A journey to 5G:

how private 5G and edge computing will drive business growth, and how to achieve it.

A report produced
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Contents

Background and aim

This report is written for business end-users, aiming to provide the knowledge needed to navigate private 5G networks and edge computing in order to help businesses achieve their goals. Produced by Digital Catapult on behalf of Verizon, it aims to fill the information gap around these technologies.

The report is based on in-depth consultation with industry professionals across the UK, Germany, Italy, Denmark and other European countries at various stages of their 5G implementation journey. It provides insights into the benefits of 5G (private 5G networks in particular) and edge computing for enterprise users.

Verizon Business Group provides services and products for business and government clients around the world, from industry-leading network solutions including private 5G and cybersecurity solutions to customer experience and collaboration services.

Digital Catapult is the UK authority on advanced digital technology, with a wealth of expertise and experience of real-world applications of 5G industrial use cases. Through collaboration and innovation, it accelerates industry adoption of advanced digital technologies to drive growth and opportunity across the economy.

Methodology

Insights in the report are built on interviews with senior industry executives carried out in summer 2021. Interviewees came from sectors ranging from Telecommunications, Transport and Manufacturing, to Live Entertainment and academia. We refer to these interviewees as experts, executives or interviewees.

In a workshop, we gathered additional insight from 13 participants from 5G end-user organisations and businesses, suppliers, research houses and academia that are exploring the use of private 5G networks and edge computing.

Insights from this primary research were complemented with secondary data and information from sources including academic journals, news articles, white papers and online sources.

01
Introduction

Introduction

5G is the next generation of mobile communication technology, but this label can suggest 'faster connectivity' without acknowledging the wide-ranging innovative capabilities 5G brings. For many industries, the business advantages will be unlocked through the use of private 5G – a local network owned and controlled by the enterprise – coupled with edge computing – positioned at the edge of the network, close to where it is used.

The potential of these technologies is vast, but 5G and edge computing are complex and in early stages of development. Relevant insight based on experience is hard to come by and it's not unusual to see current 5G capabilities either inflated or misunderstood. Experts say this makes it difficult for businesses to evaluate whether they should consider 5G and edge computing.

This report aims to address that. It supports businesses at the early stages of their 5G journey, helping to build an understanding of the new ways of working, innovative use cases and business benefits enabled by private 5G networks and edge computing. It includes recommendations and considerations for businesses looking to explore, adopt, and use these technologies.

Drawing on expertise that spans industry, network operators and innovators, it delivers insight on topics including:

- The key business benefits in sectors ranging from the creative to the manufacturing industry, including illustrative case studies

- Barriers to adoption and ways to alleviate them

- Technology capabilities and how they differ from other options

- The policy and regulatory context around private 5G networks in Europe
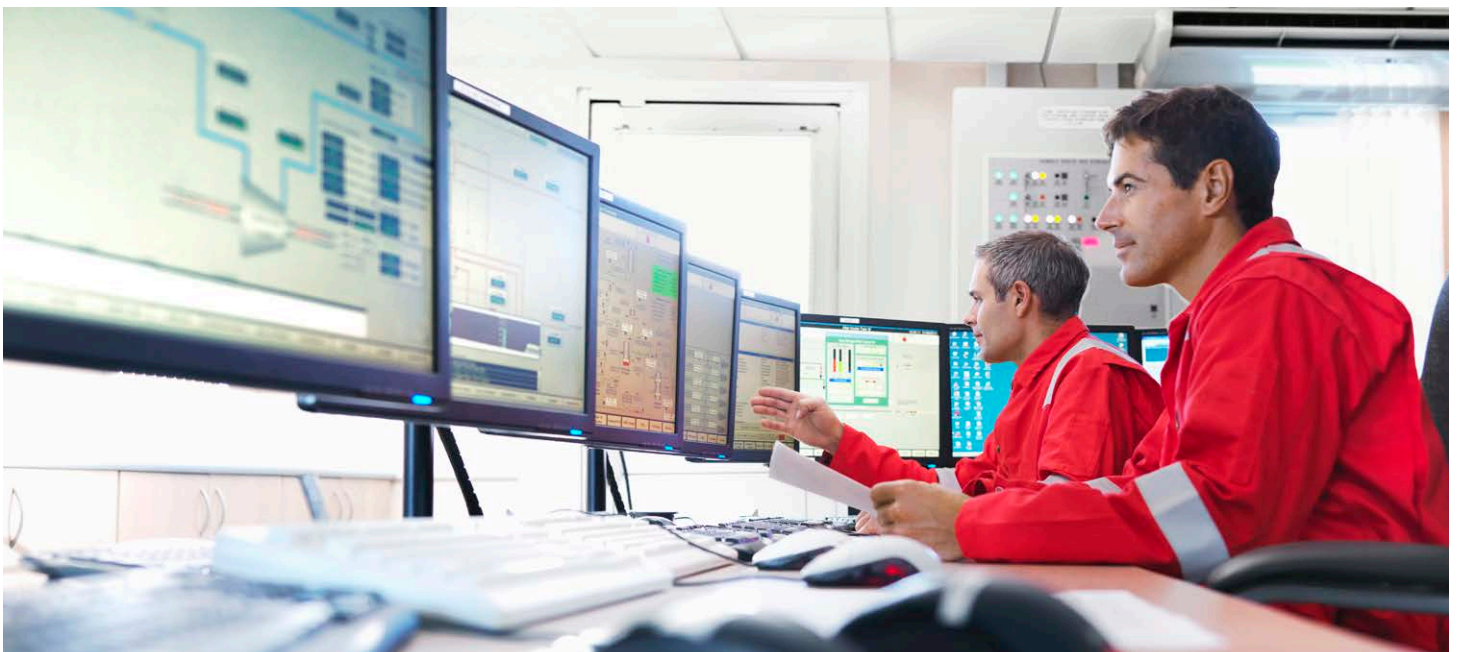
02
Defining the technologies

What are 5G, private 5G and edge computing?

5G – the 5th generation of mobile network telecommunications - represents a step change in network performance capability, providing business grade service levels, reliability and availability incomparable with earlier generations.

5G can deliver speeds up to 100 times faster than 4G, ultra-low latency, high reliability, and increased capacity. It will eventually allow up to one million devices per square kilometre to connect without interference – 4G can only manage 2,000. 5G will also provide a stable and reliable connection, even for fast moving objects. In coming years, its capabilities will support innovative use cases from smart cities to connected ports, new ways to experience live entertainment, remote collaboration and industrial training, quality inspection, and much more.

Private 5G refers to a 5G network developed for a particular organisation or enterprise. Wi-Fi networks run on shared, unmanaged spectrum, which means they may overlap and cause interference. Private 5G networks, however, operate on dedicated licensed spectrum, allowing an enterprise to connect many devices without compromising quality of service. A private 5G network operates within a well-defined geographical area such as a port, mine, campus, warehouse or factory plant, or across sites of the same organisation. By comparison, public 5G networks aim to cover large areas and reach a wide audience.

An enterprise user can design a private 5G network tailored to its specific needs and requirements.

Private 5G differs from other forms of connectivity, including private fibre optic broadband, private Wi-Fi and private 4G/LTE, in several ways. Private 5G networks offer tailored coverage, high performance, dedicated capacity, and reliability, while drastically reducing latency compared to other current network communications. Combined with 5G's capabilities and flexibility, the privacy and security strengths of private 5G can unlock entirely new applications and services.

Edge computing or edge compute is defined as computing that is done closer to the end user, or nearer the source of the data. In edge computing, the storage that computation relies on is also implemented at the edge, rather than in the cloud. Edge computing is one of the key enabling technologies for 5G and even more important for private 5G. Multi-access edge computing (MEC) exists in two general categories: public and private. With private MEC, specific MEC services are located at a business customer's site, such as a campus, factory or fulfilment centre. The computation platform is closely linked to the underlying network infrastructure, either located at the telecom carrier's network location or on the customer's premises. This can reduce the volume of data that needs to be transmitted through an external network (when it is processed locally on the business customer's premises) as well as the distance travelled. The benefits include lower latency, reduced core network traffic and lower transmission costs. Another advantage of edge computing on-premises is that data remains in-house for applications with strict security or compliance requirements.

Private 5G spectrum is a great advantage... With licensed spectrum, you are effectively paying in order to control interference. Part of the problem with Wi-Fi is that you do not know the levels of interference, and you cannot transmit at the instant you want, which can affect latency.

Petar Popovski, Professor and Head of Connectivity at Aalborg University, Denmark

A MEC platform can be used to run a wide range of workloads closer to where they are needed; from end-user applications such as immersive and industrial automation applications, to virtual network functions (VNFs) such as the centralised and distributed units (CU/DU) of the radio access network (RAN) in both 4G and 5G.

Enabling Industry 4.0

5G and edge computing are important enablers for the Fourth Industrial Revolution – also referred to as Industry 4.0 (or Industrie 4.0). The third industrial revolution was characterised by overall digitalisation. Industry 4.0 innovates based on the combination of technologies such as artificial intelligence, augmented and virtual reality (AR and VR), the Internet of Things (IoT), coupled with advanced networks: it is characterised by overall automation. This combination enables robotic systems, digital twins, predictive data analytics and visualisation. It also facilitates the use of more advanced

connected devices including sensors and trackers as well as many other functions, with enhanced capabilities such as near-real-time responsiveness.

