Ofcom
making communications work
for everyone

Supporting the expanding role of **wireless innovation** in UK industry

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Overview

In its role as the UK's Communications regulator Ofcom manages the UK's airwaves. These are used in every type of wireless communication from TV and radio to the very latest smartphones.

All industries are increasingly engaged on a journey towards "Digital Transformation". Exactly what this journey entails, and its desired impact may vary from sector to sector, as will the speed of this transformation. But it is clear that wireless connectivity will underpin this wide-ranging transformation across all industries. This paper explores what forms this wireless connectivity could take and how best to ensure it meets the needs of UK consumers and industry.

In this discussion paper:

- **we analyse the increasing role wireless technology is playing in a number of different industries – alongside other technology developments – to enable greater productivity, lower costs and improve quality of service;**
- **we describe the wide range of issues organisations and businesses should consider when seeking to leverage the benefits of wireless connectivity; and**
- **we outline a range of technological approaches and business models and explain our role in enabling these by ensuring appropriate measures are in place to support the development of a digital infrastructure.**

With this document we are inviting businesses, trade bodies and other interested parties to engage with Ofcom to ensure our regulatory regime enables industry to access the benefits of wireless connectivity. We encourage businesses and organisations of all sizes and across all sectors to get in touch with their views, regardless of what stage they are at in thinking about wireless technology.

You can reach us at industrial.innovation@ofcom.org.uk

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Introduction

Digital technologies are transforming a range of industries

Businesses are constantly evolving and innovating to achieve greater productivity, reduce costs and improve the quality of service they offer to their customers. According to research by the Confederation of British Industry, 94% of businesses believe that digital technologies are a crucial driver of increased productivity.[1]

Wireless connections are increasingly enabling different players to achieve their digital transformation objectives. Industries such as utilities and agriculture, logistics and transport are all benefiting from this. Wireless connectivity, remote sensors, control and automation are changing the way businesses deliver their services, while consumers have seen the advantages in their everyday lives through the use of smartphones and apps.

Developments in the use of Artificial Intelligence (AI) and robotics; augmented and virtual reality (AR and VR); and the Internet of Things (IoT) have the potential to support digital transformation further. The benefits from successfully using these different technologies to deliver industrial digitalisation are far reaching, and wireless connectivity is crucial to this.

A study for the Made Smarter Review estimated the positive impact of faster innovation and adoption of industrial digitalisation technologies could be as much as £455 billion for UK manufacturing over the next decade.[2] The same study estimated a growth between 1.5 and 3 percent per annum for the manufacturing sector.

Harnessing the potential of wireless connections will be crucial for companies and the economy as a whole over the coming years. Different sectors will face their own specific challenges. For example, some organisations might need to control and connect multiple robots within a factory plant to improve processes, reduce production down time and increase productivity; others – such as utility networks – might rely on sensors collecting data across the electricity grid to manage their operations more effectively. Such a range of requirements will

[1] CBI, 2018, *Ready, set, connect*, http://www.cbi.org.uk/index.cfm/_api/render/file/?method=inline&fileID=EBE91939-C93C-49DB-9DF770ACD5166F2A (Accessed 18 January 2019).
[2] Made Smarter Review 2017, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf (Accessed 17 December 2018).

need a diverse mix of technology and business models to deliver connectivity.

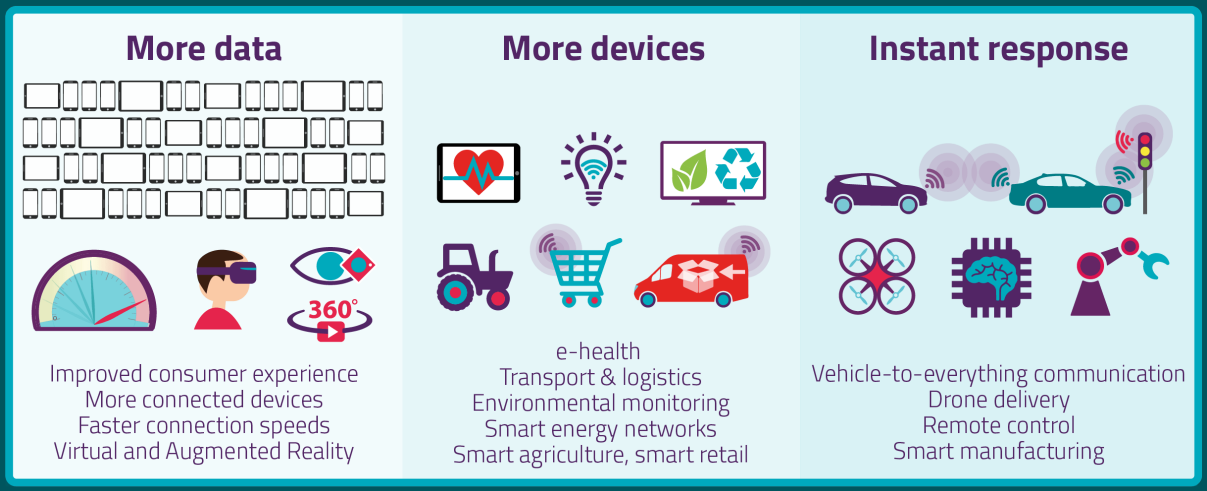
Today, a range of wireless technologies, from WiFi to IoT solutions, have already been deployed to meet connectivity requirements across many of these sectors. However, the requirements of some businesses are starting to go beyond the limits of existing technologies. The diversity and complexity of new connectivity requirements, with increased focus on security and resiliency mean that many businesses and industries are reviewing their strategy to improve efficiency, flexibility and scalability. Wireless technology developments, including 5G and evolving 4G and WiFi technology, are expected to deliver increased flexibility, reliability and capacity to help meet these performance requirements.

What is 5G?

5G, the next generation of wireless technology, is expected to play a key role across many sectors. In March 2018 we published Ofcom's plans for enabling 5G in the UK[3], in which we said 5G will go beyond the provision of mobile broadband for consumers and businesses and benefit a wider variety of industries, from connected factories for manufacturing and logistics, to smart agriculture and healthcare solutions using assisted robots.

