	Intelligent lighting system	MATILDA : smart city intelligent lighting system.
Smart environments	Outdoor environments	5G-ESSENCE : 5G edge network acceleration for a stadium with local video production and distribution.
Transportation	Smart sea port	5G-MONARCH : sea port with focus on resilience and security to meet specific requirements.

¹¹⁴ <http://clear5g.eu/>.

¹¹⁵ <https://www.5g-monarch.eu>.

	Transportation/mobility: railways	5G-PICTURE: seamless service provisioning and mobility management in high-speed railway environment with 5G railway test-bed located in Barcelona.
ONE5G¹¹⁶ - 5G new radio extensions targeting both dense urban areas (“megacities” with heterogenous requirements) and underserved rural environments (relatively homogeneous requirements) aim to boost capacity of mobile networks aim to improve energy efficiency and support vertical use cases. ONE5G focuses on services related to two 5G use case categories: mMTC (massive machine type communications) and URLLC (ultra-reliable low latency communications), covering a variety of verticals by capturing key requirements so that technical studies and components will be aligned with these requirements. Targeted verticals include factories of the future; public transportation; automotive; agriculture.		

Table 7: Overview of Vertical Industries in 5G PPP

Collectively, these 5G PPP projects can play a key role in driving future 5G deployments that will bring a variety of socio-economic benefits, while taking on board key issues like security and privacy requirements.

- **Automotive:** increased performance (low latency for quick reaction times for autonomous and semi-autonomous vehicles), increased security, and device-to-device communications. Security is imperative to keep malicious hackers from creating dangerous situations on the road¹¹⁷. Good understanding of data privacy issues as key to user trust. Effective frameworks for integrating systems and business propositions. Definitions of data privacy may need to consider interpretations of future generation users¹¹⁸.
- **Energy:** reducing costs and increasing security are dominant concerns due to regulatory and tight margins within which utilities operate, increased productivity, faster time to market and boosted efficiency. Increased security is required to protect valuable assets from attacks, and energy is included in the European Programme for Critical Infrastructure Protection¹¹⁹.
- **Entertainment and media:** full immersive experience required for the media and entertainment industry is enabled by 5G’s extremely high bandwidth over wireless networks and very low latency, which together match increasingly demanding users’ expectations. HD videos will be downloaded in a few seconds thanks to the improved downstream rates, while enhanced upstream rates will boost social networking by enabling agile distribution of user created media.
- **Factories of the Future:** increase productivity, improve customer experience and accelerate time to market. Key concerns are risk and security of manufacturing assets. Requirements include expanding video surveillance/streaming of manufacturing assets, better develop machine-to-machine sensors and improve remote site security.
- **Health:** 5G can be a change agent for services such as remote diagnosis and medical care; virtual and augmented reality for medical training. Other important drivers are improving the quality of life. Surgical and social robots will require ultra-low latency via 5G and in the long term 6G. The pervasive use of remote systems increases the need for cyber security, and is equally important as performance to stakeholders interviewed¹²⁰.
To realise the full potential of this vertical, a very supportive regulatory framework is required with common standards for recording, sharing, transferring and anonymising health-related data. Policies need to underpin developments in healthcare, ranging from issues like

¹¹⁶ <https://one5g.eu>.

¹¹⁷ Opportunities in 5G, Ericsson, June 2016, based on a survey of 650 decision makers from 8 verticals.

¹¹⁸ Connected Car Report 2016 – Opportunities, risks, and turmoil on the road to autonomous vehicles, PwC.

¹¹⁹ <https://ec.europa.eu/energy/en/topics/infrastructure/protection-critical-infrastructure>

¹²⁰ Ericsson 2016, op cit.

transparency, data ownership, privacy, data exchange, permissions around offering services and liability issues.

- **Smart cities:** better information for administrators, enhanced wireless communications with reduced costs and/or more reliable connectivity bringing potential for growth in the development of information platforms for enhanced big data analytics. Barriers like trust and privacy are expected to increase in the future if not addressed.
- **Transportation:** transport data sharing and access is fundamental to fully realise the benefits of 5G in this sector. Benefits and economic gains will only be fully realised with friendly government policy and a highly motivated industry¹²¹. Security aspects must be addressed thoroughly as transportation is enlisted as a European critical infrastructure.

4 Automotive Use Case Analysis

4.1 Use Case Overview

Autonomous vehicles belong to a broad category that includes both consumer and commercial applications. It is expected that 5G will be used to enable all forms of extra-vehicle communication (V2X), initially to provide more sophisticated advanced driver assistance systems (ADAS), and ultimately leading to fully autonomous self-driving vehicles.

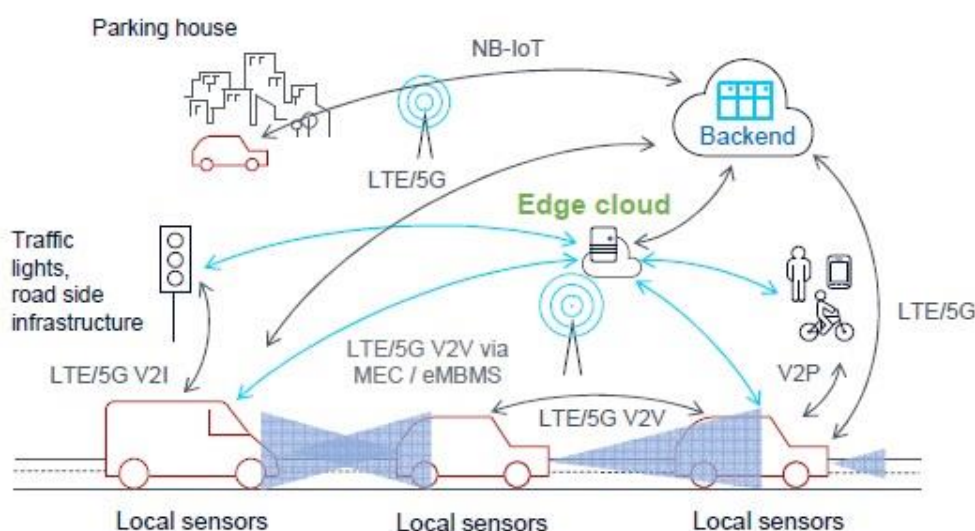


Figure 11: V2X Communications - the big picture [source: 5GAA]

Autonomous vehicles use cases will benefit from enhanced mobile broadband features of 5G and particularly the mission critical services segment. The eMBB features will be important for many data intensive, but less mission-critical activities, including the ability to receive and offload substantial amounts of mapping, sensor and delay tolerant or less time critical data. The 5G MCS features of ultra-low latency, high reliability, and high availability are vitally important for the autonomous vehicle

¹²¹ Ericsson 2016, op cit.

market to succeed. By 2035 Stage 5, fully autonomous vehicles should be in wide use in developed countries. As these vehicles will not rely on a human operator at all, the ability to provide media-rich content for passengers will be essential.

There are significant benefits related to autonomous vehicles, ranging from safer roadways to reduced impact on the environment to more efficient vehicle operation. Autonomous vehicles will also reduce the costs associated with collisions, such as down time, injuries/rehabilitation, repair and insurance. Using 5G technology to enable this will also help to reduce costs and investment in infrastructure, which would be required by alternative technologies that are dedicated to just automotive applications (e.g. 802.11p).

Additional benefits will also come from commercial and industrial applications, such as additional cost savings for reduced operating expenditures (Opex) resulting from fewer drivers, as well as anticipated benefits from more efficient routes and longer hours of operation with few breaks.

From an economic impact assessment standpoint, this is one of the use cases that should have broad overall impact, especially when considering commercial vehicles and off-road equipment, e.g. farming, mining, construction etc.). The ability to safely operate equipment for extended periods at a lower operational cost is significant, and will have a transformative impact on some industries.

The availability of autonomous vehicles and drones will do more than stimulate sales of driverless cars and unmanned aerial vehicles (UAVs) to consumers. They will also be deployed in agricultural and mining applications, ranging from the surveillance of remote natural resources to autonomous transport of ores to self-driving tractors. They will be widely used in the transportation sector for driverless transport and the delivery of commercial and consumer goods. Municipalities will integrate autonomous vehicles into their transit systems while using drones for monitoring functions. In manufacturing, autonomous vehicles will be used in intra-plant stocking and retrieval systems. Autonomous vehicles will also positively affect the insurance industry as vehicle accident rates decrease¹²².

A study conducted by Prof. David Teece¹²³ (University of California Berkeley) also noted that automotive applications enabled by 5G-V2X connectivity have the potential to provide more than just increased productivity and sales. This includes **social gains** through improvements in traffic flows, reducing GHG emissions, minimising wear and tear of road infrastructure and vehicles, and most importantly reducing collisions and road fatalities. Moreover, the 5G enabled evolution to fully connected and autonomous driving will provide obvious “consumer surplus” benefits through reduced commuting times and freeing up driving time during the commuting allowing the time to be used for consuming a richer set of media or getting work done. In the study, it is projected that that in 2035, 5G will enable more than \$2.4 trillion in total economic output from across the automotive sector (including its supply chain and customers), which is equivalent to a **fifth of the total global 5G economic impact**.

Studies from the industry provide insights into transformations from the current state of play to full automation. The Society of Automotive Engineers (SAE) currently defines driving automation on a six-level scale, as showed in the figure below¹²⁴, starting from Level 0 (no automation) to Level 5 (full automation). Vehicles with Level 0/1 automation utilising Warning, support systems and advanced driver assistance systems (ADAS) are already widely available in the market, with also some more

¹²² The 5G Economy, IHS op cit.

¹²³ D. Teece, “5G Mobile: Disrupting the Automotive Sector” Working Paper Series No. 22, UC Berkeley, May 2017, <http://davidjteece.com/5g-mobile-automotive/>.

¹²⁴ SAE International, “Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems,” SAE J 3016, September 2016 http://standards.sae.org/j3016_201609/.

recent models even incorporating Level 2 automation features (e.g. partial automated parking assistance, traffic jam assistance etc.).

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

Figure 12 SAE's driving automation levels for on-road vehicles [source: SAE International and J3016]

A 2017 road mapping study¹²⁵ by the European Technology Platform, ERTRAC, Working Group on "Connectivity and Automated Driving" has produced a timeline that estimates that the development of fully automated (Level 5) vehicles should reach maturity just after 2030, as depicted in the figure below. A 2015 study from the Boston Consulting Group (BCG)¹²⁶ projected that by 2035 partially and fully autonomous vehicles will account for 25% of the market (15% and 10% share for partially and fully autonomous vehicles, respectively).

¹²⁵ ERTRAC, "Automated Driving Roadmap," ERTRAC WG Connectivity and Automated Driving, May 2017 http://www.etrac.org/uploads/images/ERTRAC_Automated_Driving_2017.pdf

¹²⁶ BCG, "Revolution in the driver's seat, the road to autonomous vehicles," Boston Consulting Group, April 2015, http://img-stg.bcg.com/BCG-Revolution-in-the-Drivers-Seat-Apr-2015_tcm9-64351.pdf

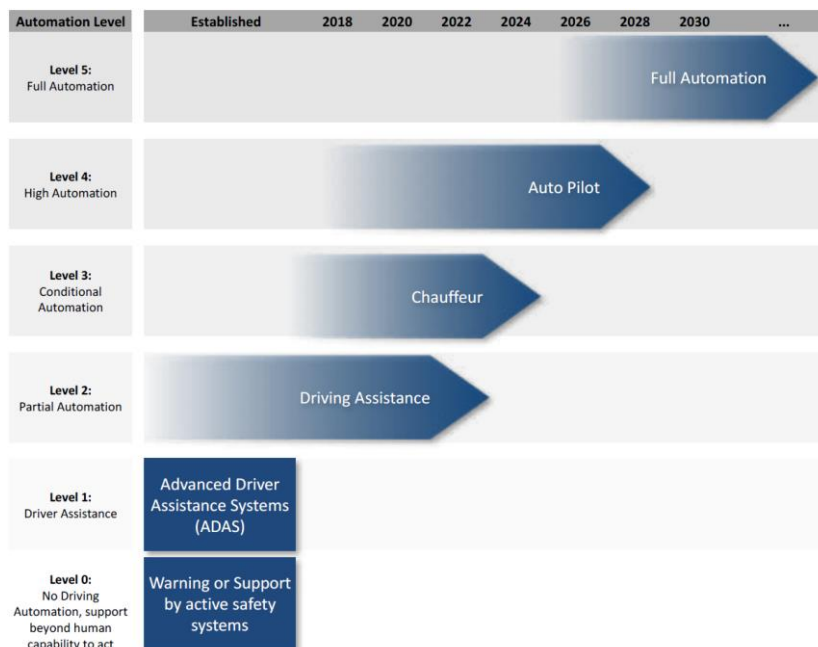


Figure 13 Estimated development timelines for vehicles at different automation levels [source: ERTRAC]

Furthermore, the term Cellular-V2X (C-V2X)¹²⁷ has been coined in 3GPP to refer the cases, whereby, 3GPP-specified cellular technologies (5G or earlier generations) provide the connectivity platform for different V2X scenarios. To that end, LTE-V2X and 5G-V2X are C-V2X implementations, whereby, the radio access technologies are LTE and 5G New Radio (NR), respectively. The LTE-V2X standards¹²⁷ already provide specifications for both short range (V2V/V2P/V2I) and wide area (V2N) connectivity modes. Thereafter, 5G-V2X will provide further enhancements to C-V2X by taking advantage of the 5G technology enhancements for providing enhanced mobile broadband (eMBB) and ultra-reliable low-latency communications (URLLC) capabilities.

4.2 Application Scenarios and Use cases

Form a review of the literature, the **automotive vertical** is the most cited sector amongst verticals and use cases in various 5G studies (SMART 2014/0008). This vertical will leverage the benefits of 5G for real-time and highly-reliable vehicle-to-everything (V2X) connectivity. As an umbrella term, V2X encompasses a range of connectivity scenarios that includes short-range Vehicle-to-Vehicle (V2V), Vehicle-to-(Roadway) Infrastructure (V2I) and Vehicle-to-Pedestrian (V2P) connectivity, as well as wide-area Vehicle-to-Network (V2N) connectivity scenarios. Information exchange among these stakeholders and systems is enabling a multitude of new applications.

Vertical Industry: Automotive	
Use Case	Main source(s)
Real-time situational awareness and high definition (local) maps	5GAA 2017 White Paper ¹²⁸

¹²⁷ 3GPP TR 22.885, “Study on LTE Support for Vehicle to Everything (V2X) Services”, <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2898>.

¹²⁸ Toward fully connected vehicles, 5GAA, op cit.

See-through (for passing)	5GAA White Paper
Vulnerable road user discovery	5GAA White Paper, 5GCAR ¹²⁹
Lane merge	5GCAR
Co-operative perception for manoeuvres of connected vehicles	5GCAR
Mobile broadband in vehicles (part of set of general 5G use cases)	“NGMN 5G White paper”, NGMN Alliance, February 2015 ¹³⁰
V2X broadcast service (part of set of general 5G use cases)	“Deliverable D2.1 Definition of Use Cases, Requirements and KPIs,” 5G-Xcast, October 2017 ¹³¹
Use Case groups/classes	
24 use cases mapped into five main use case groups (Platooning, Advanced Driving, Remote driving, Extended Sensor and General use cases)	“TR 22.886 Study on enhancement of 3GPP Support for 5G V2X Services,” 3GPP, March 2017 ¹³² .
5 use case classes (Cooperative manoeuvre, Cooperative perception, Cooperative safety, Autonomous navigation, and Remote driving). Each use case class represents a relevant driving situation with common aspects (features, functions, requirements, etc.) and may have several use cases.	“Deliverable D2.1 5GCAR Scenarios, Use Cases, Requirements and KPIs,” 5GCAR, August 2017 ¹³³ .
Sample use cases for 5G-V2X but does not define requirements.	“Leading the world to 5G: Cellular Vehicle-to-Everything(C-V2X) technologies,” Qualcomm, June 2016 ¹³⁴ .

Table 8: Summary of Automotive Use Cases and Classes

4.2.1 Identified Requirements in Technical Reports

eV2X support for vehicle platooning¹³⁵ (3GPP TR 22.886)	
Coverage	2m
Downlink data rate	Up to 1200 byte messages
Uplink data rate	Up to 1200 byte messages
Mobility	100 km/h
Reliability	90%
Latency	10ms
Battery life	Not defined
Connection density	5 UEs (group of UEs supporting V2X platooning application)

¹²⁹ www.5gcar.eu.

¹³⁰ <https://www.ngmn.org/5g-white-paper/5g-white-paper.html>.

¹³¹ http://5g-xcast.eu/wp-content/uploads/2017/06/5G-Xcast_D2.1_v1.0web.pdf.

¹³² www.3gpp.org/DynaReport/22886.htm.

¹³³ https://5gcar.eu/wp-content/uploads/2017/05/5GCAR_D2.1_v1.0.pdf.

¹³⁴ <https://www.qualcomm.com/invention/technologies/lte/advanced-pro/cellular-v2x>.

¹³⁵ Platooning is operating a group of vehicles in a closely linked manner so that the vehicles move like a train with virtual strings attached between vehicles. To maintain distance between vehicles, the vehicles need to share status information such as speed, heading and intentions such as braking, acceleration, etc. Platooning reduces the distances between vehicles, lowers overall fuel consumption, and reduces the number of needed drivers.

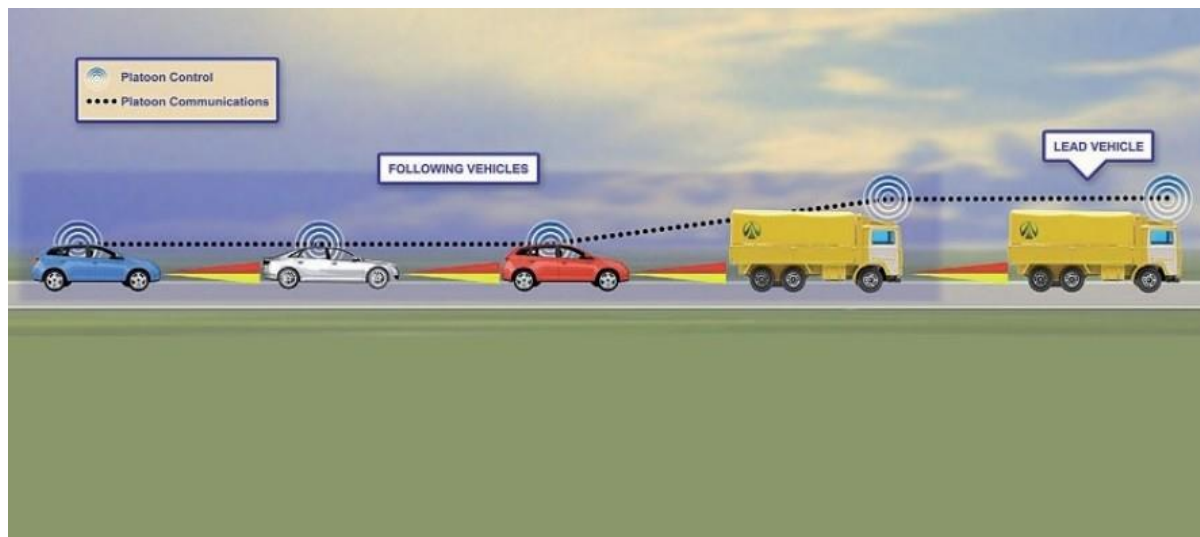


Figure 14 Example of vehicle platooning [Source: Thinking Highways]

Use case: Automotive: sensor and state map sharing (3GPP TR 22.886)	
Coverage	Not defined
Downlink data rate	Up to 25 Mbps
Uplink data rate	Up to 25 Mbps
Mobility	Not defined
Reliability	90%
Latency	<10ms
Battery life	Not defined
Connection density	High connection density for congested traffic

Use case: eV2X support for remote driving (3GPP TR 22.886)	
Coverage	Not defined
Downlink data rate	1 Mbps
Uplink data rate	20 Mbps
Mobility	Up to 250 km/h
Reliability	99.999 % or higher
Latency	<5ms
Battery life	Not defined
Connection density	Not defined

Use case: Collective perception of environment (3GPP TR 22.886, see Figure 15)	
Coverage	Urban 50 m, rural 500 m, highway 1000m
Downlink data rate	1 Gbps (in case of imminent collision)
Uplink data rate	1 Gbps (in case of imminent collision)
Mobility	Not defined
Reliability	99%, 99.99% and 99.999 % for 200m, 500m and 1000m communications range
Latency	<100ms
Battery life	Not defined

Connection density	Not defined
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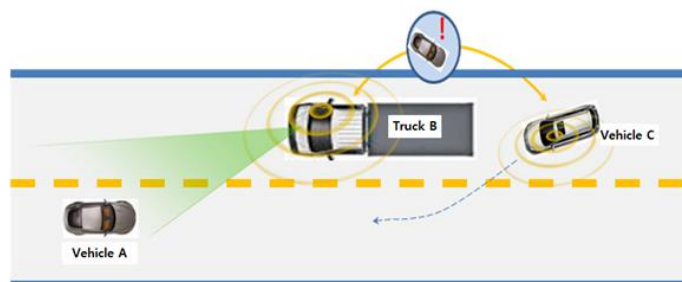


Figure 15 Collective perception of environment [Source: 3GPP]

Use case: Information sharing high/full automated platooning¹³⁶ (3GPP TR 22.886)	
Coverage	5s * maximum relative speed (m/s)
Downlink data rate	50 Mbps (cooperative perception) ¹³⁷ , 15 Mbps (cooperative manoeuvre) ¹³⁸
Uplink data rate	50 Mbps (cooperative perception), 15 Mbps (cooperative manoeuvre)
Mobility	Up to 250 km/h
Reliability	High reliability
Latency	<100 ms
Battery life	Not defined
Connection density	High density

Use case: Teleoperated support (TeSo)¹³⁹ (3GPP TR 22.886, see Figure 16)	
Coverage	Not defined
Downlink data rate	1 Mbps
Uplink data rate	25 Mbps
Mobility	Not defined
Reliability	99.999%
Latency	20ms
Battery life	Not defined
Connection density	Not defined

¹³⁶ Automated platooning at SAE Level 4/5 automation and short inter-vehicle distance.

¹³⁷ Cooperative perception requires vehicle to share high-resolution perception data (e.g., camera, LIDAR).

¹³⁸ Cooperative manoeuvre requires vehicles to share detailed planned trajectory among all involved vehicles.

¹³⁹ Teleoperated Support (TeSo) enables a single human operator to remotely control autonomous vehicles for a short period of time.

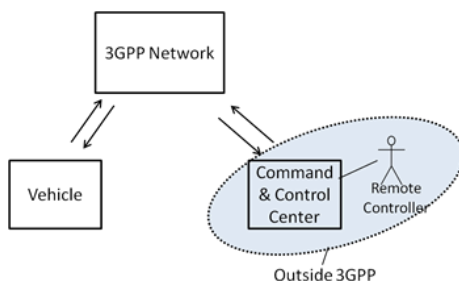


Figure 16 Description of the TeSo concept

Use case: Lane merge¹⁴⁰ (5GCAR, see Figure 17)	
Coverage	>350 m
Downlink data rate	0.350 to 6.4 Mbps
Uplink data rate	0.350 to 6.4 Mbps
Mobility	Up to 150 km/h
Reliability	99.9% (for V2V)
Latency	< 30 ms
Battery life	Not defined
Connection density	Not defined

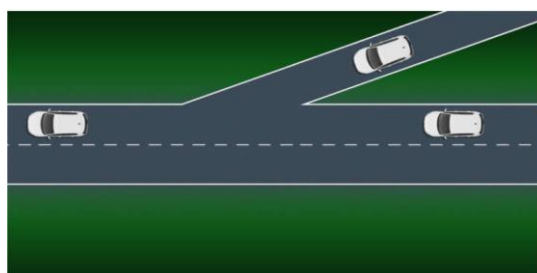


Figure 17 5GCAR lane merge use case

Use case: Network assisted vulnerable pedestrian protection¹⁴¹ (5GCAR, see Figure 18)	
Coverage	>70 meters
Downlink data rate	128 kbps
Uplink data rate	128 kbps
Mobility	0 to 100 km/h
Reliability	99% to 99.99%
Latency	< 60ms
Battery life	Not defined
Connection density	Not defined

¹⁴⁰ Vehicle preparing the merge and the one in the main lane can share their local awareness and driving intentions.

¹⁴¹ To detect the presence of vulnerable pedestrian users in proximity of a vehicle and deliver such information to the vehicle to avoid the potential collision.



Figure 18 5GCAR network assisted vulnerable pedestrian protection use case

Use case: Remote driving for automated parking¹⁴² (5GCAR, see Figure 19)	
Coverage	Several km
Downlink data rate	6.4 to 29 Mbps
Uplink data rate	6.4 to 29 Mbps
Mobility	30 to 50 km/h
Reliability	99.999%
Latency	5 to 30 ms
Battery life	Not defined
Connection density	Not defined

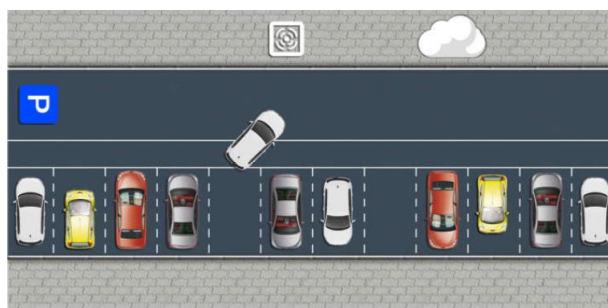


Figure 19 Depiction of the remote driving for automated parking 5GCAR use case

Use case: V2X broadcast service¹⁴³ (5GXcast, see Figure 19)	
Coverage	Not defined
Downlink data rate	Not defined
Uplink data rate	Not defined
Mobility	Not defined
Reliability	Packet loss rate of less than 10^{-5}
Latency	<5ms
Battery life	Not defined
Connection density	• Urban: 1000 – 3000 vehicles/km ²

¹⁴² To drive remotely a vehicle from a location near parking entrance to the parking spot without a human driver inside the car.

¹⁴³ Point-to-multipoint information delivery service that would benefit multiple recipients (vehicles) concurrently.

<ul style="list-style-type: none"> • Sub-urban: 500 – 1000 vehicles/km² • Highway: 100 – 500 vehicles/km²

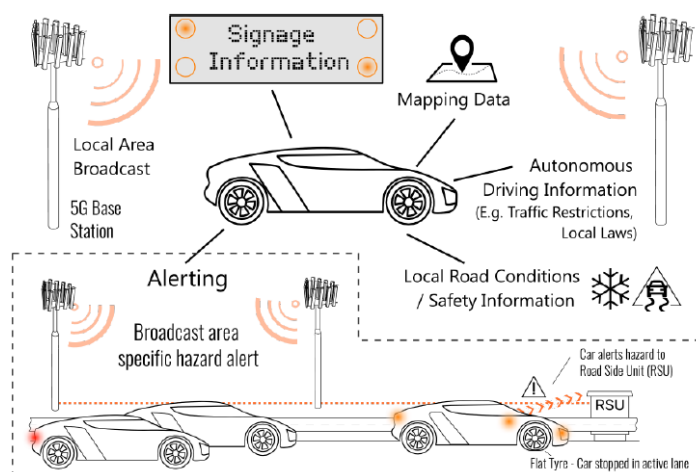


Figure 20 5GXcast V2X broadcast service

4.2.2 Use Cases powered by edge computing

Edge computing based vehicle-to-cloud solutions enable edge cloud capabilities for different levels of autonomous driving, including Highly Autonomous Driving (HAD) and Fully Autonomous Driving (FAD), corresponding to SAE levels 4 and 5 of automation, by providing different services for the driving process, e.g. high-definition real-time maps, real-time traffic monitoring and alerts, and richer passenger experiences. Benefits include supporting vehicles on roads to drive co-operatively and be aware of road hazards, better user experience and trust¹⁴⁴.

Exploitation of the edge processing power and its ability to intelligently process information can add value to the information exchanged between vehicles, infrastructure, pedestrians and network using V2X technology.

The edge computing solution introduced by the ETSI Industry Specification Group on Mobile Edge Computing – ETSI ISG MEC (See section 8) provides application and content providers with cloud computing capabilities and IT service environment at the very edge of the mobile network. This environment is characterised by the proximity, often in both physical and logical sense, to clients, enabling very low latency between the client and the server applications, high bandwidth for the application traffic, near real-time access of the applications to context-rich information, e.g. related to device locations and local radio network conditions. These qualities of the edge computing ensure an unparalleled quality of experience with highly contextualised service experience and efficient utilisation of radio and network resources.

