5G Demand and Future Business Models

Towards a Feasible 5G Deployment

Discussion paper and survey

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ensuring connectivity

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Executive Summary

Timely availability of 5G must be a priority in order to meet the emerging demand from enterprise and consumers. Collective efforts from all stakeholders is paramount to ensure that the Telecommunications industry is not burdened with an investment that does not deliver incremental returns on the provision of services until such time when enterprise and consumers are ready and willing to use and pay for 5G services. This is of particular relevance to Malta, where Gigabit fixed broadband targets will be met on a nation-wide basis in the next few months.

Amongst the European member states, Malta is unique because of its small geographical size. The country boasts three nation-wide 4.5G networks and infrastructure roll-outs that have typically fulfilled their nation-wide criteria within 12 to 24 months from spectrum awards. Some operators already have 5G-ready RAN as part of their technology refresh. Traditionally national award procedures have not focused on an auction process, noting that sufficient spectrum meeting the telecommunications industry's demands has always been made available and that supply generally exceeds demand registered. The applicability of traditional pricing methodologies is also being reviewed within the context of 5G.

5G promises to be significantly more than merely an enhancement of 4G. 5G is the first generation of cellular connectivity designed with the intent of addressing the vertical industry, including Healthcare, Automotive, Energy, Public Services and Utilities, Manufacturing and Logistics and Agriculture. This new generation of cellular connectivity may act as a catalyst for digital transformation, delivering faster, more reliable, ubiquitous hyper-connectivity. It is envisioned that 5G and the resulting digital transformation can be an enabler over which Artificial Intelligence, Machine Learning, Virtual Reality and Big Data Analytics can transform all sectors of our economy and society. Specifically, 5G is being identified as one of the pillars of Intelligent Connectivity.

For the commercial deployment of 5G to be successful it must be sustained by commercially-feasible business models that can lead to the fruition of the 5G verticals. Even though in mainland Europe some operators are already claiming commercial deployment of 5G, there is still uncertainty as to which products and services will the customers be willing to pay for and when will these services be available.

This report summarises published information about uses and applications which identify 5G as an enabler and is intended to further stimulate the discussion towards a feasible 5G deployment.

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List of Abbreviations

3GPP	3rd Generation Partnership Programme (telecommunications)
5G	Fifth Generation of Mobile Communications
5GAA	5G Automotive Association
AI	Artificial Intelligence
AR	Augmented reality
C-ITS	Cooperative Intelligent Transport System
C-V2X	Cellular Vehicle-to-Everything
CPS	Cyber-Physical Systems
eMBB	Enhanced Mobile Broadband
EU	European Union
IoT	Internet of Things
ITU	International Telecommunications Union
KPI	Key Performance Indicator
LTE	Long Term Evolution
mMTC	Massive Machine Type Communications
NFV	Network function Virtualisation
NSA	Non-Stand-Alone
PPDR	Public Protection and Disaster Relief
SA	Stand-Alone
SDN	Software Defined Networking
UHD	Ultra High Definition
URLLC	Ultra Reliable and Low Latency Communications
VR	Virtual Reality

1. Defining 5G[1]

1.1 The Digital Transformation's reliance on Intelligent Connectivity

Artificial Intelligence (AI), Machine Learning, Virtual Reality (VR), Big Data Analytics, Internet of Things (IoT) are but a few of the technological jargon making today's headlines. These technologies, although in some cases may appear unrealistic or borderline sci-fi are nonetheless the ones which will reshape our society and the economy over the next few years. They shall improve what we already do, stimulating a faster digital transformation.

A key driver for the transformation of the digital economy through connectivity lies at the intersection of emerging technologies enabling automation, namely AI, and IoT[2] with enhanced connectivity. **Intelligent connectivity** is the combination of **hyper connectivity** - connecting anything, anywhere, anytime, over ultra-high speed and low latency connectivity with these advanced automation technologies. AI and Big Data Analytics all rely on the collection of data to be fed into intelligent processes that optimize or automate various aspects of our lives. Case in point is mobility, which is expected to become safer via intelligent connectivity, potentially improving the quality of modern life with the deployment of Intelligent Transport Systems that will ultimately lead to fully autonomous driving. Fully autonomous vehicles depend on the capability of sensing the surroundings and communicating the evaluated telemetric data with other vehicles and the road side infrastructure. Creating technologies which achieve human-like reflexes, essential for achieving a Vision Zero[3] future, necessitates low latency infrastructure. The European Commission's proposed approach to enable connected and automated driving throughout the European Union (EU), recognises the importance of connectivity to enable a truly smart traffic management for the smoothest and safest traffic flows[4]. In fact the European Commission considers connectivity, cooperation and automation as intertwined elements in the digital transformation of the transportation sector as stated in COM(2018) 283:

[1] This document presents a non-exhaustive literature review gathering the insights of various key entities in the 5G ecosystem including amongst others ITU and BEREC. The information presented is an objective representation of the current state of play of 5G and its verticals in the international context and is not a reflection of the national regulatory and market development context.

[2] "Intelligent Connectivity: how the combination of 5G, AI and IOT is set to change the Americas," https://www.gsma.com/IC/wp-content/uploads/2018/09/21494-MWC-Americas-report.pdf

[3] The Vision Zero sets a stringent target of having no road fatalities on European road by 2050. From: White Paper: Roadmap to a Single European Transport Area, COM(2011) 144

[4] "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions: On the road to the automated mobility: An EU strategy for mobility of the future," COM(2018) 283 final

"As of 2020, 5G connectivity infrastructure is equally expected to be an important enabler of connected and automated mobility as well as empower innovative digital ecosystems around cars."

While fully autonomous vehicles may not be commonplace in the near future, digitisation has already started in various aspects of society. Digitisation is expected to result in cost-efficient productive factories leading to the Industry 4.0. Industry 4.0, sometimes referred to as 'factories of the futures[5]', relies on collaborative robots, integrated manufacturing and logistics. But neither automation nor remote monitoring and control of a production line will materialize without the deployment of reliable communications infrastructures. It is the wireless communications infrastructures which will allow the sharing of information of connected machinery, enable intelligent warehouse management system or facilitate maintenance of machinery remotely.

Hyper-connectivity will transform cities into intelligent spaces often referred to as smart cities, addressing modern day challenges facing an ageing population, traffic congestion and environmental concerns. A study commissioned by the European Commission identifies the following benefits as a result of the roll-out of 5G and its effect on four particular verticals (automotive, healthcare, transport and utilities) in smart cities[6]:

a. Economic Benefits:
    - Transport improvements and reductions in congestion resulting from both better road traffic management, coordination of different transport modes and real-time information allowing drivers to avoid congested areas.
    - Better information on accident black spots, crime hot spots, pollution and other factors that can be processed and studied for better policy making and mitigation measures by administrators.
b. Societal Benefits:
    - Enhanced Social Capital[7]
    - Assisting an ageing population by improving mobility and facilitating independent living
c. Environmental Benefits:
    - Reduced congestion will result in a decrease in the hydro-carbon consumption, lowering pollution and reducing CO_2 emissions.

[5] 5G PPP, '5G empowering vertical industries" https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

[6] "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe" Final Report ISBN 978-92-79-58270-7

[7] Social Capital as defined by the Office for Economic Cooperation and Development (OECD) is "networks together with shared norms, values and understanding that facilitate co-operation within or among groups" https://www.oecd.org/insights/37966934.pdf

- Better living environment from the mitigation of noise and air pollution, particularly for those with asthma and bronchial diseases.

Without the possibility of connecting any device which can either generate or collect data to then be intelligently instructed to react, Digital Transformation will remain a Sci-Fi concept. This will require not only the ability to connect anything, anywhere but also wireless connectivity that can deliver a fibre-like network i.e. ubiquitous Gigabit Speeds, improved performance and reliability.

1.2 The Fifth Generation of Mobile Systems, 5G

In view of the shift from wireless communications systems designed to solely connect people to systems designed for the coexistence of human-centric and machine-type communications, future Mobile Networks must be capable to cater for a vast number of new use cases. For this reason the ITU has defined a new Generation of Mobile Networks, IMT2020, the fifth generation of Mobile Systems, simply referred to as 5G. In this regard the ITU plays a key role at managing the global harmonization of the radio-frequency spectrum via its Radiocommunications Sector (ITU-R) and standards for 5G.

5G enables the following three main use cases as defined by the ITU as shown in Figure 1:

1. **Enhanced Mobile Broadband (eMBB)** – an enhanced user experience addressing the ever increasing demand for Mobile Broadband from human-centric applications
2. **Massive Machine Type Communications (mMTC)** - the provision of a network consisting of a large number of connected telemetric monitoring devices.
3. **Ultra-reliable and low-latency communications (URLLC)** - innovative applications that require instantaneous reaction or the execution of mission critical applications remotely.

