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Connected Nations 2021

UK Report

Strong, Secure Networks

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Overview

Ofcom's objectives include supporting investment in strong and secure networks, and getting everyone across the UK connected. In this annual Connected Nations report, we measure progress in the availability of broadband and mobile services in the UK, including the newest full fibre and 5G networks now being rolled out.[1] It also highlights the work we are doing, alongside UK and devolved governments and communications companies, to improve these services.

We have published separate reports on broadband and mobile availability in each of the UK's nations. Our interactive dashboard allows people to easily access data for different areas of the UK and specific types of services. We are also releasing the International Broadband Scorecard 2021, which compares the UK's recent position on broadband availability with a number of other European nations.

What we have found:

- **Full-fibre broadband is available to 8.2 million homes (28%).** This is 3 million more premises (10 percentage points) than a year ago, and represents the highest year-on-year increase since full fibre started being rolled out in the UK.
- **Gigabit-capable broadband is available to 13.7 million homes (47%).** This includes full-fibre and upgraded cable networks that are capable of delivering download speeds of 1 Gbit/s or higher.
- **The universal broadband service is helping some people in areas where decent broadband is not available**. Factoring in coverage from both fixed and fixed-wireless networks, we estimate that around 123,000 homes and businesses (0.4%) are still without access to a decent broadband connection. These properties may be eligible for a connection under the universal service.
- **5G rollout has continued at pace,** with the number of mobile base stations providing 5G services more than doubling over the last year, to over 6,500 sites across the UK**.** 87% of these are in England, 8% in Scotland, 3% in Wales and 2% Northern Ireland. We estimate that 5G is available from at least one mobile network operator (MNO) outside 42-57% of premises. [2]
- **Mobile coverage is generally stable.** The four Mobile Network Operators (MNOs) – EE, O2, Three and Vodafone – each estimate they provide 4G outdoor coverage to c.99% of premises. Networks' coverage of the UK landmass ranges from around 79% to around 86%. There has been

[1] This analysis is based on network availability data for September 2021. Since then, further rollouts will have occurred, including Virgin Media O2 announcing completing its upgrade to provide gigabit-capable broadband across its network. See Virgin Media O2, Virgin Media O2 completes gigabit upgrade in boost for Britain's broadband target [accessed 7 December 2021]. We estimate that this raises the gigabit capable coverage to over 60% for the UK. We shall provide confirmed figures in our Spring update.

[2] Mobile coverage statistics are based on signal strength predictions, and this estimate covers a range from a high to very high confidence of coverage.

some incremental progress in increasing coverage across each of the UK Nations by the MNOs, including 46 fresh deployments towards their Shared Rural Network commitments.

- **Networks have continued to perform well despite significant demands** as people and businesses relied on their phone and broadband connections during further periods of lockdowns due to the Covid-19 pandemic. Average monthly data usage on fixed networks has increased to 453GB from 429GB last year, and from 315GB in 2019. Whilst peak usage remains in the evening, networks continued to see high demand during the day due to continued working from home.

The UK continues to invest in faster, better networks

Full fibre and gigabit-capable broadband coverage is gathering pace

Coverage of faster, more reliable broadband services is improving across the UK.

Just over eight million (28%) UK homes now have access to full fibre connections – an increase of 10 percentage points or three million premises in the past year. This is the largest year-on-year increase in full fibre coverage that we have seen so far.

Gigabit-capable broadband – able to provide download speeds of 1Gbit/s or higher - can be delivered over full fibre networks and the latest versions of coaxial cable networks. Gigabit speeds are now available to 13.7 million (47%) homes. In most UK nations, gigabit-capable coverage is higher in urban areas than in rural ones. Full fibre and gigabit-capable availability is highest in urban areas in Northern Ireland, and lowest in rural areas of Scotland.

5G rollout is expanding

EE, O2, Three and Vodafone first started rolling out 5G in 2019 and have continued to extend their networks across the UK. 5G is estimated to be available from at least one operator outside 42-57% of UK premises. Some rollout is now extending into busy suburban areas and transport corridors, though most 5G sites continue to be added in busy urban areas and are providing additional capacity to existing mobile data services. 5G also offers new opportunities, including for the deployment of private networks, where we have seen further activity from both MNOs and other providers this year.

Good connections are available to most people across the UK

96% of UK premises have access to a superfast broadband connection with speeds of at least 30Mbit/s. Although most people have superfast broadband available to them, they do not always choose the fastest speeds. We estimate that around 69% of premises that are able to get superfast broadband actually take it.

Mobile operators provide a high level of 4G coverage outside of premises, with coverage from each mobile network in the vicinity of c.99% of premises. Indoor 4G coverage ranges between 90% and 95% of all premises. However, coverage levels remain lower in rural areas, and across the extent of the UK landmass. Individual operator geographic coverage ranges between 79% and 86%.

How Ofcom is supporting investment in new networks

Our aim is to support investment in the deployment of competing gigabit-capable networks to provide consumers with a choice of fast and high-quality services. We have put in place a regulatory framework for competition and investment for the five years to March 2026 to support this aim.