5G is expected to offer higher speeds and capacity than previous generations of mobile technology, with the ability to connect one million devices per square kilometer. In addition, 5G will enable applications that need to rely on instant response (low latency of the order of one millisecond) or need high reliability. The majority of existing applications might not require instantaneous reaction, but use cases requiring very low latencies are starting to emerge such as immersive applications like augmented and virtual reality.

5G will also enable network operators to leverage their existing network capacity and effectively offer dedicated virtual networks and better quality of experience to different customers.



[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/111883/enabling-5g-uk.pdf

Additionally, several different business models are emerging, with different players offering standalone public and private networks, as well as hybrid solutions which combine the two.[4]

How Ofcom is working to support the digital transformation

Access to radio spectrum is a critical component to enable wireless connectivity. Ofcom is the UK authority which manages access to spectrum. One of our roles is to ensure spectrum can be a facilitator for the provision of a wide range of services that will need wireless connections in the future. We already support access to spectrum for a wide range of organisations to enable wireless connectivity.

We want to ensure spectrum is not an inhibitor of innovation. Some organisations might require access to spectrum bands that support a wide ecosystem of mass market devices; others might require more local connections and a high level of control over their network, such as a factory or a warehouse. We want to make sure spectrum bands, with different characteristics, can be accessed by a wide range of players, including Mobile Network Operators, third-party service providers and directly by businesses and organisations. We also offer Innovation and Trial licences[5] across a range of bands. These licences are available to all businesses and organisations at a low cost to enable them to test a range of innovative applications and business models.

We have made more spectrum available for licence-exempt devices. Technologies such as WiFi and MuLTEfire are able to utilise licence-exempt spectrum and will continue to play a significant role in providing wireless connectivity across a wide range of industries. We recently opened access to 14 GHz of spectrum at 57 – 71 GHz for wideband data systems on a licence-exempt basis, and in 2017 we extended WiFi access in the 5 GHz band.

We're consulting on greater shared access to spectrum. In December 2018, we published our 'Enabling opportunities for innovation' consultation[6], where we consult on proposals for enabling local spectrum access in three specific bands: 3.8 – 4.2 GHz, 1.8 GHz[7] and 2.3 GHz[8] in areas unused by other licensed users. We are also consulting on proposals to allow sharing in the existing spectrum bands currently used by Mobile Network Operators to provide mass market mobile services to consumers. This proposal would allow third parties to access these bands on a localised basis.[9] We welcome responses to our consultation on shared access to spectrum from all interested parties.[10]

We are working to drive investment in fibre networks. Ultimately, most wireless networks need to be connected to physical networks which allow data to be moved off-site and

[4] In a public network the network capacity is shared between different users. In a private network the capacity is normally reserved for use by a single organisation, and a spike of traffic in proximity of the organisation does not have any impact on the quality of service for that organisation.

[5] https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/non-operational-licences

[6] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/130747/Enabling-opportunities-for-innovation.pdf

[7] 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz.

[8] 2390 – 2400 MHz.

[9] Where this does not impact on existing Mobile Network Operators' planned use.

[10] This consultation closes on the 12th March 2019.

back. Even though this document focuses on wireless connectivity, Ofcom is actively working in parallel to promote greater competition in the provision of such services and the expansion of the fibre networks and capacity across the country to enable flexible service provision.[11]

We engage with various private and public-sector organisations in the UK and internationally to understand the evolving connectivity requirements emerging from different sectors. We are keen to continue this engagement and act as a facilitator between different industry players to enable organisations and businesses to leverage the benefits of wireless connectivity and achieve their digital transformation objectives.

We are planning a series of workshops for spring 2019. These will bring together different players representing different sectors' needs. We would like to hear from organisations interested in exploring further wireless connectivity, and to continue the discussion we have commenced in this document. You can reach us at industrial.innovation@ofcom.org.uk

Managing the UK's spectrum resources

Ofcom 'authorises' users to access radio spectrum. We do this by making spectrum licence products available that businesses and organisations can apply for, or in some cases, by exempting certain devices from needing a licence.

Licence-exempt: As mentioned above, in some cases we can adopt a licence-exempt approach for certain bands.[12] For these bands, the user does not need a licence to use the spectrum, but will need to make sure that the equipment meets certain criteria and operates according to specified rules. A common example of this is WiFi which transmits at low powers and uses techniques to avoid interfering with other users. This allows for multiple devices to operate in the same location on a shared basis. Most mass-market consumer devices are licence-exempt and the frequencies are harmonised across a number of countries to allow for economies of scale. Bands used by a range of licence-exempt equipment include 2.4 GHz, 5.8 GHz and 57 – 71 GHz.

Licensed spectrum: Except for the instances where we have exempted devices from requiring a licence - users seeking access to spectrum will need to get a licence from Ofcom. We have many types of licences available; some give the user permission to use the spectrum in a very localised area (e.g. in a building) and some allow the user to use spectrum across the whole of the UK. Spectrum licences are available across a range of frequencies; as we outline below – we are also planning to make more licences available across a range of different bands. If you would like to understand more about our spectrum licence products, please get in touch at industrial.innovation@ofcom.org.uk

[11] In July 2018, we set out a roadmap of actions to support competitive investment in fibre networks. https://www.ofcom.org.uk/__data/assets/pdf_file/0025/116539/investment-full-fibre-broadband.pdf

[12] The presumption set out in the Wireless Telegraphy Act is that Ofcom adopts a licence-exempt approach if the criteria set out in the act is met. Amongst others, these include that the stations or apparatus are not likely to cause undue interference; not likely to endanger safety of life; and would not lead to inefficient use of spectrum.

Evolving connectivity requirements

Innovative technologies are delivering benefits across many sectors

Businesses and organisations across different sectors of the economy are increasingly looking to new technologies and digital solutions in order to become more flexible, agile and responsive in the way they do things. This should lead to tangible benefits such as increased efficiency and productivity and lower costs.