Industry 4.0 is about the creation of cyber-physical systems underpinning new use cases and solutions that solve long-standing challenges for industry, creating new business models and opportunities. The Industry 4.0 concept is particularly relevant for connected value chains (found in the factories of the future), smart supply chains (or Supply Chain 4.0), operations and products.

Industry experts note that, as businesses increasingly automate their operations, they find that reliable connectivity is essential, acting as an enabler for applications such as advanced predictive maintenance. As Industry 4.0 solutions and use-cases multiply, 5G will become necessary to support these data-hungry capabilities.

The higher the flexibility and modularisation of a production line, the greater the need for reliable wireless communication in real-time. Private 5G will enable this wireless connectivity and we see great potential in this technology on the way to smart factories.

Niklas Ambrosy,
Volkswagen & 5G ACIA (Germany)

03
Business
benefits

In the enterprise, 5G and edge computing can both underpin efficiencies driven by technological innovation and future-proof day-to-day business operations. Through the use of automated guided vehicles (AGVs), drones, sensor technology and industrial robotics – all of which can be enabled by private 5G networks and edge computing – businesses can become genuine enterprises of the future.

Private 5G networks

The benefits of private 5G networks for business are wide ranging. Broadly, they include:

- Increased privacy and security

- Increased productivity

- Operational efficiencies, including reduced downtime

- Increased operations sustainability

Business benefits are driven by the benefits of a private enterprise network combined with the benefits of the 5G technology capabilities:

Thanks to a private network, businesses benefit from:

- **Higher levels of privacy and security:** 5G standards are set according to "secure by design" principles, meaning that security is natively embedded in the 5G architecture. The owner/operator of a private 5G network can manage their own security programme including configuration, processes and procedures – no external network operator is in charge. Private network owners have control that may not be possible on a public network: the company can determine who gets connected and data can be contained on premises. The nature of private 5G networks means that they can offer higher degrees of confidentiality, integrity and availability – the 'CIA' triad in cybersecurity.[1]

- **Customising the network to exact needs:** Unlike a public network, a private network can be configured to an enterprise's specific needs. Its evolution can equally be precisely designed to follow the enterprise roadmap of new needs and requirements.

- **Full network control:** Once deployed, a private 5G network is still fully under the control of the owner/operator, leading to consistent and unified management of IT systems.

Benefits brought by the 5G technology to private enterprise networks include:

- **Low latency:** Low latency is a game-changing 5G capability. Latency is defined as the time elapsed between initiating a data transfer and the completion of the data delivery. Lower latency is desirable in the majority of business operations, as it reduces response time for operations. It is essential for ensuring high quality in applications such as remote collaboration. Currently, 5G can achieve significantly lower latency than other modes of connectivity, at between 17-26 milliseconds (ms), compared to 36-48ms in 4G.[2] Theoretical expectations are that latency could reach a few ms on a private 5G network, particularly when paired with edge computing, which helps cut application latency.[3] By enabling remote operations, low latency helps with a better use of enterprise human resources and the development of more sustainable operations.

- **Reliability:** 5G networks are expected to offer reliability of service that is not available from other forms of connectivity. The more robust coding schemes introduced in 5G makes it far more likely that data will be transmitted with fewer problems, which helps reduce downtime and enables efficient operations.

- **Network slicing:** With 5G, a single physical communication network can be split into multiple different virtual networks. In enterprise applications, these virtual networks can be customised with different specifications to provide dedicated services to different users and requirements. Slicing network traffic for specific uses can reduce expected downtime for priority applications even further. Network slicing offers unprecedented flexibility and greater return on investment, since a common infrastructure can be used for multiple services.

1. https://www.verizon.com/about/news/verizon-advances-5g-network-and-cyber-security
2. https://5g.co.uk/guides/4g-versus-5g-what-will-the-next-generation-bring/
3. https://www.3gpp.org/ftp/Information/presentations/Presentations_2017/2017_03_Bertenyi_5G_3GPP.pdf

- **Dedicated spectrum with no interference:** Private 5G networks operate on reserved frequencies of the radio spectrum which are allocated on a localised basis, ensuring that there is no overlap or interference. This is different to Wi-Fi in which networks may overlap with many others nearby. The lack of interference on private 5G ensures greater levels of throughput and control for businesses.

- **Full mobility:** Unlike Wi-Fi, 5G is a mobile cellular technology that enables full mobility where connected assets can move around large areas, and experience seamless connectivity with a consistent level of performance. This opens a large number of innovative industrial use cases that were previously unfeasible.

Private 5G networks combine all the benefits of an enterprise private network with the benefits of the 5G technology; making private 5G networks a truly unique solution for business end-users.
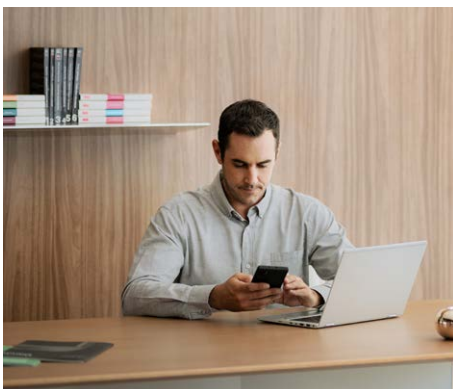
Edge computing

To truly unlock the benefits of 5G, businesses also need to consider the best mode of computation and data storage. Enter edge computing, which becomes a necessity as data loads increase through Industry 4.0 applications requiring lower latencies. In environments where vast amounts of wireless devices are used and entire factories are equipped with 5G and latency-sensitive Industry 4.0 solutions, edge computing will not only be useful but necessary.

With edge computing, latency is inevitably reduced,[4] since the computation is closer to the point of data collection. Lower latency has an immediate impact on the quality of experience (QoE) and can make new types of services feasible, such as collaborative robotics (cobotics). It also can result in a reduction in backhaul traffic and associated costs. Industrial use cases, such as robotics and AGVs, could utilise private edge computing and private network. This would keep the intelligence on-premises, improving security and potentially helping to reduce the cost of these robots.

Edge computing can also make services more resilient. Some environments are not consistently connected to the internet over high-speed links. The applications running on the edge computing platform located in the factory can continue during periods of degraded or lost connections to the internet, reducing downtime.

Experts note that edge computing is an important complement to private 5G networks for both latency and security reasons. The fact that data stays locally improves system security by isolating the data, which can help business customers maintain regulatory compliance.[5] The feature can be exploited by application providers to improve both the service delivery and the network itself.

For example, the edge can have access to certain performance-related information that is provided by the radio access network (RAN). Applications can be tailored and optimised using this information, for example to adapt a video coding scheme to enable a smoother user experience when the network is congested. Furthermore, service providers can protect their networks against attacks from users using contextual information such as geo-location. Network operators can filter out any traffic coming from unexpected locations, since it could potentially be fraudulent.

Retail is one of many sectors where edge computing could have significant impacts. By using data and analytics on the edge, retailers can analyse customer activities in store to drive conversion rates. Video captured through smart cameras can be processed at the device or edge to understand aspects such as the customer path through the store, how customers handle products and interactions between sales representatives and customers. These insights can help increase conversion as well as improve aspects such as the productivity of sales representatives and effectiveness of retail planning tools.

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4. https://www.techtarget.com/searchnetworking/answer/What-are-edge-computing-challenges-for-the-network
5. Such as, for instance, GDPR related obligations.

04

5G networks and edge computing in Europe

5G networks

Generations of wireless communications systems are launched roughly every ten years. This means global markets are now looking towards 5G to succeed 4G networks, which were introduced in 2009. European policy and industry players are striving for the region to excel in various areas related to 5G, including Open RAN[6] (Radio Access Network) availability, production of devices and more.

Although the UK and continental Europe have been at the leading edge of mobile networks – 4G was first launched in Sweden in 2009,[7] while the Global System for Mobile Communications (GSM) standard was developed in Europe in 1991 – countries including South Korea, Japan, China and the United States are leading the deployment of 5G networks in terms of geographical coverage, speeds and experience.[8] Governments in European countries aim to change this.

Policy, trials and deployment

United Kingdom
The UK government's 5G network targets reflect the country's aim to be at the forefront of 5G innovation.[9] The government aims for 5G coverage for the majority of the population by 2027,[10] with nationwide 5G coverage targeted for 2033.[11] It also plans to build an open, innovative and diverse

Case Study: 5G Innovation Centre testbed

The 5G Innovation Centre (5GIC) testbed at the University of Surrey covers an area of four square kilometres of the university campus, allowing access to 5G and edge computing capabilities to test cyber security, 5G applications, network slicing and more.

The 5GIC has indoor and outdoor testing facilities. The testbed RAN allows the development of advanced algorithms that improve the 5G user experience and tools to enable user modelling. The testbed supports various projects and has SME partners. Interested parties can contact the university to explore possibilities.[15]

5G supply chain to ensure the security and resilience of digital networks.[12] In October 2021, the UK government announced a strategic framework for the development, deployment and adoption of 5G and future networks in the UK over the next decade.[13]

Private 5G is starting to gain traction in the UK, with initiatives such as the government's 5G Testbeds and Trials programmes (5GTT),[14] and private businesses trialling 5G.

UK Mobile Network Operators (MNOs) are involved in several of these trials, working closely with partners to provide network capabilities.

UK communications regulator Ofcom is also working with operators to test the interoperability and integration of open networking solutions, including Open RAN.

The largest number of government-funded business trials in the 5GTT programme are currently in the Entertainment and Creative spaces (in particular to enable immersive experiences with augmented reality and virtual reality) alongside trials in rural areas, with use cases in Tourism.[16] Industrial Manufacturing and Construction are on a par with Mobility, Ports and Logistics as the second-largest groups of the 5GTT trials.