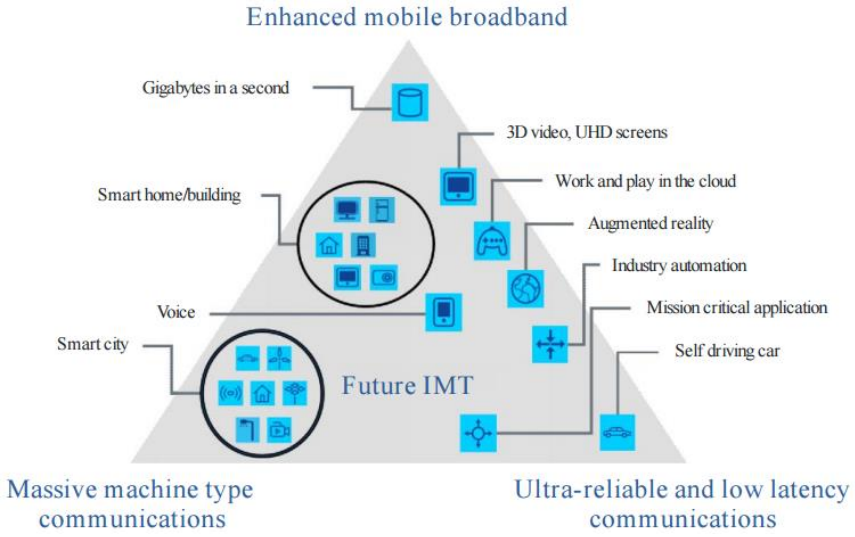

Figure 1 - Usage Scenarios for IMT for 2020 and Beyond (ITU-R M.2083-0)

The ITU has specified 8 Key Performance Indicators (KPIs) that 5G mobile networks should be able to attain[8]. The KPIs, shown in Figure 2, were purposely defined to create a standard, IMT-2020, that can address the new requirements posed by emerging applications:

- Enhanced data rates
- Lower Latency
- Lower Energy Consumption
- Support a larger and more diverse set of devices

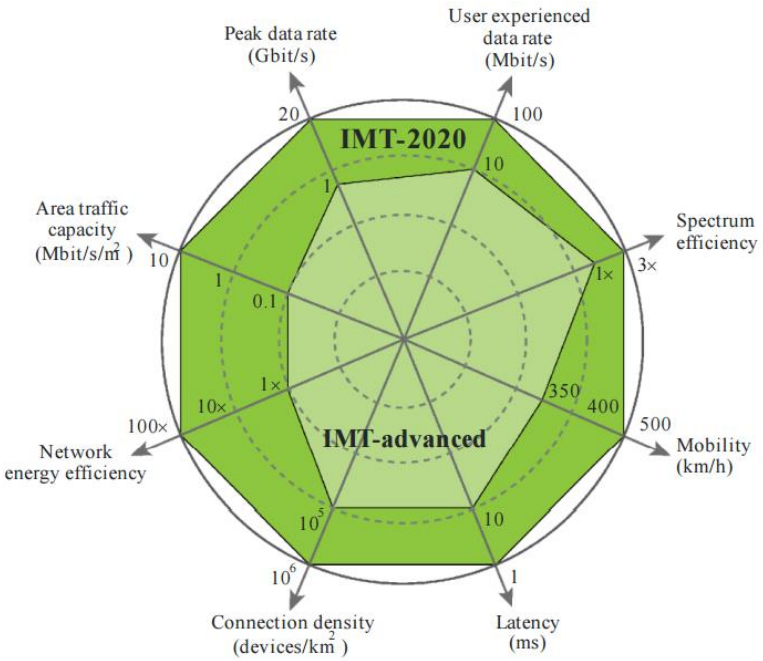

Figure 2 - Enhancement of key capabilities from IMT-Advanced (4G) to IMT-2020 (5G)

In order to reach these KPIs**,** 5G mobile networks require the use of new spectrum bands, the deployment of ultra-dense networks consisting of a massive number of small cells together with additional supporting technical developments.

The development of 5G is mainly driven by its verticals and where possible, it should deliver results that match those of the next generation fixed networks.

5G is not meant just to be an evolutionary development of 4G as the focus is not on solely improving the network but on developing a network that can cater for a number of verticals[9]. Although, 4G may be able to cater for emerging digital innovations, it may not have the capability to deliver all the needs for a full digital experience that society will eventually expect

[8] ITU-R M.2410-0 (11/2017), "Minimum Requirements related to technical performance for IMT-2020 radio interface(s)"

[9] The verticals which are considered are Automotive, Transport, Healthcare, Manufacturing, Logistics, Agriculture, Smart Cities, Media and Entertainment.

and demand. 5G promises to realise this, by providing a differentiation of services with the economic advantage of not requiring the deployment of different physical networks. The new network management possibilities will enable a single physical network to support a number of **virtual networks** with different performance characteristics. Different services falling within one of the three use cases (eMBB, mMTC and URLLC) will pose unique requirements on the network. While the transmission of Ultra-High Definition Video will require more bandwidth, a network of sensors will prioritise energy consumption. On the other hand autonomous driving will demand low latency. Table 1 tabulates the KPIs which each of the three different use cases will prioritize. Thus service differentiation is made possible by new technologies such as network slicing[10], Network Function Virtualization and Software Defined Networks.

Table 1 Key Performance Indicators which each use case will prioritize

Use Case	Key Performance Indicators
eMBB	User experienced data rate, Peak data rate, Spectrum Efficiency, Mobility, Network energy efficiency, Area Traffic Capacity
mMTC	Latency, Connection Density
URLLC	Latency, Mobility

1.3 Timeline

3GPP is a consortium formed by seven regional telecommunications associations as its primary members that develop specifications for the cellular connectivity including GSM, UMTS and LTE. 3GPP shall be submitting final specifications to the ITU-R Working Party 5D[11]. These will act an input to the standard that the ITU will publish.

3GPP Release 15, the first 3GPP specifications to be labelled “5G”, defines two deployment options, which are the “Non-Stand-Alone” (NSA) architecture and the “Stand-Alone” (SA) architecture. The NSA architecture is also known as "E-UTRA-NR Dual Connectivity (EN-DC)" or "Architecture Option 3". It uses the 5G Radio Access Network, referred to as New Radio (NR) with the 4G Radio and 4G Core i.e. the existing LTE and Evolved Packet Core infrastructure Core Network. This means that 5G-based radio technology is possible without network replacement offering 4G services with the enhanced capabilities of 5G radio. The

[10] “Network slicing allows the operator to provide customised networks. For example, there can be different requirements on functionality (e.g., priority, charging, policy control, security, and mobility), differences in performance requirements (e.g., latency, mobility, availability, reliability and data rates), or they can serve only specific users (e.g., MPS users, Public Safety users, corporate customers, roamers, or hosting an MVNO).
A network slice can provide the functionality of a complete network, including radio access network functions and core network functions (e.g., potentially from different vendors). One network can support one or several network slices.” Source: 3GPP TS 22.261 V15.7.0 (2018-12)

[11] Working Party 5D (WP 5D) is responsible of the overall radio system aspects of International Mobile Telecommunications (IMT) systems comprising the IMT-2020, IMT-Advanced and IMT for 2020 and beyond, Source: https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/default.aspx

SA architecture on the other hand uses the NR and the 5G Core Network supporting the full set of 5G Phase 1 services[12].

Release 15 will consist of three steps which as specified by 3GPP are[13]:

- 'Early' drop: contains Non-standalone 5G specifications (so called Option-3 family), ASN.1 frozen in March 2018;
- 'Main' drop: contains Standalone 5G (so called Option-2), ASN.1 frozen in September 2018;
- 'Late' drop: contains additional migration architectures (so called Option-4, Option-7, and 5G-5G dual connectivity), ASN.1 to be frozen in June 2019

The first 5G deployments will use Release 15 of September 2018 and thus have the option of either NSA or SA architecture. eMBB was made possible even with 'Early' drop, as with this architecture the 5G NR Carriers can be used to boost data rates and reduce latency[14]. mMTC and URLLC will be possible with Release 16 which is now projected for March 2020 as tabulated in Table 2.

[12] 3GPP, TR 21.915 V0.6.0, Release 15 Description, Summary of Rel-15 Work Items

[13] "RAN adjusts schedule for 2nd wave of 5G specifications", Balazs Bertenyi, Dec 2018, http://www.3gpp.org/news-events/3gpp-news/2005-ran_r16_schedule

[14] "5G-NR workplan for eMBB," D. Flore, Mar. 2017 http://www.3gpp.org/news-events/3gpp-news/1836-5g_nr_workplan