The increasing use of connected devices and sensors is extending the uses for the Internet of Things (IoT). While IoT solutions are not necessarily a new technology, the increasing number of applications being developed have the potential to deliver significant benefits to consumers, such as improved healthcare and better energy and transport services. The vast amount of data generated by these devices, can provide significant insight and generate better targeted interactions, improve processes and increase quality of service.

Additionally, the increasing use of Artificial Intelligence (AI) is leading to significant changes across many industries. The wide-spread availability of large datasets and the development of new and more efficient AI algorithms are driving a boom in Machine Learning and Deep Learning solutions.[13] With Deep Learning organisations can detect patterns in data and rely on algorithms to take autonomous decisions based on these patterns. For example, AI powered models can learn from historical data collected in the production process and predict failures; this can significantly reduce downtime and therefore production costs. AI algorithms can also significantly improve customer satisfaction as interactions with consumers are more accurate. All of these developments will require a connectivity solution that is capable of handling large quantities of data (high capacity). For instances where the data needs to be analysed instantaneously, a low latency solution will also be required.

A new generation of general purpose, reconfigurable and collaborative robots has also emerged in recent years. Together with an increase in productivity, these robots allow product personalisation and reduce the time

[13] Machine learning refers to a category of Artificial Intelligence where computers can learn without being explicitly programmed. Machine learning is based on the principle of training layers of artificial neurons (a neural network) to learn specific patterns in data. Deep learning refers to a category of machine learning algorithms, with a large number of artificial neural layers. In this way, the neural network can learn hierarchical patterns in data (e.g. there is an eyebrow on the top of each eye, two eyes in a face, a face in a person, and so on).

required for product reconfiguration, leading to overall cost reduction.

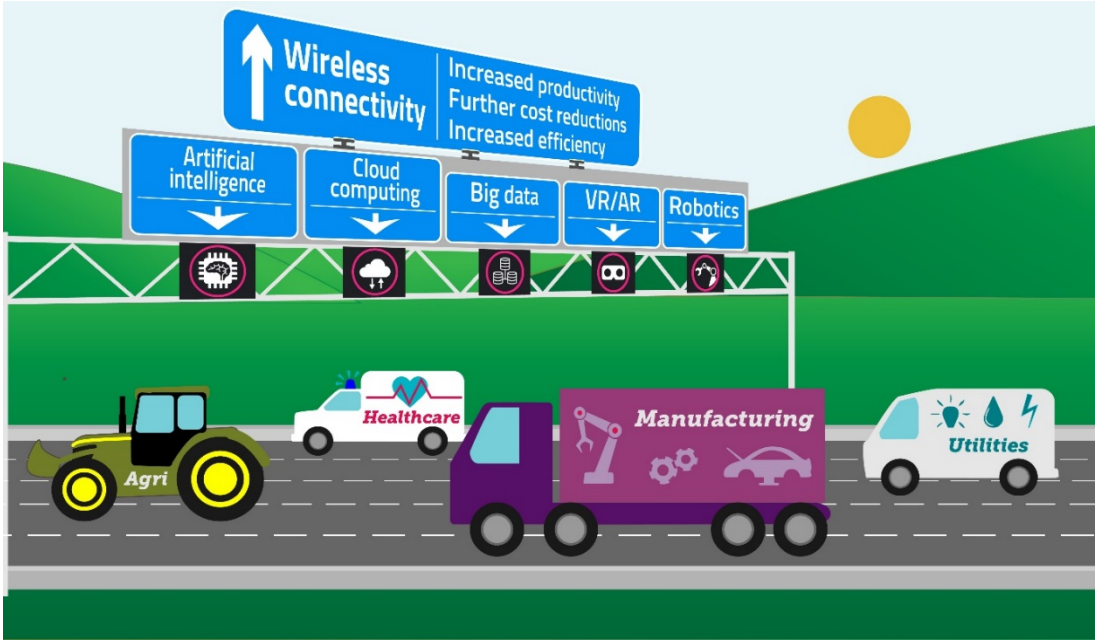
Applications relying on augmented and virtual reality are also gaining traction, from immersive gaming applications, to the use of augmented reality on site for training purposes and to solve problems remotely. To be effective, these applications require high capacity communications with very low latency.

Wireless connectivity will help to maximise benefits

Connectivity is a key component to support the innovative technologies mentioned above. The data, collected via sensors, on the production floor, on the energy grid, or by any other IoT solutions, need to be analysed in order to be acted upon. In some circumstances this information needs to be communicated to a central unit and analysed instantaneously, in order for instructions to be sent back and implemented. Automated factories can often benefit from the flexibility of coordinated robots, moving freely across the factory floor, allowing for fast reconfiguration of the production line in response to changes in demand. In case of emergencies or unexpected events, the robots can quickly send information and receive instructions back. In most cases, the increased flexibility of wireless connectivity maximises the benefits delivered by the increasing use of these technologies (see Figure 1 below).

Many organisations and businesses see connectivity as part of the solution to improve their processes and/or to develop innovative products and services. Still, very often they are not particularly concerned by the type of solution in terms of its technical aspects or the type of provider, as long as it meets their requirements – including cost – and their digital transformation objectives.

Figure 1 – Wireless connectivity will support the benefits of wider digital transformation



There will be no one-size-fits-all type of connectivity for businesses

Businesses and organisations considering wireless connectivity solutions will have very varied requirements. For example, the solution deployed to meet the needs of a farmer requiring connectivity across a wide area, will be very different from a large organisation installing connectivity inside a factory or office.