The ETSI ISG MEC solution can be deployed within the Mobile Network Operator’s infrastructure with management and orchestration, security, privacy and subscriber management frameworks already in place, making it more suitable to critical applications and for applications with high business value.

The 5GAA has recently provided concrete examples of MEC relevance to four main groups of use cases: safety, convenience, advanced driving assistance, and vulnerable road user (VRU)¹⁴⁵.

¹⁴⁴ Toward fully connected vehicles, 5GAA, op cit.

¹⁴⁵ Toward fully connected vehicles, 5GAA, op cit., pp. 7-11.

Use case group: Safety Scope: safety use cases are designed to reduce the frequency and severity of accidents. The V2X Safety use case group includes several different types of use cases supporting road safety using vehicle-to-infrastructure (V2I) communication in addition to V2V. Relevance of MEC: For some of these use cases, MEC systems could provide support for real-time data analytics, data fusion and reduced ingress bandwidth with respect to the remote cloud.		
Use Case	Description	Relevance for MEC
Intersection Movement Assist	Warn driver of collision risk through an intersection.	High
Use case group: Convenience Scope: Convenience use cases provide time-saving services to manage data and the health of the vehicle. This group of V2X use cases requires cost-effective communication to be enabled between the vehicles and the backend server (e.g. car's OEM's server). Software Over the Air (OTA) updates and other telematics use cases are typically included in this group.		
Use Case	Description	Relevance for MEC
Software updates	Deliver and manage automotive software updates.	Mid
Use case group: Advanced Driving Assistance Scope: these use cases are focused on improving traffic flow, traffic signal timing, routing, variable speed limits, weather alerts etc. This use case group collects the most challenging requirements for V2X from a MEC perspective. It can require distribution of a relatively large amount of data with high availability and low latency in parallel. The use cases would also benefit from predictive reliability. This means that vehicles moving along should have the possibility to receive a prediction of the network availability ahead of them to allow preparations accordingly.		
Use Case	Description	Relevance for MEC
Real-time situational Awareness and High Definition Maps	Alert driver of host vehicle (HV) moving forward of hazards (icy) road conditions in front.	High
See-through	Driver of the HV that signals an intention to pass a remote vehicle (RV) using oncoming traffic lane is provided a video stream showing the view in front of the RV.	High
Cooperative Lane Change (CLC) of automated vehicles	Driver of HV signals intention to change the lane with at least one RV in the target lane in the vicinity of the HV.	High
Use case group: VRU Scope: These use cases support safe interaction between vehicles and pedestrians, motorcycles, bicycles, or any other non-vehicle road user.		
Use Case	Description	Relevance for MEC
Vulnerable road user discovery	Detects and warns drivers of VRUs in the vicinity.	High

Table 9: Automotive Use Cases and Edge Computing

4.2.3 Other Automotive Use Cases

Dynamic ride sharing (3G TR 22.886)

The dynamic ride sharing scenario (see Figure 21) enables vehicles to publicise their willingness to provide ride sharing to pedestrians (searching for a ride). This matching and collaborative decision-making is enabled by the vehicle sharing information including the available capacity, route, destination and estimated time of arrival, while the pedestrian shares personal information, credentials, destination and so on. This scenario could be based on vehicle ownership models (privately owned, pooled, private hire, taxi, public transport, campus transport, etc.).

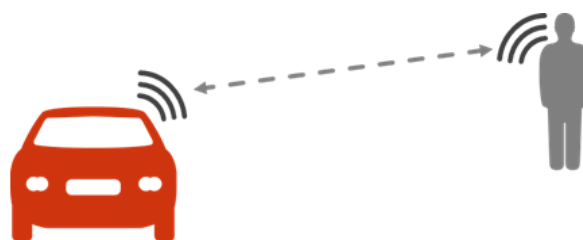


Figure 21 Dynamic ride sharing

Tethering via vehicle (3G TR 22.886)

The tethering via vehicle scenario enables to act as a mobile small cell that provides network access to both vehicle occupants and pedestrians (see Figure 22). The tethering via the vehicle provides several advantages (availability of power, higher number of antennas, size etc.) over tethering via user devices (e.g. smartphones). This scenario also provides an opportunity for mobile network operators to provide network densification without the usual high upfront costs of conventional fixed small cells.

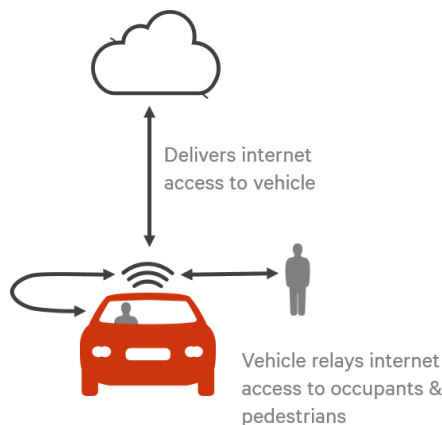


Figure 22 Tethering via vehicle

V2X augmented reality

Augmented reality (AR)¹⁴⁶ provides an opportunity to provide more enhanced information on the objects around the vehicle to the driver, typically via the windshield as shown in example of Figure 23. The additional information would greatly enhance safety by projecting warnings etc. The AR services are usually demanding in terms of capacity and low latency needs, which become further challenging in the high mobility vehicular environment. Various studies¹⁴⁷ have underlined the need for network

¹⁴⁶ Augmented reality is the integration of digital information with the user's environment in real time.

¹⁴⁷ See for example: ABI Research, "Augmented and Virtual Reality: The First Wave of 5G Killer Apps", ABI Research white paper (in conjunction with Qualcomm), 2017.

performance achievable in 5G to properly support AR (and virtual reality), particularly for automotive use cases.



Figure 23 Use of AR to project useful driver information to the windshield [Source: Continental]

4.3 Potential Issues and Barriers

While currently globally competitive, the sector is not immune to the transformation brought by the new industrial age. The GEAR2030 report presents 5 areas for the European automotive sector to address and makes several recommendations:

- **New technologies and business models** – requiring high investment.
- **Climate and health concerns** – such as the need to reduce greenhouse gas emissions.
- **Societal changes** – changes in consumer behaviour with regard to cars.
- **Globalisation** – remaining competitive and responding to international demand, as well as ensuring fair access to international markets.
- **Structural change** – the impact on the workforce as the industry moves towards automated driving and low and zero emission vehicles.

The integration of 5G capabilities in the automotive sector will see a significant increase in the number of consumer electronics and ICT companies entering the automotive sector. However, the increased convergence of the automotive and ICT sectors will bring with it challenges due to differences in the product life cycles (much faster for ICT products). In particular, the ICT sector will need to conform to the stringent testing and approval regimes that are necessary in the automotive sector due to the high system reliability demands and its safety critical applications (e.g. application of 26262 ISO standard for functional safety of electrical and/or electronic systems in production road vehicles).

The envisioned future of fully connected and automated driving promises increased safety, reduced traffic congestion and GHG emissions, and overall improvement in driver/traveller experience and convenience. However, for these foreseen impacts to be realised there are a number of regulatory and policy interventions that are required. To that end, the report by EC GEAR 2030 High Level Group (HLG) report puts forward a number of legal and policy recommendations for the years 2020 to 2030, a period which is expected to see a significant increase in the market penetration of increasingly connected and automated vehicles. These recommendations are summarised briefly in the remainder of this subsection.

Testing in open roads

<https://www.qualcomm.com/news/onq/2017/02/01/vr-and-ar-are-pushing-limits-connectivity-5g-our-rescue>.

The GEAR 2030 HLG noted the need for large-scale testing in real open road conditions for the progress of development of connected and automated vehicles. Therefore, the GEAR 2030 HLG noted the need for an EU-wide focal point to be established for better coordination of open road testing and exchange of lessons learned during the testing.

Currently the EC supports cross-border trials through Horizon 2020 and the Connecting Europe Facility (CEF). Significantly for the automotive sector this has seen the establishment of so-called “5G Corridors”¹⁴⁸, which are cross-border sections of open roads throughout Europe designated for conducting research, testing and large-scale demonstrations of the use of 5G technologies for connected and automated mobility. Some of the first wave of selected 5G corridors (at the time of writing) are shown in the map of Figure 24.



Figure 24 First wave of open road sections designated as 5G corridors

Road safety rules

Conventional measures for road safety have been addressed through rules on vehicles, drivers and infrastructure. However, connected and automated cars present new capabilities (e.g. faster reaction

¹⁴⁸ EC, “EU and EEA Member States sign up for cross border experiments on cooperative, connected and automated mobility” March 2017 <https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated>.

times compared to human drivers), but also potentially raise road safety concerns due to system misuse, driver distraction/confusion and liability issues.

The GEAR 2030 HLG notes that new introduced automated vehicles will blur the current distinction between national traffic rules applying to drivers and EU-wide harmonised vehicle approval legislation. A recommendation is then made for national traffic rules on automated vehicles (e.g. safety distance) in different Member States to follow a harmonised path and avoid conflicts with the EU-wide rules for vehicle approval.

In adherence to these rules, 5G will have key role in the sharing of data (digital state maps, highly accurate road traffic info etc.) and cooperation among the involved actors (e.g. vehicle manufacturers, road operators, local governments etc.). This will become increasingly important to ensure at all times the reliability and interoperability of the data conveyed to road users.

Liabilities

The GEAR 2030 HLG notes that as the automated vehicle systems increasingly take over the driver's tasks, it will become more complicated to assign liability in the case of a road accident. This will make it more challenging to properly compensate the victims of accidents involving automated vehicles.

The HLG recommended a legislation on the use of data recordings in a vehicle "black-box" to help clarify who was driving the automated vehicle (the automated system or the driver) during the accident. The legislation should cover the possible minimum set of data that would be needed to clarify liability and the mechanisms to regulate the data access from a technical point of view.

It is noted that some EU Member States (e.g. Germany)¹⁴⁹ are already in the process of defining national legislation that would require partially/fully automated vehicles to include black boxes. The quality of the black box data is essential in providing a clear and fair clarification of liability in case of an accident, but also provide insights on any actions needed to avoid similar accidents in the future. To that end, 5G could potentially provide the capability for more regular update of high resolution (large volume, big data) vehicle black-box data to the cloud.

Connectivity for automation (including spectrum aspects)

Connectivity of vehicles is essential for enabling collective intelligence and actions to vehicle automation, in other words (and as noted in the use cases of the previous subsection), the full value of automated driving can only be fulfilled if deployed with V2X connectivity (including 5G-V2X). Therefore, the GEAR 2030 HLG notes that while the majority of the V2X connectivity investment will come from the private sector, there will still be the need for the EU to help in providing regulatory approaches that encourage the needed investment. This includes investment-friendly incentives; ensuring technological neutrality coupled with interoperability and allocation of dedicated spectrum band for safety-critical V2X applications.

The Electronics Communications Committee (ECC)¹⁵⁰ has assigned 5.875-5.925 GHz band as the European harmonised band for Intelligent Transport Systems (ITS) [Commission Decision 2008/671/EC, ECC Decision (08)01].¹⁵¹ This 5.9 GHz band for ITS includes a sub-band 5.875-5.905 GHz assigned on a non-exclusive basis for ITS traffic safety applications (typically V2X applications), and a sub-band 5.905-5.925 GHz band for possible future extensions of the ITS spectrum. The technology-neutral nature of spectrum regulations in Europe means that both C-V2X and IEEE

¹⁴⁹ D. Etherington, "Germany wants a 'black box' in any car with self-driving features," TechCrunch, July 2016 <https://techcrunch.com/2016/07/18/germany-wants-a-black-box-in-any-car-with-self-driving-features/>.

¹⁵⁰ The ECC is one of three business committees of the European Conference of Postal and Telecommunications Administrations (CEPT).

¹⁵¹ ECC, "The harmonised use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS)" ECC Decision (08)01, approved 14 March 2008, amended 3 July 2015.

802.11p technologies have equal rights to operate in this 5.9 GHz band, subject to compliance with the relevant regulatory technical conditions. To that end, the 5GAA has recently produced a position paper¹⁵² proposing that the C-V2X and IEEE 802.11p share 30 MHz from the 5.875-5.905 GHz sub-band by allocating distinct 10 MHz channels to each of the two technologies. The remaining 10 MHz would be allocated for use by both technologies using appropriate sharing mechanisms that avoid co-channel interference. The status of this proposal remains under consideration at the time of writing.

Beyond Europe there seems to be some convergence on the 5.9 GHz band for C-ITS/V2X applications as indicated in the Table 10 and this bodes well for potential harmonisation efforts in the future. The issue of spectrum allocation in this 5.9 GHz band will also be discussed at the upcoming World Radiocommunication Conference in November 2019 (WRC-19). WRC-19 is notably an event that is expected to have great impact on the selection of 5G spectrum bands¹⁵³ and realisation of the 5G vision.

Australia	- 5850-5925 MHz is set aside for C-ITS and specifically 802.11p - but this will be reviewed once the C-V2X standard in 3GPP is completed
China	- There is no spectrum designation for safety related ITS. Discussions on-going for 5875-5925 MHz to be made available for ITS on a non-exclusive basis. - C-V2X technology will be mandated in China and in 2016, 5905-5925 MHz was allocated for C-V2X trial projects in 6 major cities
EU	- 5875-5905 MHz has been designated for safety related ITS on a technology neutral basis with co-existence measures being considered currently
Japan	- 755.5-764.5 MHz is available on an exclusive and licence exempt basis. The 5.8 GHz band is being studied for V2V and V2I safety related communications. - In Q4-2015 Toyota started shipping ARIB STD-T109 equipment (which is somewhat based on 802.11-2007) in vehicles in Japan - Road side unit deployments in fewer than 30 junctions in Q4-2015
South Korea	- In 2016, South Korea assigned 5855-5925 MHz for V2V and V2I communications
United States	- 5850-5925 MHz has been available for ITS on a non-exclusive and licensed basis for over 16 years. The focus is on the WAVE/802.11p system and a band plan has been created with specific channels for safety. - There are a number of trials, but no significant commercial deployments, with the V2I build-out proving a challenge for the auto industry - Unclear if the approach will change with the new administration and ongoing regulatory proceedings - The government is considering a mandated 802.11p in new cars by 2021-2022, with the prognosis unclear and even slightly negative, given the current US political climate - GM has incorporated 802.11p in the Cadillac ATS beginning in model year 2017

Table 10 Status of spectrum allocation for C-ITS/V2X in different regions [GSMA]¹⁵⁴

Vehicle certification

The vehicle connectivity and replacement of some of the driver's task will require new areas to be regulated (e.g. interoperability for platooning of different vehicle brands etc.). To that end, the GEAR

¹⁵² 5GAA, "Coexistence of C-V2X and 802.11p at 5.9 GHz," 5GAA position paper, June 2017 <http://5gaa.org/news/position-paper-coexistence-of-c-v2x-and-802-11p-at-5-9-ghz/>.

¹⁵³ <https://www.gsma.com/spectrum/wrc-series/>.

¹⁵⁴ GSMA, "Safer and smarter driving: The Rollout of Cellular V2X Services in Europe," GSMA Position Paper, September 2017 <https://www.gsma.com/iot/wp-content/uploads/2017/09/GSMA-position-on-CV2X.pdf>.

2030 HLG recommends that the current EU type-approval is supplemented for connected and automated vehicles. This may also involve the need to define new vehicle categories and new specific requirements for current and new categories. The introduction of new connectivity technologies like 5G also creates the need for proposals to supplement the EU type-approval with relevant 5G equipment certification that meets the stringent requirements of safety-critical automotive applications.

Societal issues

Highly connected and automated vehicles will have an impact which extends beyond the automotive industry. The long-term societal effects are yet to be fully understood, but the GEAR 2030 HLG already noted some of the following likely scenarios:

- Automation will affect the attractiveness of areas as places to live in and social inclusion especially in rural areas with limited public transport networks or for people that are now depending on others for mobility needs (e.g. children, aging population, impaired people). The substantial change of mobility will have an impact on regions and cities and their development.
- Market penetration of automated vehicles will also have implications on the labour market. These both positive (in terms of creation of new automation type jobs and businesses), but also possible negative impact on reduced business for professional drivers of trucks, buses or taxis and other related professions.

Therefore, the HLG underlined the need for a wider dialogue on societal challenges of connected and automated vehicles to ensure there is widespread driver and public acceptability of the technology when it will be ready for deployment.

From the 5G-perspective, the initiation of the 5G-PPP and 5G Action Plan is already creating an environment for enabling inclusive approach towards industry verticals (including automotive). In addition to this, the public dialogue on connected and automated driving would also be a key part of the overall inclusive process towards a truly 5G connected society. The HLG proposes that this dialogue should involve all social partners, the EC, as well as Member States, local and regional authorities, and could progress further by pilot and research projects.

5 Health Use Case Analysis

5.1 Use Case Overview

While health care will benefit mostly from MCS features, enhanced mobile broadband will also bring innovations and benefits to this vertical industry, e.g. with AR/VR. The ability to support dynamic AR content at scale will require a 5G interface. Reduced latency and multiple Gb/second speeds will enable computationally heavy AR/VR user interactions. Benefits include:

- Mobilised AR/VR (aka smart glasses) will benefit users by providing a visual display in any environment/surface, removing the need for additional hardware or display.
- Reduced costs for field support workers, creating the ability to have a core team of highly trained and experienced workers that are centrally located supporting a much larger field support team.

Health care will benefit from MIIoT for use cases related asset tracking, where 5G can offer additional benefits over current approaches, in terms of deep coverage, low power and low cost (economies of scale), and by being a 3GPP standard.

5G MCS capabilities will be most important for remote patient monitoring/telehealth. 5G will eliminate current reliance on disparate connection strategies between patients, care providers, and monitoring equipment. HD image quality should lead to the increased use of many applications such as dermatology and wound care.

A broad range of applications fall within the remote patient monitoring/telehealth use case. Applications include ubiquitous access to imaging and medical records, advanced telemedicine, including remote surgery; treatment using robotics and AR/VR, and remote clinical care.

5G will also enable health care workers to perform controlled substance management using wearables, which has the potential to dramatically improve pain management as well as to provide a tool that helps minimise the risks of abuse.

Benefits include:

- Standardised connectivity platforms leading to greater ease of use, higher implementation and lower costs.
- Medical professionals will have faster and more secure access to records for patients on their devices, easier file management, and access for providers in any location.
- The increased use of outpatient monitoring and the ability to reduce in-hospital stays will offer both reduced costs and greater patient comfort.

To be sustainable, future health care needs to be structured in a **decentralised** and **modular** way exploiting high levels of **medical specialisation** and **evolved technology support**, including the disruptive next generation network capabilities introduced by 5G.

A wide range of innovative applications in the health sector are enabled or strongly benefit from the 5G capabilities in a number of different ways.

5G is a particularly effective catalyst of the IoMT (Internet of Medical Things) thanks to: 1) Greatly enhanced mobile broadband data rates that enable ever faster flows of greater amounts of information. 2) Ultra-low latency and ultra-reliability—which is suitable for mission-critical services. 3) Ability to significantly and efficiently scale to connect a massive number of sensors. 4) Capillary, seamless connectivity that makes it “ubiquitous”, 5) Enhanced, built-in security.

- 5G will support *continuous monitoring and processing* of data from numerous *sensing devices*. This will dramatically increase the effectiveness of preventive care, which in turn will lower the burden of chronic diseases on the health care systems.
- 5G will enable *enhanced distributed computing*, harnessing the potential of the substantial amounts of health data that will be available. By enabling smart aggregation and correlation of data, 5G will support medicine research and improve our understanding of the human body.
- 5G will support application of *virtual/ augmented reality and high-quality imaging*, allowing improved diagnostics and remote medical intervention of expert practitioners.
- 5G's capabilities of *high reliability and extremely low latency* will support mission-critical applications such as the treatment of stroke patients.

The whole of the health and care system could be revolutionised over the next decade, with changes in patient-carer relationship, and new business models. This is exactly where the Health 4.0 approach comes into play as a win-win solution for all stakeholders to manage the new socio-economic landscape. The Health 4.0 concept is derived from the manufacturing industry's well-known Industry 4.0 concept which consists mainly of the combination of cyber-physical systems, IoT and cloud

computing. Development of Health 4.0, just as Industry 4.0, is based on six design principles¹⁵⁵: Interoperability; Virtualisation; Decentralisation; Real-time Capability; Service orientation; Modularity and reconfigurability.

One of the challenges of Health 4.0 is to integrate, aggregate and ultimately make sense of an exponentially growing amount of data from a variety of sensors and smart devices. Health care providers will need to adopt new roles, namely to establish the governance and develop the management skills to protect patient data on the interface between medicine and ICT.

The health sector business model will be revolutionised: the delivery of care will be **strongly decentralised**, becoming truly **patient-centric**, drastically reducing the hospitalisation of patients and allowing them to receive treatments and to be closely monitored at home. Because healthcare is a highly regulated industry, public policy has a critical role to play in enabling this transformation.

5.2 Application Scenarios and Use Cases

5.2.1 Identified Requirements

5G capabilities, spanning ubiquitous access, reliability and ultra-low latency can be embedded in wearable's and/or operate through smartphone devices. 5G capabilities can also be directly embedded in medical devices that can operate independently of consumer grade equipment. This bypassing of the smartphone and consumer equipment, while still leveraging the power of 5G networks, also presents potential avenues for disruptive service and business models.

IoT features strongly in some of the use case scenarios identified as the basis for defining requirements. Literature and standards documentation point to user-driven requirements in terms of Quality of Experience (QoE), Quality of Service (QoS), user satisfaction and speed of connection. User-driven requirements include:

- Data rate and latency per user: the performance perceived by the user in terms of capacity and latency.
- Quality of Resilience (QoR): the ability to react to failures, such as link cuts or software errors, automatically by re-directing traffic from routes affected by failures to routes that are fault-free, resulting in the user's perception of continuous service.
- User mobility: provision of continuous service to the user irrespective of movement and location, velocity and acceleration change over time. This is usually represented by mobility models for various conditions, environments and services.
- Context awareness and management (complementary to other requirements): this refers to the ability of an application to adapt to changing circumstances and respond according to the context of use. Definitions of models and architectures are still in the research phase and consensus yet to be reached, but is particularly important for use case scenarios in the health care domain.

Use cases in the health sector enabled by 5G are extremely heterogeneous: they display a varied combination of requirements spanning from very loose to very demanding ones. Moreover, implanted sensors, wearables, and portable devices cover a wide *frequency spectrum* range: from 550MHz for implanted devices all the way to the mm-Wave frequency band for 5G portable devices.

¹⁵⁵ Design Principles for Industrie 4.0 Scenarios: A Literature Review, H. M. Pentek, T.Otto, Boris.<http://www.thiagobranquinho.com/wp-content/uploads/2016/11/Design-Principles-for-Industrie-4-0-Scenarios.pdf>.

In a family scenario, health monitoring wearable devices should have the basic medical monitoring capabilities, as well as the properties of *miniaturization*, *portability*, easy operation and the capability of short-distance communication. *Densification* is fundamental for the wireless body area network (WBAN) in a home environment, whereas *coverage* is top priority for a longer range wireless local area network (WLAN) to connect patients, relatives, doctors to the remote server and data centre for instance in scenarios such as a disaster rescue and a pre-hospital emergency scenario.

Some use cases require the ability to transmit *large amounts of data* (e.g. monitoring of vital parameters, high resolution video, virtual reality) while others only need to transmit a very *small quantity of data* (e.g. smart packaging to verify patient's adherence to prescription).

Requirements on *data rate* vary largely depending on the criticality of the mission, requiring high speeds for instance for remote surgery based on VR/AR. Extremely stringent requirements on *latency* apply for the remote surgery scenario, while more relaxed requirements are sufficient for most other use cases (e.g. for tracking the medical equipment and drugs in a hospital).

Two fundamental requirements that are common to all of the health scenarios are related to high *reliability* and *security/data protection*.

On the network side, 5G, thanks to technologies such as network function virtualization (NFV) and software-defined networks (SDN) configured to provide the necessary QoS with network slicing, will enable the infrastructure network to flexibly support all the various application scenarios in a common platform, which allows time- and cost-efficient configuration.

On the device side, while the wearable devices require miniaturisation, the requirements on computation and processing power can be high. In order to limit high traffic demand, *edge cloud* and *edge computation* (i.e. where the burden of computation is set close to the production of the data itself) should be supported to process data locally. Edge computing has also the effect of potentially reducing data protection risks.

The table below summarises some of the principal aspects for a wide sample of 5G health use cases provided in the *Information Technology – Next Generation: The Impact of 5G on the evolution of Health and Care Services*¹⁵⁶

The analysis focuses on some of the most relevant use case scenarios identified and their estimated technological requirements based on experimental tests and empiric evidence¹⁵⁷.

A core feature of distributed, patient-centred care is that care elements and services are grouped around the patient. Cyber-physical systems are not yet part of the medical domain but progress has begun. Pharmaceutical companies are working in smart pharmaceuticals, which are fitted with biosensors to enable and support the link between the physical and virtual world. Big data strategies are being tested to cater for individualisation and personalised care. New strategies such as precision medicine will be based on real-time connectivity between patients (physical world) and cloud-based algorithms and autonomous systems (virtual world).

This will lead to individual combination of cross-organisational services which will be heavily dependent on real time information. This development is coming at a time when new care models call for individual patient budgets offering patients and informal carers more influence and control in managing their health and putting the necessary resources at their disposal. This will have to be

¹⁵⁶ Information Technology – Next Generation: The Impact of 5G on the Evolution of Health and Care Services <http://www.napier.ac.uk/~media/worktribe/output-842077/the-impact-of-5g-on-the-evolution-of-health-and-care-services.docx>

¹⁵⁷ Information Technology – Next Generation: The Impact of 5G on the Evolution of Health and Care S Services <http://www.napier.ac.uk/~media/worktribe/output-842077/the-impact-of-5g-on-the-evolution-of-health-and-care-services.docx>

supported by new features and functionalities of 5G such as multi-domain orchestration and multi-tenancy.

5.2.2 Use case examples

From a review of the literature, the following principal use cases are referenced.

Vertical industry: Healthcare	
Use Cases	Main source(s)
Asset tracking: asset and intervention management in hospitals covering asset tracking and management; intervention planning and follow up.	5G and e-Health, White paper, September 2015, 5G Infrastructure Association ¹⁵⁸
Robotics: remote surgery and cloud robotics for assisted living Surgery 4.0: collaborative operating room and surgical telematics	5G and e-Health, White paper, September 2015, 5G Infrastructure Association Health 4.0: How Virtualization and Big Data are Revolutionizing Healthcare ¹⁵⁹ .
Remote monitoring of health and wellness data: ageing well, lifestyle and prevention, follow-up after acute events and assisted living in chronic scenarios	5G and e-Health, White paper, September 2015, 5G Infrastructure Association
Smarter medication: applying medication remotely; smart pharmaceuticals; health behavioural change (algorithm supported) Hyper-connected asthma inhalers; smart pharmaceuticals (asthma and COPD, diabetes, epidemiology of poor adherence)	5G and e-Health, White paper, September 2015, 5G Infrastructure Association Health 4.0: How Virtualization and Big Data are Revolutionizing Healthcare
Home, hospital, disaster and pre-hospital emergency	A New Generation of e-Health Systems powered by 5G, White Paper, Wireless World, November 2016 ¹⁶⁰
Medical conditions: Glucometer for diabetes Diabetes glucometer in contact lenses and other scenarios	5G Mobile: Impact on the Health Care Sector. Qualcomm, October 2017 ¹⁶¹ Various sources ¹⁶²
Medical conditions: Multiple sclerosis	Health 4.0: How Virtualization and Big Data are Revolutionizing Healthcare A new Generation of e-Health Systems powered by 5G, November 2016 ¹⁶³

¹⁵⁸ <https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-eHealth-Vertical-Sector.pdf>

¹⁵⁹ ISBN 978-3-319-47616-2 ISBN 978-3-319-47617-9 (eBook) DOI 10.1007/978-3-319-47617-9

Library of Congress Control Number: 2016956825, Springer International Publishing Switzerland 2017

¹⁶⁰ <https://ec.europa.eu/digital-single-market/en/news/white-paper-new-generation-ehealth-systems-powered-5g>.