Rapid progress is being made in making full fibre and gigabit-capable services available. BT has committed to pass 25m homes with its full fibre network by 2026 and, since providing data to us for this report, Virgin Media O2 has said it has completed the upgrading of its existing coaxial cable network to enable gigabit-capable services across the whole of its footprint. At the same time, a large number of alternative network operators are deploying full fibre in local areas across the UK.

We are also supporting the rollout of new wireless services – including 5G. This includes making sure a diverse range of companies can access the spectrum they need to develop new services, bringing a better mobile experience to consumers and delivering economic benefits for the UK.

Ofcom is also working with UK and devolved governments to help improve access to mobile and broadband across the UK. Those governments are supporting rollout by investing public money in networks in areas which are unlikely to be covered commercially. We will work closely with the UK Government as it develops plans to invest in full fibre and gigabit-capable broadband through its UK Gigabit programme. We are also supporting programmes in the nations – Superfast Cymru in Wales, R100 and the Scottish Broadband Voucher Scheme in Scotland, and Project Stratum in Northern Ireland. Ofcom remains engaged in the development of the Shared Rural Network programme, which is seeking to expand the provision of mobile coverage across the UK. We will continue to report on progress before undertaking an initial compliance assessment against MNOs' 88% landmass coverage targets in 2024.

As the UK focuses on deploying new networks and moves away from the legacy fixed public switched telephone network (PSTN) and 3G (and eventually 2G) mobile networks, we are working closely with telecoms providers and other stakeholders to ensure a smooth transition and the ongoing support of vital services.

Some people are still struggling to get connected

A small – but significant – number of UK properties still cannot access decent broadband

Around 123,000 premises cannot get a decent broadband service of at least 10Mbit/s download speed and 1Mbit/s upload speed from either fixed or fixed wireless networks. These premises may be eligible to be connected under the universal broadband service.[3] Since its launch in March 2020, customers have placed over 1,300 orders for the universal service that will result in full fibre connections being available to almost 6,500 premises that previously had no access to decent broadband.

[3] Where the costs to provide the connection are below the cost threshold set by Parliament (£3,400), the customer can be provided a service at standard connection and rental charges without having to pay any additional installation charges. Where the cost of connection is above the cost threshold, these premises can still receive a service if the customer pays the additional costs.

We expect that many of the remaining premises will have to contribute to the costs of building a connection and, for a significant number of these, connection costs will be very high, which means they may not be able to gain decent broadband through the universal service scheme. We will work with the UK Government and industry to explore technology options and possible ways to fund providing connections to these properties, so they do not get left behind. This could include new wireless technologies and the latest generation of satellites which could offer good broadband services in rural areas not covered by other network deployments.

A small number of premises lack decent fixed broadband and 4G

We estimate that most UK premises can receive both decent fixed and good mobile services, but 38,000 (0.1%) cannot access either.[4] Providing connectivity to these premises is a particular challenge that we will discuss with government and industry when exploring how to connect the most remote premises across the UK.

The UK's networks have generally been resilient, while plans to further increase resilience, and greatly improve security, are underway

The network security and availability incidents reported to Ofcom this year show the pandemic did not result in a noticeable increase in telecoms outages, despite increased demands on the networks. The work we started last year with telecoms providers to better understand the most common causes of major outages has identified several themes, and work to tackle them is ongoing.

In this report, we highlight how software related failures have impacted on the scale and duration of reported incidents. Ofcom will continue to work with the networks, industry bodies and the UK Government to further improve network and service resilience.

Ofcom has also been working closely with the Department for Digital, Culture, Media and Sport, and the National Cyber Security Centre, in preparation for the Telecommunications (Security) Bill. The Bill has now become an Act, having received Royal Assent on 17 November 2021 and will impose new, strengthened security duties on public telecoms providers. The Act gives Ofcom extended powers and duties to monitor and enforce compliance against the obligations placed on telecoms providers.

[4] Premises are considered to have access to a decent fixed connection if the broadband speed is above a download speed of at least 10 Mbit/s and an upload speed of at least 1 Mbit/s and to have access to an indoor 4G mobile service if a connection speed of at least 2 Mbit/s is available.

Fixed broadband and voice

The importance of everyone having access to fast and reliable voice and broadband services, wherever they live and work, has continued to grow in 2021. The Covid-19 pandemic has meant people have continued to rely significantly on these services for work, education, healthcare and entertainment throughout the year.

Connectivity in the UK continues to improve, as existing networks are being upgraded and new fixed infrastructure is being built. We support the investment in full fibre and gigabit-capable networks – as do the UK and devolved governments – which give people fast, reliable and future-proofed connections.

Most homes and businesses benefit from a choice of broadband connections, which deliver superfast or higher speeds. But there are areas in the UK where faster services are not available yet. We remain concerned about the relatively small number of premises that still do not have access to decent broadband given the importance of connectivity to participating in an increasingly digital society. However, we note that this number continues to decline year-on-year.

For this report, we include data from over 40 full fibre communications providers and, for reporting on fixed wireless coverage, we have gathered, and include data from both mobile network operators (MNOs) and over 20 fixed wireless network operators.