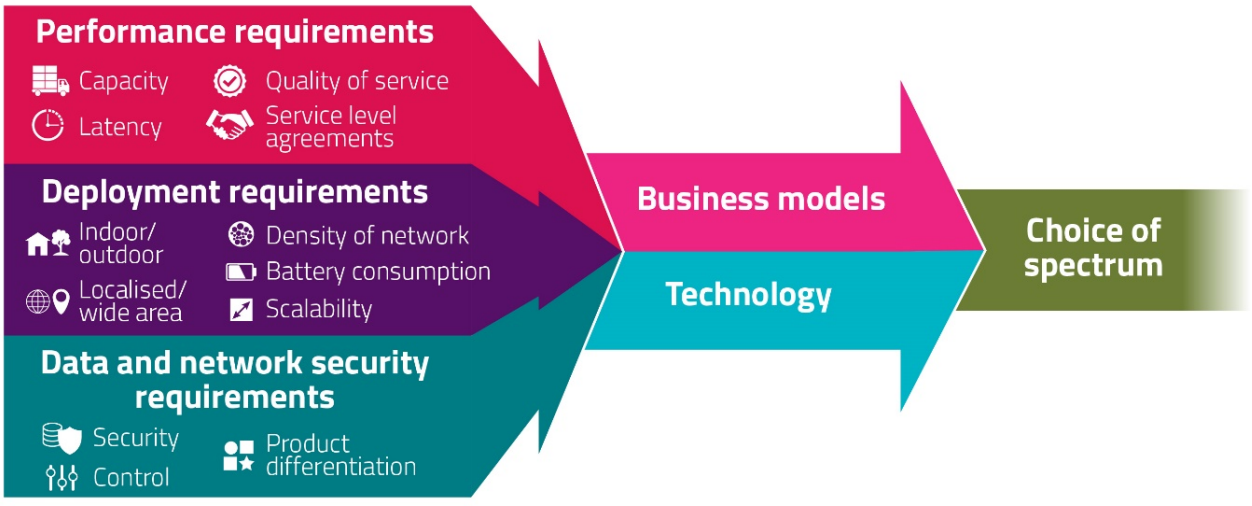
Even within the same sector, different types of users may have different requirements. Furthermore, a single user could have multiple requirements which cannot be met by a single solution. For instance, in the utility sector, the management of smart grids is time critical and has very low latency requirements while smart metering might be able to tolerate delay or some data not getting through.

Over the last few months we have engaged with different companies and organisations to discuss their needs, and the role of wireless connectivity. We have identified three categories of requirements, which cover different aspects of organisations' connectivity challenges:

- **Performance requirements**. These relate to the type of service required to address the business problem.
- **Deployment requirements.** These focus on how the connectivity solution is built.
- **Data and network security requirements.** These consider the type of control organisations might want to have over their wider data and network assets.

In this section, we discuss these requirements, which will in turn inform the technology and business models. The last section of this document will then highlight the choice of spectrum to deliver the connectivity solutions (see Figure 2 below).

Figure 2: Categories of requirements for connectivity solutions

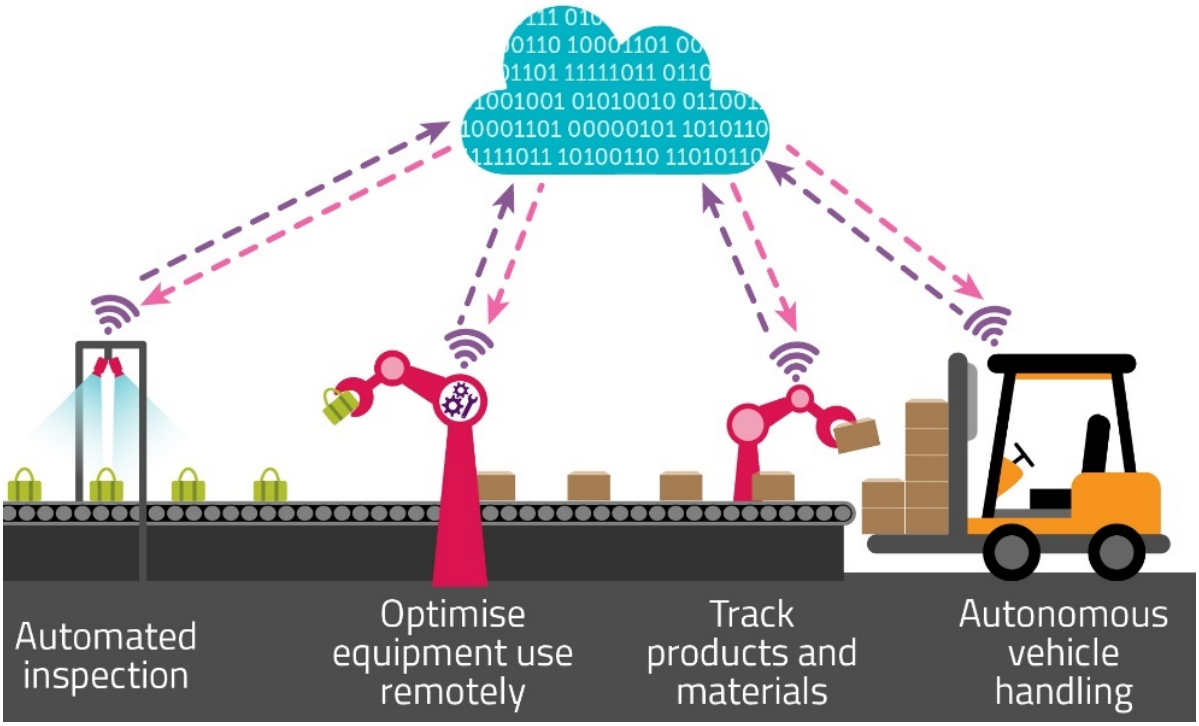


Performance requirements

Reliability requirements can vary significantly between different applications. For example, a business might have minimum tolerance for faults in its processes, in which case, a guaranteed quality of service will be critical to ensure that information is consistently transferred, and the business is able to react to any deviations. Under these circumstances, organisations might lean towards solutions that can meet very stringent service level agreements (SLAs). In other cases, the time in which the information is transferred is less critical (best effort), and there might be a higher tolerance to lose some data packages in the network.

Some use cases, where instant response is required, need very low **latency**. For example, fully automated operations rely on real-time transmission and processing of information and require an end-to-end latency range as low as sub-5ms.
In addition, real time onsite AR/VR, such as inspecting construction sites, will require extremely low latency, to make for a near real experience, as would also some applications using remote AR/VR.