¹⁶¹ David J Teece, "5G Mobile: Impact on the Health Care Sector", 26 October 2017

<https://www.qualcomm.com/media/documents/files/5g-mobile-impact-on-the-health-care-sector.pdf>

¹⁶² http://econsoc.mpifg.de/downloads/17_1/McFall_17.1.pdf; <https://labiotech.eu/contact-lens-glucose-diabetes/>;
<http://medicalfuturist.com/googles-amazing-digital-contact-lens-can-transform-diabetes-care/>;
<https://spectrum.ieee.org/the-human-os/biomedical/devices/smart-contact-lenseyeglass-combo-monitor-diabetes-and-deliver-drugs>; <https://newsroom.cisco.com/feature-content?articleId=1738492>.

¹⁶³ White Paper: A new Generation of e-Health Systems powered by 5G, Wireless world Research Forum, November 2016, <https://ec.europa.eu/digital-single-market/en/news/white-paper-new-generation-ehealth-systems-powered-5g>.

Smart pharma; precision medicine; hospital at home; surgical robotics; medical device management; artificial organs and limbs; smart packaging; emergency services; wound management; wellness and fitness.	Information Technology – Next Generation: The Impact of 5G on the Evolution of Health and Care Services ¹⁶⁴
Use Case groups/classes	
Use Cases	Source(s)
13 use cases: Remote patient monitoring/assisted living; Telehealth system for home care support; Remote patient monitoring/assisted living; Legacy mass medical examination; Travelling mass medical examination with BAN; Remote patient monitoring; Telehealth Counselling System; Telehealth management system using NFC e-health device and smart phone; Telehealth system for home care support; Ambient Assisted Living (AAL); Easy Clinic; Personal healthcare data management	ITU-T Focus Group on M2M Service Layer - M2M use cases: e-health ¹⁶⁵

Examples use cases are presented in the following tables to illustrate how they can innovate health care.

Use Case: Precision Medicine/Personalised Medicine	
5G Technology: LPWA 4G Mm Waves Multi-domain orchestration Mobility support at speed	Bandwidth/data volume: 5 Mbps
Business aspects: Tagging and tracking of personalised medicines. Time management and synchronisation. Telemedicine. VOIP, GS1 compliance.	
Regulatory aspects: Medical product legislation. International standardisation. National and EU privacy laws, ISO 27000 and ISO 80001. Governance.	

Table 11: Precision Medicine Use Case

Use Case: Hospital at Home	
5G Technology: mm Waves 4G LPWA Multi-domain orchestration Real-time	Bandwidth/data volume: 5 Mbps

¹⁶⁴ <https://www.napier.ac.uk/~media/worktribe/output-842077/the-impact-of-5g-on-the-evolution-of-health-and-care-services.docx>

¹⁶⁵ Persistent link: <http://handle.itu.int/11.1002/pub/80a4ae23-en>.

Business aspects: Transition of health care delivery to distributed patient centric care. Accelerated transition from hospital to home. Reduced nosocomial infection rate. Improved mental health management. Home diagnostics, e.g. ultrasound scanner, echocardiogram, Doppler. Empowering patients to make decisions on care priorities. Releasing “social capital” equity. Peer to peer. Self-help groups. Monitoring, e.g. blood glucose, heart rate, blood pressure, regular infusions, feeding pumps. GS1 compliance. Governance. Billing.

Regulatory aspects: Universal health and care budgets. National “social legislation”. National and EU eHealth legislation. Mandatory conformity marking, e.g. CE. National and EU privacy rules. ISO 27001 and ISO 80001.

Table 12: Hospital at Home Use Case

Use Case: Medical Device Management (in hospital and at home)	
5G Technology: LPWA mm Waves 4G Multi-tenancy Multi-domain orchestration	Bandwidth/data volume: 200 kb unit per day
Business aspects: Obligatory maintenance as defined by medical product legislation. Prevention of nosocomial infections by contamination detection. Malfunction alert. QoS monitoring for vendors and service providers.	
Regulatory aspects: Medical product legislation. Warranty. Mandatory conformity marking, e.g. CE. ISO 27000, ISO 80001.	

Table 13: Medical Device Management Use Case

Use Case: Surgical Robotics	
5G Technology: mm Waves Low latency	Bandwidth/data volume: >50 Mbps
Business aspects: Specialists supporting generalists in peripheral locations. Improved quality of care through availability of expert input in real time. Enhanced patient safety. High resolution 3D video imaging (4k plus). Augmented reality.	
Regulatory aspects: Medical device regulations. Mandatory conformity marking, e.g. CE. BEREC rules on net neutrality.	

Table 14: Surgical Robotics Use Case

Value chain organisation is paramount in the health care industry to enhance effectiveness and efficiency in the face of growing budget pressure. Good examples of shortcomings are counterfeiting issues and missed expiry of drugs and other medical consumables. Counterfeiting or selling of faked drugs can have a devastating effect on the quality of care. Counterfeiters have claimed around a third of the market, worth around \$200 billion, and are implicated in the deaths of up to one million people each year due to toxic or ineffective drugs. The uncontrolled expiry of drugs and medical consumables is a substantive challenge to health care organisations in Europe and elsewhere, worth billions of Euros each year. The use case in the table below provides an example of how 5G could

tackle this challenge.

Use Case: Smart Packaging	
5G Technology: LPWA Multi-domain orchestration 100 x connections 1/10 energy consumption	Bandwidth/data volume: 300 kb per unit per week
Business aspects: Tackling counterfeiting ¹⁶⁶ . Monitor adherence to therapy. Supply chain management of value drugs. Storage and transport conditions (cooling chain, humidity, temperature, etc.). Blockchain technology to establish audit trail. GS1 compliance.	
Regulatory aspects: Medical product legislation. ISO 80001, ISO 27000.	

Table 15: Smart Packaging Use Case

Use Case: Smart Pharma	
5G Technology: LPWA mm Waves Network slicing Multi domain orchestration 100 x connections Intelligent networks Terminal with network control capacity 1/10 of energy consumption	Bandwidth/data volume: <1Mb per unit per day
Business aspects: Business model transformation from manufacturing to service. Massive enhancement of adherence. Prevention of serious episodes sick days, hospitalisation, death. Combining pharma and non-pharma therapy. Patient feedback. Use of authorised data for research purposes. Pharma-telco joint venture. GS1 compliance ¹⁶⁷ . QoS management.	
Regulatory aspects: Medical product legislation. International standardisation. National and EU privacy rules. National eHealth legislation, e.g. Austria (ELGA ¹⁶⁸) and Denmark (Sundhed ¹⁶⁹).	

Table 16: Smart Pharma Use Case

5G driven **personalised asthma care** is another interesting use case of smart pharma. The treatment of asthma is frequently based on inhalers to apply pharmaceuticals. Commercially available inhalers do not include cyber-physical systems to interconnect the physical with the virtual world and support personalised medicine strategies. The latest generation of sensor technologies now enable the capture of important therapy key performance indicators at the point of care such as adherence, physiological parameters and timing. 5G will provide multi-frequency connectivity and multi-modal

¹⁶⁶ 1 in 10 drugs sold globally is fake. For 1,000 dollars invested, a criminal can make 20,000 dollars in profits by trafficking heroin and 400,000 dollars from dealing in counterfeit drugs, https://en.sanofi.com/Images/33151_DP_Counterfeit.pdf.

¹⁶⁷ <https://www.gs1uk.org/our-industries/healthcare>

¹⁶⁸ The Electronic Health Record (ELGA) in Austria

https://www.bmgf.gv.at/cms/home/attachments/1/7/2/CH1538/CMS1458292318057/1511_elga_the_electronic_health_record_in_austria.pdf

¹⁶⁹ <https://www.sundhed.dk/borger/service/om-sundheddk/ehealth-in-denmark/background/>

capability, including narrow band Internet of Things (NB-IoT) and mobile telephony to enable information exchange between the physical and the virtual world. This will enable the use of theragnostic algorithms and also offer the possibility of easy and seamless integration of pharmaceutical and non-pharmaceutical therapy. Meeting stringent requirements is key to successful deployment, including predicable QoS; safety and security; privacy, which is paramount; network agnostic and interoperable; safe, secure and resilient technology; anywhere, any how and any time connectivity; global product and service interoperability and network capability for global service orchestration. The impacts of doing so span:

- Reduced number of serious incidents.
- Enhanced efficiency of pharmaceutical therapy.
- Improved quality of experiences for both patients and professionals.
- Reduced number of hospital admissions, sick days and outpatient visits.
- Improved documentation and individual risk analysis.

Other examples of health use cases are provided in the following tables, including projects from the 5G PPP.

Use Case: Artificial organs endo-prosthetics Artificial Limbs (Body Area Networks)	
5G Technology: mm Waves 4G LPWA Multi-tenancy Mobility support at speed 1/10 energy consumption	Bandwidth/data volume: 200 kb per unit per day
Business aspects: Pacemaker. Insulin pumps. Brain Pacemakers. In vivo sensors. Sensors in endo-prosthetic devices.	
Regulatory aspects: IEEE 802.15.6, ISO 80001, ISO 27000. BEREC rules on net neutrality.	

Table 17: Artificial Organ and Limb Use Case

Use Case: Emergency services	
5G Technology: 4G mm Waves LPWA Terminal with network control capacity Multi-domain orchestration Multi-tenancy	Bandwidth/data volume: 5 Mbps per unit
Business aspects: Tagging and tracking. Telemedicine. Documentation. Modularity. Remote diagnostics (ultrasound).	
Regulatory aspects: BEREC rules on net neutrality. Emergency regulations. Mandatory conformity marking, e.g. CE. Medical product legislation.	

Table 18: Emergency Service Use Case

Use Case: Wound Management	
5G Technology: LPWA 1/10 energy consumption	Bandwidth/data volume: 100 kb per unit per day
Business aspects: Smart wound dressings. Decubitus monitoring.	
Regulatory aspects: Medical product legislation.	

Table 19: Wound Management Use Case

Use Case: Wellness and Fitness	
5G Technology: LPWA 4G mmWaves 1/10 energy consumption	Bandwidth/data volume: <1Mbps
Business aspects: Health insurance discount. Non-pharma therapy (e.g. diabetes, high blood pressure and hypercholesterolemia).	
Regulatory aspects: Mandatory conformity marking, e.g. CE. Potentially medical product legislation.	

Table 20: Wellness and Fitness Use Case

Use Case: SLICENET Connected Ambulance ¹⁷⁰
Objective: Advance emergency ambulance by developing collaborative models with health care stakeholders, enabling more intelligent decision support and helping to improve patient experiences and outcomes.
Scenarios: Data streaming occurs from arrival at incident scene to arrival at destination emergency room. Wearables enable the provision of enhanced patient insights with paramedics equipped with wearable clothing for real-time video feeds and sensor-related data on surrounding environment. A 2 nd scenario: life-saving remote assistance might be required if the ambulance is supervised by a specialist located elsewhere but connected to the same platform.
Technology: combining advanced technologies to enable the delivery of better life enhancing outcomes for patients: mobile edge connection hub for emergency medical equipment and wearables. Remote monitoring of patient conditions through real-time video streaming. Ability to enable fundamental improvements in emergency medical care and improve the probability of better patient outcomes.
Requirements (specific requirements are not provided): communication capabilities meeting stringent performance requirements. Real-time streaming of patient data to hospital emergency department. High-resolution video capabilities, UHD video streaming to remote site.
Market drivers capturing market potential with early 5G solutions. 567 million wearable devices will be used in Europe by 2030, a six-fold increase from the 8.5 million in 2015.

Table 21: SLICENET Connected Ambulance

5.2.3 Potential Human and Cultural Barriers

¹⁷⁰ <https://slicenet.eu/5g-ehealth-smart-connected-ambulance-use-case/>.

From the Global5G.org session on health during the IEEE 5G Summit (September 2017) it emerged that several important human and cultural barriers impeding digital transformation within the health care sector despite the widely recognised benefits. Communication should be a top priority in the drive towards making technology progress and push R&I on 5G. A better dialogue is needed between professionals in the telecommunications industry and the health care sector to fully understand the revolutionary benefits and opportunities of 5G¹⁷¹. The most effective approach to drive innovation is by bringing them together to develop concrete and challenging use cases.

Cultural and behaviour changes are also necessary the uptake of the new 5G health model uptake, as face-to-face consultation with a doctor is still mostly perceived as preferable to a remote interaction.

The increasing dependency on wearables and remote treatments makes 5G essential in providing reliable and secure services, requiring ethical issues encompassing security, privacy and safety aspects, to be systematically addressed.

However, the 5G decentralised healthcare model will not translate into a de-humanised patient-doctor relationship as many might fear. Rather, it will rather open the way for truly personalised, highly qualified, affordable care where it is most needed, regardless of the patient's location. Part of the cultural barrier is related to trust: personal health data is very sensitive data and people want to be sure it is not disclosed or misused.

Digitisation of health and the deployment of 5G will revolutionise the value chain and change business models for companies in the health sector, but it also raises ethical issues about delivering care.

Data protection and security are crucial as health data is the most personal of all data and requires specific measures and processes under EU legislation.

6 Energy Use Case Analysis

6.1 Use Case Overview

Historically, utility markets are heavily regulated and fragmented but the business of producing and distributing energy is undergoing transition. Formerly a static and slow-changing industry based on a small number of supply sources and chains, the energy sector is becoming characterised by an increasingly diverse set of suppliers and distributors, interacting with each other in a variety of modes and business models. A more distributed range of generation sources can be brought on and off stream in response to changing demand. Accordingly, energy grids are evolving away from static, fixed infrastructures dimensioned according to maximum demand, and towards more flexible, dynamic and responsive infrastructures. This requires ubiquitous, reliable and secure data communications networks for the sensing and control signals needed to operate such “smart grids”.

As the most ubiquitous form of connectivity available, mobile networks have clear potential to play a key role in the connectivity requirements of energy grids. 4G networks are already being adapted by operators in ways which go some way to making them more suitable for the needs of energy grids, such as reducing the power drain on connected devices, and increasing signal penetration in buildings and underground. 5G networks will continue the evolution of mobile networks towards the needs of the energy sector, enabling very fast and reliable distribution and consumption of energy, and leveraging spare capacity to meet the impact of population growth and urbanisation.

¹⁷¹ Presentations by Milla Immonen, VTT and Prof. Christoph Thuemmler, Napier University. Global5G.org interview with Prof. Christoph Thuemmler during the event.

Increased productivity, faster time to market and higher efficiency are key business drivers for using 5G in the energy sector. Moreover, 5G has the potential to enable a more unified connectivity platform that addresses a wide range of use cases with economies of scale.

- **Smart Meters:** deployments currently utilise a wide range of technologies, including cellular (2G/3G), LPWAN, Zigbee, and proprietary radio technologies. Consolidating on a single technology platform would allow for a significant cost savings from economies of scale. The ability for 5G to allow for private networks, use licensed and unlicensed spectrum and radio hopping/mesh mean incorporating the strengths of competitive technologies. This will potentially make smart metering (all utility types) more accessible to more types of utilities worldwide.
- **Smart Grid** (smart meters, smart appliances, renewable energy resources, and energy efficient resources; necessary condition for very large amounts of renewable electricity on the grid): the low latency of 5G should be attractive in this environment where uptime is heavily regulated and, in more developed economies, downtime is penalised. By enabling the push for cheaper, more ubiquitous low-latency radios to the market (one of the aims of ONE5G), 5G could unlock a significant case for automated real-time grid switching. Creating a more reliable grid is expected to have significant economic impact.

The 5G PPP white paper, 5G and Energy¹⁷², defines the roles that mobile networks can play in supporting smart energy grids and what support they will need to give, such as:

- Grid access networks: low voltage power grid.
- Backhaul networks: medium-voltage power grid.

Long-term potential roles include:

- Role in backbone network domain: high voltage and extra-high voltage power grids, where responsiveness and reliability requirements are at their most demanding. The network slicing capabilities of 5G would enable connectivity for access, backhaul and backbone domains to be delivered as separate virtual instances of the mobile network, each delivering levels of service according to the demands of the domain.

Key mobile network requirements identified by the 5G PPP for smart grids are listed below.

Service guarantees	Smart Grid applications are critical, so 5G networks can only be used for connectivity if they can guarantee average, maximum and minimum levels of network performance.
Cost efficiency	5G connectivity solutions need to operate within an envelope of capex and opex which the Smart Grid players can support. This is especially important for rural areas.
SLA handling	The critical nature of some smart grid applications means that 5G needs to support the monitoring and management of service-level agreements (SLAs), including situations when the connectivity solutions are partially provided by a third party. Provider and user need to be able to verify and monitor the solution
Provisioning times	For remote services, there might be the need to set up a high-quality communication path at short notice, with provisioning times in the

¹⁷² 5G and Energy, white Paper, https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White_Paper-on-Energy-Vertical-Sector.pdf

	range of 10 minutes to 1 hour.
Asset Management	As the number of connected devices such as smart meters and other sensors increases, it will be increasingly important to manage these assets efficiently and with the minimum of effort.
Coverage	Many more Smart Grid elements will need to be connected with each other, including those in rural areas such as secondary substations. 5G networks need to assure ubiquitous coverage of all relevant smart-grid elements, regardless of location.

Table 22: Key Network Requirements for Smart Grids in the 5G Era

6.1.1 5G Potential to meet Energy Industry Requirements

A brief analysis of evolutions in mobile network technology shows their increasing potential in the energy vertical. A comparison between 4G and 5G reveals the higher capabilities and performance levels 5G is expected to bring given the relative paucity of real-world use cases in this vertical industry.

As mobile network technology has implemented successive generations through to the current 4G, improvements in data-transmission capacity, and more recently in power draw, have made public mobile networks capable of supporting an increasing number of IoT applications.

- Technology upgrades such as carrier aggregation (CA) and multiple input/multiple output (MIMO) are being applied by mobile operators to their 4G networks to achieve big improvements in data transmission rates and capacity. Peak rates on uncongested cell sites using these technologies are reaching the hundreds of Mbps range, albeit in very limited geographical areas.
- 3GPP Release 14, published in mid-2016, included two standards for implementing a low-power mode on 4G networks: NB-IoT (narrowband-IoT) and LTE-M (LTE-Machine). Mobile operators are now implementing these upgrades and using them to offer connectivity which enables compatible devices to achieve battery life measured in years. An added benefit of NB-IoT is that it improves the penetration characteristics of mobile network signals, enabling connectivity for devices situated underneath roads and pavements and inside building, such as utility meters and sensors.

As mobile operators invest in these 4G technology upgrades, their networks will become capable of supporting an increasing range of applications in the energy sector, ranging from those requiring consistent transmission of large volumes of data, to those requiring large numbers of connected devices drawing insignificant amounts of power. As a result, an increasing percentage of connectivity will use public mobile networks, both in the energy sector and more generally.

However, there will continue to be aspects of 4G network performance that fall short of requirements for some energy sector applications. These areas of performance will be addressed by the forthcoming 5G mobile networks, enabling continued expansion of public mobile networks as connectivity media for energy sector use cases as 4G networks reach the limits of their capability.

Vertical Requirement	Performance	Advantages of 5G
Capacity		5G networks promise peak data rates above 1Gbps, which will mean devices will experience "real-world" data rates of several hundred

	<p>Mbps in early 5G deployments. The ITU classifies this 5G use case as enhanced Mobile Broadband (eMBB), and calls for 5G to eventually support data rates up to 10Gpbs. Improvements in data rate and capacity will result from several areas of technology development in 5G. This increase in capacity will enable 5G networks to support energy sector applications in which large numbers of connected devices produce data constantly, such as plant and grid monitoring; and in which individual connected devices produce high volumes of data, such as surveillance cameras.</p>
Consistency	<p>In 5G networks, the performance experienced by a connected device will vary less between the centre of a cell and the cell edges than is the case with today's networks. The main technology enablers for this improvement are "beam forming" and "beam tracking", whereby a mobile transmitter to focus its energy in the direction of connected devices, rather than transmitting in all directions, and to move the "beams" connecting devices as those devices move around. This will provide connected devices with more consistent connectivity as they move between, or are installed in, different areas of a cell site's coverage, in energy sector applications such as grid management and smart metering.</p>
Reliability	<p>Mobile networks are susceptible to performance degradation as the number of devices simultaneously using the same mobile cell site grows. This means that they are unable to support service-level agreements (SLAs) requiring guaranteed levels of performance. In 5G networks a technique known as "network slicing" promises to mitigate or even eliminate the impact of usage contention, enabling operators to provide virtual instances of the network for particular applications, fulfilling the needs of those applications regardless of what else is happening on the physical network infrastructure. Clearly, the critical nature of energy applications means that those requiring connectivity need to be able to rely on that connectivity being available, and performing sufficiently, at all times.</p>
Latency	<p>4G networks will remain limited in their ability to support applications with demanding responsiveness requirements. 4G has already delivered improvements in latency, that is, the time taken for a signal to travel between source and destination; but it is still several tens of milliseconds (ms), which is too long to support "instantaneous" responses to networked actions such as moving equipment responding to commands from a remote controller. 5G promises to reduce latency substantially, making the mobile network more responsive to commands and actions. There is still debate about how low latency will be in early 5G networks, but some consensus is forming around the 10-20ms range, perhaps with lower latency in isolated pockets of the network where it is specifically needed. Low latency is a crucial requirement in energy sector applications requiring instantaneous response to commands, such as remote operation of equipment.</p>
Scalability	<p>The NB-IoT and LTE-M upgrades are enabling 4G networks to support a higher number of connected devices per cell site, owing to</p>

	<p>the lower power consumption required. Eventually, somewhere between 50,000 and 100,000 per site will be possible in 4G networks. To achieve higher connection densities than that, however, the 5G core will be required, in which connected devices can generate much lower levels of signalling traffic than in today's networks. As the number of connected sensors increases with the spread of smart grid and smart metering applications, the higher connection density supported by 5G networks will be critical to support the continued growth of such applications.</p>
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Table 23: 5G Potential to meet higher Performance Requirements

6.2 Use case examples

In this section, we analyse identified application scenarios for 5G energy and then examine in detail two real-world use cases from the 5G PPP which directly involve end-users from this vertical.

5G Energy Application Scenario	Overview
Grid Asset Management and Protection	<p>Vertical pain point: Energy generation and distribution grids are expensive to build and maintain, and energy companies are continually striving both to reduce the cost of grid build and operation, and to maximise the benefit gained from the money they invest in the grid. At the same time, energy companies also need to meet more stringent demands on their grid, because of trends like distributed generation, tighter regulation and more sophisticated security threats.</p> <p>Incremental gains from 4G to 5G networks: By equipping the grid with connected sensors and actuators, operators can detect a wider a range of maintenance and security events immediately, and respond to them in real time. They can also collect, analyse and act upon data from the grid, to optimise performance on a continuous basis. As well as being used by the energy companies themselves, such data can also be shared with business partners and customers, as appropriate.</p>
Smart Metering	<p>Industry transformation: Energy companies are already undertaking programmes to replace traditional customer-premises meters with “smart meters”. Connected to the internet, these smart meters can transmit, process and receive a range of operational data, for use by both energy suppliers and their customers.</p> <p>Benefits: eliminating the need energy companies to send people to read their customers’ meters, and the ability for customers to make more informed choices when making such decisions as which energy supplier to pick, and how they use energy within their homes or business premises. Over the next few years, a substantial number of smart meters will come on stream around the world. In the UK, for example, around 5 million smart meters had been installed by March 2017, but the UK Government’s target is to equip most of the country’s 26 million homes with smart meters by 2020. Increasingly, the technology of choice for connecting these smart meters to the internet is the public mobile network, especially</p>

	<p>now that NB-IoT and LTE-M are improving the mobile network's suitability for these IoT-type installations.</p>
<p>Remote monitoring and maintenance of facilities, infrastructure & personnel</p>	<p>By equipping their plant with IoT-connected sensors, energy companies can continuously collect and analyse data about the condition and operation of facilities, sometimes enabling them to detect when maintenance on a piece of equipment is required before it fails, and thus minimise the amount of expensive down-time. The maintenance can also be carried out remotely in many cases, either by upgrading software, or by operating IoT-connected actuators. Personnel can also be monitored by using IoT-connected biometric clothing, to measure and control their exposure to hazardous situations.</p> <p>Improvement of mobile network capabilities: further enhancements of monitoring and maintenance activities. As networks' data capacity improves, monitoring input will increasingly include footage from video surveillance cameras, enabling visual inspection by human operators and, as the technology improves, by AI systems capable of handling video data. As network latency and reliability improve, it will be possible to carry out remote maintenance not just via actuators, but also via mobile robots, either under the control of remote human operators, or under the control of computer systems, as appropriate.</p>
<p>Remote control/robotics for operations in dangerous and hard-to-access locations</p>	<p>In addition to maintenance functions, there is also a great deal of potential for using remote-controlled equipment and robots in the materials-extraction activities of energy companies: drilling and mining for coal, gas, oil and nuclear fission fuels. Once 5G starts to deliver low-latency, high-reliability performance on public (or private) mobile networks, it will be increasingly feasible to carry out construction, maintenance and operational activities in mines and drilling rigs by using remotely operated machines, instead of human personnel. Clearly, in the long run, there is potential for saving costs by implementing remote control and robotics in mines and rigs. More importantly, there is potential to reduce the risk of damage to health and loss of life, by reducing the need to have people working in sites which can be very hazardous by nature.</p>
<p>Mission-critical communications</p>	<p>In the energy sector, circumstances arise in which the normal capabilities of voice communications on mobile networks are not sufficient. For example, in the aftermath of an extreme weather event such as a hurricane, the increased demand for telecommunications services means that individual users are often unable to access the network, or experience interruptions to their calls. In working to restore damaged supply & distribution facilities, energy companies need access to communications services that is reliable and is not subject to contention from other network users. Traditionally, this has been achieved mainly by using private radio networks, based on systems such as Tetra. However, technologies are now becoming available that enable public mobile networks to support mission-critical communications. Mission-Critical Push-To-Talk (MCPTT) was included in 3GPP Release 13, published in</p>

	<p>March 2016, and work is under way on mission-critical full-duplex voice communications with a view to inclusion in future 3GPP Releases.</p>
<p>Video links to remote expertise, for field operations</p>	<p>For engineers working on installation and maintenance in the field, information about the equipment and problems they encounter while on site was traditionally accessed by carrying large amounts of paper manuals around. In recent years paper has largely been superseded, of course, by putting the content of the manuals on line. However, when an engineer needs to deal with complex equipment and procedures, the effectiveness of words and pictures as a means of explanation and guidance is limited. It can be much more effective to see and hear what to do instead. Now that mobile networks can provide a good experience of video streaming there is a lot of potential for using them to improve field operations by giving engineers access to video resources to guide them through procedures. In future, as network performance improves, this could be extended to giving engineers live access to remote experts too. As well as further improving operational effectiveness, this can also enable energy companies to improve the utilisation of staff with deep expertise, by reducing the amount of time they need to spend in transit.</p>

Table 24: 5G Energy Application Scenarios

The two 5G PPP Energy Use Cases come from VirtuWind (phase 1) and NRG5 (phase 2), one testing SDN and NFV approaches on a wind farm; the other focused on mission-critical smart grid applications, advanced metering and electric vehicle charging but still at an early stage to provide and verify detailed requirements.

<p>VirtuWind (5G PPP, Phase 1)¹⁷³</p> <p>Objectives: Develop and demonstrate a networking infrastructure based on SDN and NFV for intra- and interdomain scenarios in wind parks with trials at Floe Wind Park (Brande, Denmark).</p> <p>Secure and efficient operation of wind farms requires participants to have remote access to components such as sensors, actuators and networking devices (e.g. routers).</p> <p>Energy stakeholder requirements and 5G innovations: A wind farm’s local control network connects individual wind turbines to the respective control centre. The local control centre, in turn, connects the local network to company networks or to the internet so that participants can access the farm’s devices and data.</p> <p>However, such control network structures are complex and costly to install, operate and maintain. Using SDN and NFV should make processes faster and simpler and reduce the amount of hardware needed, reducing both the capital and operational expenditure costs of a control network infrastructure.</p> <p>Potential impacts: VitruWind could support a lowering of the cost of wind energy and accelerate further wind farm deployment.</p> <p>VirtuWind Security: new security threats and risks have been carefully investigated. Two security</p>

¹⁷³ <http://www.virtuwind.eu/>.

use cases are considered representative scenarios of industrial networks. The multi-domain and vertical support demonstrates the need for a new 5G security¹⁷⁴.

Securing the network control plane: VirtuWind brings two elements on the SDN controller

- The Reference Monitor, which coordinates the component sequence of operations, and verifies all entity operations/requests against the specified access control policies.
- Security Manager, which authenticates the entities involved, keeps track of security-related activities for accounting purposes and communicates pertinent data to the backend, e.g. for more sophisticated analysis techniques. Provisions are also made to employ techniques such as controller clustering by redundancy and fault tolerance techniques (e.g. Byzantine Fault Tolerance) to localise faults and secure the distributed control plane, providing reliable and consistent control of the network even in the case that some controllers have failed or compromised¹⁷⁵.