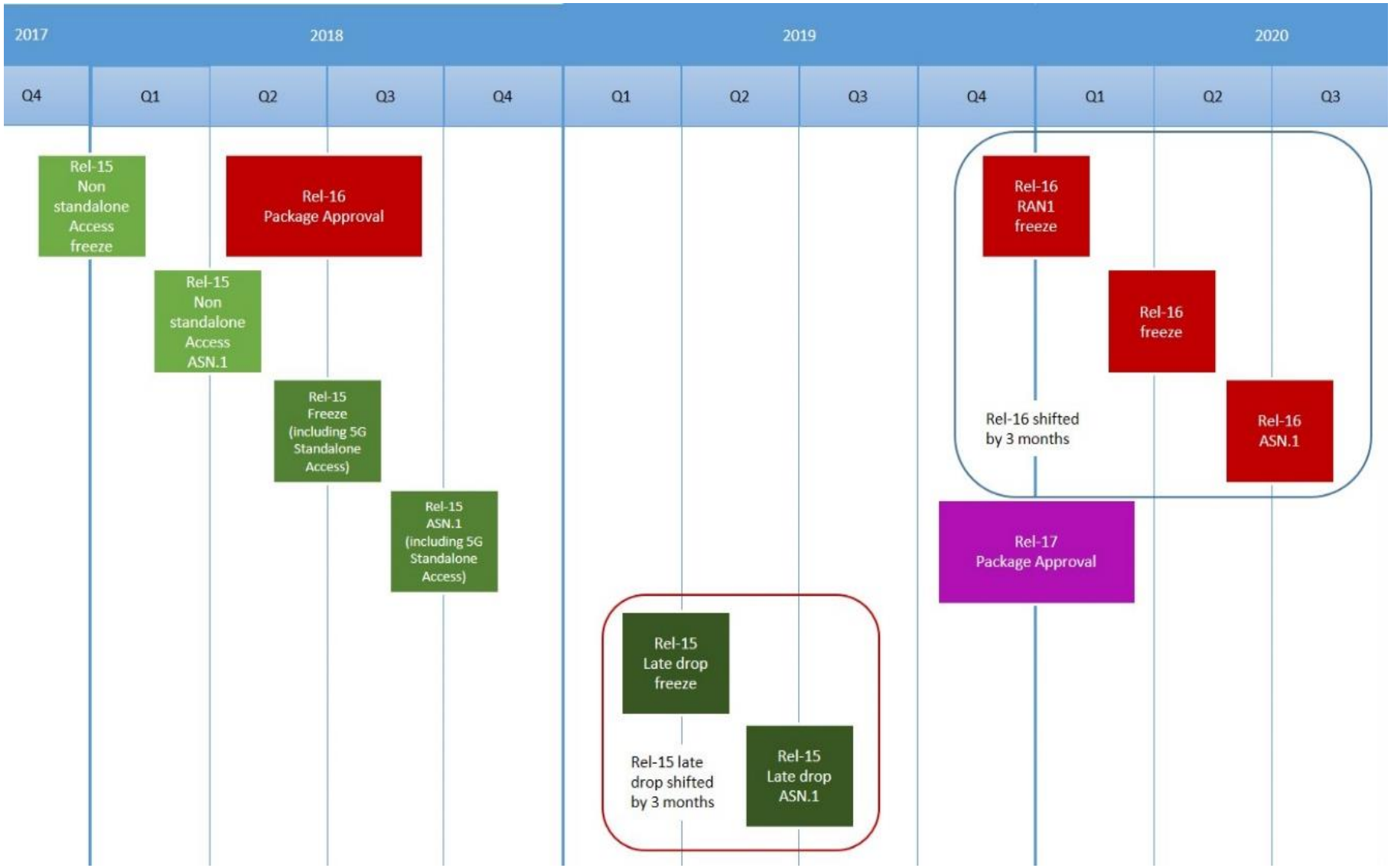

Figure 3 - Timeline for 3GPP Release 15 and Release 16[13]

Table 2 - Timeline for the availability of the 3GPP Standard for each 5G use case

Use Case	3GPP Standard	Due Date
eMBB	Release 15, Early and Main Drop	Sept 2018
mMTC	Release 16	March 2020
URLLC	Release 16	March 2020

The ITU-R WP 5D is the official standards organization for IMT-2020. Candidate Radio Interface Technologies and Set of RITS submissions including those by 3GPP will be evaluated at a meeting to be held during the second quarter of 2019.

With regards to 5G handsets, it is expected that the first 5G-ready handsets will be launched during the second quarter of 2019[15,16,17]. Ericsson[17] predict that:

> "5G will take off in 2019 and 2020 will be the year in which 5G enters the mass market"

[15] "5G: The new network arrives" https://www2.deloitte.com/insights/us/en/industry/technology/technology-media-and-telecom-predictions/5g-wireless-technology-market.html
[16] "5G Phones" https://5g.co.uk/phones/
[17] "Ericsson Mobility Report", November 2018

2. 5G Verticals

The 5G standard will define the technical specifications to cater for the requirements of three different uses cases: eMBB, mMTC and URLLC. The requirements of the use cases collectively cover a much wider spectrum of communications characteristics than any of the previous generations of cellular connectivity, i.e. 1G to 4G. The reason being that while the previous cellular network sought to address the needs of humans to communicate with each other either via text, voice or data, 5G seeks to enable Intelligent Connectivity. This promises to address the needs of different sectors of the Industry, extending the business case of 5G to new vertical industries which are referred to as the 5G Verticals. The 5G verticals as listed by 3GPP are[18]:

- Automotive and other transport (trains, maritime communications)
- Transport, logistics, IoT
- Discrete automation
- Electricity distribution
- Public Safety
- Health and wellness
- Smart cities
- Media and entertainment

The 5G use cases (eMBB, mMTC and URLLC) will address different needs for each vertical industry as shown in Figure 4.

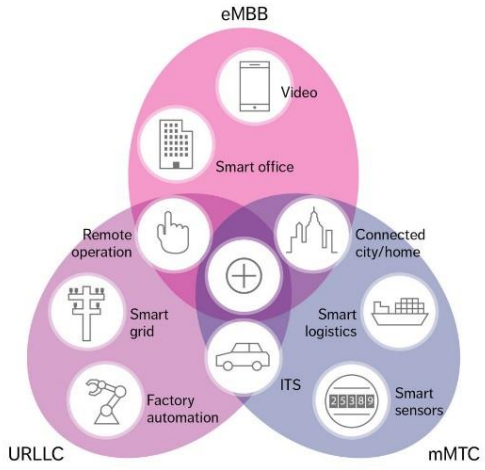

Figure 4 - The 5G use cases and possible applications[19]

[18] 3GPP, TR 21.915 V0.6.0, Release 15 Description, Summary of Rel-15 Work Items

[19] "Evolving LTE to fit the 5G future" https://www.ericsson.com/en/ericsson-technology-review/archive/2017/evolving-lte-to-fit-the-5g-future

The development of the various 5G verticals, promises to address today's and tomorrow's societal pains such as urbanization[20], ageing population, climate change and efficient resource consumption. It is however being claimed that this will only be possible with fibre-like wireless communications systems. The verticals will evolve over time until the full potential of 5G is reaped. Thus in the beginning, 4G and 4.5G will be sufficient but eventually, 5G may become a must and not an option, depending on whether the society demands more out of the 5G verticals and cellular connectivity.

Although 5G is designed to cater for three different uses cases – eMBB, mMTC, URLLC – the first use case to be realized will be eMBB. Part of the reason is due to the fact that the first release of 3GPP for 5G systems will only cater for eMBB. But this is also market driven, since it has been observed that video consumption is consistently increasing and is in fact a significant contributor to data traffic[21]:

> "Traffic growth is driven by both the rising number of smartphone subscriptions and an increasing average data volume per subscription, fuelled primarily by more viewing of video content."

Ericsson predict that by the end of 2024, video consumption will account to 74 percent of traffic. During this time, the average data consumption per smartphone is predicted to be 21GB per month[22].

A review of what is being claimed to be possible by eMBB, highlights that eMBB may be useful to create gigabit hotspots i.e. high-speed mobile broadband both indoors and outdoors. It can also be combined with modern broadcasting developments such as 'omniview' options, giving the viewers the option to for example select from which on-site camera they would like to view a race[23]. Moreover, the amalgamation of eMBB with Augmented Reality (AR) and VR promises to radically transform the media and entertainment sector providing new immersive experiences. While 4G can enable infotainment services, one must consider whether it will continue to be a suitable solution once demand

- 5G can first be deployed where existing networks experience frequent network capacity saturation.
- Gigabit Hotspots will provide ultra-high resolution content. This is the typical envisioned eMBB use case as the increase in traffic demand resulting from both the transmission of high quality video and the device density may necessitate the use of 5G.

[20] The degree of urbanisation in urban areas in Malta is the highest in the European Union with, at 89.5 https://ec.europa.eu/eurostat/cache/RCI/#?vis=degurb.gen&lang=en

[21] "Ericsson Mobility Report Q4 2018 update", November 2018, https://www.ericsson.com/en/mobility-report/reports/q4-update-2018

[22] "Ericsson Mobility Report", November 2018

[23] "First mover service providers outline 5G use case insights" March 2018, https://www.ericsson.com/en/news/2018/2/5g-user-case-insights

increases and requirements on device density, mobility and data throughput become more stringent. Also, eMBB is seen as a solution for areas where existing 4G networks are saturated or as a last-mile solution.

On the other hand mMTC will facilitate the monitoring, control and automation in various sectors, including manufacturing, logistics and healthcare. From logistics to utilities, from homes to cities, from urban to rural, mMTC will connect low-power sensors to enable the collection of telemetric data to be processed intelligently either by humans or exclusively by machines. Applications may include but not limited to asset tracking, smart homes and smart agriculture.

URLLC is the most futuristic of all three use-cases delivering intelligent automation which will become mainstream as AI and Machine Learning reach technological maturity and widespread adoption. AI and Machine Learning are expected to reach their technological maturity during the 5G era[24] through the low-latency wireless communications enabled by 5G.

[24] "The 5G era: Age of boundless connectivity and intelligence automation", GSMA intelligence, 2017 https://www.gsmaintelligence.com/research/2017/02/the-5g-era-age-of-boundless-connectivity-and-intelligent-automation/614/

2.1 The Digital Transformation that 5G can enable

5G may transform a number of sectors which are crucial to the efficient functioning of the European Union i.e. Healthcare, Automotive, Energy, Public Services and Utilities, Manufacturing and Logistics. Whilst the discussion presented below clearly highlights that the digital transformation of these verticals at the moment doesn't depend solely on 5G, 5G promises to be the technology that will allow other emerging technologies such as AI, AR, VR to radically transform our society and economy. As the introduction and the uptake of 5G is an evolutionary process, 5G may initially replace services that can be implemented with existing technologies. The transition to 5G is considered as both a risk and an opportunity as emergent use cases develop and deliver incremental revenues that could not have otherwise been achieved using the existing mobile technologies.

Healthcare

Some of the use cases observed during industry events which 5G may enable include:

- **Telemonitoring**; Remote monitoring of patients or elderly using wireless devices, decentralising the healthcare system. This provides new opportunities for monitoring and relaying medical information to healthcare providers. This will enrich the healthcare system by reducing the number of hospital or clinical visits and shortening the period when patients must be kept under observation. It will also free resources for those patients that can't be treated or monitored remotely. Telemonitoring use cases focus on enhancing the efficiency and efficacy of the health care systems while reducing the operational expenditure.