Findings from the first evaluation of the Industrial 5G Testbeds and Trials Programme suggest that it can generate £2.58 billion for the UK economy, or a return of £15 for every £1 invested, due to "...potential earlier adoption of technology in sectors such as Healthcare and Manufacturing."[17]

6. Open RAN is a term used for industry-wide standards for Radio Access Network interfaces that support interoperation between vendors' equipment and offer network flexibility at a lower cost.
7. https://techcrunch.com/2009/12/14/4g-mobile-network-sweden-teliasonera/
8. https://www.opensignal.com/2021/02/03/benchmarking-the-global-5g-experience
9. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf
10. https://www.gov.uk/government/publications/statement-of-strategic-priorities
11. https://www.gov.uk/government/publications/future-telecoms-infrastructure-review
12. https://www.gov.uk/government/publications/5g-supply-chain-diversification-strategy
13. https://www.gov.uk/government/consultations/wireless-infrastructure-strategy-call-for-evidence
14. https://www.gov.uk/guidance/5g-testbeds-and-trials-programme
15. https://www.surrey.ac.uk/institute-communication-systems/facilities/campus-testbed
16. https://uk5g.org/media/uploads/resource_files/UK5G_5GTT_Sector_and_Place_Matrix_24022021.pdf
17. https://www.gov.uk/guidance/5g-programme-findings

Industry players including US automotive giant Ford, German tech giant Siemens and UK machine manufacturer Tharsus are working alongside MNOs, Research and Technology Organisations (RTOs),[18] and other partners to test use cases, network requirements and other network characteristics to determine optimal 5G environments for business. Logistics companies and sites are also beginning to delve deeper into 5G, with organisations such as the Port of Southampton[19] working to develop a private 5G network within its territory.

Case Study: 5G Verticale ISS

As part of the French Covid-19 recovery plan, the 5G *Verticale Interoperable Souveraine Sécurisée* project (5G Verticale ISS),[25] led by telecoms provider Alsatis, aims to test use cases defined by project partners ranging from Healthcare and local authorities to industry players. In addition to bringing 5G to these sectors, the project aims to enable integration of legacy uses and networks.

Germany

In 2016, the German federal government launched its 5G strategy to make the country a leading market for 5G networks and applications by 2025.[20] The strategy focuses on five key actions:

1. Stepping up network rollout

2. Making frequencies available based on demand

3. Promoting cooperation between telecommunications and user industries – taking into account requirements, ideas and solutions of relevant user industries in standardisation

4. Targeted and coordinated research

5. Initiating 5G in towns and cities early on

The German government also seeks to work with other European countries to promote and develop private 5G networks in industry. A partnership between Germany and France aimed at promoting Europe's independence in innovative technologies[21] launched a €20 million call for funding for private 5G network solutions in May 2021.[22]

France

France is also encouraging the use and development of 5G, with the Secretary of State for Digital, Cédric O, announcing that France aims to build a "...sovereign solution for business networks by 2022." 5G deployment and trials in France are underway predominantly in the Industry 4.0 area, as well as smart cities and connected mobility.[23] In July 2021, the French government presented a strategy[24] aiming to put 5G at the heart of industry, based on four pillars:

1. Contributing to France's competitiveness by developing 5G use cases across industries and territories

2. Building up French capability in telecoms networks by 2022-2023

3. Supporting cutting-edge R&D of future network technologies

4. Strengthening training and attracting talent to meet the skills needed for the design and implementation of future networks

18. https://www.ericsson.com/en/news/3/2020/ericsson-and-digital-catapult-to-unlock-5g-potential-with-uk-smart-manufacturing-partners
19. https://www.verizon.com/about/news/verizon-european-private-5g-deal-associated-british-ports
20. https://www.bmvi.de/SharedDocs/EN/publications/5g-strategy-for-germany.pdf?__blob=publicationFile
21. https://www.euractiv.com/section/digital/news/eu-commission-greenlights-german-initiative-to-eradicate-dead-spot-problem/
22. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210525-Deutschland-und-Frankreich-starten-Foerderaufruf-zu-5G-Anwendungen-und-privaten-Kommunikationsnetzen.html
23. https://www.arcep.fr/cartes-et-donnees/nos-publications-chiffrees/experimentations-5g-en-france/tableau-de-bord-des-experimentations-5g-en-france.html
24. https://www.economie.gouv.fr/plan-de-relance/5g-lancement-strategie-nationale
25. https://www.fftelecoms.org/nos-travaux-et-champs-dactions/soutien-du-comite-strategique-de-filieres-infrastructures-numeriques-projets-innovants-lies-au-developpement-de-la-5g/#projet_engage_5g_and_beyond

The European Union
Having set the goal to advance the take-up and availability of 5G for business,[26] the European Commission in 2021 added the target to cover all populated areas with 5G by 2030.[27] The EU funds various 5G trials through collaborative research and innovation schemes such as Horizon Europe. Over 200 trials were underway across 25 of the 27 EU member states and the UK as of March 2021.[28]

The EU's 5G Roadmap 2014-2020

June 2014: 5G EU – South Korea Joint Declaration

May 2015: 5G EU – Japan Joint Declaration

End 2015: Global consensus on the '5G vision' including the broad definition, key functionalities and the target time table

Initial decision on main 5G possibilities

Development of worldwide interoperability standard of 5G

Launch of large scale trials of 5G systems and technology

Early commercial deployment of 5G systems for selected advanced uses

Full commercial 5G infrastructure deployment

WORLD MILESTONES

February 2014: Launch of the 5G Public Private Partnership

March 2015: Announcement of EU vision on 5G

Jul 2015: Launch of phase **1** of EU – funded 5G projects

Launch of phase 2 of EU – funded 5G projects

5G technology showcasing at PyongChang 2018 Olympics

Launch of phase 3 of EU-funded 5G projects

Gigabit connectivity based on 5G technology makes debut at Tokyo 2020 Summer Olympics

EU MILESTONES

START, 2014, 2015, 2016, 2017, 2018, 2019, 2020, BEYOND 2020

26. https://digital-strategy.ec.europa.eu/en/policies/5g-action-plan
27. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en
28. https://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/

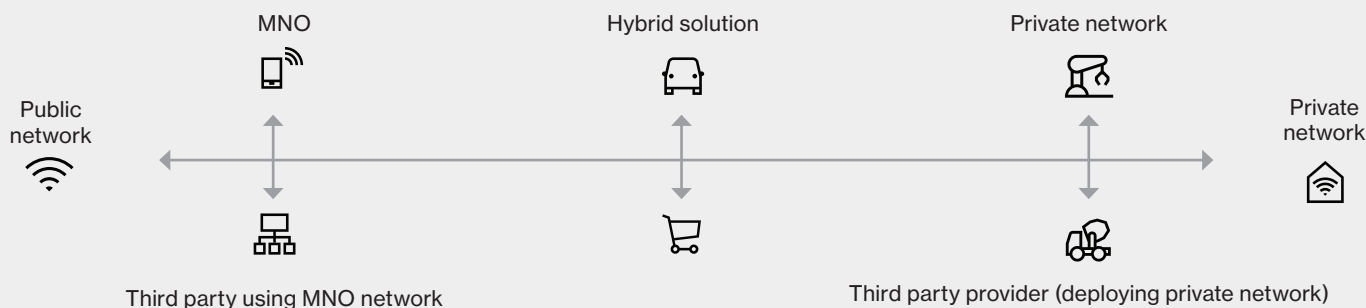# Spectrum capacity, availability and variation

Spectrum is at the core of wireless communications and 5G operates at a variety of bands within the radio frequency spectrum. Countries have designated specific frequency spectrum bands for 5G. In the 2018 Electronic Communications Code,[29] the EU mandated deadlines for member states to have allocated 5G spectrum by the end of 2020, but not all countries met this deadline. National regulators release these spectrum bands to MNOs, typically by auction, or, in countries including the UK, Germany, and France, grant it to enterprises. Spectrum auctions for public networks and MNOs were delayed due to the Covid-19 pandemic. Markets including the UK, France and Germany have begun or concluded their 5G regulations, allowing businesses to own spectrum for private 5G.

Edge computing

If you haven't heard about edge computing, you're not alone: our interviews suggest communications companies have not publicised the technology extensively. However, the increase in data generated through the advanced digital services of Industry 4.0 means that many European industrial players are considering technologies such as edge computing to manage and store data. This is reflected in increased investment in edge computing from cloud service providers (e.g. Amazon Web Services, Google Cloud Platform, Microsoft Azure). The EU views this as a substantial opportunity for Europe. EU-funded project Next Generation Internet of Things (NGIoT)[31] notes that edge computing "… paves the way for new applications, new value propositions and sustainable growth, delivering on the European Green Deal."[32]

The UK Research and Innovation body (UKRI) has funded several edge computing-related collaborative research projects, including Intelligent Edge of Things, focused on developing an intelligent three-tier Edge IoT architecture[33] and Piccolo, focused on edge computing and 5G services for automotive data processing and IoT vision processing.[34] National governments in the EU are also active in edge computing, with Germany announcing funding for an edge computing research programme in June 2020.