Run-time network adaptation mechanisms for incident response and mitigation: Reactive Security Framework, equipped with SDN and SCADA honeypots, modelled on and deployable to an actual, operating Wind Park, allowing continuous monitoring of the industrial network and detailed analysis of potential attacks, thus isolating attackers and enabling the assessment of their level of sophistication¹⁷⁶. The chaining of security function enables the routing of unknown/suspicious traffic via Intrusion Detection and Deep Packet Inspection Service Functions, to clarify it as either legitimate or malicious, and forwarding it to the Wind Park or honeypot, accordingly. Thus, malicious traffic can be isolated at the honeypot, allowing to track the attacker, identify its purpose and keep it occupied. The honeypot is modelled after the actual operating Wind Park, fully emulating both the network (SDN-based) elements, as well as the industrial-related devices (e.g. SCADA systems), by combining the appropriate Honeypot/Honeynet security tools¹⁷⁷.

Techniques for defining “isolation verticals” and runtime management/verification of isolation per tenant/user: VTN Manager on SDN controllers with multi-tenant functionality driven by principles such as abstracting the complex physical network configuration from administrators, virtual users and customer networks; introducing security protection mechanisms for VTNSs; presenting a transparent view on the network for critical tenants in the industrial infrastructure; providing strict priority for mission-critical control and operational traffic¹⁷⁸

Phase 2 developments	Virtual and programmable architectural components for proactive and reactive security mechanisms, security manager module, AAA functionality and secure interfaces.
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Table 25: The VirtuWind 5G Energy Use Case

VirtuWind adopts the approach of application-level slicing in an industrial network, where slicing is applied in the context of multi-tenancy in operational wind parks. This approach provides access network technology independence while offering flexibility to the operators to select different IoT products to be installed at the edge. The figure below shows multi-tenancy (virtual tenant networks) in SDN-enabled wind farms, with a wind turbine and substation and the virtualised IIoT sensor network.

¹⁷⁴ 5G PPP Security Working Group, Phase 1 Security Landscape, White paper, June 2017, p.15.

¹⁷⁵ VirtuWind, Deliverable 3.2: Detailed Intra-Domain SDN & NFV Architecture, January 2017, cited in 5G PPP Phase 1 Security Landscape, op cit. p. 37 and note 36, p. 60.

¹⁷⁶ VirtuWind, Deliverable 3.2, op cit.

¹⁷⁷ 5G PPP Phase 1 Security Landscape, op cit. p. 38.

¹⁷⁸ VirtuWind, 5G PPP Phase 1 Security Landscape, op cit., pp. 39-40.

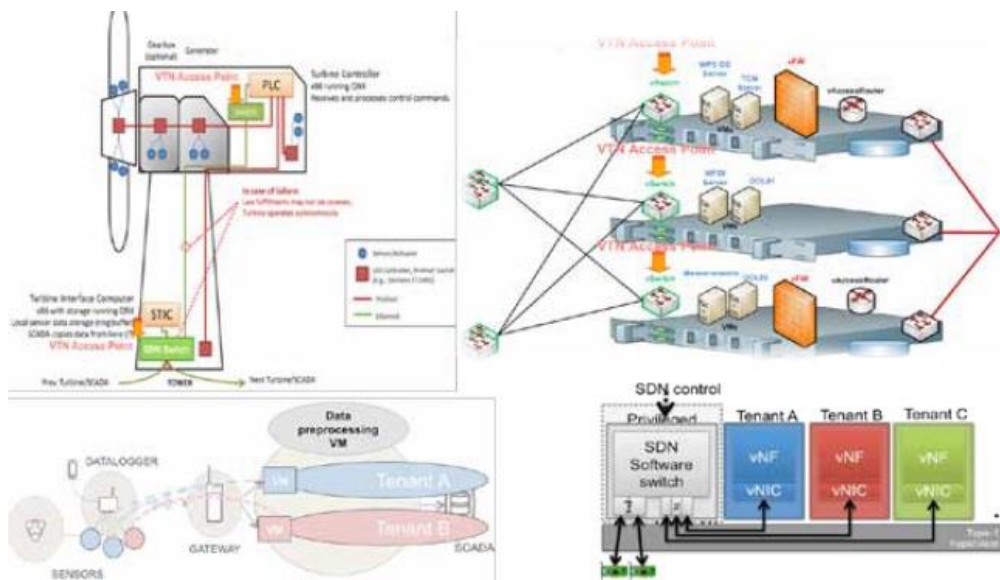


Figure 25: Network Virtualisation Slicing [Source: VirtuWind]

NRG5¹⁷⁹

Objectives: aimed at enabling smart energy as a service with mobile network advances. Three main use cases for extensive 5G deployment are investigated: mission-critical smart grid applications; advanced metering (massive deployment) and EV charging. Intrinsic requirements for smart energy are high levels of security, resilience and availability.

Energy stakeholders and requirements: The project focuses on concepts, requirements, innovative open-source prototypes, state of the art laboratory experiments, heterogeneous real-life trials and recommendations towards a Smart Energy as a Service use case that will co-develop a new 5G communication infrastructure with emphasis on security, privacy, trust and high availability.

Use cases:

#1 decentralised, trusted lock-in free plug and play vision: mMTC via vast number of smart meters; uMTC as most VNFs require real-time control of smart energy services. The VNFs should be applicable to any type of mobile hardware constrained terminal.

#2 aerial predictive maintenance for utility infrastructures: xMBB communications via the vMPA VNF for video streaming from drones and analysis to the xMEC and the utilities control centre, as well as uMTC communications via the vDFC NNFV for controlling the flight of drones.

#3 resilience and high availability via dispatchable demand response (DDR): mMTC communications via vast number of RES, DES and controlling units, as well as uMTC communications, as most VNFs require real-time control of smart energy services.

Trials

Pilot #1 - Natural gas network/LNG Terminal (France) for predictive maintenance with aerial monitoring and incident localisation by monitoring gas compressors and pumps from the selected

¹⁷⁹ <http://www.nrg5.eu>.

monitoring centres.

Pilot #2 – optimised energy network management and control (Italy) with a plug n play scenario of smart cross-network metres and optimised substation management.

Table 26: NRG5 5G Energy Use Case

7 Factories of the Future

7.1 Use Case Overview

5G in the Factory of the Future

Understanding IIoT and its use cases gives a good overview of needs and requirements for 5G in this area. Basically, IIoT is about automation¹⁸⁰ which is divided into:

- **Factory automation:** the automation of operations in the production of items such as electronics, cars, appliances, etc.,
- **Process control:** automatically controlled processes based on continuous data gathering and analysis.

These two areas are then to be analysed to get specific use cases and, from there, 5G requirements.

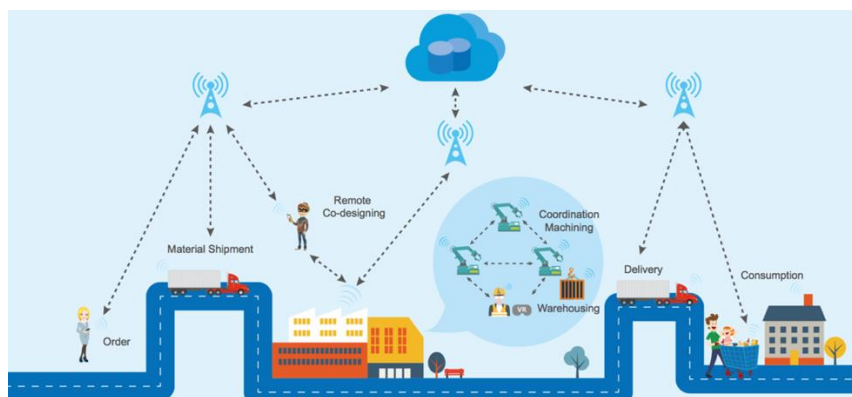


Figure 26: Vertical Specificities with respect to 5G Capabilities [Source: Huawei]

In this respect, it is also interesting to have a look at the now famous “5G usage scenarios” triangle which was first developed by the ITU. In this triangle, to each angle is assigned an application category which characterises 5G technology:

- Enhance mobile broadband.
- Massive machine type communications.
- Ultra-reliable and low latency communications.

Mapping the IIoT use cases on this triangle shows the real importance of 5G for the deployment of the Industrial IoT. Indeed, it will require low latency communications, high bandwidth in some specific cases and obviously machine to machine communications.

¹⁸⁰ <https://industrial-iot.com/2017/04/5g-enhance-industrial-iot-transform-industry-starting-2020/>.

Factory of the Future is therefore a wide topic which includes a very large number of use cases; and in terms of mobile communications, each Industrial IoT use case has specific requirements¹⁸¹. In such context, it appears that 5G will bring a high added-value to the Industry of the Future, but requirements will vary according to use cases.

5G, as a key enabler for the Factory of the Future, will impact four groups of use cases:

- **Process automation:** monitoring, diagnostic functions, real-time adaptation on demand, machines capable of contacting the 'human-support' by themselves, to repair automatically when needed, or to order malfunctioning components.
- **Production automation:** control of manufacturing processes, automatic production of goods based on customer's requirements.
- **Logistics:** mobile service robots, autonomous transport, product identification, tracking (when and where a product was manufactured), security checks (rapid and targeted recalls in case of failure) and localization of people and assets.
- **Company IT:** portable monitoring and control devices, augmented reality, integration of production facilities in company IT infrastructure, remote staff being able to repair machines remotely.

Strategic Benefits

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. 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.

At this stage, the main use cases identified on the Factory of the Future are: **time-critical process control, non-time-critical factory automation, remote control, intra/inter-enterprise communication and connected goods.**

5G will eliminate lag times between machine communications, and data connections between machines will be 10 to 100 times faster. That allows machines to catch production glitches in real time, which could **lead to big increases in productivity**. 5G's ability to handle far more data over its network means that factories can meet rising data demands resulting from adding smart technologies and **increasing production**. As a result, one of the main 5G value in the context of the Factory of the Future is in getting data from the physical environment to the computers and making better decisions based on that.

5G will also bring strong added-values to Factory of the Future, such as:

- **Increased efficiency:** up-to-date information enabled the best possible manufactured output.
- **Competitive innovation:** 5G will foster innovations.
- **Less energy used:** advanced technologies and built-in efficiencies actually lower energy bills for manufacturers. Optimisation of consumption will be based on energy efficiency (production optimised according to the cost of energy and its availability).
- **Stronger economies:** smart manufacturers bolsters production capabilities, help workers and strengthens economies.

Drivers

While specific use cases for Factory of the Future involving 5G are not yet well defined, the drivers

¹⁸¹ Afif Osseiran, Jachim Sachs, Marzio Puleri, "Manufacturing reengineered: robots, 5G and the Industrial IoT"

are clear.

Network connectivity and communications is one of the main drivers. The Factory of the Future is a merge between factories as we know them today and Internet technologies, powering the Industrial Internet of Things, which will connect machines, sensors and infrastructure all together. While the type of required connectivity will vary depending on use cases, it appears that wireless communication with high bandwidth and low latencies, such as 5G, will be a prerequisite. With connectivity comes interoperability, which will have to be addressed correctly in order to allow a smooth transition toward the Factory of the Future, thus facilitating the integration on applications/devices in the production system.

Integration of Industrial Internet of Things: as highlighted in the Factory of the future white paper¹⁸² from IEC, IoT and M2M technologies (and therefore IIoT) will affect the operational environment of manufacturers considerably, as both technologies contribute to the convergence of the classical manufacturing space with Internet technologies and the increasing intelligence of devices used to improve manufacturing environments.

Improvement of efficiency and quality and decrease of life cycle times: as presented in a KPMG report¹⁸³: thanks to FoF quality management becomes a reality: 24-hour production is monitored without interruption, along with quality, and efficiency is constantly being optimised. As a result, the target of a zero-error rate is now within reach. Machine failures also become a thing of the past, for the data that is available allows a preventive maintenance strategy and planning that avoids unplanned and unpredictable downtimes. Production can be run around the clock at maximum capacity. The “factory of the future” secures a competitive advantage for itself as a result of quicker production cycles, higher throughput with a reduced inventory and lower costs.

Real-time adaptation: real-time production optimisation through artificial intelligence, advanced analytics and big data, connectivity. For example, improved demand forecasting enables close to real-time management, avoiding the need for large and expensive warehouse facilities and stock holding thus reducing overall costs based on just in time delivery methods.

Edge computing, i.e. the capacity to collect and analyse data as close as possible from the machine which produces them is a key technology and consists in adding intelligence in the objects/machines themselves or to set-up mini clouds near the process, will be key for industrials monitoring.

Factory of the Future 5G use cases will be made possible if they bring a strong added value. They will exist, and be sustainable, only if a robust wireless telecom infrastructure is deployed, and if a wide variety of things (equipment, control systems and products) are given the ability to communicate. Some machines within these processes are connected, for instance **conveyors, robots, logistics assets, inventories and energy systems**. Facility managers and quality-control teams obtain data on these elements for security purposes or product quality assessment. However, the data collected is often limited to a specific field and does not, or barely, integrate exogenous information, on subjects such as the environment, the market, customer needs and feedback, or other data linked to the production itself, which could be provided through 5G powered solutions.

Key applications – and benefits for 5G in smart factories will include, for example:

- **Constant on-site connectivity** – to enable continuous transmission and sharing of manufacturing information. Use cases will include sharing of time critical sensor data and

¹⁸² <http://www.iec.ch/whitepaper/pdf/iecWP-futurefactory-LR-en.pdf>.

¹⁸³ <https://assets.kpmg.com/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf>.

video, non-time critical information collection, and data to enable remote control of equipment and systems

- **Constant inter-site connectivity** – for tracking materials, components and products through the manufacturing process, for collation of data in data centres, and transmission of control instructions between sites
- Use of **VR/AR technologies** to enable virtual collaboration on complex designs by engineers in diverse locations
- **Wide-area connectivity** – for employee, customer and partner collaboration, and for tracking/optimising goods following delivery. Use of wireless networks in product lifecycle management through end-to-end tracking, and supply chain enhancement - from the initial order, through materials buying and production processes, to the end consumers; and the creation of new services by analysing data collected from connected products.
- **Enhance industrial ecology** - Improve efficiency reducing the consumption of material resources and saving energy by using the information given by each machine involved in the production line and by taking into account the volume of demand, thus improving the impact on the environment: the process optimisation can include management of waste materials and monitoring of the recycling (from cradle to cradle perspective).
- **Decreased risks:** alert management systems can notably play a part in reducing industrial damages on the environment, chemical leakages for example, and providing earlier warning and hence prevention and remedial interventions.

A reliable communication layer capable of dealing with an increase in several orders of magnitude the number of assets, variety of information and reaction times in future manufacturing systems is fundamental for Industry 4.0.

5G promises to be a key enabler for factories of the future by:

- Delivering an evolution of mobile broadband networks.
- Providing the unified communication platform needed to disrupt with new business models and overcome the shortcomings of current communication technologies.

5G is therefore expected to have the potential to amplify and accelerate the on-going transformation, and unlock a next level of efficiency gains in manufacturing, including for the vast number of European SMEs. RECOMMENDATION

Future competitiveness will be influenced by two trends: the servitisation of manufacturing and the growing importance of global value chains driving the demand for truly connected manufacturing ecosystems.

Five use case families are identified in the 5G PPP White Paper: 5G and the Factories of the Future, where each family represents a different subset of stringent requirements along supply chain and manufacturing networks¹⁸⁴. They are the basis for our analysis along with pilots and trials running within the 5G PPP.

Use Case Family	Stringent Requirement
Time-critical process optimisation inside factories	Support zero-defect manufacturing, increased efficiencies, worker satisfaction and safety, leveraging the integration of massive sensing technologies including 3D scanning technologies, adoption of wearables, and collaborative robots in closed loop control systems. Communication latencies below 1ms.

¹⁸⁴ White Paper: 5G and Factories of the Future, op cit., pp. 3-4.

Connected goods	Facilitate the creation of new value-added services and the optimisation of computer aided design driven by real-time data, collected during the complete lifetime of a product. There is a need for ultra-low-power (high autonomy), and ultra-low communication platforms.
Non time-critical optimisations inside factory	Realise increased flexibility and eco-sustainability. Increase operational efficiency, e.g. through minimal stock levels. Given the harsh and metalised industrial environments, indoor coverage and high availability are key requirements.
Remote maintenance and control	Optimise the cost of operation while increasing uptime. This use case family involves the integration of 3D virtual reality, and will require increased capacity to facilitate video-supported remote maintenance, from any place in the world.
Seamless intra-/inter-enterprise communication	Allow the monitoring of assets distributed in larger areas, the efficient coordination of cross value chain activities and the optimisation of logistic flows. There is a specific need for flexible, reliable and seamless connectivity across different access technologies, as well as the support for mobility.

Table 27: Stringent Requirements for FoF Use Case Families

Factories of the Future is one of the most demanding verticals in terms of **ultra-low latencies, ultra-high availability, reliable indoor coverage in adverse environments**, as well as **energy-efficient** and **ultra-low communications costs** for produced, connected goods. In addition to the use case families summarised above, there are several challenging industry-specific requirements that must be met¹⁸⁵. These include timing (varying across industry and plant set-up¹⁸⁶), heterogeneity, security and safety, network infrastructure requirements, network and service management. 5G is expected to bring the building blocks that will help manufacturers achieve significant efficiency increases through highly connected production chains.

Technical Requirements in Manufacturing	Advances required
<i>Timing</i> (see note). The transport of less time-critical data is based on standards: IEC 61158, digital data communications and IEC 61784, industrial communication networks - profiles ¹⁸⁷ .	Meeting the same deterministic behaviour for wireless communication remains challenging (See Use Case Family #1). These requirements ensure manageable QoS.
<i>Heterogeneity</i> (e.g. different conditions; devices): Media (copper, optical, radio); technologies (industrial Ethernet,	Wireless technologies adapting to changing and diverse environments; spectrum use optimisation for all available devices. Re-configurability of the radio through SDN interfaces and

¹⁸⁵ 5G PPP White Paper: 5G and Factories of the Future, op cit., pp. 19-22.

¹⁸⁶ Process automation industries (oil, gas, chemicals, food, beverage, power plants) require cycle times of about 100ms. Factory automation (automotive production, industrial machinery and equipment, consumer products) have typical cycle times of 10ms. Motion control applications (printing machines, textiles, paper mills) have the highest demands, requiring cycle times of less than 1ms with a jitter of less than 1 μ s.

¹⁸⁷ <http://www.iec.ch>.

Technical Requirements in Manufacturing	Advances required
<p>industrial wireless, IT-networks); protocols and services (real-time protocols, best effort protocols); vendors for networked components and interoperability; implementation platforms (IoT components, embedded devices); handling and management concepts and tools</p>	<p>reconfigurable antennas, ability to switch protocols in real time; design of sensor protocols leveraging capabilities of wireless network.</p> <p>Plug-and-produce protocols semantically describing responsibilities, with zero configuration by human workers and adaptable to heterogeneous, manufacturing-specific protocol suites.</p> <p>Integrating and simplifying need for many tools and limiting need for new tools.</p>
<p><i>Network infrastructure</i></p> <p>Diverse communication technologies</p> <p>Indoor-communication in harsh manufacturing environments:</p> <p>Manufacturing focus on uptime and increasing production throughput</p> <p>The main requirements for outdoor communication relate to cost and re-use of existing communication infrastructure, ubiquitous coverage and guaranteed performance.</p> <p>Solutions facilitating (co-)management of the network by manufacturers, giving them full control of alternative configurations in case network quality impacts on production efficiency.</p> <p>Smart transformation path to migrate siloed industrial communication infrastructure to a future converged one, based on evolutionary approach.</p>	<p>Unifying infrastructure that integrates different communication technologies, connected transport vehicles, remote diagnostics control rooms, customers, suppliers.</p> <p>Increasing coverage inside the factory to enable wireless communication even in harsh, metalised regions of a plant.</p> <p>Minimising need for expensive infrastructural components; optimising coverage, availability and flexible reconfigurability of wireless nodes. Intelligent technology can monitor the wireless medium and prevent degradation of the network.</p> <p>Supporting longer-range, outdoor communication with connected goods.</p> <p>Network infrastructure with ultra-high service levels for uptime and increasing production throughput.</p> <p>Network infrastructure not solely managed by an external partner (e.g. telecom or IT partner) to cater for mission-critical communications.</p> <p>Network slicing, SDN and NVF are key building blocks within 5G, and are one of the cornerstones in next-generation communication infrastructure of manufacturers.</p> <p>Interworking needs to focus on: industrial fixed and wireless access technologies; common industrial IT and automation IT infrastructure; macro cross- and intra company cloud with local private factory cloud, including resource management/control coordination across domains to guarantee required QoS.</p>
<p><i>Service management</i></p> <p>Integrated distributed sensors, machines, parts, goods, vehicles increase the complexity of managing the data collected by these computing resources.</p>	<p>Virtualised networked capabilities (machine-learning -as-a-service, semantic-interoperability-as-a-service, protocol-translator-as-a-service) will help manage and continuously optimise the distributed intelligence of a production plant.</p> <p>New concepts for the large amount of new data sources.</p>

Technical Requirements in Manufacturing	Advances required
Lack of interfaces to combine intelligence into data-driven workflows, hindering rapid deployment of data-analytic services for faster change-overs and more optimised production schedulers and fewer outages.	Such concepts need to be flexible enough to decide where the processing of raw data is done. Solutions for local/edge data pre-processing and filters that help to manage the overall data flow. Network-embedded big technologies as enablers for real-time data processing.

Table 28: FoF Industry-specific Requirements

7.1.1 5G Potential to Meet Factories of the Future Requirements

5G has the potential to fill current technology gaps that lack capabilities in terms of wireless performance, managing heterogeneity, security and trust, leveraging internet technologies, and flexible network and service management.

Representative scenarios and Key Requirements	Main impacts
<ul style="list-style-type: none"> - Real-time closed loop communication between machines to increase efficiency and flexibility. - 3D augmented reality applications for training and maintenance. - 3D video-driven interaction between collaborative robots and humans. <p>Key requirement(s): communication latencies that can go below 1ms.</p>	<p>Increased efficiency. Increased worker satisfaction. Increased safety/security.</p>

High-level needs cover the wireless channel, latency, reliability and bandwidth; the assessment parameters on the infrastructure level are ubiquitous availability (coverage), the need for security and the need to support heterogeneous devices and technologies. The autonomy of battery-powered sensors is another key requirement that could impact the design and implementation of the embedded communication modules.

Capability and existing technologies	Expected 5G Advances
<p>Heterogeneity and existence of wireless technologies</p> <p>Novel capabilities are required to address increasing diversity of wireless IoT systems in manufacturing to ensure same levels of reliability as wired architectures.</p> <p>New challenges in managing spectrum in environments with growing number of wireless applications.</p>	<p>New protocols are needed to manage the co-operation of technologies working in the same frequency band, or to spread multiple frequency bands in a coordinated and adaptive way.</p> <p>Key objective is to increase the capacity of current wireless technologies through self-organising 5G technology and prepare future scenarios with up to 100 sensors operating per cubic metre without compromising the</p>

	availability of robots, connected machines.
<p>Plug-and-produce integration of sensors, machinery and people</p> <p>Limited flexibility of current production systems to pre-defined product types due to need for custom programming.</p> <p>Proper data formats and protocols are missing, as are common standards.</p>	<p>5G can support the convergence between promising internet technologies¹⁸⁸ and industrial protocols.</p> <p>Internet technologies are valuable in view of the migration of existing systems towards more service-oriented architectures. Adoption of generic IoT protocols in industrial protocol stacks may bring added value and competitive advantage while facilitating seamless plug-and-produce integration in manufacturing. Evolution from pure legacy systems to standardised open systems adopting open internet technologies.</p>
<p>Cost-effective network and service management by factory operator</p> <p>Commonly used technologies in manufacturing include 2G/3G, WirelessHart, ISA100.11a, WiFi and Zigbee.</p> <p>Lack of capabilities to easily manage and optimise network performance for diverse wireless technologies, protocols and data formats. Lack of technology to monitor and optimise wireless networking.</p>	<p>Leveraging plug-and-produce configuration is coupled with need for network and service management functionalities to manage workflows and data interaction patterns; allocate proper resources in the cloud; leverage machine learning and data analytics; manage and optimise the wireless network topology.</p> <p>Adoption of internet technologies will enable easier integration of workflows through standardised interfaces.</p>
<p>Autonomy</p> <p>Avoiding the onerous cost of replacing batteries is a main roadblock along with the cost of communication. New low-power, low-cost, long-range communication technologies need to be integrated in factory communication networks. The autonomy of battery-powered sensors is therefore another key requirement with possible implications on the design and implementation of embedded communication modules.</p>	<p>4G improves some 2G limitations, with expected support for long range, low bandwidth, low cost and low energy connected things. LTE Cat 1 and LTE Cat 0 specifications in 3GPP release 13 ease limitations in increasing coverage, e.g. reaching water meters.</p> <p>5G will advance 4G capabilities with more power saving techniques, e.g. reaching 15 years without charging batteries and more flexibility in terms of target performances with reliability of up to 99.999% and ultra-low latency.</p> <p>These specific characteristics will make 5G suitable for long-range communication scenarios.</p>

7.2 Use Case Families, Pilots and Trials

¹⁸⁸ Internet technologies are useful in migrating existing systems to more service-oriented architectures. They are not industry specific and could therefore be widely deployed in low-cost communication modules.

The next-generation connected factory will be part of a larger value chain, where processes take place both within the walls of the factory and between different factory buildings (e.g. logistics). These lines are already blurring with innovative concepts like virtual plants.

The five use case families illustrate the requirements along the supply chain and manufacturing networks needed to achieve the next-generation connected factory.

Time-critical process optimisation inside factories and connected goods introduce the most novel challenges with respect to seamless wireless integration:

- Time-critical process optimisation inside factories (indoor mission-critical process, where machines and robots are part of closed, time-critical loops): enhancements to the current and planned 5G technology are required to achieve ultra-low latencies combined with ultra-high reliability in a heterogeneous environment.
- Connected Goods: to deliver the virtual factory, exploiting product lifetime data from connected goods “living” in the wide area network, a new range of networking technologies is required that adheres to minimal energy consumption, ultra-high autonomy, low subscription costs, for lower bitrate communication. The frequency and latency of communication is less critical.

Factories of the Future	
Use Case Families	Main source(s)
Time-critical process optimisation inside factory	5G PPP, White Paper: 5G and the Factories of the Future, 2015: 5 use case families with stringent requirements
Non-time-critical optimisations inside factory	
Remote maintenance and control	
Seamless intra-/inter-enterprise communication	
Connected goods	
Use Cases	Main source(s)
Video surveillance/streaming of manufacturing assets and processes; machine to machine sensors; Remote site safety/security; tracking and remote control of robots; leverage remote experts via video for complex repairs in the field	Opportunities in 5G: The View of Eight Industries Ericsson, 2016.
Use case scenarios and specific requirements for industrial radio	Hans Schotten, 5G Meets Industry 4.0, May 2016
Cellular access technology requirements: cell automation; automated guided vehicle; process automation; logistics transport tracking; remote assistance; augmented reality; remote robot control	5G to Enhance Industrial IoT and Transform Industry Starting in 2020, ARC Advisory Group, April 2017 ¹⁸⁹
Industry 4.0 Smart Factory	MATILDA, 5G PPP Phase 2 ¹⁹⁰

Table 29 Factories of the Future: Use case families summary

Use Case Family 1: Time-critical process optimisation inside digital factory

New scenarios for time-critical communication are emerging with collaborative functions offered by a new generation of robots, the introduction of wearables on the shop floor, and evolutions in augmented reality. The increasing number of wireless and mobile devices demands the transfer of “heavy” data (e.g. 3D models, large historic data sets) for fast intervention, maintenance or assembly

¹⁸⁹ <https://industrial-iot.com/2017/04/5g-enhance-industrial-iot-transform-industry-starting-2020/>.

¹⁹⁰ <http://www.matilda-5g.eu/#industry-4-0-smart-factory>.

tasks. A significant amount of data is available to share and use, and enable on-the-spot decisions in a collaborative environment.

Collaboration takes place in real-time with the robot adapting to operators’ faculties when interacting with the operator’s wearables, the surrounding sensors and the machine control systems. Uncaged robots will facilitate further automation, augment the operator tasks efficiency, production yield, quality output and increase overall safety.