  Remote monitoring can also provide ***smarter medications*** i.e. the administration of medication immediately when required. It will stimulate Big Data analysis, where treatment can be analysed more in depth with the possibility of collecting more data. Drug interaction in non-trial scenarios can be better monitored and studied.

- **Connected Ambulances** which allow ambulances to transmit vital data to the hospital. Besides transmitting telemetric information, connected ambulances will transfer high definition video[25]. The advantage of this is that the paramedics can provide the information to the medical staff team at the hospital, in order to ensure that the theatre is prepared before the arrival of a patient in a critical unstable medical condition. Improving the communication between the paramedics and the staff at hospital, can augment the diagnosis made during the "golden hour"[26] leading to the

[25] "Demonstrating medical emergency ambulance services over next-generation 5G mobile networks." Dell EMC and Red Zinc, https://extendedcampus.cit.ie/contentfiles/casestudies/DellEMC%20and%20RedZinc.pdf

[26] The initial period during an emergency when the prompt medical and surgical treatment will increase the likelihood of the patient's survival.

application of the required medical treatment[27]. On the other hand, it has also been suggested that in a significant amount of the cases patients can be treated on the spot[27].

- **Teleconsultation** involving remote video-based medical consultation for both doctor to patient and doctor to doctor. The latter is useful to connect clinics, homes for the elderly and hospitals.

- **Remote Surgery** will allow specialists to assist in operations remotely especially in cases where the patient is in a remote or dangerous location and requires the immediate attention of specialists. The specialists will carry out the operations using received video footage of the patient, a console through which the specialist will simulate the operation and robotic arms with surgical tools to carry out the operation at the remote location. Moreover, there has already been research[28] to augment this via VR and Haptic technology providing the surgeon with the sense of touch. It has been stated that[29]:

  > "Besides the high cost, the major limitation factor that hinders the current robotic system to become the standard technique of minimally invasive surgery worldwide is the lack of effective haptic feedback including force (kinaesthetic) and tactile (cutaneous) feedback."

  The mission-critical nature of remote surgery imposes stringent constraints on data speed, latency, jitter, packet loss and security. Haptic feedback requires a latency of less than 10ms and a packet loss rate of less than 0.1%[29] It is imperative that the communication, both ways, is uninterrupted and caters for a 'zero perceived delay'.

Automotive

Proponents of 5G claim that this new generation of cellular connectivity may potentially enable a number of new services which will radically transform mobility as we know it, including the enablement of intermodal use of different means of transport such as ferries and buses. According to the 5G Automotive Association (5GAA)[30], a global association of companies from both the telecommunications and automotive industries, Cellular Vehicle-to-

[27] "Smart ambulances: the hi-tech future of accident and emergency healthcare", http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/star/index_en.cfm%3Fp%3Dsf-20160225-saepp&calledby=infocentre&item=Infocentre&artid=38377

[28] "Access to remote healthcare specialists" https://www.ericsson.com/en/cases/2017/kings-college/kings-healthcare

[29] "Towards 5G Enabled Tactile Robotic Telesurgery," Q. Zhang et al, Mar. 2018, arXiv preprint arXiv: 1803.03586

[30] "5GAA is pushing for the Cellular Vehicle-to-Everything (C-V2X) technology – technology that helps making roads safer while also laying the groundwork for fully automated vehicles" http://5gaa.org/news/5g-automotive-association-at-ces-2019-highlighting-connected-mobility-through-5g/

Everything (C-V2X)[31] is to improve road safety eventually leading to fully autonomous vehicles. Services include:

- **Parking management systems** which can indicate the availability and location of free parking spaces. This will require the use of connected sensors that can sense the status of parking spaces to either display the amount of parking spaces in an area using monitors that are part of the road-side infrastructure or by informing drivers directly of the location of potential parking spaces via smartphone applications.

- **Intelligent traffic systems** can include various services such as Hazard Warning, Public Transport Prioritization, and Intersection Assistance. This could also enable the synching of traffic lights with ambulances to further increase road safety and support the healthcare sector in carrying out their duties.

- **Monitoring and law enforcement** that can monitor vehicles to intelligently detect breaches and issue enforcement measures to the respective drivers. Moreover, it will enable incident detection and management to facilitate a quicker response.
  This will require a platform that can perform both video and image processing fed data from various cameras. Wireless connected cameras will provide the additional flexibility with regards to the installation location as it doesn't depend on the existing available wired connectivity or the laying of new fixed infrastructure. It is being envisioned that 5G may then provide the economic advantage of transmission of video and images over wireless cellular networks.

- **Cooperative, Connected and Automated Mobility**[32]: 5G may bring to fruition various changes to mobility which can decrease road fatalities. Human error is estimated to factor in 94 per cent of the accidents[33]. Thus automated driving should increase road safety. Moreover, it has been quantitatively proven that seamless and reliable connectivity will augment traffic conditions reducing traffic congestions[34]. Once traffic is decreased, carbon emissions and fuel consumptions are lowered providing a key environmental advantage.

[31] Cellular Vehicle-to-Everything refers to the use of cellular connectivity such as 4G and 5G to enable vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-pedestrian and vehicle-to-network communication.

[32] Five level of Automated Driving are defined. Level 1 and 2 provide assistance to the driver. Level 3 is referred to as conditional automation, where the driver must be in a position to resume control, although not expected to monitor the system continuously. Level 4, referred to as High Automation, will require that the driver takes control only is specific situations. Level 5, Full Automation, does not require a driver to be present.

[33] "Commission's report on Saving Lives: Boosting Car Safety in the EU," COM(2016) 787. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016DC0787

[34] "Connected and Automated Vehicles on a freeway scenario. Effect on traffic congestion and network capacity," Makridis. M, et al., April. 2018, https://ec.europa.eu/jrc/en/publication/connected-and-automated-vehicles-freeway-scenario-effect-traffic-congestion-and-network-capacity

It is foreseen that the Automotive Vertical will disrupt the market in such a manner that self-driving cars will lead to car-sharing models replacing the vehicle ownership model. Therefore autonomous driving, will enable 'Mobility as a Service'[35,36] (selling rides, not cars). Society will see a shift by which, instead of owning a car, you use and pay for the car when and for how long you need. With the eventuality of driverless vehicles and car-sharing becoming mainstream, urban planning will be improved as existing parking spaces will be freed up.

A decision has been adopted by the European Union on the regulatory framework for Cooperative-Intelligent Transport Systems (C-ITS), which favours IEEE 802.11p, also known as ITS-G5 over cellular connectivity. Whilst, this may shed doubt on whether 5G will be used for Intelligent Transport Systems and Cooperative, Connected and Automated Mobility, one must bear in mind that the European Commission has made available funding for the testing of 5G across cross-border corridors including through its 5G-PPP and Horizon 2020 funding[37, 38, 39, 40]. Even Member States themselves have given importance to this use case particularly Germany[41]:

"Other funding programmes address applications where 5G plays a central role. This applies, for instance, to the A9 Digital Motorway Test Bed programme for the trails of automated and connected driving."

Energy

- **Smart Grids** refers to the introduction of intelligent-connectivity to the grid i.e. connecting the possible devices to be monitored and controlled, enabling better management of the energy generation. Given the importance of energy provision, smart grids require ultra-reliable and secure networks. While this can depend on full-fibre fixed connections, wireless connectivity may be a cheaper solution to connect energy-consuming devices to accurately monitor and enhance demand-side management to support load balancing, reduce electricity peaks and reduce energy

[35] "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe" Final Report ISBN 978-92-79-58270-7

[36] "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions: On the road to the automated mobility: An EU strategy for mobility of the future," COM(2018) 283 final, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0283&from=EN

[37] ICT-18-2018 – 5G for cooperative, connected and automated mobility (CCAM), https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-18-2018

[38] 5GCROCO: https://5gcroco.eu/

[39] 5G-CARMEN: https://www.5gcarmen.eu/

[40] 5G-Mobix: www.5g-mobix.com

[41] "5G Strategy for Germany", The Federal Government

costs. Downtime can be reduced as real-time diagnosis of a power failure will be possible.

- **Smart Metering** is useful to provide consumers information on their consumption in real-time. Given the instantaneous availability, the expected effect of smart metering is a reduction in costs, as customers will pay more attention to efficient usage. The advantage of smart meters over manual readings is accurate billing.

Public Services and Utilities

Governments can leverage hyper-connectivity to develop services that improve both the well-being of citizens and drive economic growth. These can include for example the use of **Intelligent Street Lightning** which adapt to the intensity of natural light, the deployment of sensors to monitor pollutions to develop better policies or smart surveillance to provide citizens with peace of mind but also to ensure the compliance with national law and safeguarding against act of vandalisms on national heritage sites.

Smart surveillance is an example of how intelligent connectivity may drive developments in other sectors. The deployment of wirelessly connected video cameras will increase the need for cybersecurity applications to ensure that such devices are not susceptible to attacks. Moreover, smart surveillance will require video and image processing to facilitate face recognition or the extraction of vehicle registration plates.

5G can provide an enhanced communications network for Public Protection and Disaster Relief (PPDR) thanks to the Mission Critical Push to Talk, Mission Critical Video and several other new features included in the 3GPP family standards as per the PPDR community's needs[42]. The use of standard mobile network equipment being used for the next-generation PPDR network will result in a system which is cost-effective. Sweden have considered the deployment of a state-owned PPDR mobile network as this will provide further governmental control and enhanced security. The use of existing commercial mobile networks as the basis for a PPDR service has been considered by other countries including the United Kingdom and America.