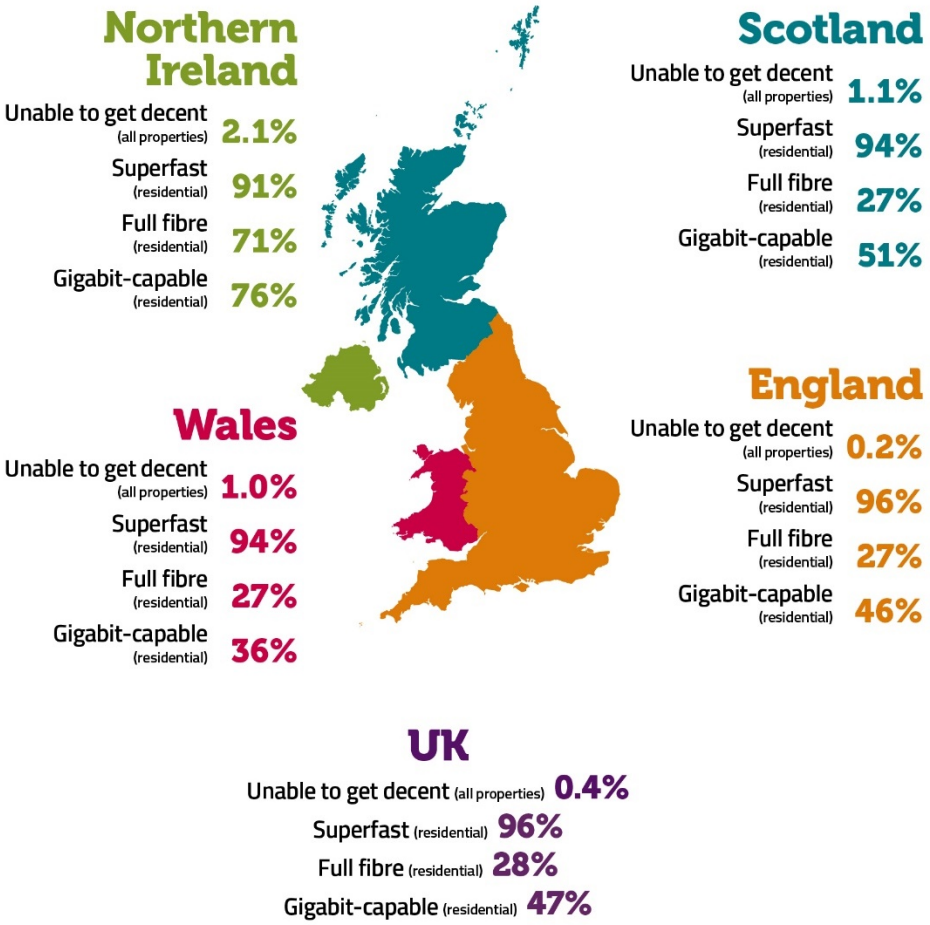
Key highlights:

- **Coverage of faster networks is increasing rapidly. Full fibre coverage is at 28% / 8.2m premises** – an increase of 10 percentage points / three million premises since our 2020 report. **Gigabit-capable coverage is at 47% / 13.7m premises** and we expected this will quickly increase further as Virgin Media O2 has announced it has completed the upgrade of its cable network.[5] **Superfast coverage remains at 96%.**

[5] Our coverage data was collected at September 2021. Virgin Media O2 announced it had completed its upgrade in December. Virgin Media O2 completes gigabit upgrade in boost for Britain's broadband target - Virgin Media O2 [accessed 7 December 2021]. We estimate that this raises the gigabit-capable coverage to over 60% for the UK. We shall provide confirmed figures in our Spring Update.

- Almost all **UK premises have access to a decent broadband connection.**[6] The number of premises without access to decent broadband has fallen further to around 0.4% / 123,000. Some of these 123,000 premises will be connected via publicly funded schemes in the next twelve months. We estimate this could leave around 100,000 premises. The **Broadband Universal Service Offer (USO)** will provide connections to some of these premises.
- Average monthly data use has continued to grow, and now stands at **453 GB per connection compared to 429 GB last year.**
- **Customers are upgrading to higher speeds and over two-thirds of consumers that have access to superfast broadband have upgraded to a superfast service.** We estimate that around 24% of premises with access to full fibre take a full fibre service, with take-up increasing by at least 750,000 premises since last year. And 69% of premises able to get superfast broadband actually take a superfast or faster service.

Summary of broadband coverage at a fixed location across the UK and Nations



[6] Unless otherwise specified, coverage figures for decent broadband count all UK premises (residential and commercial). Coverage for all other speed tiers counts residential premises only, unless otherwise specified.

In this section, we report on the following key areas of fixed connectivity:

- the rollout and upgrade of networks across the UK (including, a summary of investment in fixed networks);
- the deployment of fixed wireless and new satellite networks and how these help provide connectivity to decent broadband services;
- progress of the broadband USO, which launched in March 2020;
- the take-up of different broadband services;
- the data customers are using over these services; and
- environmental sustainability.