Some applications may require very **high data rates,** whereas other applications require low data rates, but may need to support **hundreds of thousands of devices over a wide range,** for example environmental monitoring or smart grids. These solutions drive the demand for increased **capacity**. Intelligent machines which rely on numerous sensors can produce hundreds of megabytes of data per second. Also, collaborative machines require a frequent exchange of information between themselves. Machine learning provides more accurate prediction when the algorithms are run centrally, thus requiring the information to be sent from the device to the main processor and back to the device.



Deployment requirements

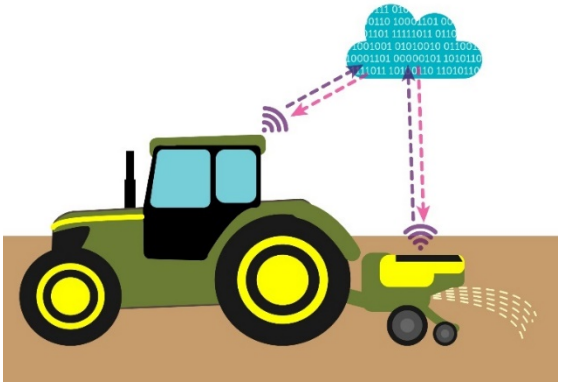
Deployment requirements are also likely to vary substantially by business. In manufacturing, for instance, an individual factory may host a network of **dense** and **highly-localised indoor** sensors controlling a swarm of robots, with no link to the internet and therefore creating a completely private network, whereas tracking freight from the factory would require **outdoor** coverage, across a **wide area**.

Other applications may require wireless clients to move through **indoor and outdoor** spaces**.** This could be the case for monitoring deliveries, or for robots used to move items between the factory floor and an outdoor forecourt.

Some applications might need devices with **very low power consumption**, that last for a long time, to reduce overall maintenance costs. This could be the case for applications where high number of sensors are deployed in difficult to reach places, e.g. sensors deployed on the blades of a wind turbine or in the structure of a bridge.

Flexibility and scalability are also relevant requirements. A factory might want to be able to make changes in the network deployment at short notice and without the need to renegotiate a contract, for example to increase capacity or to update the technology used.

Some organisations may have deployed multiple separate networks to meet different requirements. In order to reduce the cost and overhead of running these separate networks, organisations are likely to look for solutions that can offer **consolidation** into a single optimised network.



Data and network security requirements

All businesses and organisations deploying wireless solutions need to consider security aspects. Depending on what they are requiring the connectivity for, they may need differing levels of both data and network **security**. For instance, high levels of cyber security are required for business critical, and even more so for mission critical, services.

Connectivity in a manufacturing plant may need a high level of **control** over the network and the data, and therefore some organisations may prefer a bespoke, fully controlled solution that does not connect with the internet i.e., they might prefer to go for a private network. Conversely, other organisations might prefer relying on a public network or buy connectivity as a service either directly from an operator or from a third-party service provider. For example, businesses and organisations for which connectivity is not a defining factor of competitiveness, tend to outsource the deployment of their connectivity solution.

More and more organisations are migrating part or all their information technology services to public **cloud platforms**, like Amazon Web Services, Microsoft Azure or Google Cloud Platform. This trend is impacting connectivity requirements, as more and more data is exchanged with the cloud. For example, connected smart cameras require a large amount of uplink bandwidth to send

high-resolution videos to the cloud, where these videos are then analysed using machine learning algorithms. However, moving valuable data assets from private to public platforms may require a whole new approach to how security and resilience are handled.

Some organisations, for which the connectivity solution is a source of **differentiation**, might opt for a customised, non-standardised solution, relying on a private and proprietary network solution. Whereas organisations for which wireless connectivity does not have an impact on differentiation, might go for a standardised solution.

Wireless technologies

Organisations can achieve their connectivity objectives using different wireless technologies

Currently many different industrial applications are delivered using connectivity solutions supported by WiFi, mobile and IoT technologies including proprietary technologies. New connectivity platforms based on 5G and WiFi evolutions could enable more innovative applications in order to increase flexibility, agility and responsiveness.

Some applications might require low power and long-range connectivity (over 20km) using devices with long battery life in case of deployments in remote and hard to reach areas; common applications are: smart metering, smart lighting, asset monitoring and tracking, smart cities, livestock monitoring, energy management, manufacturing, and industrial IoT deployments. These solutions can be offered by **Low Power Wide Area (LPWA)** technologies. There are currently no live deployments of LPWA networks by the four UK Mobile Networks Operators. However, trials have taken place and Vodafone plans to launch NB-IoT in the UK in 2019.[14]

Low Power Wide Area technologies

Sigfox is a proprietary technology that uses licence-exempt spectrum and offers good coverage with very low transmission power. WNDUK is the Sigfox network operator in the UK. It has recently announced the deployment of 1000 base stations covering 50m people.

LoRa, developed by the non-profit LoRa Alliance is an open source technology also using licence-exempt spectrum. LoRa provides a good coverage with very low transmission power and allows building an end-to-end private solution.

Narrowband IoT (NB IoT) has been recently commercialised as a wide-area solution to connect a very large number of devices and is also optimised for a very long battery life. NB-IoT networks can be deployed in mobile bands and integrated on existing mobile base stations.

[14] https://www.vodafone.com/business/news-and-insights/press-release/vodafone-to-double-size-of-nb-iotnetwork-to-expand-enterprise-possibilities

Local connectivity solutions requiring short-range coverage can use **Wireless Local Area network technologies**, with WiFi being the most common technology currently delivering a wide range of applications supporting smart home connectivity and connected factories.

Wireless Local Area Networks

WiFi has been used as a (off-the-shelf or customised) solution in the enterprise, logistic, transport and industrial sectors. Recently, a new version of WiFi[15] has been announced which will offer increased speed, longer range, a lower latency and lower battery consumption.

MuLTEFire is a 4G based technology that operates in licence-exempt and shared spectrum. It enables services including voice, mobile broadband, user mobility and security and Industrial IoT.