[42] "Four different models for next-generation emergency networks using commercial mobile technologies" Analysis Mason http://www.analysysmason.com/About-Us/News/Newsletter/next-generation-emergency-networks-Jul18/

Manufacturing and Logistics

Digitisation in manufacturing and logistics is expected to reduce costs and increase production. It is expected to be driven by creating the factories of the future[43], which will rely on connectivity to enable a more effective, efficient and automated manufacturing process. This digital transformation, sometimes referred to as the 'fourth industrial revolution' will be driven by cyber-physical systems (CPS) and the IoT.

5G is expected to act as a catalyst to the digitisation in manufacturing and logistics. The type of applications which it will stimulate include mainly the use of mMTC and URLLC. The need for precision in Industrial Automation may necessitate 5G's URLLC. A 5G-PPP[44] study on the factories of the future categorized the Industry 4.0 use cases which 5G will enable as:

- Time-critical, reliable process optimization inside digital factory using real-time monitoring: This may employ a number of sensors that communicate at low-bitrates with ultra-low latency and ultra-high reliability and/or **vision-controlled robotics.** In the case of vision-controlled robotics, reliable high-bandwidth communication will be required.

- Non time-critical communication inside the digital factory: This case scenario will be useful for **the localization of assets** including forklifts and goods in on-site production and logistics processes for **intelligent warehouse management systems**. This should increase efficiency and effectiveness as it can reduce human errors whereby a consignment is loaded on the wrong truck. In this use case, sensor data from the shop floor can be used to gather diagnostics of the machine to enhance maintenance and to optimize the production process reducing the number of defects.

  When selecting the most appropriate wireless connectivity solution for industrial environment, one must consider the high level of interference experienced in such environments.

- Remote controlling digital factories refers to the end-to-end communication between remote workers and the factory. With the addition of AR devices, this use case can enable a realm of new possibilities including support in production and assembly procedures which require precise position to ensure that operators know exactly the actions that are necessary. It will provide assistance for maintenance and repair as technical personnel can be assisted remotely to repair machines without training using augmented information and operational guidance.

[43] '5G and the factories of the future' 5G-PPP White Paper, 2015.
[44] "5G and the Factories of the Future" 5G-PPP, https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Factories-of-the-Future-Vertical-Sector.pdf

- Seamless intra-/inter-enterprise eco-system communication enabling communication between different production sites and also between the various actors in the value chain.

- Connected goods - incorporating product lifetime whereby usage data is communicated over the entire lifetime of a product to augment the production process.

Costs and energy consumption has played a significant role in the determination of the amount of storage and processing on both standalone robots and networked robots. But cloud robotics where intelligent processing is offloaded from the robot onto the cloud, may address these limitation. According to the GSMA, cloud robotics will be a reality thanks to 5G[45]:

> "Mobile technology has the potential to play a key enabling role in this emerging cloud robotics ecosystem; namely, connecting the cloud-based system to the robots and controllers. 5G has the potential to deliver the extremely low latency and high bandwidth needed to enable the exchange of huge amounts of data and information, and to allow cloud-based processing to seamlessly control remote robots."

Agriculture

Similar transformations that are projected for the manufacturing and logistics sector are claimed also for the agriculture sector. By ensuring ubiquitous reliable highly-available mMTC, and the deployment of a number of sensors to enable the digital transformation of farming, new applications may be delivered, such as:

- Precision Farming: Sensors can be used to measure crop yields, moisture level and terrain topography. This data can be processed to develop location-specific plans that can for example highlight the exact locations where fertilizers are required. This will result in reducing overheads, increasing yields, generating better revenues and protecting the environment.

- Smart Irrigation Systems that measures humidity, soil moisture and temperature to calculate precise requirements for water increasing the irrigation efficiency.

[45] "Global Mobile Radar", GSMA, Sept. 2018

- Farm Management System can use IoT to enable crop monitoring and precision livestock farming. This will require the collection of data periodically to monitor data and alert when the data collected shows changes in patterns or statistics that indicate issues with crops or livestock.

Technological innovations are automating labour-intensive tasks and providing farmers with greater knowledge and insight into their crops and environmental factors that can be used to increase efficiency and yield.

2.2 Is 5G Essential?

One may wonder whether there is an actual need for 5G especially when considering that Mobile Network Operators across Europe are still in the process of delivering the full expected return on investment of 4G. Although 4G was designed to support mobile video, 5G shall also support new capabilities which 4G does not, such as mMTC and URLLC. 5G promises to be the sole standard which can address society's needs most efficiently. It is designed with the intent to enable solutions for vertical industries such as Automotive, Healthcare, Transport and Utilities. In this respect, it is the first generation which aims to target the socio-economic benefits that can result from a multitude of verticals.

It is true that many of today's use cases can be served by alternative technologies. End users will however make adoption decisions based on cost effectiveness, functionality and flexibility that a connectivity solution provides. For example, 5G deployment for massive IOT will not introduce an additional challenge to the service-provider or end-user to deploy new infrastructure such as Access Points as would be the case with low-power wide area networks. On the other hand, some use cases relying on existing non-cellular wireless networks, may simply evolve towards reliance on 5G, using it as a complement to existing technologies.

Taking a closer look at the applications mentioned in the previous section, 5G promises to provide a number of benefits over existing wireless broadband technologies. For example remote monitoring of patients is already possible with existing wireless networks but 5G may ensure that the network can handle the significant larger number of connected devices that a decentralised health care system will require. Therefore in this case, the connection density capability of 5G may be the main differentiator from existing wireless connectivity solutions. Moreover, since m-health applications can also be used to raise alarms should the patient require immediate assistance, the fact that cellular connectivity can ensure that the device in question is always connected is a significant advantage when compared to other solutions which depend on unlicensed spectrum and hence can be susceptible to significant interference or lack of nation-wide coverage. The decentralisation of the healthcare system via remote monitoring will mostly rely on smart wearables. Quantitative research carried out

by industry[46] has determined that users of smart wearables are mostly concerned with the battery lifetime, which among other factors, is subject to the wireless communications systems. Therefore while existing cellular and non-cellular networks can serve smart wearables, 5G aims to ensure the maximisation of the smart wearable's battery lifetime.

Another application which can already be served with existing networks is connected ambulances. Connected ambulances necessitates a stable reliable secure fast wireless connection with ubiquitous coverage. This means that while 5G will be beneficial, it is not the only wireless technology which can enable it. In fact, the connected ambulance concept has already been piloted by various research groups. Amongst which, one finds the European-funded research project called, *"Smart ambulances: the hi-tech future of accident and emergency healthcare"*[47] which had recommended the use of video to augment the paramedics services. ViaSat in conjunction with the University of Aberdeen's Centre for Rural Health, NHS Highland and the Scottish Ambulance Service have worked on a pilot program to transmit high-resolution video and ultrasound images from connected ambulances using Satellite Communication[48]. This highlights the importance of connected ambulances that is dependent on the communication medium. For urban and non-remote areas the wireless medium can be cellular, which is not only cheaper than satellite connectivity but also has higher bandwidth capability. 5G's eMBB may ensure that UHD video and ultrasounds can be transmitted over cellular networks in a cost-efficient manner thanks to 5G's increased spectral efficiency. Tests of this application using 5G are already projected in the near future including in the 5G test-bed being developed in the UK's West Midlands.[49] In this case using 5G can be beneficial in providing cost-efficient ubiquitous, reliable coverage to transmit bandwidth intensive files.

Another benefit of 5G is the fact that via network slices, one physical 5G network can provide differentiated services, adapting the characteristics of each network slices using software reconfiguration. This may prove to be a good business opportunity to Mobile Network Operators opening up new possible markets via especially the Business-to-Business-to-Customer model.

In summary, the key differentiators which 5G proponents advertise are:

- Delivery of high data rates at a reduced cost as required for applications which will rely on ultra-high definition video. While this is beneficial for the ever increasing data-intensive demand by mobile data subscribers using video daily, this will even facilitate

[46] "From healthcare to homecare - The critical role of 5G in healthcare transformation" https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/transforming-healthcare-homecare

[47] "Smart ambulances: the hi-tech future of accident and emergency healthcare", http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/star/index_en.cfm%3Fp%3Dsf-20160225-saepp&calledby=infocentre&item=Infocentre&artid=38377

[48] "Connected Ambulance Program Trial" https://thespacehub.com/viasat-2-launched-1-june-2017-2/

[49] "West Midlands to become UK's first large-scale 5G testbed", https://www.gov.uk/government/news/west-midlands-to-become-uks-first-large-scale-5g-testbed

the transformation of video consumption as we know it[50]. Besides the spectral efficiency that 5G will unravel, higher data rates will be possible thanks to the deployment of small cells using mmWave bands;

- The ultra-low latency required for mission-critical application to enable human-like reflexes;
- Augmented communications for faster moving devices enabling automotive infotainment and also connected ambulances;
- Support of massive number of connected devices, which may be a key enabler of smart homes, smart agriculture, smart factories, smart grid and smart cities;
- Low-energy requirements, facilitating the use of sensors and smart wearables via which IoT will be realized.

2.3 Timeline for the realization of the 5G Use Cases

5G may enable intelligent connectivity over cellular networks. There are a set of applications which have stringent connectivity requirements that may benefit from intelligent connectivity and 5G as listed in Table 3.