Potential business models for deploying wireless connectivity, including 5G

Source: Ofcom's spectrum management strategy for the 2020s[30]

29. https://www.europarl.europa.eu/legislative-train/theme-a-europe-fit-for-the-digital-age/file-5g-action-plan
30. https://www.ofcom.org.uk/__data/assets/pdf_file/0017/222173/spectrum-strategy-statement.pdf
31. https://www.ngiot.eu/
32. https://www.ngiot.eu/report-iot-and-edge-computing-opportunities-for-europe/
33. https://gtr.ukri.org/projects?ref=106199#/tabOverview
34. https://gtr.ukri.org/projects?ref=106196

05
What can private 5G do for innovation?

Many regard 5G as an enabler of new trends and use cases in advanced manufacturing, live entertainment, healthcare and beyond, with applications including AR/VR solutions, remote collaboration and co-creation, or quality inspection. Industry experts point out that these technologies and applications are not necessarily new. They typically haven't reached their potential due to the lack of a reliable, high-speed, and secure wireless connection. Private 5G networks can solve this problem, unlocking innovation.

Private 5G can also impact the rapidly changing world of work. The Covid-19 pandemic meant that most industries needed to find more alternate business models and often remote ways of working. Industry experts are looking to 5G as a means to improve existing operations, as well as enable more innovative ways of working and new value propositions.

Current status of private 5G network innovation

Of the organisations consulted for this study, those that are using 5G and edge computing are mostly at a relatively early stage. This is true for the whole ecosystem of end users and integrators: most organisations are in the planning and ideation stages, while a small minority have started trialling and implementing the technology.

A Global mobile Suppliers Association (GSA) report[35] on private networks globally highlights 370 companies known to be deploying LTE (4G) or private 5G mobile networks, or known to have been granted a licence suitable for deployment. This is an increase from 311 organisations in May 2021. According to Dr Esmat Mirzamany, International 5G Solution Lead at Verizon, the number is continuing to grow,[36] and industry expert Mathieu Lagrange, Networks & Security Director at French research and technology institute b<>com, also stated that the "demand for private network solutions is very strong" and that the European market will experience "around 20% growth year on year until 2030".[37]

Enterprises remain relatively cautious about implementing private 5G networks, however. Many applications are still in their Proof of Concept (PoC) or Proof of Value (PoV) phases, while devices and equipment are often at prototype stage. The PoC and PoV phases demonstrate how a product works and identify the value of the product based on use cases, respectively.

The greater the number of PoVs, the more the value of 5G will become clear and companies will be more willing to explore it. But as with any new technology, it will take time for (private 5G networks) to reach their full commercial maturity.

Dr Esmat Mirzamany, International 5G Solution Lead, Verizon

35. https://gsacom.com/paper/private-mobile-networks-executive-summary-august-2021/
36. Interview conducted by Digital Catapult with Dr Esmat Mirzamany, Verizon
37. https://b-com.com/en/accelerate/do-you-really-need-this-private-5g-network

Creative industries

The nature of entertainment consumption and production is changing rapidly. Creative industries have to remain innovative – in content production and distribution models as well as in the experiences they provide to ever-more demanding consumers.

5G is increasingly used in conjunction with other innovative technologies, such as AR/VR. Technical benefits of 5G, particularly those of low latency and high capacity, mean that new creative ideas, applications and streams can be enabled across the creative industry, including live sports, gaming, theatre, music, TV, film and beyond.

One of the greatest opportunities that (private) 5G can bring to the arts and culture sector is the seamless pivot to hybrid experiences – bringing together physical and digital worlds.

Donna Close, Digital Culture Associate, Brighton Dome & Brighton Festival (BDBF)

Case Study: 5G Festival

The 5G Festival taking place in South East England is one of the world's first 5G powered hybrid immersive festival experiences. It showcases connected, innovative and functional platforms enabling musicians and artists to write, rehearse and produce music jointly despite geographical barriers and delivers new ways for audiences to interact with live performances. The 5G Festival uses a private 5G network for in-venue trials and public 5G for in-home experiences.

Trials in the award-winning festival tested critical aspects of 5G required to enable remote music collaboration. This included tests of how much audio latency that can be tolerated for remote performers to successfully collaborate and how spatial audio delivery (3D audio) instead of stereo can aid seamless collaboration.[38]

Another use case will enable venues to bypass capacity restrictions to deliver a broadcast of live entertainment to at-home audiences. This can be done with limited equipment: a point-to-point network with a venue camera crew in place at one end, sending the audio and video feed direct to the studio to be mixed live and distributed back out to audiences.

The festival was funded by the £200 million 5G Testbeds and Trials programme (5GTT) from the UK's Department for Digital, Culture, Media & Sport. It was put together by partners including Brighton Dome, Metropolis Studios, O2, Sonosphere, Digital Catapult, Audiotonix, BDBF, Warner Music Group, Mativision, and Live From.

5G FESTIVAL

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38. https://uk5g.org/discover/testbeds-and-trials/5g-festival/

Gavin Newman, Brand Director at London-based recording and mastering studio Metropolis Studios, notes that the ongoing 5G Festival project acts as "an eye opening experience about (private) 5G and its benefits... It will enable seamless performance, communication and workflows". Newman highlights applications including the possibility to collaborate and rehearse remotely, noting this is "groundbreaking for the live music industry and wider arts community". Such applications are expected to save the industry time and reduce cost. "The Remotes" is a musical group formed for the 5G Festival trials. The low latency and high capacity of 5G enabled the musicians to rehearse and perform from physically separate locations throughout the country, using augmented reality glasses from device manufacturer Nreal's Mixed Reality (MR) and 360° video. The Nreal glasses provided a fully immersive experience. These applications on 5G "really gave a glimpse into the future," says Newman.[39]

5G combined with the Internet of Things (IoT), in the form of wearables, can also enable audiences to interact and respond to artists in real-time, effectively co-creating with artists by affecting changes in a performance.

Alongside the Creative sector, football clubs are beginning to explore ways in which a private 5G network could enhance audience experiences and offer new ways of engaging with the sport.

Case Study: 5G VISTA

5G VISTA (Video in Stadia Technical Architecture) is a partly-government-funded collaborative R&D project taking place in London, UK. It aims to deliver next-generation viewing experiences for event spectators by providing live multi-angle HD video streams and interactive content from an event directly to devices in stadiums as well as to audiences across the UK, using Multi-access Edge Compute (MEC).

The goal of the project is to demonstrate consumer demand and deliver the business case for 5G-powered sporting events. A full demonstration at a live sports event is planned for February 2022 using 5G LTE feMBMS (further evolved multimedia broadcast multicast service). The audience will be able to enjoy instant replays via smartphones during events and access content from multiple camera angles.[40]

39. Interview conducted by Digital Catapult with Gavin Newman, Metropolis Studios
40. https://uk5g.org/discover/testbeds-and-trials/project-vista/

Ports, Airports and Transport Hubs

Ports, airports, and other transport hubs are an important focus for 5G vendors and service providers. These large-scale coordination and exchange hubs already generate large investments into public cellular (indoor and outdoor), Wi-Fi and other wireless technologies.[41]

For instance, the Cologne Bonn airport in Germany is building a private 5G network to experiment with innovative applications such as intelligent luggage checking and border control and to increase operational efficiency overall.[42] The airport has been awarded a licence by the German Federal Network Agency, with frequencies ranging from 3.7GHz to 3.8GHz.

Case Study: ABP Ports

ABP Ports, operator of the Port of Southampton in the UK, is working with industry partners to enable secure connectivity across selected areas of the port. Integrating 5G into the port will:

- Simplify connectivity systems
- Strengthen the security and reliability of communications between terminals
- Enable the development of additional and more automated operations

Increased use of IoT, AI, machine learning and data analytics requires the capacity of a private 5G network due to the volume of data being generated and used. 5G will underpin much of the infrastructure to enable these advanced technologies.[43]

Manufacturing, Logistics & Construction

Germany, Italy, France and the UK are four of the world's ten largest manufacturing nations.[44] However, the competitiveness of the European Manufacturing sector is being challenged by other regions, both in volume of goods produced and the adoption of industrial digital technologies (IDTs), including 5G.

The Manufacturing and Logistics sectors are at the forefront of 5G innovation, with Manufacturing being one of the sectors experimenting most with private 5G networks.[45] Global multinational manufacturers including automotive manufacturers Ford and Volkswagen Group, aerospace company BAE Systems, and cable manufacturer Prysmian Group are exploring how they can improve operations.[46]

The low latency of 5G can optimise manufacturing activities with remotely automated functions, including collaborative robots, autonomous vehicles, digital twins and predictive maintenance of shop floor equipment as well as quality control and anomaly detection. 5G can also drive productivity gains. One trial by Worcester Bosch in the UK found that private 5G enabled a 2% productivity improvement for some applications.[47]

41. https://stlpartners.com/research/airports-the-roles-of-5g-private-networks/
42. https://www.airport-technology.com/news/cologne-bonn-airport-ntt/
43. https://www.abports.co.uk/news-and-media/latest-news/2021/verizon-business-signs-its-first-european-private-5g-contract-with-associated-british-ports/
44. Make UK, UK Manufacturing Facts 2020/21
45. https://uk5g.org/attend/driving-smart-x-world-with-private-5g-networks/
46. Expert interviews conducted by Digital Catapult, Summer 2021
47. https://www.ericsson.com/en/cases/2020/the-5g-factory-of-the-future

Case Study: 5G Factory of the Future

Led by a consortium of industrial, academic partners and SMEs including BAE Systems, IBM, AMRC NW, Digital Catapult, aql, Miralis and MTT; 5G Factory of the Future trials 5G connectivity in five use cases common in manufacturing. The project tests the capability of 5G in:

- RTM real time monitoring and closed loop control of a machining process to control the input variables and ensure extremely tight tolerances are maintained

- Factory Ecosystem Monitoring (FEM) of the factory to enable reconfigurable assembly cells

- Optimised packing & asset condition monitoring through the supply chain, for improved transparency and digital handover

- XR/AR usage for remote assistance, collaboration and inspection

- The use of Digital Twin Technology (DTT) to create a reference architecture and enable scenario mapping — with the ability to to simulate real life situations and using historical data to predict behaviours in the process, or to optimise factory layout and flow

The testbed is expected to result in reduced downtime of factory equipment, reduced infrastructure requirements and a future connectivity blueprint.[48]

Research has found that 76% of manufacturers across four countries plan to use private 5G by 2024.[49] One example is a Volkswagen factory plant in Germany, which currently has a line production with an AGV fleet, which is used as part of the production process and runs on Wi-Fi. The automotive manufacturer plans to move to matrix production in the near future and become more flexible. The vehicles being produced will only be brought to the stations required for their configuration and features. This will increase productivity as steps that are not needed for specific vehicles can be skipped. Production will become more complex and Volkswagen will need to evaluate suitable concepts such as a centralised guidance control system in the cloud to control its AGV fleet. The company plans to make use of a private 5G network to meet the requirements of future production systems.[50] Because of 5G and the low latency that comes with it, AGVs will be able to drive much faster whilst maintaining safety, and as such will be more efficient.