ISO 10218 standard¹⁹¹ defines the robotic collaborative operation. However, 5G will play a differentiating role in terms of ultra-fast and ultra-reliable access to moving objects.

A flexible convergent and seamless connectivity offer across different radio access technologies will be required to adapt instantaneously variable capacity and mobility needs to changing environments.

This use case family also needs to address open questions for time-critical closed loop communication scenarios, such as co-existence of different wireless protocols and systems and of different wired protocols; interoperability between communication systems; seamless engineering taking into account collected real-life data.

High-level needs for the communication							
Req.	Latency	Reliability	Bandwidth	Coverage Availability	Security	Heterogeneity	Autonomy
Time-critical optimisation	Ultra-low	Ultra-high	Low to high	Indoor	Critical	Important	Less critical

Table 30: High-level needs for time-critical optimisation

Use Case Family 2: Connected goods – incorporating product lifetime

The servitisation of physical goods is strategically important for factories of the future. Proper monitoring of machines and parts will allow selling engine hours, km, drills etc., as indicated in the forward-looking stakeholder perspectives, where new business models focus on product lifecycle data, personalised usage and context data. Factories will evolve to a data-driven ecosystem by reinforcing a product-service relation.

The vision is that products remember how they were made and augment production-related data with usage-related data collected during the lifecycle of the product. Cost-effective communication scheme will accelerate data collection scenarios. Computer-aided design will be driven by smart data filtering and scalable data analytics. Model-based optimisation will become key in a world of virtualisation, where simulation data can immediately be validated against real-life product data.

Representative scenarios and Key Requirements	Main impacts
<ul style="list-style-type: none"> - Connecting goods during product lifecycle to monitor product characteristics, sense its surrounding context, and offering new data-driven services. <p>Key requirements: ultra-low-power (high autonomy) and ultra-low-cost communication platforms</p>	<p>Increasing sales (new products/services). Improved product/process design.</p>

¹⁹¹ ISO 10218-1:2011 – Robots and Robotic Devices, Safety requirements for industrial robots -- Part 1: Robots, <https://www.iso.org/standard/51330.html>.

High-level needs for the communication							
Req.	Latency	Reliability	Bandwidth	Coverage Availability	Security	Heterogeneity	Autonomy
Connected goods	Less critical	Low	Low	Wide area	Important	Important	Critical

Table 31: Requirements for Connected Goods

Use Case Family 3: Non time-critical communication inside the digital factory

Less time-critical communications involving the localisation of assets and goods in on-site production and logistic processes, non-time critical quality control, or data capturing for later usage in virtual design contexts. Human response times on the shop floor are typically much higher than machine-level response times.

Logistics: accurate localisation of forklifts, auto guided vehicles, trolleys, vessels etc. can significantly reduce error rates in picking and packaging by validating the source and destinations of picked goods or parts in real time with intelligent warehouse management systems (VMS). This means avoiding products being moved into the wrong truck with significant cost savings along the value chain.

Successful capturing of sensor data on the shop floor: key to further digitisation of the factory and facilitating virtualised design processes that integrate simulator data with real-life, data sensed during production. Successfully combining this data will help minimise product lead times and lead to the design of superior products that are produced with a minimal number of defects.

Challenges: ensuring high availability of wireless networks, even in harsh environments. Indoor coverage with connectivity of complete locations is a key requirement to guarantee full availability and reliability.

The following use cases are less demanding in terms of performance of the wireless channel (e.g. latency and bandwidth) channel but present challenges for coverage, heterogeneity, security and autonomy.

Use Case Family 4: Remote maintenance and control

Representative scenarios and Key Requirements				Main impacts			
<ul style="list-style-type: none"> - Remote quality inspection/diagnostics. - Remote virtual back office. Key requirements: increased capacity to facilitate video-supported remote maintenance from any place in the world to enable the integration of				Increased product/process quality.			
High-level needs for the communication							
Req.	Latency	Reliability	Bandwidth	Coverage Availability	Security	Heterogeneity	Autonomy
Remote control	Less critical	High	Low	Wide area	Critical	Important	Less critical

Use Case Family 5: Intra-/inter-enterprise communication (II-EC)

Representative scenarios and Key Requirements	Main impacts
- Identification/tracking of goods in the end-to-end value	Increased efficiency (cost, time).

chain. - Reliable and secure interconnection of premises (intra-/inter-enterprise). - Exchanging data for simulation/design purposes. Key requirements: flexible and seamless connectivity across different access technologies and the support for mobility.							
High-level needs for the communication							
Req.	Latency	Reliability	Bandwidth	Coverage Availability	Security	Heterogeneity	Autonomy
II-EC	Ultra-low to less critical	High	Low to high	Wide area (onsite/outdoor)	Critical	Important	Less critical

Table 32: Requirements for Intra-/Inter-enterprise communication

In the presentation entitled “5G Meets Industry 4.0” (May 2016), Hans Schotten provides an overview of four use case scenarios for Industry 4.0, covering process automation, factory automation, Production IT and Logistics, along with a set of specific requirements for industrial radio. These include closed-loop control, condition monitoring, process automation and human-technology interaction (HMIs)/Augmented Reality (AR).

	Closed-loop control	Condition Monitoring	Process automation	HMIs/AR
<i>Latency</i>	50µ ...1 ms deterministic	10 ms >1s	5ms ... 1 s	Down to 1-4ms
<i>Jitter</i>	≤~10µs, determ.	>5-10ms	>5-10ms	<1ms
<i>Packet loss rate</i>	<1e9	<1e-4	<1e-4	<1e-4
<i>Data rate (per node)</i>	Up to 100 kbit/s	Kbit/s	Kbit/s	Mbit/s-Gbit/s
<i>Node density</i>	high	high	low	Low-medium
<i>TX Distance</i>	Up to 100m	Up to 100m	Up to 1km	1m...100m, multi-cell
<i>Topology</i>	Star	Mesh/Star	Mesh/Star	Star/Ad-hoc
<i>Bands</i>	2.4/5 GHz	2.4GHz and <1GHz	-	2.4/5/60GHz
<i>Energy efficiency</i>	-	>10 years	>10 years	>10 years
<i>Co-existence</i>	Yes	Yes	Yes	Yes
<i>Mobility support</i>	No	-	-	Yes
<i>Security</i>	Yes	Yes	Yes	Yes

Localisation	unclear	-	-	Yes, resolution	cm
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On-going National and 5G PPP Projects

<p>Clear5G¹⁹² (5G PPP – phase 2) EU-Taiwan</p>	<p>Investigating and demonstrating key enablers for Machine Type Communications (MTC) traffic in 5G networks, especially in the Factories-of-the-Future (FoF) environment. Optimisation of radio network architectures. Validation and demonstration of FoF use cases in factory prototyping. Test-bed (5GIC, University of Surrey): large-scale, C-RAN test platform supporting clusters of remote radio heads supported by high performance core processing facilities. Standardisation. Use case requirements: massive connection density; extremely low latency; high reliability; reduced signalling and control overhead; high energy efficiency; high spectrum efficiency; wireless networking heterogeneity; scalability.</p>
<p>5GTANGO¹⁹³</p>	<p>“Blanking” as an on-demand activity. A customer does in-house molding and assembles the outputs in-house as well. For best efficiency and best products, the blanking process needs to exchange data with the molding and assembly process. The described scenario will be validated in a real industrial scenario provided by industrial partner Weidmüller. Functionality is downloaded from the customer into the blanking machine similar to deploying a virtual network function (VNF). If a Provider works for multiple customers concurrently, the traffic between these two customers and their leased machines must be isolated from each other.</p>
<p>MATILDA¹⁹⁴</p>	<p>Addressing scenarios in and in-between manufacturing facilities. The first part of this use case addresses inter-enterprise integration. Main challenges are caused from multiple stakeholders (OEMs, suppliers, logistics service providers), all of which running different technologies and management solutions, which have to be smoothly interconnected. Collaborative manufacturing production will be addressed (e.g. tracking, process/product co-designing, task planning), which relies on process data from suppliers of raw material, from production/assembly as well as from logistics service providers. The second part of this use case addresses intra-enterprise integration. An assembly chain scenario will be considered, where interconnection provides for the different machinery collaborative working on manufacturing goods such as cars. The concept of robot farming will be applied, in which collaborative process components (robots, cameras, laser scanners, employees, PLCs, etc.) can collaborate by sharing</p>

¹⁹² <http://clear5g.eu>.

¹⁹³ <https://5gtango.eu/index.php/about-5g-tango/18-smart-manufacturing>.

¹⁹⁴ <http://www.matilda-5g.eu/#industry-4-0-smart-factory>.

	<p>and analysing time critical data (coordinates, videos, collision detection) to ensure productivity, flexibility and safety. Deploying and orchestrating network-aware applications that will reflect both scenarios of this use case. Required performance, security, reliability and real-time communication characteristics will be facilitated by 5G access and MATILDA enabling architecture through the proper integration of VNFs and application components. MATILDA multi-site management will be an enabler for the first scenario while monitoring, analytics and optimisation will drive complex decision making in both scenarios. BIBA smart factory infrastructure facilities will be exploited in this use case, while the application will be implemented mainly by BIBA and validated over Bristol Is Open provided infrastructure.</p>
<p>5GEM - 5G-Enabled Manufacturing¹⁹⁵ (Sweden)</p>	<p>Project funded by VINNOVA, a government agency for research and development.</p> <p>5GEM will create a pilot production system for world-class industrial manufacturing based on wireless and mobile 5G-communication. 5G wireless communication technologies offer new means for Swedish industry to achieve radically increased manufacturing productivity, flexibility, and competitiveness.</p> <p>The project will provide demonstrators for manufacturing system design, deployment, operation and maintenance which are the key life-cycle phases for competitive and sustainable manufacturing.</p>
<p>5G-based robot as a service¹⁹⁶ (Germany)</p>	<p>Huawei has signed an MoU with German industrial control and automation company Festo to jointly explore the 5G network application of manufacturing. Their joint aim is to promote the digital transformation of the manufacturing industry with 5G slicing technology, as well as further Huawei's ongoing commitment to what it calls the Smart Factory.</p> <p>The MoU is based on 5G Cloud Robotics to test a Robot as a Service (RaaS) concept, which is part of the digital transformation within the manufacturing industry that supports the shift from mass production to mass customisation and offers value-based services in smart factories. The idea is that computation is moved from the robot to the fabrication cloud and that due to the requirements for low latency in the control loop, 5G must be used to link both cloud and robot.</p>

Table 33: Overview of current initiatives

The 'Transition Numérique¹⁹⁷' is an initiative launched and supported by the French Government in 2012 to support SMEs in their digital transformation, and to accelerate their growth through digital skills and offers. It makes available to SMEs advisors and consultants from both public and private sectors.

¹⁹⁵ <https://www.chalmers.se/en/projects/Pages/5GEM.aspx>.

¹⁹⁶ <http://www.telecomtv.com/articles/5g/huawei-advances-its-smart-factory-push-with-5g-based-robot-as-a-service-15913/>.

¹⁹⁷ <http://www.transition-numerique.fr/>

Smart manufacturing may also include a holistic approach to systems development: starting from the actual design of the product the entire process is revolutionised. By shifting a considerable portion of the development effort to the initial phases, system verification can be performed early in the development process thanks to the combination of rigorous design of the system and its components, sophisticated simulations and formal verification methods. This model-based development paradigm strongly relies on the formal definition of requirements, and on the ability to execute extremely reliable simulations. Through early verification it is possible to highlight feasibility problems and integration issues long before the actual development is started, avoiding a high percentage of the costly and time-consuming re-works due to issues that would otherwise be discovered only after integration testing or (worse) system verification and validation.

This innovative development approach is already widely adopted for instance in the space and avionic industry, due to the particularly prohibitive costs of production. The uptake of new methodologies, however, requires a cultural change especially for the smaller industries, as it implies an increase in initial investment (in terms of time and analysis). Adaptation of regulations and contractual responsibilities may also facilitate the change of perspective needed at the management and procurement level.

8 Standardisation: Initial Analysis of the Industry and Vertical Landscape

8.1 Drivers for 5G Standardisation

5G communication networks enable seamless global communication between diverse kinds of 'nodes', connecting data, vehicles and other objects, smart sensors or voice. 5G is expected to become the essential global infrastructure for communication. Given its global nature, and the connections it makes between ICT and non-ICT sectors, 5G critically depends on standards to ensure interoperability, security, privacy and data protection. Standardisation is also key for SMEs to scale up and reach larger markets in the global marketplace. Moreover, 5G standardisation is one of the priorities for realising the Digital Single market. The European Commission 5G Action Plan defines the steps for EU wide deployment of 5G networks beyond 2020, which will leverage take up of 5G standards.

Standardisation is a key requirement for new technologies like Massive Machine Type Communication (mMTC), infrastructure virtualisation (SDN, NFV), and network resource sharing, also in the face of growing cyber threats and the increasing need to defend national and European critical infrastructure through cyber security. These technologies introduce or allow for more stakeholders with more complex trust relationships, and lead to new security and resilience requirements along with new opportunities to implement extensive and accurate security solutions.

Standards introduce benefits also under the economic perspective: standards-compliant devices and infrastructure allow for interoperability and compatibility. Standards make products more valuable to consumers since compatible products can be interconnected to each other, enabling the emergence of large networks of users. These large networks also add value to manufacturers of standards-based products, because these manufacturers can benefit from economies of scale in development and production. Innovators and developers also benefit from reduced uncertainty¹⁹⁸.

5G will be even more reliant on standards than previous mobile telecommunication networks because of the expected broad impact on society and the many ways in which 5G networks will interact with

¹⁹⁸ David J Teece, "5G Mobile: Impact on the Health Care Sector", October 26th 2017, <https://www.qualcomm.com/media/documents/files/5g-mobile-impact-on-the-health-care-sector.pdf>.

each other and other systems. As 5G will impact diverse technologies, many standards bodies will be involved in standardisation efforts, spanning the main industry standard, as well as ITU, IETF, IEEE, OneM2M, Broadband Forum, 5GAA, 5G PPP, and major industry associations like GSMA and the Next Generation Mobile Network Alliance (NGMN). In addition,

The need is therefore impellent for collaboration among all stakeholders in industry, academia and standard bodies, as highlighted also by the European Commissioner for Digital Economy and Society: “Involvement of vertical industries is important from an investment and deployment perspective,” said Oettinger. “There’s a real necessity to associate the vertical industries to 5G standardisation work through closer partnerships.”^{199,}

- Open, public standards allow scrutiny and analysis by a wide range of industry experts, academics, and other stakeholders, and therefore promote transparency and trustworthiness.
- Standards are the best guarantee of interoperability. In a secure context, this means that not only different systems can interact but that security levels are also consistent on all sides thus avoiding any undermining on one side or the other.
- Adherence to standards can help ensure safety and a reliable environment for society and the economy. Users perceive standardised products and services as more dependable, increasing consumer confidence, sales and uptake of innovative technologies.
- Standards help ensure a minimal security baseline based on consistent technology and procedures by identifying the security functionality and mechanisms that the 5G infrastructure needs to support. Standards can also provide additional security functionalities that can be instantiated based on specific services or contexts.
- Standardisation has several business benefits:
 - Opening up market access.
 - Economies of scale.
 - Encouraging innovation.
 - Increased awareness of technical developments and initiatives.

8.2 Overview of standardisation Efforts on 5G

The tables below provide an overview of the main standardisation efforts mostly at the 5G industry level and their relevance for vertical industries, showing how they offer opportunities for contributions within the 5G PPP and projects dealing with specific vertical use cases for dedicated support from Global5G.org.

Standardisation Body/Industry Association	Status ²⁰⁰ and Plans ²⁰¹	Related Global5G.org Activities
<p>3GPP (3rd Generation Partnership Project): international body that formulates international standards and specifications for 5G.</p> <p>The 3GPP²⁰² and its groups on</p>	<p>Release 15 (open): 01-06-2016 to 14-09-2018.</p> <p>Release 16 (open): started 22-03-2017.</p> <p>First 5G NR Specs Approved at 3GPP TSG Plenary meetings, in Lisbon, December 21, 2017²⁰³.</p>	<p>Analysis of coverage of Release 15 Drop 1 and Drop 2 expected in June 2018.</p> <p>Gap analysis for SA1 – Requirements in relation to verticals</p>

¹⁹⁹ https://www.theregister.co.uk/2016/02/24/mobile_industry_courts_verticals_for_5g/.

²⁰⁰ <http://www.3gpp.org/specifications/releases>.

²⁰¹ <http://www.3gpp.org/ftp/Specs/html-info/GanttChart-Level-2.htm>.

²⁰² <http://www.3gpp.org/specifications-groups/specifications-groups>.

²⁰³ http://www.3gpp.org/news-events/3gpp-news/1934-nr_verticals.

<p>RAN (Radio Access Network); SA (Services and Systems Aspects) and CT (Core Network and Terminals) defines the features of 5G radio and core network necessary to achieve requirements and use cases and in relation to the identified deployment scenarios, based on a contribution- and results-based approach.</p>	<p>Submission of initial 5G description for IMT 2020²⁰⁴ TSG CT: 5G core stage 3 work²⁰⁵. SA1: Services²⁰⁶ SA3: Security topics currently under discussion (March 2018)²⁰⁷. SA6: mission-critical applications²⁰⁸.</p>	<p>covered, especially health and energy to help fill current gaps. Analysis of other relevant groups in relation to verticals, including security. Awareness-raising across vertical industries and through 5G PPP WGs to foster sharing of knowledge and results.</p>
<p>3GPP 1st Release 15²⁰⁹: first set of New Radio (NR) standards was agreed upon (December 2017, during the 3GPP Plenary Meetings in Lisbon²¹⁰). This first drop of Release 15 provides non-standalone 5G radio specifications with an LTE anchor and 5G NR cell. Control plane and control plane communications are via LTE with a boost of user data capacity coming from 5G NR and the new radio control plane support for 5G radio. The first drop of Release 15 (mobile broadband boost) was anticipated to enable early market rollout (expected in late 2018). This is considered a positive step as it will allow early operator adopters to bring back into the process experiences of the new technology and its initial set of features.</p>		
<p>Engagement with vertical industries: key to fully realising the 5G vision²¹¹ Engagement with vertical industries needs to intensify from early 2018 onwards as a much broader approach is needed from the system level, to achieve goals defined. The notion of slice ‘types’, that focus initially on eMBB, mMTC, and URLLC, is ensure that we are aimed at achieving these targets by the time we provide the IMT-2020 delivery. Investigations into these verticals is specifically aimed at delivering services with industries that are actively engaged – not only by using the standards, but providing guidance, both at the requirements level and by being engaged in doing the standardisation work itself. Direct engagement with all the verticals targeted is very important for achieving the 5G vision, and it should be intensified and with players from other industries. This is the key to making 5G a success. One of the barriers is that many of the other vertical industries lack a focal point for 5G and ecosystem development. Forums like the 3GPP on the standards side and GSMA on the industry side are the ‘place to go’ for the wireless industry. The 5GAA was created for this purpose. However, other verticals currently have no such forum. Better engagement could be achieved by</p>		

²⁰⁴ http://www.3gpp.org/news-events/3gpp-news/1937-5g_description.

²⁰⁵ TSG#78 meetings, December 2017, update on the CT aspects of the 5G network, covering the Stage 3 level work for the completion of areas such as Slicing, the Service based architecture and the necessary transport protocols, also detailing the significance of RESTful and the possible use of QUIC transport and security protocols from Release 16 onwards, http://www.3gpp.org/news-events/3gpp-news/1940-ct_5g.

²⁰⁶ <http://www.3gpp.org/specifications-groups/sa-plenary/sa1-services/home>.

²⁰⁷ Key hierarchy; Key derivation; Mobility; Access Stratum security; Non-Access Stratum security; Security context; Visibility and Configurability; Primary authentication; Secondary authentication; Interworking; non-3GPP access; Network Domain Security; Service based architecture; Privacy.

²⁰⁸ <http://www.3gpp.org/specifications-groups/sa-plenary/sa6-mission-critical-applications>.

²⁰⁹ <http://www.3gpp.org/DynaReport/38-series.htm>.

²¹⁰ http://www.3gpp.org/news-events/3gpp-news/1929-nsa_nr_5g; TelecomTV interview with Balazs Bertyny (TSG RAN Chairman) and Erik Guttman (TSG SA Chairman) <https://vimeo.com/249849088>.

²¹¹ http://www.3gpp.org/news-events/3gpp-news/1934-nr_verticals.

setting up such a forum.	
Standards Group & Overview	Related Global5G.org Activities
<p>ETSI Industry Specification Group on NFV (ETSI ISG NFV) Develops requirements and specifications for NFV²¹². Its overall aim is to produce the technical specifications to enable the development of an open, interoperable, commercial ecosystem based on network virtualised functions.</p>	<p>Track progress towards end goals and relevance for verticals. Analyse expected impacts and benefits of involvement of OS community and multi-stakeholder approach.</p>
<p>ETSI Industry Specification Group on Multi-access Edge Computing (ETSI ISG MEC) Introducing a set of standards to allow hosting applications with ultra-low latency and high reliability in a distributed cloud and especially at the edge of the network. The optimised location close to the users and catered with the contextual information and the APIs offered within the MEC environment enable innovative and powerful services for connected AD vehicles.</p>	<p>Analyse and track progress on relation to vertical industries: The current baseline MEC standard already covers many vertical market segments. In the context of the automotive vertical, a new work item, “MEC support for V2X use cases”, has recently been submitted by the ISG MEC²¹³. The work focuses on identifying the available support that MEC can provide for V2X applications. Work item stakeholders will analyse the relevant V2X use cases (including findings from external organisations) to evaluate gaps from already defined MEC features and functions, identify new MEC requirements, including new functions and features, such as new MEC service APIs or interfaces, and changes to existing APIs. The 5GAA is actively working on edge computing as a key area for automotive use cases, through member companies common in both ETSI MEC and the 5GAA.</p>
<p>ETSI Industry Specification Group on Zero Touch Network and Service Management (ETSI ZSM ISG) Initial focus on 5G end-to-end network and service management, such as network slicing management, with plans to extend to the management for future network generations²¹⁴. The goal is to work towards 100 per cent automation (ideally) for all operational processes and tasks: delivery, deployment, configuration, assurance and optimisation.</p>	<p>Analyse challenges driven by the wide range of 5G requirements, massive (seemingly infinite) capacity, imperceptible legacy, demand for personalised services and unmatched degree of experience, global web-scale reach and support for massive machine communication. Evolution of networks towards programmable, software-driven, service-based and holistically-managed architectures, using the technology enablers, and catalysts like NFV, SDN, and MEC; automation as means to deal with exponential increase in complexity coming from technology advances like network slicing and bringing new business models, new markets, unprecedented operational agility</p>

²¹² <http://www.etsi.org/technologies-clusters/technologies/nfv>.

²¹³ ETSI MEC work item MEC-0022: “Study on MEC support for V2X use cases”;
https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=52949.

²¹⁴ <http://www.etsi.org/news-events/news/1245-2017-12-news-etsi-launches-zero-touch-network-and-service-management-group>.

	and higher co-operation across network domains.
<p>ETSI Industry Specification Group 'Experiential Network Intelligence' (ETSI ISG ENI) Define a Cognitive Network Management architecture based on the “observe-orient-decide-act” control model. It uses AI (Artificial Intelligence) techniques and context-aware policies to adjust offered services based on changes in user needs, environmental conditions and business goals.</p>	<p>Monitor emerging requirements of the operator's experience in and across legacy and virtualised networks including 5G networks, and a model-driven architecture that supports adaptive and intelligent service operation through Cognitive Network Management. Monitor the agreed collaboration with phase 2 project SLICENET on a series of inter-management team conference calls were agreed. The proof of concept was discussed and further discussions are in the offing in the future²¹⁵.</p>
<p>IETF Deterministic Networking (DetNet) WG²¹⁶ Define an intra-domain architecture supporting deterministic flows in heterogeneous networks. This architecture is based on open standards such as those developed by the IETF. Use cases: requirements in several diverse industries to establish multi-hop paths for characterised flows with deterministic properties.</p>	<p>Analyse current contributions from the 5G PPP and potential future ones. The VirtuWind consortium is actively contributing to the WG by providing a set of requirements derived from the wind farm industry and related scenarios. These requirements are used to drive the standardisation efforts of this IETF WG and guide the industry towards the improvement of communication protocols and technologies in the backbone of the network²¹⁷. Contributions have also been made by 5G-Crosshaul (phase 1; 5G-MONARCH phase 2).</p>
Global5G.org also monitors the following standardisation activities in terms of their relevance for verticals:	
<p>IEEE 802.1AR-2009²¹⁸ The IEEE standard for local and metropolitan area networks: secure device identity. It enables the secure association of locally significant device identities with manufacturer provisioned identities for use in provisioning and authentication protocols.</p> <p>IEEE project 15.9²¹⁹ IEEE Draft Recommended Practice for Transport of Key Management Protocol (KMP) Datagrams. It provides guidelines for the support of key management in IEEE 802.15.4. A variety of Societies within the IEEE are Sponsoring standards development activities that are directly related to the applications that will support the ultra-high bandwidth, ultra-low latency and ultra-low power requirements of 5G applications such as networking vehicles, massive IoT and industrial automation. These standards span IEEE Computer society standards; antennas and propagation; instrumentation and measurement; microwave theory and techniques; vehicular technology society/intelligent transport system; SASB/SCC39-SCC39 – international committee on electromagnetic safety²²⁰.</p>	

Table 34: 5G Standardisation of interest to Global5G.org

²¹⁵ <https://slicenet.eu/eni-workshop/>.

²¹⁶ 5G PPP Phase 1 Security Landscape, op. cit., p53. For more information on the WG scope and charter, see, <https://datatracker.ietf.org/wg/detnet/about/>, <https://datatracker.ietf.org/wg/daetnet/charter/>.

²¹⁷ 5G PPP Phase 1 Security Landscape, op. cit., p53.

²¹⁸ <https://standards.ieee.org/findstds/standard/802.1AR-2009.html>.

²¹⁹ <https://standards.ieee.org/findstds/standard/802.15.9-2016.html>.

²²⁰ <https://5g.ieee.org/standards>.

8.3 Healthcare Standardisation

8.3.1 Drivers for Standardisation

Standardisation is fundamental and urgent as it plays a crucial role enabling interoperability to fully exploit the potential of the huge amount of health data generated by sensors and connected health platforms. The health industry is still a painfully fragmented sector with each company developing systems and producing data in silos: interoperability among patients' records is still a mirage: even simple interpretation of health data from various sources is often complicated and requires experts' conversions. *"Until now the consumers have accepted a situation which would be unthinkable in most other sectors (just imagine a credit card that would work only with card readers from the same bank)"* says Ian Hay (Continua Health Alliance, interviewed at the 5G Session during IEEE 5G Summit).

Now it is exactly the right moment to develop 5G health use cases, also because *"we are still in time to affect standardisation and network developments"*²²¹. However, gaining consensus across major stakeholders may prove challenging also because of the very high number of industries and actors in the health sector.

In recognising the crucial role of standardisation, the health authorities of Denmark, Norway, Sweden and Finland have joined forces developing a shared reference architecture for personal connected health and care technology²²² based on the work of the Continua Alliance (PCHA)²²³ to facilitate market access and accelerate the uptake of integrated e-health solutions reaping the benefits of the shift to a personalised distributed health system. At the same time, also other countries are acknowledging the need for a coordinated approach to foster harmonisation among health systems, data and applications. Interestingly the countries or regions of Austria, Catalonia, Denmark, Finland, Norway, and Sweden have written a joint letter²²⁴ urging the EC to "make time for a European evaluation of an end-to-end interoperability framework based on international standards for personal connected health [...] towards a common European approach". With 5G coming into play the potentialities of connected health and benefits can grow exponentially allowing high-quality healthcare to be affordable and close to all patients. Reaching wide consensus on standards is crucial for not missing this opportunity.

In *Digital Healthcare Interoperability*, the GSMA provides compelling arguments on the socio-economic benefits of interoperability of digital health systems and devices²²⁵. Interoperability is required at foundational, structural and semantic levels to realise the projected benefits of digital health solutions. Interoperability at all these levels will enable the secure, reliable and consistent exchange of data between devices, applications and platforms. Interoperability will also facilitate the seamless design and integration of services, for ease of use by patients, clinicians and consumers. Semantic interoperability is key to ensuring that data exchanged across devices and systems is understood, interpreted and acted upon in the correct manner.