Throughout this section we generally report data for residential premises unless stated otherwise. However, for reporting of premises not able to get decent broadband which may be eligible for the USO, we report all premises. This year we have also introduced a short section setting out the coverage available to small and medium sized enterprises (SMEs).

A variety of fixed broadband networks and services are available in the UK

Fixed broadband in the UK is available at a variety of speeds, delivered over different technologies

Different technologies used to deliver fixed broadband connections

- **Copper (ADSL)** [7] **–** Copper cables are used to connect from the exchange to the premises (also known as 'standard broadband'). Maximum download speed is up to 24 Mbit/s. Actual speeds delivered by copper connections diminish with distance. Copper can also be affected by poor weather. Since the copper network is old, it can be susceptible to faults.

- **Fibre to the cabinet (FTTC)** – Fibre to the cabinet, with copper cables used to connect from the cabinet to the premises. FTTC uses very high-speed digital subscriber line (VDSL) technology. Maximum download speed is up to 80 Mbit/s (except for G.fast). [8] As with ADSL, actual speeds diminish with distance, and the network can be affected by poor weather and is susceptible to faults.

- **Hybrid fibre coaxial cable (HFC)** – The cable TV network.[9] It uses fibre to a street cabinet and coaxial cable from the street cabinet to the premises. There is decreased signal loss compared to the copper network as described above, which means co-axial cables are capable of delivering much higher speeds. Broadband is supported using the DOCSIS standard, which shares the capacity downstream and upstream between multiple customers.[10] The latest standard of cable

[7] ADSL: Asymmetric Digital Subscriber Line.
[8] Openreach deploys G.fast at some cabinets. It uses fibre to the cabinet, and copper from the cabinet to the customer. By using a higher frequency signal on the connection to the customer, G.fast can offer higher speeds than normal FTTC deployment, with Openreach offering wholesale services at up to 330 Mbit/s. But the signal degrades more quickly so the customers able to get ultrafast speeds are limited to those closest to the cabinet.
[9] Most cable broadband in the UK is provided by Virgin Media O2.
[10] DOCSIS: Data Over Cable Service Interface Specification.

technology, DOCSIS 3.1, is capable of delivering download speeds of up to 10Gbit/s and upload speeds of up to 1Gbit/s, although in practice speeds average out significantly below this – and since capacity is shared among users, it may not be the case that each user can simultaneously receive gigabit speeds. Depending on the configuration of the access network in any particular area, this can lead to localised congestion. This may be particularly acute in the upstream direction where total capacity is more limited.[11]

- **Full fibre or 'fibre to the premises' (FTTP) –** The connection from the exchange to the premises is provided entirely over optical fibre. Generally, distance to the premises does not affect the speed delivered. Full fibre is less susceptible to faults and is not usually impacted by poor weather. Most full fibre implementations utilise Passive Optical Network (PON) approaches where capacity in the downstream and upstream direction is shared.[12] The number of customers connected to each shared PON is usually 32 or less, which is generally fewer than shared infrastructure on a cable network. This, along with managing the maximum guaranteed throughput provided to each customer, can be used to manage congestion. PON technology has an upgrade path that allows for speed to increase from a shared 2.5 Gbit/s down/1 Gbit/s up to 10 Gbit/s in both directions, and future generations will expand this further.

- F**ixed Wireless Access (FWA) via mobile networks:** Fixed wireless access on mobile networks is offered on licensed 4G and 5G networks, usually to an indoor router. These services share the network capacity with mobile users, meaning that the capacity of the network has to be carefully managed between the demands of existing mobile users and FWA customers. There may be areas of high mobile demand where a reliable FWA service cannot be offered.

- **Fixed Wireless Access via Wireless ISPs (WISPs**): The majority of these services are delivered over wireless networks that communicate via a wireless link between a provider's mast site and an external antenna fixed to a customer's premise. These networks generally use license exempt or lightly licensed spectrum. Due to the frequencies where this spectrum is available, performance may be limited by line-of-sight issues.

[11] Virgin Media O2 has announced its plan is to upgrade its cable network to full fibre to deliver further enhancements to services. Q2 2021 Earnings Release (virginmediao2.co.uk)

[12] Virgin Media O2 is also deploying some full fibre networks as part of its network expansion. Currently this uses a technology called Radio Frequency Over Glass (RFOG) which allows the DOCSIS signals to be carried over fibre end-to-end. This deployment is capable of also supporting PON technologies and Virgin Media O2 are now trialling the use of XGS-PON with the intention of using this to replace both RFOG and HFC during this decade. Virgin Media O2 UK Update on Wholesale and FTTP Upgrade Plan - ISPreview UK

Figure 1: Summary of characteristics of different types of fixed broadband

Type of broadband[13]	Speed	Use cases	Fixed broadband technologies that can provide this service
Decent[14]	10 Mbit/s download; 1 Mbit/s upload	Making a high definition video call using applications like Zoom, Teams, WhatsApp or Facetime. Downloading a 1 hour HD TV episode (1GB) in almost a quarter of an hour.	Copper (ADSL) FTTC (VDSL) HFC Cable Full Fibre
Superfast	At least 30 Mbit/s download	One person streaming 4K/UHD video. Downloading 1 hour HD TV episode in under 4 and half minutes. Several devices working simultaneously.	FTTC (VDSL) HFC Cable Full Fibre
Gigabit	1 Gbit/s and above download	It is feasible to download a full 4K film (100GB) in under 15mins. May be delivered over technologies that give greater reliability and that are future proofed as more high demand services are developed.	HFC Cable (when upgraded to DOCSIS3.1) Full Fibre

FWA (both that provided by MNOs and by WISPs) can also provide decent, superfast and gigabit speeds, but this will be dependent on the specific deployment, available capacity at the site, and the number and location of users.