WiGig is an evolution of WiFi working in the 57 – 71GHz band. It supports an extremely high speed and high capacity service, but over a short range.

Connectivity solutions based on **mobile technologies** (**2G, 3G and 4G**) have already been deployed to support industrial use cases such as traffic control and waste management. Evolutions of these existing technologies will improve performance by enabling greater capacity, and the ability to offer very short response time (low latency).

Mobile technologies

5G, the next generation of mobile technology is expected to deliver greater speed and higher capacity. In particular, the very low latencies delivered by **5G**[16] are expected to enable solutions that rely on the instantaneous analysis of huge amount of data. These capabilities are likely to enable use cases, like immersive remote applications using virtual and augmented reality.

LTE-M is another technology based on mobile standards. Like NB-IoT, LTE-M is a suitable mobile communications for devices with long battery life. The main difference between NB-IoT and LTE-M is that LTE-M supports higher data rates (up to 1Mbit/s), while also having better latency. It also supports mobility and potentially voice services. However, it has a higher cost and battery consumption compared to NB-IoT.

[15] Referred as 802.11ax or WiFi 6.
[16] Low latency communications will be realised with 3GPP Release 16, which is expected to be finalised in December 2019.

Additionally, we are seeing the emergence of open-source base stations and the availability of open radio APIs. This may allow the low-cost deployment of connectivity solutions, based on open source rather than proprietary standards, tailored for specific use cases. Moreover, the availability of open network APIs could spur the development of a business-to-business ecosystem for the verticals' market,[17] which would enable third parties to offer applications targeting specific segments.

Across the UK, a number of trials are currently taking place, looking at the role of different technologies and connectivity solutions on digital transformation. These include trials that have received funding from the Department for Digital, Culture, Media and Sport (DCMS) as part of the 5G Testbeds and Trials Programme.[18]

UK trials and case studies

In **Worcestershire**, a consortium of businesses including Worcester Bosch and Yamazaki Mazak, led by the Worcestershire Local Enterprise Partnership, are exploring ways to increase productivity by using robotics, big data analytics and augmented reality connected with 5G.[19]

5GRural First is currently trialing 5G technology, including network slicing, to provide connectivity to different industries including agriculture and broadcasting in rural areas. Use cases being trialed include localised connectivity to support sensors for agriculture – see Hands Free Hectre.

Also looking at rural connectivity, **5GRIT** is trailing a crop monitoring use case. Using an algorithm, the crop monitoring service will be able to distinguish between crops and weeds based on images captured by drone-mounted cameras, creating a report in real time for the farmer. The connectivity solution will allow for the real time communication of data and images.[20]

[17] By verticals' market we mean the businesses and organisations deploying wireless connectivity solutions. This group is often referred to by (industry) verticals."
[18] https://www.gov.uk/government/collections/5g-testbeds-and-trials-programme
[19] https://www.gov.uk/government/case-studies/worcestershire-5g-consortium-testbed-and-trials
[20] http://www.5grit.co.uk/precision-farming/

Business models

Organisations can meet their connectivity requirements using different business models

We want to make sure that organisations and businesses, big and small, have access to a wide range of connectivity solutions to meet their needs.

Many of the requirements considered above can be delivered by Mobile Network Operators leveraging their existing public network, or system integrators providing the infrastructure and bespoke solution to businesses and organisations in a particular location. They could also be self-deployed to meet organisations' specific requirements.

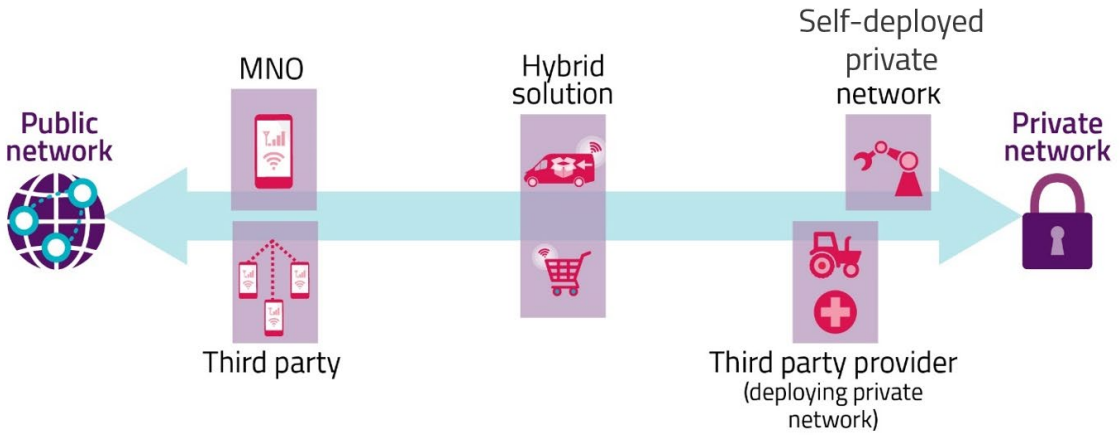
In Figure 3 below, we provide an overview of new and existing business models ranging from fully public to fully private networks.

Public vs private networks, what is the difference?

In a public network the network capacity is shared between different users. When using a public network, a peak in demand in close proximity to a factory (e.g. due to a concert or a football match) could lead to a decrease of available capacity for the factory.

In a private network the capacity is available for use by a single organisation, and a spike of traffic from any other user, in proximity of that private network, will not affect its level of service.

Figure 3: Potential business models for deploying wireless connectivity



Public networks

Public networks can be deployed by both Mobile Network Operators and third parties such as system integrators offering capacity to multiple users.

Mobile Network Operators provide wide area coverage that could enable solutions requiring connectivity over large geographies, such as tracking fleets across the road network.

They could also offer a dedicated slice of their network to meet more specific requirements. 5G developments are enabling the delivery of different virtual networks on the top of a shared infrastructure much more easily. Each slice of the network will be able to offer services with predefined specifications and service level agreements (SLAs).