Interoperability means the ability of health information systems to work together within and across organisational boundaries, advancing the health status of, and the effective delivery of healthcare for,

²²¹ Milla Immonen - senior scientist and project manager in Smart Health at VTT Technical Research Centre, Finland – presenter at IEEE 5G Summit in Helsinki September 2017.

²²²

https://www.inera.se/globalassets/tjanster/tjanstepattform/dokumentblock/nyhetsbrev/nordic_reference_architecture_for_personal_connected_health_technology_2017-03-19.pdf.

²²³ <http://www.pchalliance.org/>.

²²⁴ http://www.pchalliance.org/sites/pchalliance/files/eHealth%20Network%20LETTER%20FINAL_2.pdf.

²²⁵ Digital Healthcare Interoperability, GSMA, October 2016, <https://www.gsma.com/iot/digital-healthcare-interoperability/>.

individuals and communities²²⁶. Yet, lack of interoperability is often cited as one of the barriers to realising the projected healthcare benefits of Digital Health solutions²²⁷.

Healthcare system architectures need to open up and become more semantically interoperable, with common interfaces supporting 'plug-and-play' devices to integrate information into healthcare systems along with a standard interoperable interface to exchange data between backend solutions.

Four major benefits will stem from widespread semantic interoperability:

- 1. Easier and faster access to patient information.** Interoperable systems will permit automatic data sharing and retention, giving professionals more time to focus on patient care. Benefits include: better access to information, including Internet and mobile access; reduced data (re)capture errors; reduced duplicated effort: reduced administrative workload; improved coordination of care across personal, primary, secondary and tertiary pathways; continuity of care; increased involvement of patients.
- 2. Opportunities for better diagnosis, quality of treatment and patient safety.** Faster access to patient data records increases potential for more accurate diagnosis, better quality treatment and care delivery, improved patient safety through improved knowledge of health, social status, family and personal history; improved care coordination across multiple healthcare professionals; better communication between professionals and with their patients; avoiding medication interactions and errors.
- 3. Improved cost effectiveness.** Reduced administrative costs from reduced manual data capture and duplicated effort for clinical and administrative staff. Costs of implementing new IT systems can be lower when built using open access technologies that are easier to integrate. Hospitals and primary care centres may benefit from lower costs of maintenance and vendor support. It may also support the introduction of new business models promoting healthcare and wellness, where users pay directly for a service.
- 4. Increased consumer choice and increased competition.** Greater interoperability of systems promotes competition and opens up opportunities for new vendors to enter the market. This can result in increased choice for consumers and healthcare providers, and also amplifies the rate of innovation, stimulating development of new services and supporting technologies. A good example of this is the evolution of the mobile industry since the introduction of standards for network interoperability.

Global standards are also key for improving health outcomes, such as metrics for major diseases and conditions. The Organization for Economic Cooperation and Development (OECD) and the International Consortium for Health Outcomes Measurement (ICHOM) have agreed to collaborate on creating such standards and using them to compare the quality of care across OECD member nations. This is a landmark milestone on the path towards value-based healthcare because standardized measurement around the world creates an unparalleled opportunity to learn from high-performing clinical teams and innovators, no matter where they operate²²⁸.

8.3.2 Current Standardisation Efforts

²²⁶ HIMSS Dictionary of Healthcare Information Technology Terms, Acronyms and Organisations, 3rd Edition, p. 75.

²²⁷ In a report published by the European Commission on the public consultation on eHealth Action Plan 2012–2020 lack of interoperability was also identified as one of the main barriers preventing the large-scale deployment of eHealth in Europe, http://ec.europa.eu/economy_finance/publications/european_economy/2015/pdf/ee3_en.pdf.

²²⁸ http://www3.weforum.org/docs/WEF_Insight_Report_Value_Healthcare_Laying_Foundation.pdf.

Efforts are under way to structure the relevant standards. However, interoperability allowing an easy plug-and-play approach among components is still a challenge. Besides sector-specific organisations, several technology organisations are working towards standardisation for digital health. For example, ETSI is working towards harmonisation in the telecom sector contributing to the telecommunication element of e-Health. Standards such as ISO and IEEE also play a role in the healthcare domain and need to be considered. The Association for Internet of Things Innovation (AIOTI) is working towards harmonisation of the IoT domain within the e-health domain²²⁹.

In this section, we provide an overview of established and emerging global standards for interoperability and the organisations (standards bodies and industry associations) focused on defining and aligning them.

- **IEEE 11073 Personal Health Devices (PHD) standards²³⁰**. These standards enable communication between medical, health care and wellness devices with external computer systems. Developed to specifically address the interoperability of personal health devices (e.g. thermometers, blood pressure monitors) with emphasis on personal use and a simple communication model. This family of standards ensures that the user of the data knows exactly what was measured where and how, that the information is not lost when transported to and from the sensor, to a gateway and then to the EHR (Electronic Health Record).
 - The **Personal Connected Health Alliance** (formerly Continua Health Alliance) has progressed towards aligning the 11073 standards to modern health services and provides certification routes for adoption of this standard in collaboration with IHE.

- Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing and transmitting information in medical imaging. It is defined by the National Electrical Manufacturers Association (NEMA)²³¹ and is known as **NEMA Standard PS3** and **ISO standard 125052:2006** “Health Informatics – Digital Imaging and Communication in Medicine (DICOM) including workflow and data management”.

DICOM enables the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a picture archiving and communication system (PACS). Devices come with DICOM conformance statements indicating the DICOM classes they support. It is widely adopted in hospitals and gaining increasing interest in smaller health care facilities (dentist and doctor surgeries), with near universal level of acceptance amongst medical imaging equipment vendors and health IT organisations. In terms of limitations, DICOM addresses technical interoperability issues in medical imaging, but does not provide a framework for achieving a useful clinical workflow.

- **Logical Observation Identifiers Names and Codes (LOINC)²³²**: developed as a common terminology for lab and clinical observations for the electronic transmission of data. LOINC is a rich catalogue of measurements, including lab tests, clinical measures like vital signs and anthropomorphic measures, standardised survey instruments, etc. LOINC enables the exchange and aggregation of clinical results for care delivery, outcomes management and research by providing a set of universal codes and structured names to unambiguously identify things that can be measured or observed²³³.

²²⁹ Health 4.0: How Virtualisation and Big Data are revolutionising healthcare, C. Thuemmler, C. Bai (eds.), Springer 2017.

²³⁰ www.11073.org.

²³¹ www.nema.org.

²³² www.loinc.org.

²³³ www.loinc.org/background.

- **SNOMED CT**²³⁴ was developed to encode the meanings used in health information and support effective clinical recording of data to improve patient care. It enables consistent, processable representation of clinical content in EHRs.
- **Health Level 7 International (HL7)**²³⁵, ANSI (American National Standards Institute), is aimed at providing a comprehensive framework and related standards for the exchange, integration, sharing and retrieval of electronic health information. HL7 is supported by over 1,600 members in over 50 countries. Its purpose is to enable global health data interoperability by developing standards and facilitating adoption and implementation²³⁶. Licence and IP are issued free of charge. Revisions have been made to HL7. Variations in use between v2.0 and v3.0 in systems can potentially cause complications if the version is not explicitly mentioned as the interfaces can be significantly different. While the use of HL7 v2.x dominates, there is a gradual shift towards HL7 v3.0 and FHIR. HL7 is one of the most widespread, health-based open messaging standards available. As such, it is the most likely mechanism for widespread standards adoption at this level of communication.
- **Fast Healthcare Interoperability Resources (FHIR)**²³⁷ is an emerging standard from HL7, currently available as a draft standard for trial use (DSTU) as the specification is still in development. FHIR addresses about 80% of use cases, with extensions covering the remaining 20%. FHIR combines features of the HL7 v2.x²³⁸, HL7 v3.0²³⁹ and CDA²⁴⁰ product lines. It leverages the latest web standards with a focus on implementation and an attempt to overcome the incompatibility issues between HL7 v2.x and HL7 v3.0. As a standard for exchanging healthcare information electronically, FHIR defines a set of “resources” that represent granular clinical concepts. Resources can be managed in isolation or aggregated into complex documents. Technically, FHIR is designed for the web with resources based on simple eXtensible Markup Language (XML) or Java Script Object Notification (JSON) structures with a hyper-text transfer protocol (http)-based (Representational State Transfer RESTful protocol where each resource has a predictable uniform resource locator (URL). REST is an architectural style for networked hypermedia applications and underlies most web-based services. Where possible, open internet standards are used for data representation²⁴¹.

FHIR is gaining momentum with stakeholders across the health IT ecosystem. Being based on a modern web services approach makes it easier for systems to exchange very specific items of information, rather than entire documents. The main benefit of FHIR is that it can make the exchange of health information faster and more efficient while maintaining a proper context for such exchanges across systems. FHIR could therefore improve patient engagement by helping developers produce applications using specific personal healthcare information, such as medication reminders.

- **ETSI TR (Technical Report) 102 764 V1.1.1 (2009-02)**²⁴², a technical report on eHealth; architecture; analysis of user service models, technologies and applications supporting eHealth for future standardisation; produced in the context of the EC's Mandate M/403 to CEN, CENELEC, and ETSI. The report describes the eHealth user service models for

²³⁴ <https://www.snomed.org/>.

²³⁵ www.HL7.org.

²³⁶ <http://www.hl7.org/about/index.cfm?ref=common>.

²³⁷ <http://www.HL7.org/fhir>.

²³⁸ http://www.hl7.org/implement/standards/product_brief.cfm?product_id=185.

²³⁹ https://www.hl7.org/implement/standards/product_brief.cfm?product_id=186.

²⁴⁰ http://www.hl7.org/implement/standards/product_brief.cfm?product_id=7.

²⁴¹ <http://wiki.hl7.org/index.php?title=FHIR>.

²⁴² http://www.etsi.org/deliver/etsi_tr/102700_102799/102764/01.01.01_60/tr_102764v010101p.pdf.

identifying interoperable solutions for healthcare data collection, transmission, storage and interchange. The model identifies the requirements for ubiquity, security, privacy and reliability across the eHealth system and the supporting information technologies. The TR identifies where additional standardisation is required in IT generally and in ETSI in particular to support eHealth. It is intended for standards developers and equipment manufacturers and providers in eHealth; developers and providers of eHealth related services.

- **ETSI SR (Special Report) 002 564 V2.0.0. (2007-05)**²⁴³: "Applicability of existing ETSI and ETSI/3GPP deliverables to eHealth", as the supporting analysis for TR 102 764.
- **CEN Health Informatics Technical Committee (TC 251)**²⁴⁴ focuses on eHealth standardisation to achieve compatibility and interoperability between independent systems, and enable modularity. Work includes requirements on health information structure to support clinical and administrative procedures, technical methods to support interoperable systems and requirements for safety, security and quality. Many standards have been published to date²⁴⁵; some of the most recent include standards related to data protection and personal health devices:
 - **EN ISO 25237: 2017: Health Informatics – Pseudonymisation**²⁴⁶: principles and requirements for privacy protection using pseudonymisation services for the protection of personal health information. It is applicable to organisations undertaking pseudonymisation processes for themselves or for organisations wishing to claim trustworthiness for operations engaged in pseudonymisation services (Clause 5). Clause 6 defines a basic methodology for pseudonymisation services, including organisational and technical aspects. Clause 7 specifies a policy framework and minimal requirements for controlled re-identification. Annex A gives an overview of different use cases for pseudonymisation, both reversible and irreversible; Annex B gives a guide to risk assessment for re-identification; Annex C provides an example of a system that uses de-identification; Annex D provides informative requirements regarding interoperability to pseudonymisation services; Annex E specifies a policy framework and minimal requirements for trustworthy practices for the operations of a pseudonymisation service.
 - **EN ISO 11073-10441:2017**²⁴⁷: Health informatics, personal health device communication Part 10441 (device specialisation – cardiovascular fitness and activity monitoring (ISO/IEEE 11073-10441:2015). Within the context of ISO/IEEE 11073 family of standards for device communication, this standard establishes a normative definition of communication between personal cardiovascular fitness and activity monitoring devices and managers (e.g. mobile phones, personal computers, personal health appliances, set top boxes) to enable plug-and-play interoperability. It leverages

²⁴³ http://www.etsi.org/deliver/etsi_sr/002500_002599/002564/02.00.00_60/sr_002564v020000p.pdf.

²⁴⁴ https://standards.cen.eu/dyn/www/f?p=204:7:0:::FSP_ORG_ID:6232&cs=18CA078392807EDD402B798AAEF1644E1.

²⁴⁵ https://standards.cen.eu/dyn/www/f?p=204:32:0:::FSP_ORG_ID,FSP_LANG_ID:6232,25&cs=1FFF281A84075B985DD039F95A2CAB820.

²⁴⁶ https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:60823&cs=1234A481478F1BD4BFF7A1879697478BC.

²⁴⁷ https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:60668&cs=182BBBEEACB3010A7E1690575B543D8DF.

relevant portions of existing standards (e.g. ISO/IEEE 11073) terminology and information models. The standard specifies term codes, formats and behaviour in telehealth environments restricting optionality in base frameworks in favour of interoperability. It defines a common core of communication functionality for personal telehealth cardiovascular fitness and activity monitoring devices that measure physical actions and physiological responses (broadly defined to cover diverse uses).

- **ITU-T eHealth Standardisation Coordination Group (eHSCG)**²⁴⁸: a platform for promoting stronger coordination in eHealth standardisation by developing co-operation mechanisms, such as identifying areas where further standardisation is required and who should contribute, providing guidance for implementations and case studies; providing functional sets for key health applications and supporting activities to increase user awareness of existing standards and case studies²⁴⁹.

8.3.3 Organisations supporting interoperability and standardisation

- **Integrating the Healthcare Enterprise (IHE)**²⁵⁰: global initiative by care providers and vendors to improve the way IT systems communicate to support patient care. IHE has created a framework for passing health information seamlessly across applications, systems and settings. It does not create standards but drives the adoption of existing standards addressing specific clinical needs by defining IHE integrating profiles. IHE removes ambiguities, reduces configuration and interfacing costs, thus ensuring a higher level of interoperability. It supports the coordinated implementation of communication standards, such as DICOM, HL7 and W3C and security standards, with precise definitions of how standards can be implemented to meet specific clinical needs²⁵¹. Mobile access to health documentation (MHD) is an example of an IHE profile framework supplement directly applicable to mobile health²⁵².
- **Personal Connected Health Alliance (PCHA**; formally Continua Health Alliance, which merged with PCHA in 2014)²⁵³: advocating global technology standards to enable interoperable solutions for personal connected health through the involvement of members from technology, medical device, health care industry, consumer electronics, healthcare service and life science companies, as well as government agencies. Since 2013, PCHA Design Guidelines have the status of International Standards for personal health systems (ITU recognised).

The guidelines provide a flexible implementation framework for plug-and-play or seamless interoperability of personal connected healthcare devices and systems, based on open standards developed by recognised industry groups or standards organisations. They define interface and standards at the interfaces along with constraints within those standards that enable the secure flow of medical data among sensors, gateways and end services. The guidelines also aim to remove ambiguity and ensure consistent implementation through product certification. The guidelines encapsulate a set of standards (IEEE's 11073 Personal Health Device Standards, IHE Patient Care Device PCD-01 Transaction, and the HL7 Personal Health Monitoring Report (PHMR).

²⁴⁸ <https://www.itu.int/en/ITU-T/studygroups/com16/ehscg/Pages/default.aspx>.

²⁴⁹ In 2014, the ITU-T Focus Group on M2M service layer, provided a study on M2M standardisation activities and gap analysis on e-health, <http://handle.itu.int/11.1002/pub/80a4ae22-en>, which will be further reviewed based on the initial analysis provided herein.

²⁵⁰ www.ihe.net.

²⁵¹ <http://www.ihe.net/Profiles/>.

²⁵² http://www.ihe.net/uploadedFiles/Documents/ITI/IHE_ITI_Suppl_MHD.pdf.

²⁵³ www.pchalliance.org.

PCHA has also established a reference architecture and product certification programme with a recognisable logo to signify product interoperability with other Continua-certified products. A defined set of system interfaces support the end-to-end delivery of healthcare services: personal health device interface; services interface; health information service interface.

PCHA has built on the work completed by IHE by providing guidance on the specific use of data within configurable fields in the IHE profile. The implementation of these interfaces enables a full ‘plug-and-play’ solution.

The figure below shows the coverage of the Continua Design Guidelines.

Standards Landscape covered by CDG

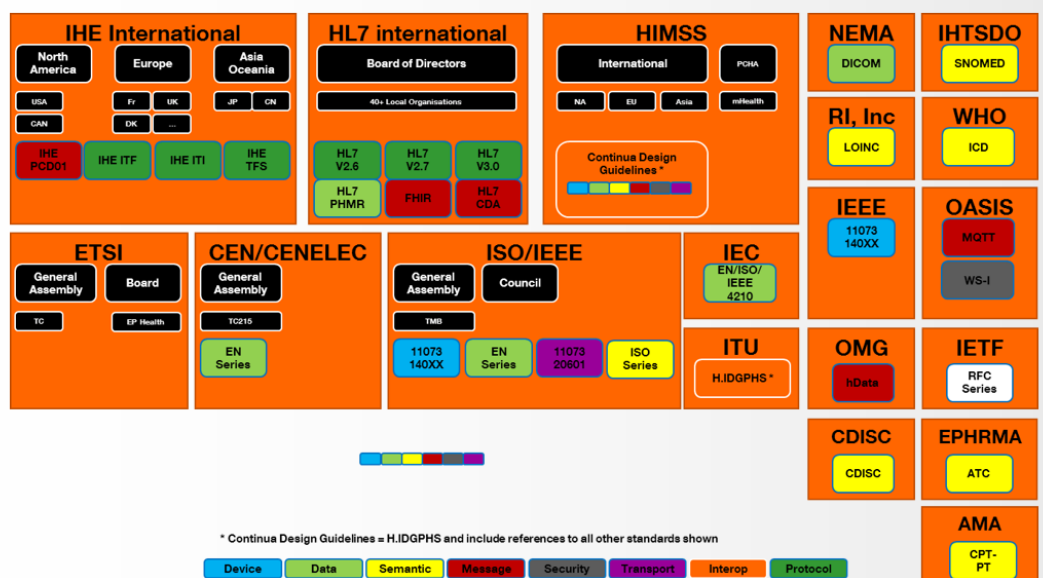


Figure 27: Coverage of Standards Landscape in the Continua Design Guidelines [Source: PCHA]

8.3.4 The way forward

Semantic interoperability is key to enabling digital health to scale. The main challenge to semantic interoperability is the adoption and consistent use of existing standards. The following main barriers were identified for the uptake of improved e-health scenarios:

- Current standards are sufficient to achieve semantic interoperability. The core issue is lack of adoption/use of standards.
- Awareness of the importance of interoperability is generally low, often due to a lack of experience.
- Interoperable systems are complex to implement.
- Electronic Health Record usage is still not broad enough/consistently implemented.

Stakeholder engagement with standards and industry organisations is of paramount importance

Healthcare providers and the clinical community, medical device and pharmaceutical companies, governments and mobile industry can help further the adoption of standards that deliver semantic interoperability.

Collective actions by these stakeholders can help realise the Digital Health opportunity at scale, thereby delivering the promised socio-economic benefits to citizens, healthcare providers and industry.

Sample of stakeholder roles:

- **Mobile industry** should raise awareness on the importance of interoperability standards; advise on the application of standards; promote end-to-end interoperability; ensure interoperability with existing clinical workflows.
- **Healthcare providers** and the **clinical community** should help to educate users on the use of data and standards that maximise the interoperability of systems and serve to assist in the delivery of improved patient centred care.
- **Medical devices** and **pharmaceutical companies** should aim to adopt open standards and interoperability in their design processes and final product solutions; Governments can help drive adoption by encouraging procurers to specify open standards in their medical device and healthcare ICT system acquisitions, and; The mobile industry can help by advising on the application of standards and by working with their healthcare industry partners to deliver services based on the principle of semantic interoperability
- **Governments** should identify best practices from effective leadership in pioneering countries and consider adopting frameworks for interoperable digital health standards. A top-down approach is needed with governments demanding interoperability and standards in services. Countries currently committed to Continua Guidelines (PCHA) for open and interoperable personal connected health include Austria, Catalunya (Spain), Denmark, Finland, Norway and Sweden²⁵⁴. The ITU approved the standard – Recommendation ITU-T H.810, which contains reference to PCHA’s Continua Design Guidelines for “Interoperability design guidelines for personal health systems”.

8.4 Automotive Standardisation

8.4.1 Drivers for Standardisation

According to the 5G Automotive Vision, “high-quality standards are a fundamental requirement to connect devices and industries through fast, secure and reliable wireless communications and to enable truly interoperable pan-European IoT services”²⁵⁵.

To avoid fragmentation in the EU digital single market, standards should be based on open solutions, developed on a voluntary and consensus approach by industrial stakeholders for the broadest level of marketplace acceptance and interoperability, while enabling innovation in the face of substantial industry investments.

A recent white paper by the 5G AA highlights additional benefits of standardisation, particularly enabled by mobile edge computing, such as ensuring an unparalleled quality of experience with highly contextualised service experience and efficient utilisation of radio and network resources²⁵⁶.

²⁵⁴ <http://www.pchalliance.org/sites/pchalliance.org/files/nodecontent/ehealth-network-letter.pdf>.

²⁵⁵ 5G Automotive Vision, October 2015, p.55, <https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf>.

Other key benefits of standardisation include adding value to the information exchange between vehicles, infrastructure, pedestrians and networking using V2X technology by exploiting edge processing power and intelligent information providing while at the same time providing useful low latency service experiences. A key value lies in enabling a multitude of new applications, which can also lead to new business models within the automotive industry.

- The network infrastructure for connected Autonomous Driving (AD) vehicles will provide not only Network as a Service (NaaS) but also Infrastructure as a Service (IaaS) in a multi-tenancy fashion.
- The edge computing infrastructure represents a pool of connected resources that can be used by the Mobile Network Operators (MNOs), and by diverse service/application providers who commercialise services as well as micro-services (e.g., Augmented Reality to serve multiple services, Video Analytics to serve diverse services) for connected AD vehicles.

Such infrastructure can lead to new opportunities for business models, spanning²⁵⁷:

- B2B: car makers monetise application providers for user experience (UX) services to passengers; CSPs monetise the use of cloud by car makers; MNOs monetise the use of the network by application providers and “over the air” (OTA).
- B2C: Car makers monetise personalised services to passengers; MNOs and CSPs monetise car makers for driving assistant and passengers’ experience.
- B2B2C: MNOs monetise the network infrastructure for compute/storage by Application providers (e.g., HD maps providers, Virtual reality applications); Application providers monetise car makers for the provision of applications; car makers monetise users (passengers, drivers in non-fully autonomous vehicles).
- C2C: Passengers (and drivers in non-fully autonomous vehicles) share road hazards information with vehicles in non-line of sights in a mutual way.

The qualities of edge computing ensure an unparalleled quality of experience with highly contextualised service experience and efficient utilisation of radio and network resources. The 5GAA has identified the focus of the ETSI Industry specification group on mobile edge computing (ETSI ISG MEC) as a key driver for realising these new business models.

A key advantage of the ETSI ISG MEC solution is that it can be deployed within the Mobile Network Operator’s infrastructure together with the management and orchestration, security, privacy and subscriber management frameworks already in place. This way the environment for edge applications is secure and well managed, making it more suitable for critical applications as well as for applications with high business value.

The increased interest in Edge Computing and the progressive introduction of 5G systems are demonstrating the maturity of this technology as a suitable enabler for the use cases described by the 5GAA (white paper 2017).

Especially for these use cases, the deployment of a service is involving many **actors and a diverse ecosystem of stakeholders**, so the value of a standardised solution is essential to avoid market fragmentation and ensure interoperability.

²⁵⁶ Toward fully connected vehicles: Edge computing for advanced automotive communications, 5GAA White Paper, December 2017, http://5gaa.org/wp-content/uploads/2017/12/5GAA_T-170219-whitepaper-EdgeComputing_5GAA.pdf.

²⁵⁷ 5GAA White Paper, December 2017, op cit.

Finally, ownership and responsibility of the applications on the future connected car platform are important aspects to be resolved. There are many potential actors in the ecosystem who could take this responsibility, e.g. road traffic operators, mobile network operators, and automakers. It is therefore likely that different standards in various standardisation organisations will be required depending on the actor(s) concerned.

8.4.2 Current Standardisation Efforts

While the automotive standards landscape (V2X and mobile edge computing) is currently led by three standards bodies, it is expected that additional organisations will be engaged in the standardisation process to cover the many different actors within the ecosystem. Current standardisation organisations involved are: IEEE 802.11 Wi-Fi family; the C-V2X based on the 3GPP family of LTE standards (and evolutions thereof); ETSI MEC with new work items recently presented by the 5GAA.

- **IEEE 802.11**

In 2004, IEEE began standardising a new V2X standard based on the 802.11 Wi-Fi standards family. The initial motivation to use the IEEE 802.11 family was to take advantage of the Wi-Fi ecosystem. However, as Wi-Fi was initially designed for low mobility devices, several enhancements for support of high mobility were included resulting in the IEEE 802.11p stack that was finalised into IEEE 802.11 in 2012 designed to operate in the 5.9 GHz band.

The development of 802.11p related V2X standards occurred in parallel in the US and Europe, producing two standards constituting two different profiles IEEE 802.11p. In Europe the resulting standard built on 802.11p was referred to as ITS-G5, with a notable addition of Distributed Congestion Control (DCC) to 802.11p. ITS-G5 was specified and first released in 2014 by the European Telecommunications Standards Institute (ETSI), technical committee (TC) on ITS. In the US the standard produced was the Dedicated Short-Range Communication (DSRC) standard, also referred to by the broader label of Wireless Access In Vehicular Environments (WAVE). The higher layers of the DSRC protocol stack are based on standards defined by the IEEE 1609 Working Group and by SAE International. In DSRC, the V2V communication is typically done using the lightweight WAVE Short Message Protocol (WSMP) rather than the traditional Transmission Control Protocol/Internet Protocol (TCP/IP) stack used by Wi-Fi. The TCP/IP transport and network protocols are generally used for V2I and V2N communications. The lower layers, Physical layers and Medium Access Control (PHY/MAC), of the DSRC protocol stack are defined in IEEE 802.11p.

- **C-V2X (3GPP Release 13/14/15)**

The distinct feature of C-V2X is the use of cellular networks as the V2X connectivity platform. To that end, 3GPP began developing enhancements for the LTE standard to be able to support the requirements emerging use cases, services and applications of the automotive industry for connected and automated mobility. The first output of this work was a feasibility study conducted in 3GPP Release 13 with the objective of understanding the required modifications in conventional LTE to be able to support V2X communications. The recommended modification were then part of the LTE enhancements developed in 3GPP Release 14.²⁵⁸ These LTE-V2X specifications included the following models of communications:

Direct communications: Vehicles are able to communicate directly (via a newly defined PC5 interface) with other entities, that is, Vehicle-to-Vehicle (V2V), Vehicle-to-(Roadway) Infrastructure (V2I) and Vehicle-to-Pedestrian (V2P). This communication occurs without necessarily the need for support from the mobile network in allocating of radio resources. As a result, the communications can also occur in locations outside the coverage area of the public mobile networks.

²⁵⁸ 3GPP TR 22.885 “Study on LTE Support for Vehicle to Everything (V2X) Services,” June 2016.

Mobile network assisted: Vehicles connect to the mobile network (V2N) through the traditional LTE air interface of existing public mobile networks. This model requires the vehicle to be in an area with public mobile network coverage.

The LTE-V2X modules installed in vehicles can utilise both models simultaneously. For instance, a vehicle could be using direct communications to exchange messages with other vehicles in the same platoon while simultaneously using mobile network to download high-resolution traffic information maps from the cloud. In this way, LTE-V2X is able to support wide range of C-V2X use cases for V2V (e.g. forward collision warning, wrong way driving warning etc.), V2P/V2I (e.g. pedestrian warning) and V2N (e.g. traffic flow optimisation).

In 3GPP Release 15, work has already begun on the next generation of C-V2X use cases that will leverage the capabilities of 5G to meet the more stringent V2X service requirements in terms of data rate, reliability, latency, communication range and speed. To that end, 3GPP has specified use cases and potential requirements²⁵⁹ to enhance 3GPP support for the following scenarios:

- Non-safety V2X services (e.g. mobile high data rate entertainment, mobile hotspot, dynamic digital map update etc.).
- Safety-related V2X services (e.g. autonomous driving, car platooning etc.).
- V2X services in multiple 3GPP RATs, such as, handover between LTE and 5G-NR V2X systems, and interoperability with non-3GPP V2X technology (e.g. ITS-G5, DSRC).