Both interviews and desk research suggest that Manufacturing and Logistics are likely to continue to lead in early adoption of 5G, creating more learnings, demonstrating use cases and testing technical requirements that can be shared with other industries. Equipment and technological infrastructures used in manufacturing are likely to develop to include specifications that require 5G as a standard, both internally and to interact with other partners in digital supply chains.

In the next 5-10 years, when looking at the future of digital twins and connected supply chains, and as more peripherals emerge that support 5G, it will become more important to connect with it.

Farooq Yaqub, Innovation Engineer & XR Lead, Ford

48. https://uk5g.org/discover/testbeds-and-trials/5g-factory-future/
49. https://accedian.com/wp-content/uploads/2021/09/Accedian_Accelerating-Smart-Manufacturing-with_Analyst-Research.pdf
50. Interview conducted by Digital Catapult with Niklas Ambrosy, Volkswagen DE

Similarly, the construction and built environment industry, although traditionally slow to adopt digital technologies, is exploring how private 5G and edge computing can help improve functions including monitoring and connectivity for commercial use in infrastructure projects such as airports and highways. Industry experts note that it is particularly important for these sectors to build for future needs. Buildings and infrastructure are built to last a long time and must be equipped for the future.

Construction sites are often in areas with poor coverage, since necessary infrastructure is in the process of being built. By its nature, a construction site is also a rapidly and drastically changing environment. It is more likely to require frequent changes to the network configuration, which is easily done with private 5G solutions. Furthermore, construction sites can be seen as temporary manufacturing sites, with low latency required to enable site control. Studies suggest that the use of edge computing in the Construction industry may also improve the efficiency and quality of Construction safety management (CSM).[51]

Case Study: 5G Smart Roads

Spanish Transport Infrastructure and Mobility services company Ferrovial is working with international partners Microsoft, 3M, Kapsch TrafficCom and others to develop the 5G-enabled AIVIA smart roads platform.

Launched in early 2021, the project uses private 5G and other technologies in the construction and operations of the roads of the future. These roads will form critical parts of the connected infrastructure required for connected and autonomous vehicles, while providing better safety for conventional vehicles. Private 5G will be used for construction, while public usage of the smart roads will use public 5G. This will help reduce congestion, improve journey times and provide 5G connectivity to road users.[52]

Hospitals and Healthcare

Within hospitals, private 5G networks can support new applications and improve collaboration and automation. One key benefit of a private 5G network is data privacy: hospitals can deploy on-site mobile networks without transmitting data through public networks. A private 5G network's speed, reduced latency, and high bandwidth connectivity (combined with mixed reality and AI capabilities) could enable real-time precision medicine and the rapid sharing of large files to improve patient care. One recent study[53] notes that healthcare applications that 5G could support include:

- Telemetry and VR training on surgical procedures

- Quick and reliable transport of huge data files of medical imagery

- More resilient and higher-speed connectivity for hospital machines

51. https://www.itcon.org/papers/2020_25-ITcon-Chen.pdf
52. https://newsroom.ferrovial.com/en/press_releases/ferrovial-launches-aivia/
53. https://accedian.com/wp-content/uploads/2021/09/Accedian_5G-Brief_Healthcare.pdf

Case Study: Engage 5G & Beyond

As part of France's Covid-19 recovery plan, the Government funded the "Engage 5G & Beyond" project led by b<>com, one of eight institutes of research and technology backed by the French Government. The project aims to develop solutions to allow better remote monitoring of patients through the deployment of a private 5G network at the Rennes University Hospital.[54] This will enable operational efficiencies such as seamless sharing of large files, provision of patient data directly to their rooms, and freeing up Wi-Fi for patient access. Over the next three years, the Engage 5G & Beyond project will also enable 5G experimentation in Industry 4.0 and Energy sector use cases.
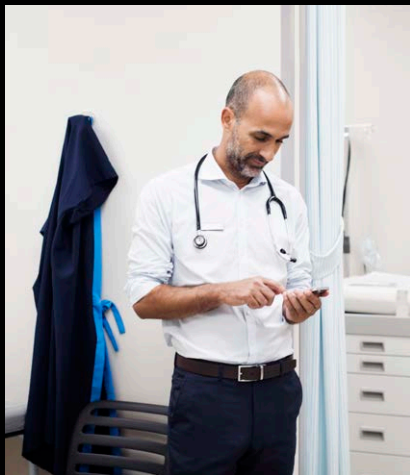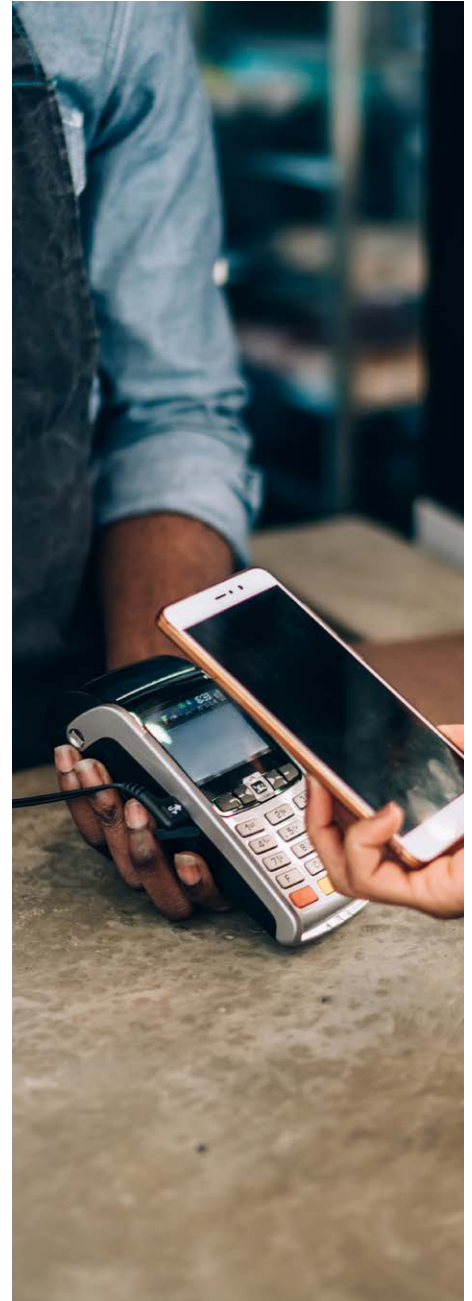
Similarly, the private 5G network set up by the city of Liverpool, UK[55] aims to demonstrate 5G solutions for Health and Social Care services that reduce costs and create extra capacity for staff. At Kings College London (KLC) UK, a 5G network in combination with surgical robotics was used to show how the remote transfer of haptic, tactile, audio and visual technologies can support a surgeon or doctor performing a diagnosis, or even surgery on a patient anywhere in the world.[56]

Other use cases: Higher Education and Retail

On university campuses, private 5G networks can allow users to increase the efficiency of daily operations, improve connectivity for students and faculty members and enable academic exploration of 5G.