Table 3 - Applications which will benefit from Intelligent Connectivity

Healthcare	Remote Surgery
Automotive	Fully Autonomous Vehicles
Media and Entertainment	Immersive Experience, Ultra-High Definition Video
Manufacturing	Cloud robotics[51], Remote control
Energy and Utilities	Machine Intelligence, Real-time control

The realisation of these applications necessitate the advancement of the application per se and not just the underlying connectivity. However, one can note that the development of the

[50] https://5g-xcast.eu/

[51] Cloud robotics is the third stage of the development of robots. "The concept refers to systems that leverage the memory, computing and shared services of the cloud to create smarter autonomous robots, so that in effect the robot's brain is offloaded to the cloud." From: "Global Mobile Radar" GSMA, September 2018

above mentioned applications are quite advanced, with some already being available whilst others may be available in the near future as described below.

Remote Surgery: Experimentation with robotic surgery started before the conceptualisation of 5G. It was primarily a request from NASA to study remote surgery to be able to carry out surgery on astronauts. The first transatlantic remote surgery took place in 2001, when surgeons in New York used remotely controlled robots to operate on a patient in France[52]. Connectivity in this case was high speed fibre-optic connections. Despite, this successful demonstration, telesurgery is still not widely adopted as the existing communications systems are not cost-effective and subject to long latency and lack of reliability. 5G URLLC promises to make possible local remote surgery through wireless connectivity as the latency will be reduced drastically. The low latency of 5G will enable haptic technology to provide a sense of touch[53] to the surgeons in addition to controlling robots remotely. Recently, a doctor has performed surgery on a laboratory test animal remotely over 5G connection having a lag time of 0.1 seconds.

Fully Autonomous Vehicles:

Up to Level 2 automation where the system has longitudinal and lateral control with continuous driver oversight is already available on the market. Level 3 up to Level 5 Automation are predicted to be available on the market from 2020 onwards. [54]

Media and Entertainment:

Immersive experience depends on AR and VR. The first wave of devices employing AR and VR came to market in 2016 from companies including Oculus VR, Sony and Google. The strongest demand for immersive experiences currently comes from media and entertainment but is foreseen to also penetrate other sectors such as healthcare and education. A study carried out by Goldman Sachs estimates that VR and AR market will continue with its steady growth[55]. South Korean operators also claim that VR and AR are the principle uses of mobile data observed within their market, where 5G has been commercially available for a number of months.

Ultra-high definition video and movie production using 8K is already a reality. Korea telecom has used 360° VR, Time-Slice for high-definition video providing the viewer also the

[52] "Surgeons perform transatlantic operation using fibre optics," S. Gottlieb, British Medical Journal, Sep 2001, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1121281/

[53] "Not just speed: 7 incredible things you can do with 5G" March 2017. https://www.cnet.com/news/5g-not-just-speed-fifth-generation-wireless-tech-lets-you-do-vr-self-driving-cars-drones-remote/

[54] "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions: On the road to the automated mobility: An EU strategy for mobility of the future," COM(2018) 283 final

[55] "Augmented and virtual reality: the promise and peril of immersive technologies," World Economic Forum, Sept 2017, https://www.weforum.org/agenda/2017/09/augmented-and-virtual-reality-will-change-how-we-create-and-consume-and-bring-new-risks/

capability of adjusting camera angle with very little latency, and omni-view during the 2018 Winter Olympics in Korea[56]. The 2020 Tokyo Olympics is to be broadcast using 8K[57].

TIM have reported the following development[58]:
"Moreover, for the first time in Italy a virtual visit service in real time has been achieved on an experimental 5G network system. It was possible to visit Piazza Carlo Alberto from the Politecnico of Turin despite it being on the other side of the city. An avatar guide accompanied the visitor – equipped with a VR headset and sensors – in the historic venue, thereby testing the capacities of virtual reality. An immersive experience made possible by the top speed of the 5G network which makes interaction between the guide, the virtual environment and the visitor immediate in terms of thousandths of a second".

It has been reported that take-up of 5G-enabled applications is an **evolutionary** process introducing new applications according to the development of both the application and the 5G network. Table 4 tabulates Ericsson's prediction on the services that will be provided according to the status of the 5G roll-out for the automotive sector[59].

Table 4 - The evolution of the Automotive Industry

Current systems	On the Road to 5G	5G experience
• Real-time Information and Location Sharing Ex: Uber and Lyft • Real-time driver statistics • Personalized insurance services based on driving behaviour • Connectivity within the vehicle • Assisted driving • Traffic Jam Warning	• Vehicle-to-Vehicle communication systems • Connected Ambulances	• Autonomous Vehicles • Advanced infotainment

[56] "Five ways KT used 5G at the PyeongChang Olympics — and three lessons learned" May 2018, https://www.rcrwireless.com/20180517/5g/five-ways-kt-5g-at-the-olympics-tag6-tag99
[57] "Intelligent Connectivity, How the Combination of 5G, AI and IOT is set to change the Americas", GSMA
[58] "TIM switches on Italy's first 5G antenna with millimetre waves in Turin, record connection at over 20 Gigabit/s" December 2017, https://www.telecomitalia.com/tit/en/archivio/media/note-stampa/market/2017/Nota-Stampa-TIM-5G-Torino-14-dicembre-ENG.html
[59] "The guide to capturing the 5G industry digitalization business potential," Ericsson, Sept 2018

2.4 Trials

Deployment of commercial 5G networks are expected to commence after 2020, following the completion of the 5G standards[60]. GSMA refer to the period from 2020 as the 5G era, when commercial 5G networks will be widely deployed, forecasting that there will be 1.1 billion 5G connections by 2025[61]. In the meantime, various key stakeholders have formed consortia to carry out 5G tests and trials. It has been observed that such test and trials are not driven by Mobile Network Operators on their own, but via collaboration with Universities, Research Centres, and Original Equipment Manufacturers as the latter have a vested interest in the development of 5G[62]:

> "Both the equipment and handset suppliers are keen supporters of 5G because potentially, it is their next wave of sales and they are enthusiastically investing in key patents via research or acquisition"
>
> "At member state level, no-one wants to miss out on what could be the next mobile technology race. Many of the academic centres have industry partners who finance and share the research"

The European Union has played a key role in stimulating the development of 5G across its Member States. The first action included in the European Commission's Action Plan[63] states:

"The Commission will work with Member States and industry stakeholders towards the voluntary establishment of a common timetable for the launch of early 5G networks by the end of 2018, followed by a launch of fully commercial 5G services in Europe by the end of 2020"

In line with this action, various 5G test and trials are underway in a number of EU Member States. Some of these trials were stimulated by the Public-Private Partnership in the area of advanced 5G network infrastructure for the future internet – the 5G PPP[64]. The funding opportunities provided by the 5G PPP, were published as a number of Horizon 2020[65] calls.

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[60] "Setting the scene for 5G: Opportunities and Challenge," ITU, September 2018

[61] "The 5G era, Age of boundless connectivity and intelligence automation," GSMA Intelligence, 2017 ....

[62] "European Leadership in 5G," 2016, http://www.europarl.europa.eu/RegData/etudes/IDAN/2016/595337/IPOL_IDA(2016)595337_EN.pdf

[63] Commission Communication: "5G for Europe: An Action Plan" - COM(2016)588 and Staff Working Document - SWD(2016)306.

[64] The 5G PPP is a Public-Private Partnership between the European Commission and the 5G Infrastructure Association. The 5G Infrastructure Association's founding members are Alcatel-Lucent Bell NV, Ericsson AB, Nokia Solutions and Networks Oy, Orange and SES.

[65] Horizon 2020 is a European Union's financial instrument to fund Research and Innovation

Other trials were stimulated by National Governments. Governmental input or the involvement of public entities influence whether the experimentation focus solely on enabling a wireless link to verify the technical characteristics of the 5G equipment or whether experimentation focus on the 5G verticals and their related business models.

Those trials which are driven by National Governments can be categorized as follows:

- Purely investment-led such as the approach adopted by the Italian Ministry of Economic Development in 2017. The Italian Ministry launched an Expression of Interest to award spectrum in the 3.6 GHz band to carry out pre-commercial trials of 5G Verticals in five defined areas. It also stipulated that the trials should address one or more of the 5G use cases (eMBB, URLLC and mMTC) employing 5G technological solutions, including network slicing. The successful consortia were awarded the right to use the 3.6GHz spectrum band in the defined areas for the duration of the trials.

- Co-investment: The United Kingdom adopted a contrasting approach to the Italian one whereby the UK Government's Department for Digital, Culture, Media, and Sport Government has allocated public funding to promote beneficial 5G use-cases and reduce risks around 5G investments. The Government has set up a £1.1 billion digital connectivity package to ensure that gigabit-capable, reliable and highly available digital connectivity is available throughout the UK. This package includes funding for new fixed and mobile networks, fibre network deployment and 5G Testbed and Trial Programme[66].

[66] "5G Testbeds and Trials Programme" https://www.gov.uk/government/collections/5g-testbeds-and-trials-programme

3. The 5G Business Model – Risks and Challenges

5G is not solely an evolution of 4G, although 5G's eMBB can be perceived as an augmentation of 4G's mobile broadband transformation. However, unlike the previous standards, 5G is designed with the provision of verticals in mind. Therefore, these two elements i.e. the roll-out of 5G and the provision of its verticals are intertwined. The roll-out of 5G infrastructure must be sustained by commercially-feasible business cases that can lead to the fruition of the 5G verticals. This demands that a number of elements which can deter the deployment of 5G must be considered. These are presented below.