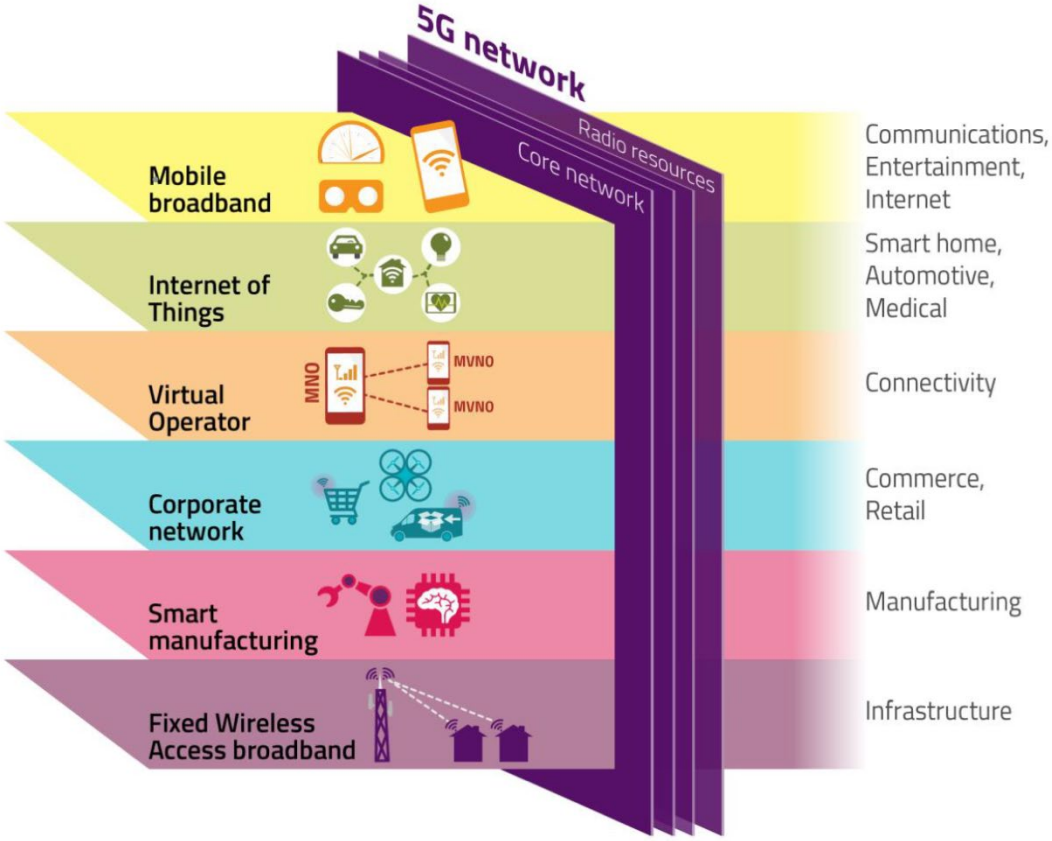
Network slicing and net neutrality

Network slicing is a technology that allows partitioning of a network into independent "slices". It can be used to slice a public network to serve different organisations with independent virtual networks in a way to be able to provide a quality-of-service and a degree of control that is closer to the one achievable in a private network. With network slicing different users are sharing the same capacity, but some specific users may have specific service level agreements to ensure they have the capacity they need. For example, two slices of this public network could serve a factory (e.g. one for IoT services and another to provide broadband connectivity), a third slice could provide connectivity to cars and a further slice to provide mobile broadband to consumers. If more demand emerges, many more slices – and sub-slices – could be added. We note that network slicing cannot usually provide the same type of control and data ownership than a private network. For example, the security and data privacy policies could be under control of the network provider and not of the organisation.

Net neutrality rules are designed to preserve the benefits of the open internet. They aim to maintain innovation in the services delivered over it, while at the same time keeping the incentives for network operators to invest and innovate intact. To this end, the rules currently require that all traffic related to internet access is treated equally.

This also means the rules don't apply to private networks or "specialised services". As discussed in this document, there may be several use cases which require both private and public solutions or could be considered as specialised services. At the moment, we don't see net neutrality regulation as a blocker for deploying these kinds of solutions. We continue to monitor developments and are working to provide clarity in this area.

Figure 4: Network slicing examples



This type of solution could be more challenging where deep indoor coverage is required on private property and there isn't already coverage from that mobile network. This could require additional infrastructure to be built by the provider.

Connectivity using a public network could also be provided by a third-party player, such as a system integrator, which has built a network aggregating similar type of demand and offering a shared platform for different users with similar requirements. These solutions can be delivered using either WiFi-based solutions, mobile solutions or IoT technologies to cover a wide area, such as LoRa, Sigfox etc.

Private networks

Self-deployed private network

Private networks work well when access to the internet is not needed and businesses and organisations can rely on closed network solution. These can vary from nationwide to geographically defined networks and can be both indoor and outdoor.

Private networks can also meet the requirements of businesses and organisations across different sectors that want to keep full control of their processes and/or of their network. This option could also be driven by requirements that cannot be met by a slice of a public network. Depending on their exact requirements, businesses and organisations could use a range of technologies from WiFi to mobile technologies including 5G.

We note that slicing can also be used in private networks, to help an organisation to provide services with different connectivity requirements using the same physical network.

Private network delivered by a third party

An alternative business model would be for a third-party (e.g. a Mobile Network Operator or system integrator) to build the network. This model has many different variations: the third party could provide either just the infrastructure or the infrastructure with the application and service layers.

Hybrid solutions

Some organisations and businesses may have wide-ranging needs that cannot be met by a single solution, and as such may require a hybrid model which includes connectivity delivered by both private and public networks, for different uses. For instance, in logistics, the requirements for connectivity within a warehouse will be different from the requirements for connectivity when parcels/trucks leave the warehouse.

While the first type of requirements could be met by different network solutions and providers, the second use case needs to rely on a wide-area network. Third-party providers/aggregators might play a role in offering hybrid solutions, by leveraging access to Mobile Operator networks and private networks.

Hybrid solutions could allow for orchestrating the network in a way that provides a seamless experience across public and private networks. For example, a truck leaving the factory would be seamlessly handed over from one network to the other, and the data would be handled by the same application server.