Retail and Leisure venues are testing 5G to provide new customer experiences and test high volume network access. 5G-enabled shopping centres including The Square in Camberley, UK and Finland's Mall of Tripla are working with Research, Technology and industry partners to trial new methods of connectivity to provide data-driven customer experiences, offer innovative value propositions and support the evolution of smart cities.
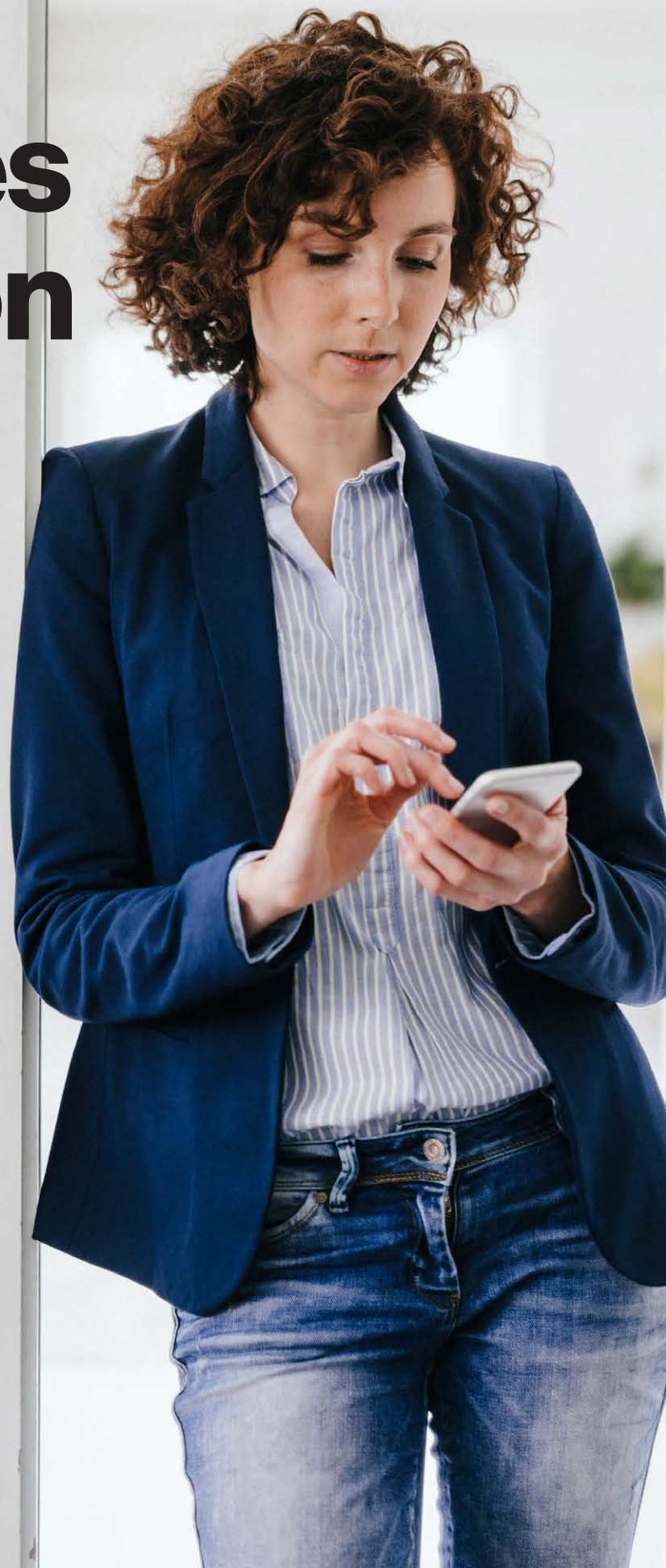
54. https://www.entreprises.gouv.fr/fr/presse/france-relance/france-relance-developper-des-applications-5g-dans-domaine-de-la-sante
55. Liverpool 5G: The network was set up for a consortium of public sector, health and social care suppliers, the NHS, university researchers, third sector organisations, local SMEs and a UK 5G technology vendor.
56. https://www.kcl.ac.uk/archive/news/informatics/newsrecords/king's-demonstrates-how-5g-technology-can-enable-mission-critical-services

06
Challenges to adoption

All early-stage innovative technologies have growing pains. Private 5G and edge computing are no different. From issues of integration with legacy networks and a lack of compatible devices to problems identifying the appropriate use cases for each business vertical,[57] the adoption of private 5G networks in enterprises faces challenges.

Misconceptions

5G is a complex technology. It's not surprising that there are misconceptions and a lack of knowledge around it.

On a basic level, a common misconception is that many of the benefits of 5G and edge computing are already available with Wi-Fi and other connectivity alternatives. They are not. For example, later evolutions of LTE and Wi-Fi 6 can offer high capacity, but can't manage radio resources as efficiently as 5G. 4G has network slicing of sorts, but this requires replicating some core elements and is not end-to-end. At the other end of the spectrum, expert interviewees point to a problem of grandiose 5G myth-making by some companies marketing the technology. Claims made for the emerging technology can seem excessive, to the point where some see them as misleading. The truth about 5G sits somewhere in the middle.

Knowledge and skills gaps

Our expert interviewees suggest that often only select teams within companies – such as R&D or those responsible for digitalisation, automation and innovation – have a good understanding of private 5G networks. Knowledge held by individuals who work directly with private 5G networks often remains in internal silos. According to a study from Accedian, 68% of manufacturers interviewed across four countries would like to outsource private network management rather than manage it internally, due to the complexities of the task.[58] To broaden the internal 5G knowledge base, a first-stage fix for those with specialised technology expertise is to share knowledge and best practice within their organisations.

Where management teams resist exploring 5G, this is often due to knowledge gaps: decision-makers most commonly hesitate because the immediate benefits are not clear. A clear business case includes having an understanding of what, specifically, 5G can deliver across all teams – not just IT. Interviewees point to the fact that boards and management teams need to be convinced of 5G advantages through demonstrated use cases and best practices. Support from 5G technology suppliers is also needed.

5G is often presented as a panacea and solution for everything. This narrative does not manage expectations nor give an accurate perspective from a business, cost, and technology standpoint.

Stefano Brandinali, Chief Digital Officer, Prysmian Group, (Italy)

57. https://www.capgemini.com/gb-en/wp-content/uploads/sites/3/2021/06/Final-Web-Report-5G.pdf
58. https://accedian.com/wp-content/uploads/2021/09/Accedian_Accelerating-Smart-Manufacturing-with_Analyst-Research.pdf

The biggest problem will be around changing people's mindsets rather than implementing (5G) technology itself. There are many learnings to be acquired from it, but people need to accept some level of change and potential risk first. There are challenges but the benefits will largely outweigh them.

Senior Engineer at a leading data storage service provider

Enterprises lacking in-house knowledge need to upskill or hire more specialised talent if they are serious about 5G. In some sectors, there is significant curiosity and interest in the technology, but this is often dampened by limited 5G technical and business know-how.

Interest in private 5G networks is growing in the Live Entertainment sectors, for example. Stakeholders believe the technology could allow them to transform their current capabilities and create new business models, in areas from writing processes and recording workflows to new types of performances. While the pandemic provided impetus for developing theoretical 5G know-how, it did not allow businesses to experiment.

A Capgemini Research Institute survey[59] further notes that potential end-users of private 5G networks still need the appropriate skill sets to buy the relevant infrastructure and industry-specific solutions for their business.

Coupled with generally risk-averse attitudes which, according to industry experts, are more common in Europe than in other parts of the world, the lack of in-house expertise and the need for upskilling does not allow for much-needed 5G experimentation.

Industry insights indicate that staff across sectors and industries are eager to both learn and upskill, but it is not always clear to management where quality, industry relevant training can be found. The problem is how to train staff and provide practical upskilling rather than recruiting for new roles. In some specialised, technology intensive industries, some staff may already have the skills required to use and implement 5G, but external support in upskilling a larger part of the workforce is still needed. The best solution may be to ask trusted peers for recommendations and to encourage continuous research and knowledge-seeking from staff being trained.

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59. https://www.capgemini.com/gb-en/wp-content/uploads/sites/3/2021/06/Final-Web-Report-5G.pdf

Lack of information resources

The experts we interviewed highlighted the lack of information resources about private 5G use cases and learnings. Given the early stage of overall adoption, industry knowledge sharing often happens through specialised conferences, trade groups and forums such as 5G-ACIA.[60] However, some interviewees also cited some dependence on device manufacturers for specific information.

To overcome some of these difficulties in knowledge sharing, businesses can gain knowledge by participating in collaborative R&D projects, speaking with industry peers, seeking out details of successful trials and working with network operators. Governments, national innovation agencies (e.g. UK Research & Innovation) and research, development and innovation organisations (such as Digital Catapult in the UK, the Carnot Institutes in France or the Fraunhofer Institute in Germany) can play an important role in supporting these R&D and innovation activities and enabling proof-of-value concepts to point the way towards ROI.

We are still unable to consider private 5G as an official part of our budget or usage due to the lack of understanding around it, as well as the absence of rate cards to understand the cost for on-location data transfer. This could change if more academic papers and resources with different use cases and descriptions of workflows of the technology could be used as inspiration, best practice, and learnings.

Tomasz Witkowski, Director of Technology & Engineering, Twickenham Film Studios

60. https://5g-acia.org

Affordability and ROI

The success of a technology is typically based on public engagement, demonstrations and better understanding of the ROI. Early adopters have noted that it is predominantly multinational organisations that are willing to run trials with industrial 5G. They believe it will likely take around three years for smaller companies to start their 5G experimentation.

Thorough planning around experimentation and deployment for a defined use case is essential to ensure maximum ROI from 5G. As noted by Chris White, Electrification Manager at Ford Europe at the May 2021 Private Networks Forum:[61] "…there is a business case for all of the things (private 5G) enables within the enterprises –

whether that is Industry 4.0, or augmented reality and preventive maintenance via IoT sensors. All those things have a business case, but (the market) has to realise you cannot just put a 5G network in and get a return; you need a plan for everything to launch off the back of it."[62] In other words, organisations should not only consider the fact that it may take some time between 5G being implemented and positive outcomes, but also make sure that the use case behind their implementation of a private 5G network is well defined.

The fact that many of the most exciting possibilities of 5G come by combining it with other technologies potentially puts 5G in a difficult position. For companies considering 5G, this combination of several new technologies can seem too risky when there are limited proof-points.