Fixed broadband coverage has continued to increase across the UK

Full-fibre broadband is now available to 28% of premises, with gigabit-capable broadband available to 47%

Full-fibre (FTTP) broadband is now available at 28% / 8.2m premises

Our data shows that 28% / 8.2m residential premises in the UK are now served by full fibre – an increase of 10 percentage points, representing over three million additional premises, in the past year. This year we have increased the number of fibre network providers that we gather data from. The new providers we have included tend to be smaller and often target rollout in less well served areas. As such they do not necessarily significantly alter the national figures, but they are important in providing full fibre coverage at the local level. The big increase in national coverage is largely due

[13] In previous years we have reported on ultrafast broadband as well. Ultrafast is broadband at speeds of 300Mbit/s and above. As network rollout focuses on full fibre and Virgin Media O2 has completed its upgrade of its cable network to DOCSIS3.1, we have focused this year on gigabit speeds (and gigabit capable networks). We have removed ultrafast broadband from our main reporting, although the numbers are still available in the interactive report.

[14] The UK government defines a decent broadband service as one that delivers at least 10 Mbit/s download speed and 1 Mbit/s upload speed. This is the level of connection deemed necessary for consumers to participate in a digital society.

to the continued investment in the rollout of fibre networks in the UK from providers planning wider geographic coverage, such as Openreach, Virgin Media O2 and CityFibre.[15]

Gigabit-capable broadband is now available at 47% / 13.7m premises

As shown in Figure 2 below, when all technologies are combined, our data shows that 47% / 13.7m residential premises now have access to gigabit-capable broadband. Some of these premises have access to more than one gigabit-capable network: around 7% / 2 million residential premises have access to a gigabit-capable broadband service over both cable and full-fibre technology, and 3% / 870,000 have a choice of two (or more) full fibre networks.

Figure 2: Residential full fibre and gigabit-capable coverage

	Full Fibre	Urban	Rural	Gigabit capable	Urban	Rural
England	27% (6.5m)	27% (5.7m)	25% (0.8m)	46% (11.3m)	49% (10.5m)	26% (0.8m)
Northern Ireland	71% (0.5m)	85% (0.5m)	36% (0.1m)	76% (0.6m)	92% (0.5m)	36% (0.1m)
Scotland	27% (0.7m)	30% (0.6m)	17% (0.1m)	51% (1.3m)	58% (1.3m)	18% (0.1m)
Wales	27% (0.4m)	29% (0.3m)	24% (0.1m)	36% (0.5m)	39% (0.4m)	24% (0.1m)
UK	28% (8.2m)	28% (7.2m)	24% (1.0m)	47% (13.7m)	50% (12.7m)	25% (1.0m)

Source: Ofcom analysis of provider data.

In the last year, across the UK, full fibre rollout has increased by ten percentage points. The largest percentage increase has been in Northern Ireland. There has been rollout in both urban and rural areas, but urban areas continue to have greater access to full fibre.

Gigabit-capable coverage has increased by twenty percentage points to 47%. In addition to full fibre, Virgin Media O2's upgrade to DOCSIS3.1 is a key driver of this increase. This means that whilst there has been an increase in gigabit capable coverage in both urban and rural areas, there has been a greater increase in urban areas.

Rollout of full fibre and gigabit-capable networks

Significant progress has been made over the past year in the roll-out of full fibre and gigabit-capable networks. We expect availability of these networks to continue to increase in the coming years. Different providers are taking different approaches to their business models for deploying these networks:

- Openreach is the incumbent wholesale infrastructure provider for almost all of the UK.[16] It has the largest network and connects the most premises. It plans to reach 25 million

[15] Virgin Media O2 has rolled out full fibre to a significant number of premises under Project Lightning.
[16] KCOM is the incumbent in and around the city of Kingston upon Hull. KCOM committed to full fibre deployment a number of years ago and availability is approaching 100%. KCOM is also extending its full fibre footprint beyond its traditional area of operation.

premises with full fibre by December 2026.[17] This includes 6 million homes in harder to reach areas by 2025/26.[18]

- Virgin Media O2 has announced it has completed upgrading its cable network, bringing 'gigabit speeds' to over 15 million premises.[19] This should be reflected in our first update in 2022, after which we would then expect to see further increases being driven by full fibre deployment with the gap between full fibre and gigabit-capable coverage reducing in future.
- CityFibre plans to pass 'up to 8 million premises' (both residential and business) across 285 towns and cities by 2025.[20]
- Some providers, like Hyperoptic and Community Fibre, focus on connecting premises in urban areas, while Gigaclear, B4RN and a number of others focus on connecting more rural areas. There are a range of approaches taken by these providers. Some work closely with local communities to determine areas with demand, and may include the local community undertaking some of the work. Others plan their own commercial builds in areas they assess as less well served by providers such as Openreach. Some may also bid for public funding to support rollout. Providers may follow one of these approaches, or a combination of them.