The work to develop 5G technology enhancements to support the above scenarios is ongoing in 3GPP Release 15 and later in Release 16 (see also roadmap of ²⁶⁰). This includes enhancements in network architecture and 5G-NR (e.g. proximal group management, mobility management, switching between direct and mobile assisted networking etc.).

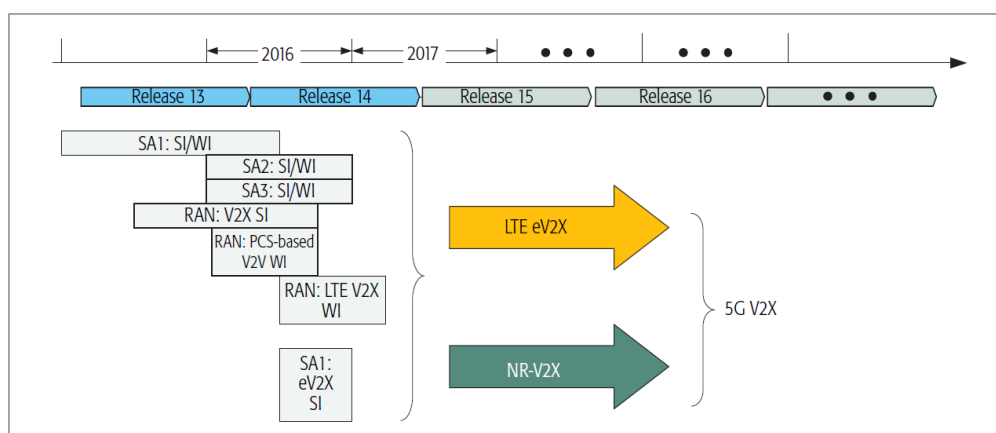


Figure 28 High-level view of 3GPP C-V2X standardisation roadmap

8.5 Energy Standardisation

8.5.1 Drivers for Standardisation

²⁵⁹ 3GPP TR 22.886 “Study on enhancement of 3GPP Support for 5G V2X Services,” 3GPP, March 2017

²⁶⁰ S. Chen et al., “Vehicle-to-Everything (v2x) Services Supported by LTE-Based Systems and 5G,” IEEE Communications Standards Magazine, vol. 1, no. 2, pp. 70-76, 2017.

There are many advantages of standardisation for the energy sector, as highlighted in the 5G PPP White Paper on 5G and Energy²⁶¹:

- Compliance with standards helps ensure safety, reliability and environmental care. Users perceive standardised products and services as more dependable, increasing user confidence, sales and take-up of innovative technologies.
- Interoperability, enabling devices to work together through standards compliance of products and services.
- Protecting user and business interests is often referenced as a requirement by regulators and legislators, as well as in government policies. Standards are a key element of the EU's Digital Single Market Strategy.
- Standardisation provides a solid foundation for developing innovative products and to enhance existing practices, where standards help open up market access; provide economies of scale; encourage innovation and increase awareness of technical developments and initiatives.
- Standards provide the foundation for new features and options, increasing consumer choice and improving daily life. Mass production based on standards provides greater variety of accessible products to consumers.

While the utilities recognise the need for standardisation, they are also dependent on their implementation by suppliers. By contrast, the telecommunications industry has a track record in deploying standards worldwide, as testified by the 2G-3G-4G standardisation success stories. Besides performance guarantees, this is one of the reasons why 5G is considered a natural choice for smart grid and smart meters.

8.5.2 EU Standardisation Coordination

The Smart Grid Mandate m/490 was issued by the EC in 2011. It requested CEN, CENELEC and ETSI to develop a framework enabling standards bodies to perform continued standard enhancement in the smart grid field. The CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG) was created in July 2011 to coordinate such standardisation in response to M/490²⁶².

One of the main outcomes is the **SG-CG Framework Document**²⁶³, which provides an overview of how sustainable processes, consistent standards, a reference architecture, information security and data privacy fit together to provide a coherent framework for smart grids as per the M/490 mandate.

In 2014, the CEN and CENELEC Technical Boards and the ETSI Technical Board approved a series of mandated reports covering an extended set of standards supporting smart grid deployment; an overview methodology and related annexes (general market model development, smart grid architecture model user management, flexibility management); smart grid interoperability and tool; smart grid information security.

Follow-up has focused on the standardisation gaps identified during phase 1 of M/490, with the aim also of providing best practice examples on smart grid specific use cases showing the applicability of existing and upcoming standards.

While the role of the SEG-CG is to advice on European requirements relating to Smart Energy Grid standardisation, the work of the Cyber Security and Privacy (CSP) working group is based on the results of the Smart Grid Information Security (SGIS) working group²⁶⁴, which have addressed cyber

²⁶¹ 5G and Energy, op cit., pp. 31-32.

²⁶² M/490 EN - Smart Grid Mandate - Standardization Mandate to European Standardization.

²⁶³ <https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx>.

²⁶⁴ SG-CG/M490/H_ Smart Grid Information Security (Phase 1)

security within the European Commission Smart Grid Mandate M/490.

To maintain consistency and promote continuous innovation in the field of smart grids, two reports were produced by the Coordination Group. These reports form the basis of the analysis of relevant standardisation provided in this Deliverable in relation to smart grids.

1. **Smart Grid Set of Standards Report 1**²⁶⁵: An updated framework of standards that can support smart grid deployment in Europe. The report sets out the most common smart grid systems and a relevant set of existing and upcoming standards for consideration from CEN, CENELEC and ETSI, as well as from IEC, ISO, ITU and other bodies. The report explains how the standards can be used, where and for what purpose. It also identifies additional gaps. The framework is designed to assist Member States, Smart Grid System Owners and others in specifying their smart grid solutions based on their own requirements and taking into account specific national legislation and local situations. The report is valuable from a Global5G.org perspective in providing a selection guide that sets out the most appropriate standards to consider based on the targeted system and layer, e.g. component layer, communication layer, information layer, thus serving as a reference for future monitoring of the 5G vertical industries selected for analysis.
2. **Coordination Group on Smart Energy Grids Cyber Security & Privacy**²⁶⁶: the report analyses security standardisation specific to Smart Energy Grid and security standardisation targeting generic standards with the focus on two use cases, **decentralised energy resource (DER)** and **substation automation**. It shows the applicability and interrelationship between these two groups of standards. It also shows the applicability of different standards on the selected, specific use cases for smart energy grid deployments.

Key points to note on Smart Grid Set of Standards Report 1:

- The smart grid represents a technical challenge beyond building infrastructure. The smart grid cannot reach its full potential if every company and country builds it based on different standards. Having a set of international standards ensures the smart grid can grow by relying on optimal compatibility and the ability of one system or device to communicate with others.
- Relevant standards and their maturity levels are categorised by: Transmission; Distribution; Distributed Energy Resources (DER); Customer Premises; Market; Administration and Cross-cutting.
- Most of the standards for building the smart grid are currently provided by the IEC, which aims to lower the barrier to international standardisation.
 - New standards are being added to the IEC portfolio on an on-going basis.
 - Relevant national or regional standards are brought into the international consensus process through a fast track system. This creates the demand for better transparency in IEC work, giving a better overview of which standards are already available and suitable for the smart grid and how they can be applied. Such an approach speeds up

<http://ftp.cen.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/Security.pdf> 1574 SG-CG/M490/H_Smart Grid Information Security (Phase 2)

http://ftp.cenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_SGIS_Report.pdf.

²⁶⁵, SEGCG/M490/G-version 4.1, CEN-CENELEC-ETSI Coordination Group on Smart Energy Grids (CG-SEG), January 2017,

http://ftp.cenelec.eu/EN/EuropeanStandardization/Fields/EnergySustainability/SmartGrid/CGSEG_Sec_0042.pdf.

²⁶⁶ CEN-CENELEC-ETSI Coordination Group on Smart Energy Grids (CG-SEG), Cyber Security and Privacy, December 2016,

http://ftp.cenelec.eu/EN/EuropeanStandardization/Fields/EnergySustainability/SmartGrid/CGSEG_CSP_Report.pdf.

implementation and avoids duplication of resources.

- The IEC System Committee Smart Energy SYC1 has come up with a multi-dimensional and interactive “Mapping Tool” on the smart grid, enabling smart grid managers around the world to quickly identify IEC and other international smart grid standards, positioning them in relation to technical components and systems, verifying the feasibility of workflows and use cases. The Mapping Tool is an open resource, helping reduce the complexity of building smart grids by simplifying the identification and application of smart grid standards²⁶⁷.
- Other relevant existing and on-going standardisation is taking place in standards bodies, such as: CEN/CENLEC; ETSI; ITU; ISO, as well as ENTSO-E; IEEE; IETF; OASIS; W3C. 3GPP Release 13 is also considered relevant.

8.5.3 Selected Standards for Smart Grid

The IEC Smart Grid Standardisation Roadmap²⁶⁸ provides an overview of its Standards Portfolio. Some of these are considered core standards for any implementation now and in the future, and which is expected to have considerable impact on any Smart Grid application and solution, thus providing the backbone of a future Smart Grid.

The following are considered core standards.

- **IEC 61970/61968:** Common Information Model (CIM). Applies mainly to Generation Management Systems (GMS); Energy Management Systems (EMS); Distribution Management Systems (DMS); Distribution Automation (DA); Substation Automation (SA); Decentralised Energy Resource (DER); Advanced Metering Infrastructure (AMI); Demand Response (DR); e-Storage.
- **IEC 62325:** CIM (Common Information Model) based, Energy market information exchange. Applies mainly to Generation management systems, EMS; DMS; DER; AMI; DR; meter-related back-office systems; e-Storage.
- **IEC 61850:** Power Utility Automation, Hydro Energy Communication, Distributed Energy Resources Communication. Applies mainly to Generation management systems, EMS; DMS; DA; SA; DER e-Storage; e-mobility.
- **IEC 62056:** Companion Specification for Energy Metering (COSEM). Applies mainly to DMS; DER; AMI; DR; Smart Home; e-Storage; e-mobility Data exchange for meter reading, tariff and load control.
- **IEC 62351:** Applies mainly to security for all systems.
- **IEC 61508:** Applies mainly to functional safety of electrical/electronic/programmable electronic safety-related systems.

Other relevant standards for smart grids include:

- **IEC 62357:** Power utilities Reference Architecture – SOA Applying mainly to EMS; DMS; DER operation systems, market & trading systems, DR systems, meter-related back-office systems.
- **IEC 60870-5:** Telecontrol. Applies mainly to EMS; DMS; DA; SA.
- **IEC 60870-6:** TASE2 Inter Control Center Communication. Applies mainly to EMS; DMS.
- **IEC/TR 61334:** “DLMS” Distribution Line Message Specification. Applies mainly to AMI.
- **IEC 61400-25:** Wind Power Communication. Applies mainly to DER operation systems (Wind farms); EMS; DMS.

²⁶⁷ <http://smartgridstandardsmap.com>.

²⁶⁸ IEC Smart Grid Standardization Roadmap - Prepared by IEC SMB Smart Grid Strategic Group (SG3) - 425 June 2010; Edition 1.0 – a new release prepared by the newly created IEC System Committee Smart 426 Energy should be available by beginning of 2017. A draft document (v3.0e) already circulated to IEC 427 National Committees in March 2016.

- **IEC 61851:** EV-Communication. Applies mainly to e-mobility; Home & Building management systems.
- **IEC 62051-54/58-59:** Metering Standards. Applies mainly to DMS; DER; AMI; DR; Smart Home; e-Storage; e-mobility.

8.5.4 Information Security Standardisation for the Energy Vertical

The CG-SEG CSP (December 2016) is used as a reference document for this initial analysis of security standardisation in relation to the energy vertical. The report aims to support smart energy grid implementation in Europe by providing analyses on standards and best practice examples on the applicability of these standards on energy grid deployments. The common base-line for the report's findings are SGIS key elements, namely the Smart Grid Architecture Model (SGAM) and the SGIS Security Levels (SGIS-SL)²⁶⁹.

The standards investigated are partially continuative actions and partially new standards. They are categorised in the SGAM to show their immediate applicability, and their relevance for product vendors, solution integrators, and operators to assist the architecture and solution designer in selecting the right standards to follow. Recommendations are provided both for identified gaps in standards and for the two main use cases: decentralised energy resource and secure substation automation.

Key points emerging from the CG-SEG CSP Report

- The reliability of a European Smart Energy Grid depends critically on the use of standards for dedicated security levels with regard to technical, organisational and procedural levels.
- Standards have been investigated based on their coverage at technical or operational level (interoperability is dealt with elsewhere, as discussed above).
- The **IEC 62443 security framework for industrial communication networks: network and system security** is a relatively complete framework of specifications. It covers specific requirements and side conditions of industrial and energy automation systems like high availability, planned configuration (engineering info), long life cycles, unattended operation, real-time operation, and communication, as well as safety requirements that must be considered when designing a security solution. The IT security requirements defined in IEC 62443 can be mapped to different automation domains, including energy automation, railway automation, building automation, process automation, and others. The framework has different stages of completion with some serving as basis for certification or assessment activities.

The CG-SEG CSP report applies this framework to the **substation automation use case** with the security levels of IEC 62443-3-3. Its combination with IEC 62351 allows a comprehensive protection concept on cyber security in the implementation and offers a reference model to address cyber security on system level.

An important gap identified is that privacy by design is currently not considered as design criteria in IEC 62443.

- Applying cyber security to smart energy grid deployments can provide substantial protection when built on international standards.
- Cyber security requires a continuous effort to incorporate existing and upcoming technologies, architectures, use cases, policies, best practice and other forms of security diligence, as highlighted in the ETSI TR report on the NIS Directive.

²⁶⁹ <https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx>.

8.6 Factories of the Future Standardisation

8.6.1 Drivers for Standardisation

In the factory of the future self-contained systems will communicate with and control each other cooperatively. Standards are essential for the successful implementation of Industry 4.0²⁷⁰ by providing a common language for ensuring the reliable and efficient interaction of very different systems in the smart factory. It is also important to promote cyber-physical systems, where digital information flows across company boundaries present a security challenge with regard to information-sensitive activities in the value chain. Cyber security as well as physical security will be a primary concern and key performance indicator in the factory of the future. Enabling technologies such as CPS and IoT will play a fundamental role in the adoption of a more flexible connectivity in the industrial value chain. As a result, the factory of the future will be highly modular and connected.

International consensus-based standards taking into account existing national and regional standards for industrial automation are an essential requirement as a wider market with solid standards will support the interoperability necessary for the expansion of replicable and more affordable technologies globally.

Industry-driven alliances aimed at accelerating the introduction of innovative technologies through industry standards will help transform the manufacturing industry. In Europe, the most prominent of these alliances is the German **'Plattform Industrie 4.0'**, which was established as a collaboration between major public and private initiatives in April 2015 to ensure Germany can harness the opportunities of Industrie 4.0²⁷¹. The goals of the German movement are now extended to the Vanguard Initiative through a political commitment at regional level aimed at using their smart specialisation strategy to boost new growth based on a bottom-up entrepreneurial innovation and industrial renewal in European priority areas²⁷².

Working groups: Plattform Industrie 4.0 has several working groups dealing with issues of standards and standardisation, security of networked systems, legal frameworks, research, and training. Collaborative work focuses on developing potential solutions and recommendations for action, as well as identifying meaningful examples showing how Industrie 4.0 applications can be successfully implemented.

Support for SMEs: Plattform Industrie 4.0 has developed one of the world's largest networks for the digitisation of industry, including the launch of Labs Network Industrie 4.0 initiative, which helps companies to get started on Industrie 4.0 by testing new technologies, and the Standardisation Council Industrie 4.0²⁷³ to accelerate standardisation efforts on Industrie 4.0 solutions.

International co-operation: As a global trend, Industrie 4.0 requires the development of joint standards and interoperability of different systems in global value chains based on consensus-building through the establishment of partnerships with other leading platforms around the world. Major steps on co-operation at EU and international levels include:

²⁷⁰ <http://www.bmwi.de/Redaktion/EN/Dossier/industrie-40.html>.

²⁷¹ <http://www.bmwi.de/Redaktion/EN/Dossier/industrie-40.html>. The initiative brings together the Federal Ministry for Economic Affairs, the Federal Ministry of Education and Research, the German Association of Energy and Water Industries (BDEW), the Federation of German Industries (BDI), BITKOM, the Association of German Chambers of Industry and Commerce (DIHK), the German Association of the Automotive Industry (VDA), the German Engineering Federation (VDMA), the Central Association of the Electrical Industry (ZVEI), academia (Fraunhofer Gesellschaft), standardisation organisations and trade unions.

²⁷² <http://www.s3vanguardinitiative.eu/>.

²⁷³ <https://sci40.com/de/home.html>.

- In July 2015, a memorandum of Understanding on Industrie 4.0 co-operation was signed by the respective government departments in Germany and China²⁷⁴. A joint working group on Industrie 4.0 standardisation has also been set up.
- In March 2016, co-operation with the Industrial Internet Consortium (IIC) based in the U.S. was initiated.
- In March 2016, a joint action plan with the French Alliance Industrie du Futur set out four areas of co-operation, including scenarios for Industrie 4.0 applications tailored to customer needs and the establishment of international testing centres.
- In April 2016, Germany adopted an agreement with Japan to encourage co-operation between companies in both countries and extend co-operation on international standards²⁷⁵. The joint action plan adopted by Plattform Industrie 4.0 and Japan’s Robot Revolution Initiative (RRI)²⁷⁶ supplements these efforts.

RAMI 4.0 – standardised Reference Architecture Model^{277,278,279}: Plattform 4.0 was at the heart of the development of RAMI 4.0, which combines the crucial elements of Industrie 4.0 in a three-dimensional layer model so Industrie 4.0 technologies can be classified and further developed. RAMI 4.0 provides orientation to stakeholders from a wide range of different areas as new standards are developed, and can support the process of consensus-based standardisation based on fair, transparent and open procedures both at national and international level.

The Industrie 4.0 Component²⁸⁰, which describes principles of Industrie 4.0, supports businesses and developers in the implementation of hardware and software. It is the first model based on the RAMI 4.0. RAMI 4.0 and the Industrie 4.0 Component²⁸¹ develop and combine the concepts of the automation sector. Taken together, they provide the basis for developing future products and business models.

RAMI 4.0 is linked to international standards IEC 62890. ISO/IEC 62264 (hierarchical arrangement of enterprise domains and automation system integration framework) and IEC 61512.

Standard	Standards Body	Purpose and Scope
IEC 62890:2016 (Draft)	IEC	Life cycle and value stream in RAMI 4.0. Life-cycle management for systems and products used in industrial-process measurement, control and automation

²⁷⁴ <http://www.bmwi.de/Redaktion/DE/Downloads/A/absprache-zwischen-bmwi-und-china.html>; in German.

²⁷⁵ <http://www.bmwi.de/Redaktion/DE/Downloads/J-L/joint-statement-on-cooperation-regarding-the-internet-of-things-industrie-4-0.html>.

²⁷⁶ <http://www.plattform-i40.de/I40/Redaktion/EN/News/Actual/2016/2016-04-05-aktionsplan-mit-japan.html>.

²⁷⁷

https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/ZVEI-Industrie-40-RAMI-40-English.pdf.

²⁷⁸ <http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/AreasOfAction/NormsAndStandards/norms-and-standards.html>.

²⁷⁹ RAMI 4.0 Status Report (July 2015),

https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/5305_Publikation_GMA_Status_Report_ZVEI_Reference_Architecture_Model.pdf.

²⁸⁰ <https://www.zvei.org/en/subjects/industry-4-0/the-reference-architectural-model-rami-40-and-the-industrie-40-component/>.

²⁸¹

https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/ZVEI-Industrie-40-Component-English.pdf.

		Scope This International Standard establishes basic principles for Life-Cycle-Management of products and systems focused on industrial-process measurement, control and automation. These principles are applicable to various industrial sectors.
ISO/IEC 62264 IEC 62264-1:2013 – Enterprise control system integration, Part 1: Models and Terminology (published) ²⁸²	ISO/IEC	Hierarchy Level in RAMI 4.0 IEC 62264 describes the manufacturing operations management domain (Level 3) and its activities, and the interface content and associated transactions within Level 3 and between Level 3 and Level 4. This description enables integration between the manufacturing operations and control domain (Levels 3, 2, 1) and the enterprise domain (Level 4). Its goals are to increase uniformity and consistency of interface terminology and reduce the risk, cost, and errors associated with implementing these interfaces.
IEC 61512 <ul style="list-style-type: none"> ▪ IEC 61512-1:1997, Batch Control – Part 1: Models and terminology ▪ IEC 61512-2:2001, Batch Control – Part 2: Data structures and guidelines for language ▪ ANSI/ISA-95.00.01:2000, Enterprise-Control System Integration – Part 1: Models and Terminology ANSI/ISA-95.00.02:2001, Enterprise-Control System Integration – Part 2: Object Model Attributes 	IEC	Hierarchy Level in RAMI 4.0 Defines a reference model for batch production records containing information about production of batches or elements of batch production. This standard is intended for batch processes.

In parallel with RAMI 4.0, the Industrial Internet Consortium (IIC) has developed its own Industrial Internet Reference Architecture (IIRA v1.7, 2015)²⁸³. Recognising the complementary nature of the two models, the IIC with its cross-domain approach and Plattform 4.0 with its roots in the

²⁸² <https://www.iso.org/standard/57308.html>.

²⁸³ <http://www.iiconsortium.org/IIRA-1-7-ajs.pdf>.

(ECISO) has identified standards and schemes on IT standards and schemes for Industry 4.0 and Industrial Control Systems in a recent publication on cyber security standards across domains²⁸⁸. Selected national, European and international standards and frameworks are summarised in the table below, with some discussed in more detail as a starting point for the Global5G.org Standards Tracker.

Standards and Schemes for products used in Industry 4.0 and ICS, including cyber security		
Standard/Scheme	Body	Geographical coverage
ISA/IEC 62433 (Security for Industrial Automation and Control Systems) ²⁸⁹²⁹⁰	ISA/IEC	International
IACS Cybersecurity Certification Framework (proposed) ²⁹¹	JRC	Europe
Standards and schemes for service providers and organisations: Industry 4.0 and ICS		
Standard/Scheme	Body	Geographical coverage
ISA/IEC 62433 (Security for Industrial Automation and Control Systems) ²⁹²²⁹³	ISA/IEC	International General ICS
ANSSI Cybersecurity for Industrial Control Systems ²⁹⁴	ANSSI	France General ICS
BSI ICS Security Compendium ²⁹⁵	Bundesamt für Sicherheit in der Informationstechnik (BSI) – Federal Agency for Security in IT	Germany General ICS
International Frameworks		
NIST SP 800-82: Guide to Industrial Control Systems (ICS) Security	National Institute of Standards and Technology (U.S.)	International

The French Cyber Security Agency **ANSSI**²⁹⁶ is the official national body for cyber defence, network and information security (NIS). It issues regulations and verifies their application, provides monitoring, alerts and rapid response, with a priority on government networks. Its working group on cyber security in ICS, which comprises stakeholders from automated industrial process control systems and specialists in IT3 security, provides pragmatic measures for system vulnerabilities in Industry 4.0 based on a straightforward methodology illustrated by real situations²⁹⁷. The guidelines aim to limit cyber-related damages and safeguard the continuity of core business functions to an acceptable extent.

The **BSI ICS Security Compendium** covers several architectural, technical and organisational best practices for ICS asset owners. The best practices are measures proven to work in practice and can be derived from standards, in terms of:

- Security-specific processes and/or policies.

²⁸⁸ ECISO, State of the Art Syllabus: Overview of existing cyber security standards and certification schemes v2, December 2017, <http://www.ecs-org.eu/documents/uploads/updated-sota.pdf>.

²⁸⁹ <https://webstore.iec.ch/searchform&q=62443>.

²⁹⁰ <http://www.isasecure.org/en-US/>.

²⁹¹ <https://erncip-project.jrc.ec.europa.eu/networks/tqs/european-iacs>.

²⁹² <https://webstore.iec.ch/searchform&q=62443>.

²⁹³ <http://www.isasecure.org/en-US/>.

²⁹⁴ https://www.ssi.gouv.fr/uploads/2014/01/industrial_security_WG_Classification_Method.pdf

²⁹⁵ https://www.ssi.gouv.fr/uploads/2014/01/industrial_security_WG_detailed_measures.pdf.

²⁹⁶ https://www.bsi.bund.de/SharedDocs/Downloads/EN/BSI/ICS/ICS-Security_compendium.html.

²⁹⁷ <http://www.ssi.gouv.fr/en/>.

²⁹⁷ <https://www.ssi.gouv.fr/guide/la-cybersecurite-des-systemes-industriels/>.

- Selection of the used systems and components as well as of the assigned service providers and integrators.
- Constructional and physical securing.
- Technical measures.

Examples of related standards include IEC 62443 and ISO 27001, as well as ISO 62351 (power systems management and associated information exchange – data and communications security), a multi-part specification of security measures for communication protocols in the ICS industry, developed by IEC.

The compendium also describes a methodology for performing audits in ICS installations but does not include an evaluation scheme though TÜVIT provides security checks and penetration tests designed to help reduce security vulnerabilities in production infrastructure.

ISA/IEC 62433 (Security for Industrial Automation and Control Systems) is an international standard for ICS security in the operational technology domain initiated by ISA (International Society of Automation) and being further developed by IEC.

The standard applies to all types of factories/plants, facilities and systems in all industries, including:

- Hardware and software systems, e.g. Distributed Control Systems (DCS), Programmable Logic Controllers (PLC) and Supervisory Control and Data Acquisition (SCADA) systems.
- Associated interfaces, APIs or HMIs used to provide control, safety and manufacturing operations.
- Continuous, batch and discrete processing systems.

The standard comprises four groups corresponding to the primary focus and intended audience: general (topics common to the entire series); policies and procedures (associated with IACS security); systems requirements; component requirements (elements providing information about more specific and detailed requirements associated with the development of IACS products). Some of the standards are technical reports, i.e. not formal standards and with no binding requirements.

NIST SP 800-82: Guide to Industrial Control Systems (ICS) Security provides guidance for securing industrial control systems (ICS) through the development and deployment of an ICS security programme; integrating security into network architectures and the implementation of the security controls from NIST SP 800-53. The document is not intended to be used purely as a checklist to secure a specific system. It encourages risk-based assessments of systems and tailor the recommended guidelines and solutions to meet specific security, business and operational requirements.

9 Cross-cutting Issues for 5G and Vertical Industries

9.1 Security, Privacy and Trust

Security and privacy are cornerstones for 5G to become a platform for the networked society, driving new requirements due to new service delivery models with new business and trust models, in an evolved threat landscape with increased concerns around security. Security and privacy are transversal across the new verticals that are expected to benefit from 5G, with new security permeating all parts of the supporting infrastructures²⁹⁸.

The analysis of vertical industries points to the increasing importance of security, privacy and trust as we move towards the mission-critical/ultra-reliable low-latency communications rollout phase. Their critical importance for 5G was also highlighted by ETSI CTO, Adrian Scrase at URLLC 2017.

²⁹⁸ ETSI Security Week, 12-16 June 2017, <http://www.etsi.org/etsi-security-week-2017>.

Forthcoming EU legislation, most notably the NIS Directive and GDPR) will further reinforce their role in network and IT services. The former applies to Operators of Essential Services (OES) and Digital Service Providers (DSP); the latter to any organisation dealing with the data of EU citizens. The stakes for the telecom and vertical industries are very high indeed, especially where an operator and critical infrastructure are both part of the same equation.

The underlying EU values of the NIS Directive and GDPR represent an important opportunity for the industry if it can roll out timely security-as-a-service solutions based on risk-management approaches and compliance levers. Trusted brands and eminence will play key roles in this respect. These opportunities not only include vertical markets in the era of Industry 4.0 but also, potentially, the important SME market segment, and particularly so as 5G deployments progress from phase 1 to phase 2.

The Directive on the security of Network and Information Systems (NIS Directive), (Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July), focuses on strengthening cyber authorities at the national level, increasing coordination and introducing security requirements for key industry sectors. Member States are required to transpose the Directive into national law by 9 May 2018. Legal and technical requirements cover the sharing of information and network based risks and incidents, necessary defence measures, and incident notifications. After May 2018, member states have six months to designate critical infrastructures. ETSI TR 103 456 V1.1.1 (2017-10)²⁹⁹ provides useful indications for a harmonised implementation of the NIS directive across network and service sectors and member state legal and operational environments, bearing in mind the applicable technical and legal requirements.