Industry research suggests that trials of private 5G networks based on multiple use cases can help justify investment. Service providers need to work across departments to aggregate use cases, gain management approval and make sure the team responsible for network/IT infrastructure renewal is involved from the start.[63]

The business case will be made stronger by considering network flexibility: since the network can be used for additional, not-yet-conceived services and helps future-proof connectivity, the ROI goes beyond the specific use case. Experts have also noted that if their companies could leverage a public 5G network, this may lower costs, but would come at the expense of control and flexibility.

61. https://www.privatenetworksforum.com/home
62. https://enterpriseiotinsights.com/20210525/channels/news/enterprises-dont-understand-the-tech-or-the-business-case-ford-on-what-to-fix-with-private-5g
63. https://accedian.com/wp-content/uploads/2021/09/Accedian_Accelerating-Smart-Manufacturing-with_Analyst-Research.pdf

Lack of case studies

An increasing number of industrial use cases for 5G are currently emerging. These include the ability to remotely control and operate machinery and conduct quality controls and inspections, run AGVs and other autonomous robots, industrial training, digital twins and remote collaboration using AR/VR.[64] However, these are not widely publicised and known.

The shortage of known case studies inhibits 5G experimentation. There is a need to identify and document existing use cases and to share knowledge among industry players and academia.

Some organisations are convinced that 5G will enable the introduction of new products, services, and business models – therefore driving revenues and justifying initial investments. Insights gathered for this report suggest that, to fuel the market, technology providers and operators need to define 5G use cases as well as estimate ROI. There is an opportunity for companies to partner with suppliers to experiment.

Limited device ecosystem and interoperability

New technologies tend to have growing pains of availability, interoperability and compatibility of devices and infrastructure. The current lack of 5G compatible devices is expected to be temporary: it is likely to be resolved as the 5G ecosystem matures.[65] Experts noted that although 5G-ready smartphones and home broadband devices are becoming available in consumer markets, products suitable for industrial and business use cases are not as easy to come by. Some experts note that the issue creates a chicken-and-egg situation: an organisation has little incentive to invest in 5G if 5G devices aren't available. Others note that 5G-enabled devices would need to be backward compatible with 4G. This may, however, come with security risks.[66]

Similarly, interoperability of devices from different operating systems has been raised as an important issue for device manufacturers and systems integrators to address. For 5G systems to be used to their full potential, it is of key importance to industry that the service architecture of 5G devices seamlessly integrates with legacy systems. Several parts of the 5G ecosystem are working to achieve this.

64. https://www.capgemini.com/gb-en/wp-content/uploads/sites/3/2021/06/Final-Web-Report-5G.pdf & interview/workshop findings
65. https://www.capgemini.com/gb-en/wp-content/uploads/sites/3/2021/06/Final-Web-Report-5G.pdf
66. https://www.electropages.com/blog/2020/10/vulnerability-old-tech-how-5g-may-face-problems

Regulatory misalignment and standards

Although 5G has global standards, government approaches to 5G and edge computing differ; there is no consistent regulatory framework across Europe and allocation of 5G spectrum has been delayed. The development of standards furthermore slowed down due to the Covid-19 pandemic. This makes it harder for companies to plot a 5G business case. One expert interviewee notes: "...given that most initiatives involving 5G are at the prototype hardware phase, rather than widely available on the market, financial estimates today cannot tell what the total cost of ownership will be tomorrow because many standard specifications are not yet implemented".

5G Releases can also make things confusing for industries looking to use the technology. Industry body 3GPP creates cellular communications standards and uses a system of parallel "Releases" which provide developers with a stable platform for implementation of features at a given point, with addition of new functionality in subsequent Releases.[67] The four Releases already announced for 5G are Releases 15, 16, 17 and 18, but 3GPP may add more as needs evolve over time.

Differences in definitions

Experts also highlighted differences in definitions as an issue. For instance, different companies look at the term 'edge computing' differently, which impacts how important a private 5G network is for the solution.

If edge computing is at the cloud level and requires ultra low latency, then 5G is necessary. If, however, computation is done at the level of the device itself, a private 5G network may not be needed, unless there is a large transfer of data from that device back to a central virtual machine and cloud. However, specific use cases may still require private 5G. For instance, if a company uses IoT sensors whose data is processed through AI/ML at the edge (without the use of the cloud), private 5G can help achieve near-real-time response.

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67. https://www.3gpp.org/specifications/67-releases

Impact of Covid-19 on 5G & digital innovation

The Covid-19 pandemic affected nearly every aspect of society. Companies across the majority of sectors were forced to switch to remote operations. Digital became key as remote working required companies to ensure they provided a robust IT infrastructure capable of supporting this large-scale, unprecedented change. Technology and 5G is no exception.

Expert interviewees noted both positive and negative impacts of Covid-19 on 5G implementations. The pandemic meant that some cultural organisations accelerated their uptake of technology, because they were forced to find new ways to engage with audiences. The sector has previously been slower to embrace virtual experiences, but advanced networks such as private 5G allowed Brighton Dome & Brighton Festival (BDBF) and others to get closer to the immediacy and full immersion of physical experiences. Covid-19 has stimulated venues to focus on exploring new ways for artists to co-create and collaborate – as seen in the example of the 5G Festival project (see Case Study above). BDBF believes that the 5G Festival is a genuine "engine for innovation".[68]

The pandemic also accelerated some governments' 5G experimentation. For instance, the Italian Government's plan to build back from the Covid-19 crisis, the National Recovery and Resilience Plan (NRRP),[69] is heavily focused on energy transition and infrastructure. The concept of 'smart villages', which was previously only theoretically envisaged, was tested and demonstrated during the Covid-19 crisis. In the future, this will allow first-hand experimentation with a private 5G network in territories that were previously unconnected and amongst social communities that often have less access to technological advances.[70]

Covid-19 meanwhile impacted 5G negatively by slowing down the development of 5G standards – particularly the launch of Release 16[71] – as well as disrupting spectrum auctions worldwide. More generally, cash and financial pressure reduced investment in innovation overall.[72]

Many venues have real limits for how many people they can accommodate within the space comfortably. Private 5G networks may be able to create an experience that operates outside of the building, whether it starts at home or en route to the destination. Private 5G networks could offer a different way of delivering an enhanced experience that isn't predicated on people being physically present in one location.

Stephen Hilton, Founder and Director, City Global Futures Ltd and Fellow, University of Bristol Digital Futures Institute

68. Interview conducted by Digital Catapult with Donna Close, BDBF
69. https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/
70. Interview conducted by Digital Catapult with Stefano Brandinali, CDO, Prysmian Group
71. Release 16 is the next release of 5G standards, with key features including NPN (non-public - i.e. private networks), enhanced services for IoT and time sensitive networking (useful for industrial automation) and Cellular IoT over 5G.
72. https://www.capgemini.com/gb-en/wp-content/uploads/sites/3/2021/06/Final-Web-Report-5G.pdf

07
Conclusions

While immediate benefits shouldn't be overstated, private 5G networks and edge computing have much to offer European end-users. Private 5G, especially when coupled with edge computing, can optimise operations, facilitate innovation and enable new value propositions. Whilst private 5G networks are on the radar for early 5G adopters, edge computing as a companion to 5G is not always considered up-front. When paired, private 5G and edge computing complement each other. The combination is particularly relevant when planning future infrastructure.

Part of Europe's strength lies in the region's industrial verticals. The industries' ecosystem is advanced in many aspects that makes it well placed to innovate in 5G. Businesses can take steps now to start realising this potential.

Key benefits – a reminder

The capabilities of a private enterprise network

- **Full network control:** A private 4G/5G network can be configured to an enterprise's and location's specific needs and is controlled by the owner

- **Higher levels of privacy and security:** The ability for a 5G network owner/operator to manage their own security program including configuration, processes and procedures

- **Customising the network to exact needs:** The ability to configure a network to an enterprise's specific needs - a benefit that public networks can't offer
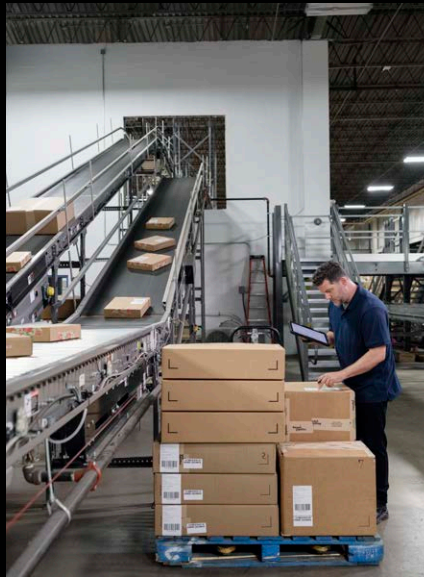
The technological capabilities of 5G

- **Low latency:** Desirable in the majority of business operations, low latency reduces response time for critical and non-critical operations

- **Reliability:** 5G networks offer greater reliability of service than other forms of connectivity

- **Network slicing:** A single physical communication network can be split into different, multiple, customised virtual networks, offering improved flexibility and ROI

- **Dedicated spectrum with no interference:** The lack of interference on private 5G ensures greater levels of throughput and control for businesses

- **Full mobility:** Full mobility for connected assets to be moved around in large areas, and experience seamless connectivity with a consistent level of performance

To consider when starting your 5G journey

The fact that 5G and edge computing are in such early stages of adoption means that various parts of the puzzle are not in place. As with other emerging technologies, the full market availability of products will not happen overnight but the ecosystem is rapidly developing.

As the case studies in this report show, it is possible to experiment now. For those who want to stay ahead of the curve, now is the time to join the experimenters. The best way to learn about solutions that utilise private 5G and edge computing is to try them out.