Deploying these new networks requires significant investment and engineering resources. The cost and timeframes for deployment can be reduced if a provider can roll out its network by using Openreach's c.470,000km of duct and c.4,000,000 poles. From April 2021, our Wholesale Fixed Telecoms Market Review put in place rules to allow easier access to Openreach's physical infrastructure (PIA).[21] As at the end of September 2021, 134 providers had registered with Openreach as customers of PIA, and over 80% have already built network using PIA or have placed orders to do so. Providers have ordered c. 53,000km of duct (8,000km of which has been delivered) and c. 405,000 poles (33,000 of which have been delivered) to deploy networks.

The UK Government has been working with industry and other stakeholders to ensure that the process for installing full fibre in new-build and multi-dwelling units is simplified. Alongside this, Government has also been working to reduce the administrative burden required when agreeing access to private land. This has led to proposed changes to legislation through the Product Security and Telecommunications Infrastructure Bill (PSTI).[22] Progress has been made in bringing together site providers and their representatives with telecoms providers building new infrastructure. However, there remain significant challenges, not least balancing between site providers' and telecoms providers' rights. In addition, the process of agreeing site access and information sharing between parties to ensure each can discharge their responsibilities to an acceptable standard will in the future need to take account of the provisions in the building safety bill which is currently progressing through parliament.[23]

[17] BT Group press release, 13 May 2021 [accessed 22 October 2021].
[18] Openreach press release, 28 May 2021 [accessed 22 October 2021].
[19] Virgin Media O2 press release, 7 December 2021 [accessed 7 December 2021].
[20] CityFibre press release, 3 November 2021 [accessed 8 November 2021].
[21] Ofcom, Wholesale Fixed Telecoms Market Review Statement, 18 March 2021.
[22] The Product Security and Telecommunications Infrastructure (PSTI) Bill - factsheets - GOV.UK (www.gov.uk) [assessed 9 December 2021]
[23] The Building Safety Bill

We will collect and report on future network deployments as part of our Connected Nations reporting

Following the revision of the Communications Act 2003 in December 2020, Ofcom is required to collect proposals for future network deployments from telecoms providers, in addition to information on existing networks that is already used to inform our Connected Nations reports.[24] The process of collecting this information is now in progress with the first results and insights derived expected to be published in 2022 as a supplemental annex to this report.

Most homes in the UK have access to a superfast broadband connection

Superfast broadband is available to 96% / 28.1m of UK premises, an increase of 275,000 over the year.

Figure 3: Residential superfast coverage

	Superfast	Urban	Rural
England	96%	98%	85%
Northern Ireland	91%	99%	70%
Scotland	94%	98%	73%
Wales	94%	98%	80%
UK	96%	98%	83%

Source: Ofcom analysis of provider data.

There will continue to be investment in superfast broadband networks, mainly due to publicly funded rollout under a number of schemes (described below). However, investment is now heavily focused on deploying gigabit-capable networks and in future will mainly deliver increased availability of full fibre. As such, we expect future increases in superfast broadband coverage to be modest.

[24] s.134B(1)(j) Communications Act 2003 was added by The Electronic Communications and Wireless Telegraphy (Amendment) (European Electronic Communications Code and EU Exit) Regulations 2020 (S.I. 2020/1419). This requires Ofcom to collect any proposals within the next 3 years to bring into operation a new very high capacity network, other than a mobile network or extend or upgrade any part of a fixed line network or its equivalent in order to provide a download speed of at least 100 Mbit per second.

Small and medium sized enterprises have good access to full fibre, gigabit capable and superfast broadband, but availability lags behind that for residential premises

Our reporting above on the availability of full fibre, gigabit capable and superfast broadband reflects the coverage of residential premises. But access to these services is also vital to businesses across the UK, and so this year we are also reporting on coverage for businesses.[25]

Figure 4: Business broadband coverage

Size of business premises	Superfast broadband availability	Full fibre availability	Gigabit capable availability
Micro (1 – 9 employees on site)	93%	26%	46%
Small (10 – 49 employees on site)	89%	23%	36%
Medium (50 – 249 employees on site)	85%	21%	33%

Source: Ofcom analysis of provider and business data.

We note that availability of full fibre, gigabit capable and superfast broadband networks is lower for small and medium enterprise business locations than for residential premises. Micro business sites, which make up around 90% of all business premises in our analysis, have the highest coverage. This may be because micro-business premises are often located in residential premises, or in residential areas and can make use of residential services.

Whilst coverage is lower for larger business sites, our network coverage data does not include networks deployed specifically to connect businesses (in particular, we do not gather data on leased lines specific networks), and so these sites may be able to get good connectivity, albeit via leased lines rather than broadband products.