Ofcom's role in enabling connectivity for organisations and businesses

We understand this is an evolving market. We want to ensure organisations and businesses can benefit from the use of wireless technologies to meet their objectives in terms of productivity, efficiency and cost savings. Spectrum is a critical enabler and our objective is to ensure spectrum is not an inhibitor to innovation.

As part of our duties and responsibilities, we make spectrum available to users in a range of different ways. Some spectrum requires a licence, whereas other spectrum bands can be used without a licence as long as the equipment complies with specific rules.

We are currently in the process of making more spectrum available to enable players to leverage opportunities offered by wireless technology developments, including 5G.

Enabling future connectivity solutions

In our March 2018 publication 'Enabling 5G in the UK'[21], we identified spectrum bands for 5G and other wireless services which can be used by different players to meet their communication requirements for consumers and businesses.

Last year we auctioned 150 MHz of 5G suitable spectrum in the 3.4 GHz band. We plan to award further spectrum in the 700 MHz[22] and 3.6 – 3.8 GHz bands by Spring 2020.[23]

In Table 1 we outline different spectrum bands that can be used to enable different business models and technology solutions.

In December 2018, we published our 'Enabling opportunities for innovation' consultation[24], where we consult on proposals for enabling local spectrum access in three specific bands: 3.8 – 4.2 GHz, 1.8 GHz[25] and 2.3 GHz[26]. We welcome responses to our

[21] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/111883/enabling-5g-uk.pdf
[22] The 700 MHz spectrum is currently suitable for 4G mobile services. In the longer term, low frequency spectrum such as the 700 MHz band could be suitable for 5G.
[23] https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf
[24] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/130747/Enabling-opportunities-for-innovation.pdf
[25] 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz
[26] 2390 – 2400 MHz

consultation on shared access to spectrum from all interested parties.[27]

We are also looking at how we might enable third-party access to all mainstream mobile bands (these are currently the 800 MHz, 900 MHz, 1400 MHz[28], 1800 MHz, 1900 MHz, 2100 MHz, 2300 MHz, 2600 MHz and 3.4 GHz bands).[29] These proposals could enable a wide range of solutions including connectivity on a localised basis.

We welcome further engagement from all players interested in further discussing our map of technology solutions business models and spectrum bands.

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[27] This consultation closes on the 12th March 2019.
[28] 1452 – 1492 MHz.
[29] Where this does not impact on existing Mobile Network Operators' planned use.

Table 1 Spectrum bands to enable wireless connectivity solutions

<table>
<tr><th colspan="2">Technology[30]</th><th>Business model</th><th>What it delivers</th><th>Spectrum</th></tr>
<tr><td rowspan="2">Mobile network technologies</td><td>4G</td><td rowspan="3">Supports public and private networks, over wide areas and locally. Wide-area public networks are usually deployed by Mobile Network Operators. Local solutions can be deployed by different players using public or private networks. 5G developments will enable flexible end-to-end (E2E) slicing of the network into virtual networks.</td><td>High speed and high capacity.
LTE-M is a variant of LTE, optimised for IoT. It provides a lower latency and higher throughput than NB-IoT, but at a higher cost and higher power consumption.</td><td rowspan="2">Mobile bands[31] and bands currently under consultation to enable local shared access (1.8 GHz, 2.3 GHz and 3.8 – 4.2 GHz).</td></tr>
<tr><td>5G</td><td>Very high speed and capacity, E2E security. Latest version will enable low latency and high resilience.</td></tr>
<tr><td rowspan="3">Local area network technologies</td><td>WiFi</td><td rowspan="3">Wide range of off-the-shelf solutions.</td><td>2.4 GHz and 5 GHz licence-exempt bands.</td></tr>
<tr><td>MuLTEFire</td><td rowspan="2">5 GHz licence-exempt bands and additional bands[32]</td></tr>
<tr><td>WiGig</td><td>Extremely high speed and capacity, but over a short range</td><td>57 – 71 GHz licence-exempt band.</td></tr>
<tr><td rowspan="3">Low-power wide area network technologies</td><td>Sigfox</td><td>Supports wide area coverage over a public network only.</td><td rowspan="2">Good coverage with very low transmission power.</td><td rowspan="2">868 MHz licence-exempt band.</td></tr>
<tr><td>LoRa</td><td>Supports business models based on both public and private solutions.</td></tr>
<tr><td>NB-IoT</td><td>Supports public and private networks using mobile spectrum.</td><td>Good coverage, low transmission power and possibility of integration with a mobile network.</td><td>Mobile bands</td></tr>
</table>

[30] We note that we haven't included in this list wireless personal network technologies, like Bluetooth and Zigbee, because they mainly play role for smart home and wearable applications.
[31] These are currently, 800 MHz, 900 MHz, 1400 MHz, 1800 MHz, 1900 MHz, 2.1 GHz, 2.3 GHz, 2.6 GHz and 3.4 GHz.
[32] 800 MHz, 900 MHz, 1.9 GHz and 2.4 GHz.

Next steps

As we have highlighted throughout this document, we see this area as an ongoing discussion and we want to ensure our proposals are enabling digital transformation across many businesses and organisations.

We plan to hold a series of workshops throughout spring in order to:

- ensure that businesses and organisations have access to the required information on connectivity solutions and highlight our role as the spectrum regulator; and
- bring organisations facing connectivity challenges together with solution providers, to explain the wider range of options available.

We are also planning to work with organisations that represent the interests of UK businesses to reach a wider audience.

We will also continue to work with different public-sector organisations such as DCMS, who is running several 5G trials covering different sectors, and Digital Catapult who has created a 5G Manufacturing working group to identify the impact of 5G on Industry 4.0, as well as encouraging cooperation between different regulatory authorities within the UK to ensure a fit for purpose regulatory regime is in place to realise the benefits of digital transformation.

We encourage businesses and organisations who have questions, comments, or want to explore the different options available, to contact us at Industrial.innovation@ofcom.org.uk.