When exploring the adoption of 5G and edge computing, consider:

Planning & use cases

The potential of private 5G and edge computing is vast, but will only be realised if the technology is applied to concrete industrial problems and opportunities. It goes without saying that technology investment needs a purpose. While there are multiple benefits to 5G, use-cases demonstrating these have been lacking. The number of 5G use-cases is now increasing, providing points of reference for those interested in experimenting with the technology.

By looking both inside and outside their own industries, businesses can identify early-stage case studies to help inform their experimentation and – in turn – showcase their own trailblazing activities. It is essential to focus efforts on the specific business challenges 5G will be used to tackle, with a clear plan and use-case providing the starting point for experimentation. Consider where the unique capabilities of these technologies can make a difference in your business and thoroughly plan to consider costs, funding and ROI from there.

Building the business case & ROI

Businesses should expect 5G investment to take some time to pay off, but for many, it's a necessary investment for the data-hungry future. 5G requires a long-term view of ROI, factoring in a wide range of potential benefits. More than other technologies, it requires businesses to weigh the balance of initial costs of equipment, training, and running costs versus the long-term benefits of future-proofing company infrastructure. Research suggests early adopters of 5G are predominantly large corporations that have the capital and breadth of

skills required to test the conditions, configurations and operational structure necessary to benefit from 5G.

Many 5G users can reduce their initial investment by integrating necessary components into existing IT and communications infrastructure. The entire communication infrastructure typically doesn't need to be replaced immediately. When considering how private 5G experimentation and adoption can be funded, explore a range of avenues, including collaborative R&D, governmental grants and self funding. Businesses should also consider alternative ways of measuring value to not only include measures of efficiency, but also less tangible ones such as customer satisfaction, brand value and improved quality control. Immediate savings such as reduced energy expenditure, as well as longer term savings such as the avoidance of fines and recalls may be considered, as well as innovating to attract and retain the best talent.

Invest now or wait and see?

Use of 5G and edge computing is not widespread. Early adopters often struggle to find real-life applications that are relevant to their use case and can provide useful insights and learnings.

In fact, the number of use cases is growing. Both interviews and desk research suggest that manufacturing and logistics are likely to continue to lead in early adoption of 5G, creating more learnings, demonstrating use cases and testing technical requirements that can be shared with other industries.

To learn more, use a multitude of sources, from academia, non-profit organisations and government to industry forums both inside and outside your own sector. Running hackathons and engaging with academia also provide ways to engage with the 5G ecosystem and the innovators that are developing solutions and new findings for the market. 5G business users need continued discourse about trials and real-world 5G experiences. This increases the likelihood of successful deployments. Attending conferences and participating in collaborative research projects that use private 5G can be particularly valuable. Businesses should also consider that the risk of experimenting early may be significantly lower than the risk of missing the advantage of being an early adopter. This may be particularly true when considering that technology needs time to experiment with - both to fully understand it, its benefits and to generate ideas on the ways in which it could work.

Sharing knowledge & 5G blueprints

As more organisations begin to deploy private 5G networks and edge computing, early adopters can share findings that are relevant to their industry. Roadmaps to 5G may begin to be crafted to create a blueprint for adoption within specific verticals.

Experimenters are encouraged to share knowledge where possible. Blueprints for verticals can include infrastructure requirements and ways to ensure interoperability and compatibility between connected devices, as well as the development of either industry-specific or generalised standards and regulation. This can drive insight for valid business cases and ROI.

Embracing innovation

Innovation and new technology always carry some risk, but also bring rewards and future-readiness. Our interviewees suggest that risk-averse mindsets can hinder progress. Companies are beginning to realise that there is enormous value in data that they are gathering through various processes and not actively using. 5G will help companies move to the next phase of IoT where data is used for multiple purposes such as digital twins.

Innovation needs a culture of openness and courage to thrive, enabling a business to build a foundation for future growth. Proceed with care, but don't let a closed mindset prevent the progress and competitiveness of your organisation.

Acknowledgements & Appendix

Acknowledgements

Private spectrum allocation in the UK and EU

The UK, Germany, and France are all part of a short list of countries allocating spectrum to private companies without necessarily involving MNOs.

UK

UK communications regulator Ofcom has introduced two new mechanisms providing localised access to spectrum bands supporting mobile technology: Shared Access licences and Local Access licences.

Enterprises can apply for coordinated access to Shared Access bands in specific locations, on a first-come-first-served basis. The bands assigned so far are:

- 1800 MHz band: 1781.7 to 1785 MHz paired with 1876.7 to 1880 MHz

- 2300 MHz band: 2390 to 2400 MHz

- 3800 to 4200 MHz band

- 24.25-26.5 GHz (only available for indoor low-power licences)

Ofcom anticipated the indoor low-power licences in the 24.25-26.5 GHz band to be suitable for industrial and enterprise users looking to deploy their own private networks. It also anticipates that the 3.8-4.2 GHz band could enable 5G for private industrial networks and is not permitting this band to be used to provide national mobile broadband, instead making the 3.6-3.8 GHz band available for that purpose.[73]

Through Local Access Licences, Ofcom introduced a way of accessing spectrum that is already licensed to mobile network operators (MNOs), but is not being used (or planned for use) in a particular area within three years of the date set.[74]

To reach its spectrum management objectives, Ofcom has committed to making spectrum available in a variety of ways, including licences specifically for innovation and trials (such as the 5GTT programme).

Germany

The regulator Bundesnetzagentur (BNetzA) reserved 100MHz of spectrum in the 3700MHz-3800MHz band for use by private companies. These are referred to as campus or local networks in Germany, or 'lokale Netze'. As of October 2021, it had allocated local 5G spectrum to 158 enterprises in various industries and verticals - from university campuses, to manufacturers, government departments, and multinational consultancy firms - including Accenture, Airbus, Audi and BMW. This spectrum is allocated to allow enterprises to operate 5G networks on their property, provided that they demonstrate that the spectrum is used to enable specific use cases that would otherwise not be possible. Germany is also one of the few countries where the regulator publishes numbers on licence applications and allocations.[75]

France

French regulator ARCEP has granted 5G spectrum for experimental industrial purposes including in 'Industries of the Future', connected mobility, IoT, Smart Cities and Gaming. Spectrum is offered to businesses through an online portal that was launched in May 2019. In February 2020, airport operator ADP Group and subsidiary HubOne were granted a 10-year 4G and 5G licence, which Air France also benefits from. Electricity company EDF was offered a 10-year license for the Blayais nuclear power plant. Mobility company TransDev was granted spectrum in Rouen for a four-year period (2020-2024).

European Union

The European Commission, together with member states, develops EU-wide spectrum policy and coordinates spectrum harmonisation and implementation to support innovation. EU radio spectrum policy has three overall goals:

- Harmonising the use of radio spectrum

- Working towards a more efficient use of spectrum

- Improving the availability of information about the current use, future plans for use and availability of spectrum

Member states coordinate the use of radio spectrum by implementing Commission decisions at a national level. The latest Commission decision was adopted in June 2021 regarding Wi-Fi and harmonised the use of the 6 GHz band for wireless networks across the EU.

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3GPP's 5G Releases

For each release drop, a list of features are defined, developed and approved by 3GPP. Once approved (or when there is a "freeze") specifications cannot be changed and the drop is complete.

- **Release 15** (approved March 2017) is the first full set of 5G standards. It is currently the most commonly used 5G release. Release 15 can seem limited but is largely sufficient for early testing and experimentation. It includes speed and capacity increases and mobile broadband, allowing for more advanced capabilities such as multiple input and output. Subsequent releases provide more of the essential features for business deployments, but waiting for these can mean less of an early-mover advantage.

- **Release 16 (**approved June 2018) was mainly adopted by vertical industries such as non-terrestrial networks (NTN), vehicle to everything (V2X), public safety, and Industrial Internet of Things (IIoT). Release 16 aimed to enable 5G to substitute for private wired Ethernet, Wi-Fi, and LTE networks.

- **Release 17** (expected to complete June 2022) and Release 18 will demonstrate clear benefits across verticals. Similar to Release 16, Release 17 will improve on features from Releases 15 and 16, including private 5G network capabilities. Release 17 will also include new features, such as improved battery life and satellite access.

- **Release 18** The list of features to be defined and included will close at the end of 2021. The Covid-19 pandemic has delayed the release. 3GPP's projected timeline anticipates approval of Release 18's initial package in December 2021.

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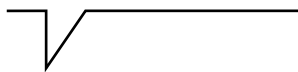
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Verizon

Verizon Communications Inc. (NYSE, Nasdaq: VZ) was formed on June 30, 2000 and is one of the world's leading providers of technology, communications, information and entertainment products and services. Headquartered in New York City and with a presence around the world, Verizon generated revenues of $128.3 billion in 2020. The company offers data, video and voice services and solutions on its award-winning networks and platforms, delivering on customers' demand for mobility, reliable network connectivity, security and control.

Digital Catapult

Digital Catapult is the UK authority on advanced digital technology. Through collaboration and innovation, it accelerates industry adoption to drive growth and opportunity across the economy.

Bringing together an expert and enterprising community of researchers, startups, scaleups and industry leaders to discover new ways to solve big challenges that will unlock the UK's future potential. Through Digital Catapult's specialist programmes and experimental facilities, we make sure that innovation thrives and the right solutions make it to the real world.

Digital Catapult's goal is to accelerate new possibilities in everything it does and for every business it partners with on the journey – breaking down barriers, de-risking innovation, opening up markets and responsibly shaping the products, services and experiences of the future.

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