By nation, England has the greatest availability of superfast broadband for SMEs, whilst Northern Ireland has the most coverage of full fibre and gigabit capable. As for residential premises, coverage of superfast, full fibre and gigabit capable is generally better in urban areas than in rural areas.

Figure 5: Business broadband coverage by nation

	Superfast broadband			Full fibre			Gigabit capable		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
England	**94%**	95%	79%	**25%**	24%	26%	**45%**	48%	27%
Northern Ireland	**84%**	95%	62%	**55%**	69%	28%	**60%**	78%	28%
Scotland	**89%**	95%	64%	**23%**	24%	14%	**44%**	50%	15%
Wales	**89%**	96%	70%	**27%**	27%	26%	**34%**	37%	26%

Source: Ofcom analysis of provider and business data.

[25] We have used a database of business premises, matched to our premises database, for this analysis. Our reporting is based on the size of the business premises (so, for example, small outlets of high street retailers are included even though the business is considered a large business overall). Our methodology explains the approach in further detail.

Decent broadband over a fixed connection is available to almost all homes and businesses

Taking into account all fixed line connections (but excluding FWA coverage), 98% of UK homes and businesses have access to at least decent broadband, the same percentage as in 2020. Around 651,000 premises do not have access to decent broadband via a fixed connection. This shows a slight increase from our report last year. As explained in our spring 2021 update, this is due to a small change in our methodology.[26]

Figure 6: Premises unable to receive decent broadband from a fixed line

	Total	Urban	Rural
England	2% (451,000)	1% (217,000)	7% (234,000)
Northern Ireland	6% (45,000)	1% (6,000)	17% (39,000)
Scotland	4% (100,000)	1% (13,000)	17% (87,000)
Wales	4% (55,000)	1% (11,000)	12% (43,000)
UK	2% (651,000)	1% (248,000)	9% (403,000)

Source: Ofcom analysis of operator data.

Specifically for small and medium sized enterprises, coverage of decent broadband from fixed networks is lower than generally across all residential and business premises as shown above:[27]

Figure 7: Business premises unable to receive decent broadband from a fixed line

Size of business premises	Total	Urban	Rural
Micro (1 – 9 employees on site)	3%	1%	12%
Small (10 – 49 employees on site)	4%	3%	12%
Medium (50 – 249 employees on site)	6%	4%	15%

Source: Ofcom analysis of provider and business data.

[26] In our Spring 2021 update, we refined the way that these properties are identified and 'address-matched' to operator data to more precisely provide estimated speed data for individual apartments and similar premises. Previously we had included premises in our figures where we had no operator coverage data but they were closely associated with adjacent properties. We have since refined the way that these properties are identified and 'address-matched' to operator data to more precisely provide estimated speed data for individual apartments and similar premises. In doing so, the number of properties for which we have no operator data increases, which results in the higher figure given here. See also footnote 4 in our Connected Nations Spring Update 2021.

[27] As noted above, some business premises (particularly larger premises) may be able to be served by leased lines networks which are not included in our coverage data.

Broadband services are also available across large parts of the UK using wireless networks

Fixed Wireless Access on mobile networks

Of the four MNOs in the UK, only O2 does not currently offer FWA services. Based on the MNOs' claimed coverage, we estimate that 94% of UK premises have access to an MNO FWA service.[28] MNOs claim average download speeds up to 100-200Mbit/s on their 5G FWA services. Download speeds on 4G FWA are lower.

These services are provided to an indoor router, although EE offers an external antenna for its FWA services in areas with poor indoor coverage. The end users' experience of the service could be affected by where they place the router, their indoor mobile coverage, the capacity available in the wireless access network and the backhaul network, and the number of users at that location.[29]

Based on the data provided by the MNOs, 88% of mobile FWA customers have access to a 4G FWA device compared to 11% who have access to a 5G FWA router.[30]

Fixed wireless access from WISPs

This year, we have expanded our collection of WISP coverage data; asking operators to provide their own estimate of coverage, factoring in network capacity constraints, interference and other external factors.[31] Based on providers' estimates, over two million homes and businesses have coverage from a WISP network.[32] As with FWA provided by MNOs, localised issues may mean a particular premise may not be able to receive a service despite being predicted to do so. These services are primarily delivered using licence-exempt spectrum in the 5GHz band.

We have carried out some research this year, looking into the speeds that can be delivered to consumers using WISP networks. We have a long-established programme on home broadband performance research on fixed networks,[33] and using the same approach, we conducted measurements on five WISP networks. Our results show that WISP networks are capable of delivering decent and superfast speeds.[34]

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[28] This estimated coverage figure is based on coverage data provided by EE and Three. While Vodafone provides an FWA service across its mobile network, we do not have data at the level of granularity needed to map its coverage to UK premises and so it is not included in this figure. More generally, coverage forecasts are determined by predictive modelling tools, localised issues may mean that particular premises may not be able to receive a service despite being predicted to do so.

[29] Backhaul here refers to the connection between the cell site and the mobile network core.