Cyber security must be included as a built-in characteristic of 5G networks, due to the pervasive presence of 5G in every sector of our highly connected future. However, enforcing security measures cannot eliminate risks altogether. Therefore, risk assessment, and risk mitigation are necessarily at the basis of 5G policy. Critical infrastructures must be systematically protected: already in 2008, the European Programme for Critical Infrastructure Protection (EPCIP) identified energy and transport as the top priority critical infrastructures to be protected, in the Council Directive 2008/114/EC³⁰⁰.

For example, following the NIS Directive, any presumed attack to the energy infrastructure will need to be reported to the Computer Security Incident Response Teams (CSIRTs), a competent national NIS authority for several sectors, and a national cyber security information security. Due to the borderless nature of potential attacks a cooperation framework among Member States is set up to support strategic and operational coordination.

The new EU legislation was one of the main discussion points during ETSI Security Week 2017, looking at the most appropriate standards to address the legal and technical requirements of the NIS Directive, and the obligations under the General Data Protection Regulation, as well as the proposal for a Regulation on Privacy and Electronic Communications Code. Security is as vitally important in all segments³⁰¹. In this respect, it is important to prioritise new types of threats introduced by the virtualisation of network functions and the means to mitigate them, as well as carefully investigate future challenges of securing 5G networks and shaping related standards.

Work within the 5G PPP Security Work Group provides a foundation for identifying and addressing security risks and requirements, captured in the white paper 5G PPP Phase 1 Security Landscape (June 2017), with contributions from nine Phase 1 projects³⁰². The paper covers major 5G security

²⁹⁹ http://www.etsi.org/deliver/etsi_tr/103400_103499/103421/01.01.01_60/tr_103421v010101p.pdf

³⁰⁰ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0114&from=EN>

³⁰¹ <http://www.etsi.org/etsi-security-week-2017/standards-legislation>; presentations, https://docbox.etsi.org/Workshop/2017/201706_SECURITYWEEK/01_STANDARDSandLEGISLATION.

³⁰² <http://5gensure.eu/files/5g-pppwhite-paperphase-1-security-landscapejune-2017pdf>; 5G-ENSURE, 5G-Ex,

requirements and risks; 5G security architecture and how it fits with that of the 3GPP; access control in 5G; privacy in 5G; trust in 5G; security monitoring and management; slicing; standardisation on 5G security, while also identifying several areas for future research directions. Industry and research perspectives on 5G security progress and priorities are captured in the 2017 open consultation, the findings of which have been communicated across the 5G PPP and beyond³⁰³.

Preliminary plans for the 5G PPP Security WG in phase 2 include:

- An updated white paper with contributions from phase 2 projects covering new security needs and proposed approaches.
- A white paper dedicated to vertical security/safety covering potential new liability schemes and trust relationships between actors.
- Actions to drive common work in terms of a cartography on existing security standards to cover, security risks to be addressed and the evolution of 5G architecture, considered to be fundamental for the progress of the Security WG (5GIA)³⁰⁴.

The table below provides an overview of currently identified requirements and challenges in three vertical industries based on initial findings for this report.

Factories of Future: Requirements	Challenges
<p>Factories of the Future is one of the most demanding verticals in terms of ultra-low latencies, ultra-high availability, reliable indoor coverage in adverse environments, as well as energy-efficient and ultra-low communications costs for produced, connected goods.</p> <p>A complete Industry 4.0 project requires different segments working together. Security is therefore vitally important and needs to be accounted for in all segments.</p>	<p>Current technologies for Factories of the Future lack capabilities for security and trust. Key security and safety requirements include:</p> <ul style="list-style-type: none"> ▪ Avoiding new vulnerabilities in mission-critical processes that could affect the overall guaranteed uptime and throughput of machines. ▪ Guaranteeing security in the connected factory: resource-constrained connected sensors and components not capable of providing adequate encryption and decryption algorithms. ▪ Heterogeneity of platforms makes security challenging because of the number of distributed components (several tens of thousands of nodes). ▪ Compliance with safety integrity levels defined in standards, e.g. IEC 61508. ▪ Meeting industry-specific requirements for the safe functioning of machines and devices in a wide range of environmental conditions. ▪ Compliance with climatic conditions (dust, humidity, temperature, etc.), mechanical conditions (shock, vibration) and intrinsic safety conditions, e.g. limiting power consumption to avoid

5G-NORMA, CHARISMA, COGNET, SONATA, SPEED-5G, SELFNET, and VirtuWind.

³⁰³ <https://5g-ppp.eu/newsletter-11-2/#lien4>.

³⁰⁴ 5G PPP SEC WG Face-to-face meeting, October 2017, Turin.

<p>Automotive: Requirements Guiding principles including issues of security, data privacy and data protection are provided in the C-ITS platform report³⁰⁵ with follow-up recommendations (by GEAR 2030 High Level Group HLG):</p> <p>Data Protection and Privacy: The introduction of 5G will enable significant increase in the volume and variety of shared data in the automotive ecosystem. Access to this data must be done within agreed privacy boundaries and protect against potential threats from exposure of private data.</p> <p>Recommendations on data privacy and protection in the context of V2X from the C-ITS Platform WG4 on Data Protection & Privacy are aimed at ensuring a sound level of data protection and privacy when V2X is deployed.</p> <ul style="list-style-type: none"> ▪ Ensuring “informed consent” from the driver, providing an opt-out possibility to be offered to the drivers, authorising the drivers to shut down the data broadcast/sharing (while fully informing them about possible adverse consequences). ▪ For V2X road safety and traffic management applications where a "vital or public interest" is at stake and demonstrated, a limited number of applications can process the data without drivers' explicit consent, provided that the legal basis to process the data and those applications are strictly defined, and the data collected are not further processed or re-purposed beyond those applications. <p>Security³⁰⁶: Requirements to support a secure and safe deployment of V2X in Europe include</p> <ul style="list-style-type: none"> ▪ Identification and definition of the roles 	<p>explosions.</p> <p>Challenges</p> <ul style="list-style-type: none"> ▪ New concerns around security, privacy and trust due to the increased connectivity and automation in vehicles. ▪ Socio-economic impacts of cyber-attacks as illustrated by high-profile hacks, which in one case³⁰⁷ demonstrated how the hackers can take control of a car's engine, transmission, sensors, GPS, radio, and even climate controls. ▪ Changes in the way transport and vehicle data are operated (and serviced). Access to this data will change the way services are proposed to customers and enable actors of the automotive value chain (both current and new) to develop new services and business models and create additional value for users and society. ▪ Security assurance is crucial now with 5G becoming a more critical infrastructure (compared to preceding mobile generations) for applications including automotive³⁰⁸.
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³⁰⁵ C-ITS Platform, Final Report, January 2016
<https://ec.europa.eu/transport/sites/transport/files/themes/its/doc/c-its-platform-finalreport-january-2016.pdf>. In Europe, the Platform for the Deployment of Cooperative Intelligent Transport Systems in the European Union (C-ITS Platform) was created by the European Commission services (DG MOVE) in November 2014 with the clear intention to help support the emergence of a common vision across all actors involved in the connected vehicle value chain.

³⁰⁶ C-ITS WG5 on Security & Certification.

³⁰⁷ R. Kam, “Connected cars: security and privacy risks on wheels,” IAPP, February 2016
<https://iapp.org/news/a/connected-cars-security-and-privacy-risks-on-wheels/>.

³⁰⁸ Ericsson, “5G Security: Solutions and Scenarios” Ericsson white paper Uen 284 23-3269, June 2017
<https://www.ericsson.com/assets/local/publications/white-papers/wp-5g-security.pdf>.

<p>of the entities at European level to support the deployment and operations of V2X in Europe (e.g. roles within a European C-ITS security credential management system or within the compliance assessment process).</p> <ul style="list-style-type: none"> ▪ Addressing gaps in standardisation activities for the noted gaps (e.g., revocation of trust). ▪ A time plan for the design and deployment of the security elements of an EU wide V2X. 	
<p>Energy: Requirements</p>	<p>Challenges</p>
<p>Identified areas where action should be taken to improve cyber security and risk management in the energy sector as a critical infrastructure³⁰⁹, including compliance with the NIS Directive. Dealing with increased risks when 5G networks serve critical infrastructures like energy grids as attractive targets for cyber-criminals and potential for substantial socio-economic impacts. Requirement for measurable security assurance and compliance to verify the presence, correctness and sufficiency of security functions³¹⁰. Users in the energy sector will need reassurances about the deployment of a virtual machine on a given piece of hardware, security testing applied to software, adequate protection of data in the form of isolation and efficient transport of protected (encrypted/authenticated) data. The trend towards decoupling software and hardware in cloud-controlled networks means that telecom software can no longer rely on the specific security attributes of a dedicated hardware platform. Standardised interfaces to computing/network platforms, such as those defined by ETSI NFV work, are necessary to ensure a manageable approach to security. Stronger isolation properties will be a requirement for operators that increasingly host 3rd-party applications in their telecom clouds executing on the same hardware as native telecom services.</p>	<p>Significant challenges facing the energy sector in ensuring secure energy systems that provide essential services to European society, and in protecting data in energy systems and the privacy of European citizens:</p> <ul style="list-style-type: none"> ▪ Grid stability in a cross-border interconnected energy network. ▪ Protection concepts reflecting current threats and risks. ▪ Introduction of new highly interconnected technologies and services. ▪ Outsourcing of infrastructures and services. ▪ Integrity of components used in energy systems. ▪ Increased interdependency among market players. ▪ Handling of cyber-attacks within the EU. ▪ Effects of cyber-attacks not fully considered in the design rules of existing power grids or nuclear facilities. ▪ Availability of human resources and their competences. ▪ Constraints imposed by cyber security measures in contrast to real-time/availability requirements.

³⁰⁹ Cyber Security in the Energy Sector Recommendations for the European Commission on a European Strategic Framework and Potential Future Legislative Acts for the Energy Sector, February 2017, https://ec.europa.eu/energy/sites/ener/files/documents/eecsp_report_final.pdf.

³¹⁰ 5G security – scenarios and solutions; Ericsson, June 2017, <https://www.ericsson.com/en/publications/white-papers/5g-security-scenarios-and-solutions>.

<p>Increased privacy concerns: Impacts from failure to protect customer data are apparent in the TalkTalk breach. The protection of personal data within the EU framework is a discussion point within 3GPP, IETF and other forums. Work within Phase 1 has aimed to address user privacy and is now part of the standardisation process for 5G³¹¹. However, compliance with GDPR raises the bar with respect to earlier generations and calls for specific measures to be put in place.</p>	
<p>Perspectives from the 5G PPP Security WG (Phase 1 and Phase 2 projects)³¹²:</p> <p>VirtuWind (Phase 1): adoption of virtualisation and softwarisation technologies for industry control network has required a careful investigation into new security threats and risks, risk assessment and analysis of security requirements. Definition and analysis of two security use cases as representative scenarios in industrial networks. Design of a virtual and programmable architecture with some components which will be developed in Phase 2 related to Proactive & Reactive Security Mechanisms, Security Manager module, AAA functionality and Secure Interfaces, drawing also on 5G PPP results on security.</p> <p>NRG5 (Phase 2): Enabling smart energy as a service via 5G Mobile Network Advances. Identification of three main use-cases for extensive 5G deployment: Smart Grid application (mission-critical), advanced metering (massive deployment) and EV charging. Addressing need for stringent security, resilience and availability as requirements intrinsic to the smart energy vertical.</p>	

Table 35: Security and Privacy Requirements in Vertical Industries

The need for security assurance in 5G networks implies the need to undergo similar certification standards as those used by the automotive sector (e.g. compliance with ISO 26262 for functional safety), which do not have fully overlapping compliance requirements (with conventional 5G certification). This might have some implications on the costs incurred in developing the 5G networks that are also used for automotive verticals. However, 5G-related developments, such as, network slicing are considered as a solution to provide isolated sub-networks or slices that enable confining of security assurance demands of critical automotive applications to individual slices (rather than the whole network). An illustrative example could be conceived from the figure below, whereby, network slicing could be used as a mechanism to segment critical and non-critical applications to reduce/eliminate attacker's ability to affect the vehicle's critical components³¹³.

³¹¹ On this privacy issue, see the work of 5G-ENSURE and its enablers, <http://5gensure.eu/security-enablers>, particularly Device-based Anonymisation.

³¹² 5G PPP Security WG F2F Meeting, October 2017, Turin, Italy.

³¹³ Ericsson, "5G Security: Solutions and Scenarios" Ericsson white paper Uen 284 23-3269, June 2017 <https://www.ericsson.com/assets/local/publications/white-papers/wp-5g-security.pdf>.

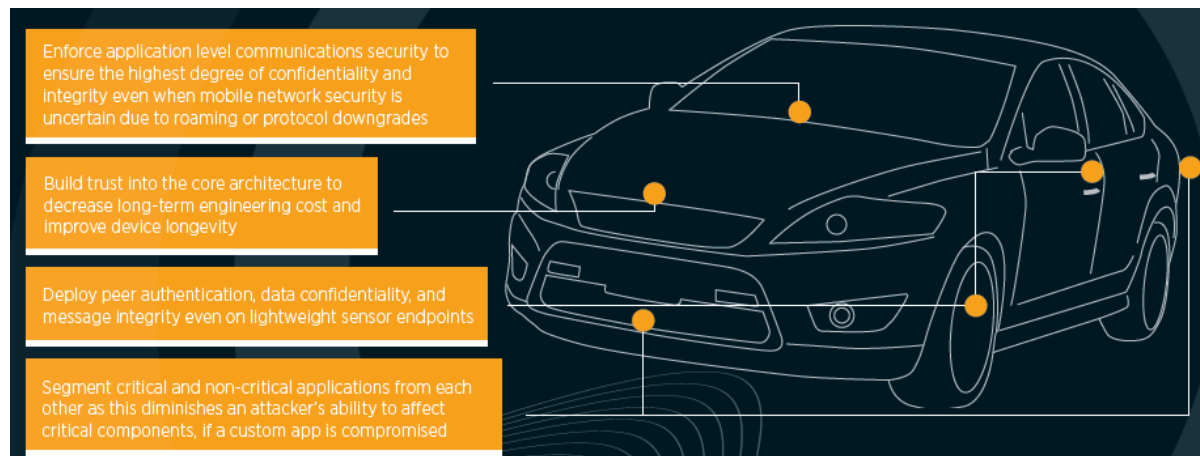


Figure 29: Example automotive security strategies [Source: GSMA]³¹⁴

New Trust models

Trust is a response to risk. A decision to trust someone (or something) is a decision to accept the risk that they will not perform as expected. To manage risk in a socio-technical system such as a mobile network we need to understand what trust decisions are being made, the consequences of those trust decisions and we need information on the trustworthiness of other parties to make better decisions.

New business models and new domains of operation in 5G networks facilitated by network function virtualisation (NFV) and software defined networking (SDN) bring increased dynamicity compared to 4G and an increase in the number of stakeholders and associated trust relationships. New relationships bring new risks that must be understood, and controlled. In a system as complex as 5G this implies the need for a trust model which can model the system, highlight potential risks and demonstrate the effect of adding controls or changing the design.

For current mobile systems, the trust model is straightforward, involving a subscriber (and their terminal) and two operators (the home and serving networks). But 5G will give rise to extended requirements in areas such as authentication between various actors, accountability and non-repudiation. Devices have so far been assumed to comply with standards and not to deliberately attempt to attack networks. But how well protected are very low-cost devices? Could a single connected device be used as a stepping stone for cyber-attacks deep into the system? And what is the attack surface of a 5G system with billions of inexpensive, connected devices? To ensure that 5G can guarantee sufficient security, the trust model map must be redrawn to take account of these new end-point characteristics.

In the 5G context there can be certification authorities that are used to assure the correct operation of network elements or functions. For instance, different VNFs can be certified, so that the infrastructure provider can have some certainty as to the trustworthiness of the functionality that might be externally introduced into their infrastructure, for instance, by VMNO. It still needs to be determined whether the certification authorities (and relevant testing laboratories) are industry bodies, such as GSMA, or some other entities. The GSMA-based approach seems to be at least adopted in 3GPP when they have been considering the certification aspects of network elements through their Security Assurance Methodology (SECAM).

³¹⁴ GSMA, "Automotive IoT Security: Countering the most common forms of attack," GSMA white paper, March 2016 <https://www.gsma.com/iot/automotive-iot-security-countering-the-most-common-forms-of-attack/>.

The C-ITS WG5 on Security & Certification has investigated the main security aspects, which must be addressed to support a secure and safe deployment of V2X in Europe. Recommendations include

- A common trust model all over Europe shall be deployed to support full secure interoperability at the European level and common certificate policy of the trust model.
- Appropriate legislative framework to be set in place quickly to support V2X deployments.

Initial steps within the 5G PPP to define a trust model for 5G have been made by 5G-ENSURE³¹⁵, an initial version of which is covered in the 5G PPP SEC WG Phase 1 whitepaper. The main conclusions for the Trust Model are that in the most general case, trust dependencies in 5G networks will be extensive. We speculate that vertical applications will seek to isolate themselves (using virtualisation) from many of the concerns identified here, so in practice most 5G networks can manage with a subset of our trust relationships. The main findings were presented to the GSMA FSAG Working Group on Trust in December 2017, while further work continues on dissemination within the industry.

9.2 Policy and Regulations

An important lesson from 2G, 3G and 4G technologies is that the mobile industry is more successful when it avoids fragmentation in spectrum, technology and operator services. It is therefore important that fragmentation is minimised and that operator services are included in the standards from the onset to achieve maximum scale benefits.

5G will add a new level of complexity to policymaking and regulation as new business models emerge and old ways of delivering goods and services either dramatically alter or disappear. Such transformations require re-examining and perhaps even modifying current rules to ensure a favourable policy framework for essential investments by the industry.

Given the heavy investment required to deliver 5G and provide reliable connectivity for all, it is important for policymakers to provide a transparent and predictable pro-investment and pro-innovation policy framework. Key to this is supporting regulatory modernisation as a key precursor to the 5G era. Ultimately, the way 5G is developed, regulated, funded and commercialised will determine the future of the mobile industry.

Policymaking will be affected at all levels of government – national, state/provincial and local. The pervasiveness of 5G technology and the pace of technology change place an even greater burden on policymakers to keep up with 5G transformations in daily lives and across industries. The outcome of these deliberations will have a significant impact on some of the potential applications of 5G. For example, in the energy sector, applications involving ultra-reliable/mission-critical connectivity.

The 5G-ready world calls for policy and regulation modernisation. Public safety, cyber security, privacy, public infrastructure, healthcare, spectrum licensing and permitting, small cell permitting, education, training, and development are just some of the areas for policy and regulation modernisation.

A summary of the key findings for the verticals shows that they will all be affected by policy and regulation. Examples for healthcare and factories of the future are provided.

Healthcare: There are different regulatory policies needed to underpin development in healthcare, ranging from issues such as transparency, data ownership, privacy, data exchange, permissions around offering of services, and liability issues.

³¹⁵ 5G-ENSURE, D2.5 Trust Model (Final), last update February 2018, http://5gensure.eu/sites/default/files/5G-ENSURE_D2.5%20Trust%20model%20%28final%29%20v2.2%20inc%20history.pdf.

Also, the implementation of smart pharmaceuticals depends on resolving several regulatory issues. Regulatory authorities need to incentivise the use of smart pharmaceuticals for clinical studies. Data has been collected electronically for years by using patient self-reports and electronic measures. Moving to smart pharmaceuticals to monitor prescription adherence and clinical conditions' progression should make the studies more reliable, reducing the level of subjectivity and uncertainty.

Factories of the future: In recognising the significant impact smart manufacturing can have for economic growth, many countries have set up initiatives to coordinate efforts and accelerate the transition to digitised factories of the future.

To facilitate the development of Smart Factories and to fully exploit their potential, there is a need for a specific regulatory framework to suitably address liability issues and privacy concerns. Public administrations should also take action investing in the education of the next generation of workers who must have the needed digital skills and expertise to maximise the impact of new technologies.

Beyond the verticals but also key to their deployment are the following areas calling for the modernisation of policy and regulation.

- Net neutrality, the idea that Internet service providers should provide access to all services without favouring specific providers, has been adopted as a strong principle by European regulators, both on a regional level and by national regulatory authorities (NRAs). The emergence of network slicing in 5G networks will require some re-thinking of the assumptions underlying net neutrality. Network slices are virtual instances of the network, each providing performance characteristics to applications that need them in to function correctly. Are each of these virtual instances to be considered as networks in their own right, from the standpoint of net neutrality? If not, do they violate net neutrality, by requiring minimum resources from the physical network? Without the ability to support service-level agreements, 5G networks will be unable to service the requirements of mission-critical applications in the energy sector, so regulators must work to reconcile this capability with the net neutrality principle.
- As a means of mitigating the cost of building and operating networks, sharing of parts of the infrastructure by several network operators has been a feature of the mobile industry for more than a decade. Network sharing agreements range from sharing masts and towers, through sharing of facilities such as power and backhaul, to sharing of the radio access network (RAN) itself. In each case, the network-sharing agreement needs regulatory approval, and in considering whether to approve, the regulator needs to balance the benefits of network sharing for the operators (and thus, indirectly, for their customers) with the need to preserve the strength of competition in the market. 5G networks will use higher-frequency spectrum than previous generations of network. This is likely to increase the cost of coverage rollout, because of the shorter distance over which high-frequency signals propagate, and because they penetrate into buildings less well than lower-frequency signals. Thus, to facilitate the rollout of 5G networks as rapidly as possible, regulators will need to re-examine their stance on network sharing, to consider whether there is scope for moving to a more favourable attitude.
- The radio frequencies being considered for 5G networks include those in the millimetre (mm) wavebands (26GHz and above). Although these frequencies can carry very large amounts of data, signals propagate over very short distances and are completely blocked by solid obstacles such as walls. As such, millimetre wave spectrum will be used for deploying very high capacity in localised areas of need, rather than for providing coverage over a wide geographical area. However, licences to use spectrum for mobile networks are currently awarded on a national basis, typically with minimum coverage requirements. Regulators will need to consider modifying their approach to spectrum licensing for mm wave bands, to account for the more localised nature of this spectrum. Regulators may also consider the

possibility of licensing mm wave spectrum, in consortium or perhaps even solely, to players who are not public mobile network operators. An energy company, for example, might be interested in having control over access to some mm wave spectrum in areas where network performance is especially critical and where there is limited public need for access to the spectrum, such as around a drilling rig.

GSMA has also stressed the importance of wise spectrum management and policies. Fair and transparent spectrum regulation creates an environment that is conducive to investment, and ensure the expansion of next-generation mobile networks and services. This includes:

- Greater certainty and predictability over future rights of use.
- Greater consistency among Member States over approaches to awards.
- The right balance between licensed spectrum and general authorisations, and between exclusive and shared.
- Predictable license conditions.
- Spectrum fees limited to ensuring efficient and effective use, and reflecting extended coverage commitments.
- Freedom to compete and differentiate through voluntary sharing and under competition
- **Small Cell Deployments:** complex and lengthy procedures for telecom installation permits represent an important barrier to the successful rollout of 5G (as extensively analysed in the Small Cells deployment regulatory issues study, see Deliverable 3.1). GSMA has three broad requirements for the creation of the Gigabit Society:
- Regulation based on function rather than structure – look at what is being provided rather than who is providing it.
- Regulation should not be set in stone but dynamic and flexible.
- New thinking – regulators should regulate only when the benefits exceed the cost.

10 Next Steps

Having analysed the four vertical industries in the overall 5G context, standardisation and cross-cutting issues, Global5G.org will now intensify its activities around stakeholder engagement. Core activities include:

- Interacting closely with 5G PPP projects dealing with one or more of the four vertical industries, as well as the industries directly.
- Identifying tangible benefits of 5G use case deployments, particularly within the 5G PPP; clarify any cross-cutting policy, privacy and security issues, and potential implications for trust in new scenarios.
- Determining the capabilities that distinguish the use cases/pilots as 5G deployments.
- Classifying high-level use case requirement across the four verticals relevant for 5G standardisation.
- Pinpointing current contributions to the standardisation process, in synergy with the 5G PPP Pre-Standardisation WG.
- Providing a cartography of relevant standards for the four verticals, including interactions with the 5G PPP (IA) Security WG, which plans a similar activity on security requirements. This activity will take on board the recent 5G security specifications from 3GPP SA3 (announced 05.03.2018).

- Liaising with the 5G PPP Trials WG on vertical mapping activities and share relevant outcomes from engagement with the four verticals.
- Sharing relevant requirements on requirements from energy and health to 3GPP SA1 to help fill current gaps.
- Monitoring the overall 5G landscape, trials and test-bed usage, vertical industries, standardisation, privacy, policy and security issues.
- Analysing vertical application domains that would benefit from 5G and associated challenges in the context of the 5G PPP Vision and Societal Challenges WG.

Overall, Global5G.org fosters cross-fertilisation with all relevant 5G PPP WGs to ensure results feed into the work plans in a timely manner and further boost collaborative efforts.

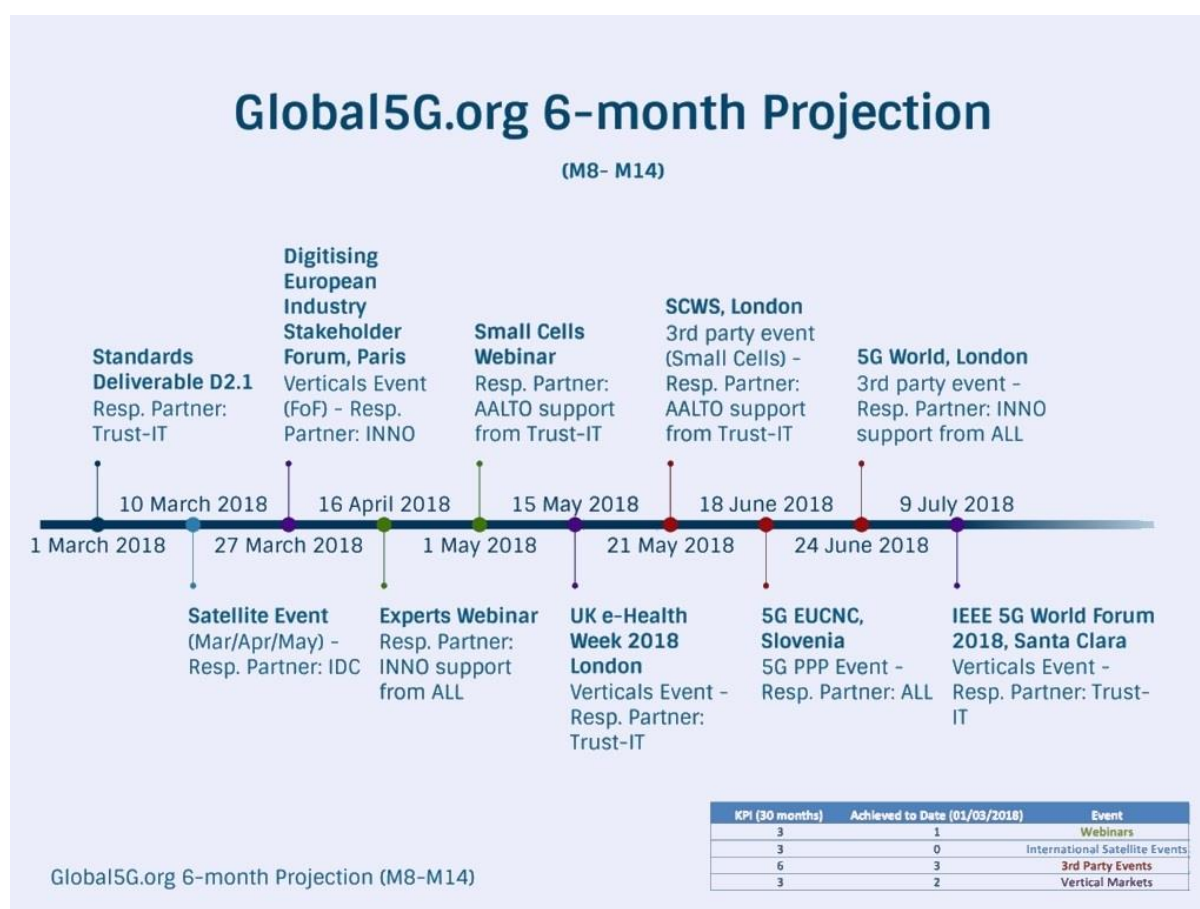


Figure 30: Summary Timeline for Global5G.org short-term Activities