3.1 The 5G Ecosystem

As stated previously 5G promises to address the needs of three different types of use cases: eMBB, uRLLC, and mMTC. This means that it is expected to act as a facilitator for a number of applications which require different performance characteristics i.e. a combination of speed, latency, reliability and/or device density. The provision of multi-services is not the only projected differentiator of 5G. 5G promises to bring extra flexibility via virtualisation and programmability. One important element of 5G, is in fact network slicing, where via a combination of SDN and NFV, a number of logical/virtual networks can be created over the same physical network infrastructure, each providing a set of virtual network functions. Thanks to network slicing, the same Mobile Network Operator or as explained below the Infrastructure Provider, may provide different services to different verticals using the same physical network infrastructure. Each network slice may have its own network architecture, protocols and security settings.

This feature of 5G may open up a realm of new business opportunities involving[67]:

- **Infrastructure Provider**: the entity which traditionally has been referred to as Mobile Network Operator. The 5G Infrastructure Provider may be further classified as a RAN infrastructure provider and cloud infrastructure provider where the former owns the physical RAN infrastructure such as antenna sites and hardware equipment and the latter is responsible for the local and central datacentres providing the virtual resources such as computing, storage and networking.

- **Mobile Service Provider**: an entity which provides various services to end users. These services may be sold to tenants over network slices each realising a specified service. If the Mobile Service Provider is not a Mobile Network Operator, then it will lease the required physical and virtual resources from one or more Mobile Network

[67] "A study on 5G V2X Deployment," 5G-PPP Automotive Working Group, Version 1.0, February 2018

Operator to provide the end-to-end mobile network. Case in point is Cubic Telecom[68], a connectivity management software provider, which via a collaboration with Microsoft, will enable the Microsoft Connected Vehicle Platform[69]. Cubic Telecom will employ the use of over 65 mobile operator partnerships.

- **Tenants**: a business entity that rents and leverages a 5G connectivity provided by the Mobile Service Provider. A tenant can be any entity which relies on communications networks and/or services for its business. The 5G connectivity used by the tenant may be a network slice. A tenant could also be any entity who needs a next-generation local area network i.e. a private network[70] such as factory owner. The advantage of deploying a private 5G network is that it is completely dedicated to the owner and it can be independently managed including its security levels.

- **End User**: who the end user is and what the end user is consuming depends strongly on the business model being considered.

Therefore if one were to consider the smart meter as a use case, the end user is the person or entity who will use the smart meter, the tenant is the Utility Service Provider who will liaise with the Mobile Service Provider to ensure that the necessary service level agreements and costs are negotiated to provide connectivity to each smart meter. The Mobile Service Provider may be the same entity as the Infrastructure Provider or a completely independent entity who has approached multiple Infrastructure Providers to obtain the necessary network slices.

This classification shows that with 5G the number of participants for the provision of a service can be various. Mobile Network Operators must be open for new business relationships in order to justify the deployment of 5G. DotEcon Ltd and Axon Partners Group stated the following in a study commissioned by BEREC[71].

> "where network investment and 5G deployment would be very costly or unattractive, but verticals foresee significant advantage associated with 5G connectivity (i.e. there is a large private value for connectivity), then they may be willing to support the MNO investment under co-investment models. However, given that the requirements for connectivity might only be for particular areas or be quite niche, it may be unlikely that such arrangements (if made at all) would contribute significantly to the widespread rollout of 5G networks, for example at a national level."

[68] "Cubic enables Microsoft Connected Vehicle Platform" http://www.cubictelecom.com/Media/PressRelease/43

[69] Microsoft Connected Vehicle Platform is a set of service built on Microsoft Azure designed to empower the automotive industry to create customer connected driving experience.

[70] "Also known as a local 5G network, a private 5G network is a local area network (LAN) that will use 5G technologies to create a dedicated network with unified connectivity, optimised services and a secure means of communication within a specific area. It will deliver the speed, latency and other benefits promised by 5G to support next-generation applications." Source: https://5g.co.uk/guides/what-is-a-private-5g-network/

[71] "Study on Implications of 5G Deployment on Future Business Models," DotEcon Ltd and Axon Partners Group, No BEREC/2017/02/NP3, March 2018

To date an application which promises incremental revenue to justify 5G deployed hasn't yet been developed and made available to the market. Despite the promises of enriching the digitisation transformation of the various verticals, it is still foreseen that the first application of 5G will be based on meeting the demand for increased data usage. The study commissioned by BEREC also refers to the role that **intermediaries** may play in identifying new applications for 5G and facilitating agreements between the connectivity provider and end user.

3.2 Pricing Scheme

Various reports discuss what is the 5G killer application[72]? One survey of 46 Chief Technology Officers has shown that while they do believe in 5G's potential, there is uncertainty on which products and services customers are willing to pay for and when these services will be available[73].

Adequate pricing schemes that guarantee an incremental revenue opportunity must be identified. With 3G and 4G, pricing schemes traditionally focused on data bundles. This approach may not suffice for 5G. The typical customer may not be willing to pay for 5G eMBB, especially during the period when the service provided by 4G are enough to address the customers' needs. This may also be the case with other services such as mMTC, as competing cellular IOT services or low power wide-area networks may already be fulfilling the existing market's needs.

Also, pricing schemes focusing on bundling data may not fit well with services enabled by the other 5G standards, including mMTC. A customer interested in deploying a dense sensor network will not be willing to pay a data bundle per connected sensor. The price will be too expensive, considering both the fact that the sensors will not consume a lot of data and that other standards can provide the same service for a potentially cheaper cost. On the other hand, since an IOT will mostly consist of battery operated devices, providing a communications network which conserves power to maximize the battery lifetime is more useful than offering the cheapest data bundle possible. In this case, a pricing scheme which makes the deployment of a number of 5G-connected sensors feasible while also optimizing energy consumption, is more suitable and attractive. In the case of massive IoT, the question

[72] "Study on Implications of 5G Deplyoment on Future Business Models" DotEcon Ltd and Axon Partners Group, No BEREC/2017/02/NP3, March 2018.

[73] "Cutting through the 5G hype: Survey shows telco's nuanced views," Grijpink et al. Feb. 2019. https://www.mckinsey.com/industries/telecommunications/our-insights/cutting-through-the-5g-hype-survey-shows-telcos-nuanced-views

also lies in whether there should be a price per device, as this may hinder the uptake of massive IOT.

On the other hand, mission-critical applications which will rely on URLLC, will be willing to pay for the ultra-low latency and also for any other characteristics that will provide sufficient guarantees related to liability. Absent an appropriate pricing scheme, and given the availability of other services, customers and/or service providers may not resort to 5G.

3.3 Cost

A feasible business model is further challenged by the cost to roll-out 5G, which will amongst others, include cost related to **spectrum** and the **deployment** of ultra-dense small networks and the requisite backhaul.

Costs related to Spectrum: The ITU World Radio Conference of 2015 has identified that 5G will require the allocation of spectrum bands below and above 6 GHz. The spectrum bands identified for 5G are the 700MHz capable of providing nation-wide coverage, 3.6 GHz which will be a compromise between coverage and capacity and the 26 GHz band (mmWave bands) which will provide capacity. Given the diverse characteristics of the spectrum bands, the amount and frequency bands awarded to an entity will determine the type of communication links that can be deployed. This is the reason, why certain auctions that took place across Europe are awarding 5G spectrum at a premium. While operators participating in such auctions, have not yet identified the full commercial benefits of 5G and which services will result in the necessary incremental revenue, they will not risk ending up without an appropriate swath of spectrum.

Costs related to Deployment: Successful uptake of 5G will result in the deployment of ultra-dense small cell networks using mmWave bands. These bands are the most appropriate bands to cater for the continuously increasing demand for more capacity. However, they have limited coverage and penetration capacity.

Initially, the need for ultra-dense small networks to provide additional capacity will be within a limited coverage area creating hot spots. Eventually ubiquitous 5G networks involving ultra-dense small networks may be required to provide URLLC. Another key consideration is the reliance of time-critical services and guarantees between the service provider and customer. Without such agreements the customers may opt out of using such mission-critical applications. The service provider will in turn expect the ubiquitous availability of the low-latency that can be provided by 5G, necessitating an increase in 5G small cell deployment. Some studies are claiming that this may possibly result in having a small-cell base station deployed at every lamp post.

It is worth noting that various entities view early site acquisition for small-cell radio equipment using 4G technology as an important preparatory step towards 5G and facilitating the transition from 4G to 5G, having already taken care of site acquisition, backhaul connectivity and power supply for each cell. Site planning and acquisition is a cumbersome task which can slow down the roll-out of 5G. Site acquisition can be subject to various regulatory measures which do not fall within the remit of the Competent Authority responsible for the electronic communications networks and services, such as planning permits, and environmental concerns. Site planning must take into consideration the challenges related to powering the site and deploying backhaul connectivity. Moreover, BEREC's[74] study highlights the risk that a site owner will only be willing to allow one infrastructure provider to install its equipment at a premium cost. While the site owner doesn't fall within a Competent Authority regulating the telecommunications sector, one must still consider whether such commercial agreements can distort competition.

When considering the costs related to the deployment of small cells, the cost related to the backhaul infrastructure, the density of which will increase with the amount of small cells deployed may become an important factor. 5G Small Cell deployment will result in a significant financial burden, which can't be postponed once the demand for applications relying on URLLC increases.

To address 5G uncertainties Mobile Network Operators/Infrastructure Providers are considering new business models, including infrastructure sharing and neutral host[75]. These models can reduce the cost and the complexities foreseen with network densification. In the case of a neutral host, an entity such as one owning a shopping mall may itself install the 5G infrastructure allowing infrastructure providers to use it at a cost. Business models must strike a balance between competition and sustainable investment in infrastructure.

3.4 Regulatory uncertainty of emergent use cases

The evolutionary process behind the provision of the various 5G verticals is strongly linked with the end-users acceptance of the services offered. The end-user who may also be an organisation or a government, must trust that the service provided has implemented all the necessary safeguards related to liability, ethics, privacy and cyber-security.

[74] "Study on Implications of 5G Deplyoment on Future Business Models" DotEcon Ltd and Axon Partners Group, No BEREC/2017/02/NP3, March 2018.

[75] This refers to a network operated by a single company where resources are being shared by multiple mobile network operators (MNOs) and mobile virtual network operators (MVNOs) to achieve a multi-operator environment using different methods. The term can also refer to the special case of network sharing through the use of the same small cell equipment with the capability of hosting multiple RANs

Liability, ethics, privacy and cyber-security require special attention in cases related to health, which may endanger both the end-user and instil doubts in the use of such services. Prior to implementing any new healthcare applications, these need to be tested and certified. Moreover, society must evolve in terms of its culture and acceptance towards e-health and m-health. Society's willingness to adopt m-health is also dependent on clear definition of who is liable for what. A clear example of this can be made by taking the most complicated healthcare service as an example i.e. remote surgery. If something goes wrong which hospital is liable, the one where the patient is located or the one where the specialist is?

Ethical issues will also come into play with the increase in automation and AI. Before driverless cars can be fully realised, the automotive industry must address how for example such a car will be expected to react in the case of an unavoidable accident.

Concerns related to privacy will arise with the uptake of smart cities making use of surveillance cameras with face recognition. While the 5G verticals may generate significant data that can be monetized fuelling the ever-growing data economy, issues related to privacy and who owns the data must be taken into consideration before commercializing emerging data-driven services. The European Commission also highlights the importance of regulatory frameworks to address cybersecurity, car data sharing and various other issues.

5G poses a challenge in identifying new services, new market segments and the right business models. In the early stage of 5G deployment, one must address concerns related to whether 5G is actually essential and if it is, whether a pricing model can be determined that will guarantee the incremental revenue opportunity to justify the required investment for 5G roll-out. Despite the challenges that must be addressed, the GSMA predicts that 5G will deliver revenue growth to mobile operators, with a 2.5% CAGR in the early 5G era[76].

[76] "The 5G era: Age of boundless connectivity and intelligence automation", GSMA intelligence, 2017, https://www.gsmaintelligence.com/research/?file=0efdd9e7b6eb1c4ad9aa5d4c0c971e62&download

4. Survey on the feasibility of 5G deployment in Malta

Kindly request a copy of this survey to complete electronically by contacting us via: **5G@mca.org.mt.**

The advent of 5G promises to bring about a number of benefits which will enhance the way we communicate, empower us to better safeguard our society and change the way we do business. However, 5G is primarily the reaction to three different possible use cases which are a combination of society's desire for more data, faster data communications links and hyper-connectivity. The three use cases are enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC) and Ultra-Reliable and Low Latency communication (URLLC).

Supply must meet demand in an economically feasible manner. Without sufficient demand and/or the willingness to pay for such demand, one may question whether 5G is necessary and rely on existing 4G or 4.5G.

In view of the various factors which may influence when 5G is deployed in Malta, the Malta Communications Authority invites you to participate in the following survey. The questionnaire intends to shed light on the market use elements which may accelerate the feasibility of 5G.

1. 5G is the technological adaptation to various number of user-driven developments, such as the continuous increase in mobile video consumption, the ubiquitous Internet of Things and the uptake of various emerging latency-constrained applications. Consequently, 5G shall cater for three use cases: eMBB, mMTC and URLLC. Out of these three, the first 5G use case that is foreseen to be deployed will be eMBB.

   Will applications requiring communications link capable of a data rate of at least 200Mbps (eMBB applications) be the first stimulus for the deployment of 5G networks in Malta?

2. When do you estimate that the following 5G services will be introduced in Malta (please select from the drop-down list):

   - Services requiring at least 200Mbps - eMBB: Choose an item.
   - Services that support a connection density of at least 10^5 devices/km^2 - mMTC: Choose an item.
   - Services that require a latency of up to 1ms – URLLC: Choose an item.

3. Answer the following question if you represent an industry that can benefit from the **use** of 5G (please select from the drop-down list:

    a. Do you feel that current solutions can continue to meet your business needs in the next 5 years? Choose an item.
    b. Do you feel that current solutions can continue to meet your business needs in the next 10 years? Choose an item.
    c. If you replied yes, to any of the above (3a and/or 3b) kindly mention the solutions which will fulfil your needs: Click here to enter text.

4. Answer the following question if you represent a Mobile Network Operator (please select from the drop-down list):

    a. Do you feel that current solutions can continue to meet the needs of the Maltese society including its businesses in the next 5 years? Choose an item.

    b. Do you feel that current solutions can continue to meet the needs of the Maltese society including its businesses in the next 10 years? Choose an item.

    c. If you replied yes, to any of the above (3a and/or 3b) kindly mention why do you think this is so by selecting all which apply from the below:

☐ The demand is not increasing at the same rate as it is internationally

☐ Assigned Spectrum is such that it can cater for the estimated increase in capacity

☐ Services which will rely exclusively on 5G such as mMTC and URLLC will not be adopted in Malta.

☐ The existing 4G network is dense and can cater for the estimated increase in capacity

☐ It is more feasible to acquire more spectrum than to roll-out 5G given the local user needs

5. Rate the probability each of the following possible use cases being introduced in Malta with the next 10 years (please select from the drop-down list):
   1 indicates **low probability** of the use case being introduced in Malta and
   5 indicates **high probability** of the use case being introduced in Malta.

Fixed Wireless Access example to provide fixed Broadband	Choose an item.
Automotive – To provide assisted or autonomous driving	
Intelligent Transport Systems	Choose an item.
Vehicle-to-Vehicle Communication	Choose an item.

Vehicle-to-Infrastructure Communication	Choose an item.
Media and Entertainment	
Gigabit Hot Zones during Large Events	Choose an item.
Transmission of Ultra-High Resolution Content indoors using wireless connectivity – 4K video for indoor use	Choose an item.
Virtual Reality Applications for Tourism	Choose an item.
Virtual Reality for Gaming	Choose an item.
Manufacturing and Logistics	
Industry 4.0 example automation	Choose an item.
Intelligent Logistics - Assets Tracking, Stock Management, Temperature Control, Order Tracking	Choose an item.
Machine-to-Machine Communications – Sensors and Connected Wireless Devices	Choose an item.
Energy and Utilities	
Smart Buildings	Choose an item.
Smart Utilities such as Intelligent Street Lighting	Choose an item.
Smart City	Choose an item.
Monitoring of supply infrastructures[77]	Choose an item.
Smart Grids	
Healthcare	
TeleMonitoring	Choose an item.
Connected Ambulances	Choose an item.
Teleconsultation (Doctor-to-Patient)	Choose an item.
Teleconsultation (Doctor-to-Doctor)	Choose an item.
Public Safety	
Monitoring and Law Enforcement (Video Surveillance)	Choose an item.

6. Is it envisaged that certain vertical industries would prefer existing non-5G solutions over 5G? If yes (please select from the drop-down list),
    a. Identify clearly the verticals being referred to
       Click here to enter text.
    b. Why would non-5G solutions be preferred over 5G?
       Click here to enter text.

[77] Infrastructures such as Water Sewage or Ventilation Systems

7. Demand will increase as a result of emerging next generation applications that rely on intelligent connectivity. Indicate how critical 5G is for the development of applications which rely on the following (please select from the drop-down list):
   1 means 5G is not necessary and
   5 means 5G is necessary

Artificial Intelligence	Choose an item.
IOT	Choose an item.
Big Data	Choose an item.

8. As applications evolve what comes first the use case or the network that can enable it?
   Click here to enter text.

9. Will there be a need for higher levels of specialised services with tailored or customised products rather than off the shelf solutions?
   Click here to enter text.

10. What regulatory, planning and other key challenges need to be overcome to support the rapid and cost effective deployment of 5G across Malta?
    Click here to enter text.

11. Are there planning or wider legal issues which have the potential to hold back the deployment of 5G networks?
    Click here to enter text.

12. What are the challenges of cross-industry collaboration in the deployment of 5G networks?
    Click here to enter text.

13. a. What are the infrastructure requirements for 5G deployment likely to be?
    Click here to enter text.

    b. What do the services and uses for 5G suggest about the infrastructure requirement?
    Click here to enter text.

14. a) What level of 5G coverage will be optimum?
    Click here to enter text.

b) What does this level of 5G coverage mean for the challenge of delivering higher speeds and lower latency?
Click here to enter text.

c) Are there particular issues to be faced by urban, suburban and rural areas?
Click here to enter text.

15. a) In what ways could collaboration between infrastructure sectors speed up and improve deployment?
Click here to enter text.

b) How can this be incentivised?
Click here to enter text.

16. a. 5G enabled cities are cropping up across Europe as a showcase for use cases enabled by this technology. If you were to collaborate with a consortium to deploy a 5G-enabled city in Malta, what role do you best fit in:
<Choose all that apply>
☐ Neutral Host
☐ Infrastructure Provider
☐ Mobile Service Provider
☐ Tenant providing different use cases

b. Which use cases do you think would be most appropriate and commercially-feasible for the first 5G-enabled Maltese city?
Click here to enter text.

c. Taken into consideration the use cases listed in (b.) what are the characteristics that a 5G-enabled city should have?
Click here to enter text.

d. What is the estimated capital investment necessary to deploy a 5G-enabled city in Malta?
Click here to enter text.

17. Are there any relevant international examples in the deployment of telecoms infrastructure that Malta can learn from?
Click here to enter text.