[30] Consumers with a 5G FWA device but who cannot receive a 5G signal would be served by a 4G network where there is coverage.

[31] Previously, we have rolled over coverage data where WISPs have not provided updates. This year we have issued a new request to WISPs for an updated set of information about their network and have not rolled over submissions based on our previous requests. Therefore, our coverage estimates are not comparable to those reported in previous years. See our methodology for more information.

[32] The number of premises covered by a WISP is up by more than 600,000 on last year but as noted in the previous footnote, a change in methodology means the figures are not directly comparable.

[33] This research uses a panel of consumers, who have a monitoring unit connected to their broadband router. This measures the performance of the home broadband services, including metrics such as download and upload speeds, latency, jitter and packet loss.

[34] See our interactive report for more information.

Fixed Wireless Access delivered by WISPs can be used to provide gigabit speeds using spectrum in higher frequency bands. Some WISPs are beginning to offer these services, but it has not yet been very widely deployed, due to the high cost of equipment. Over the next year, we will continue to work with FWA providers to understand how they manage the capacity of their networks and the performance of these services.

Figure 8: Coverage of MNO and WISP FWA networks with at least decent broadband

	MNO FWA	WISP FWA
England	94%	6%
Northern Ireland	82%	3%
Scotland	93%	2%
Wales	91%	31%
UK	94%	7%

Source: Ofcom analysis of provider data.

FWA and the impact on the availability of decent broadband

As shown in our research, both MNOs and WISPs networks can deliver a decent broadband service and can be an alternative network technology for consumers who cannot receive a decent broadband connection from their fixed network.

Based on the coverage estimates provided by FWA providers, we estimate that 528,000 premises that do not have access to a decent broadband service from a fixed network could have access via a FWA network. Some premises that can get decent broadband on a WISP network may also be covered by an MNO FWA service. Figure 9 below shows, by nation, premises without access to decent broadband from a fixed network, of these, which have access to decent broadband from only an FWA network, and, as a result, those remaining with no access to decent broadband from either fixed or FWA.

Figure 9: Access to a decent broadband service by different types of technology

	Has no access to decent broadband from a fixed network	Has access to decent broadband from an FWA network	Remaining premises without access to decent broadband
England	451,000	390,000	61,000
Northern Ireland	45,000	28,000	17,000
Scotland	100,000	70,000	30,000
Wales	55,000	40,000	15,000
UK	651,000	528,000	123,000

Source: Ofcom analysis of operator data.

A small – but nevertheless important – subset of UK premises still cannot access decent broadband

Our latest estimate is that around 0.4% / 123,000 premises in the UK still do not have access to a decent broadband service via either a fixed or fixed wireless network. This figure has reduced from around 190,000 last year, which we believe is due to a combination of factors, including that we have gathered data from more small fibre networks and FWA providers and because of some providers using more up to date premises data to report their coverage.[35] Some of the 123,000 premises will be due to receive a decent broadband service under a publicly funded scheme within the next 12 months. Based on data we gathered on public schemes, we expect this will leave around 100,000 premises without decent broadband. We discuss these schemes below.

We also note that modelling by BT based on data from our report last year and our spring and summer updates indicates it is able to connect some premises shown in our Connected Nations reports as being unable to receive decent broadband. Based on BT's modelling on the spring and summer updates, the number of premises without decent broadband may be as low as 80,000.[36]

The remaining premises may be able to have a new connection built under the broadband Universal Service Obligation (USO).[37]

We report on 4G indoor mobile coverage in the next section and, when we analyse the 123,000 premises against this data, we estimate that 38,000 premises cannot access either a decent fixed broadband service, or good 4G indoor coverage (of at least 2Mbit/s).

The Broadband Universal Service Obligation (USO)

The broadband USO provides everybody with the right to request a broadband connection with the following technical characteristics:

- a download sync speed of at least 10 Mbit/s;
- an upload sync speed of at least 1 Mbit/s;
- a contention ratio of no more than 50:1;
- latency which is capable of allowing the end user to make and receive voice calls effectively; and
- the capability to allow data usage of at least 100GB per month.

Where an affordable service with the above characteristics is not available, or due to become available in twelve months under a publicly funded scheme, the customer is eligible for the USO if the costs of providing the connection are below £3,400 or, where the costs are above £3,400, the

[35] We have gathered data from more networks; whilst these are small networks their footprint may sit in more remote areas where larger networks have not been deployed and so may help reduce the number of premises. In addition, we have worked with providers to improve reporting. In particular, BT has updated its reporting of its fixed wireless network coverage which has had a large impact on the reduction we have reported.

[36] We set out our approach to modelling coverage in our methodology. We use the latest available Ordnance Survey data to select the premises where a broadband service could be provided. Where operators use a different premises base than the one used by Ofcom, this can lead to gaps in reporting. While the impact is likely to be small overall, this can have an impact on decent broadband reporting given the relatively small number of premises.

[37] The Electronic Communications (Universal Service) (Broadband) Order 2018 [accessed 6 December 2021].

customer agrees to pay the excess. [38] In calculating whether the costs are below or above £3,400, the Universal Service Provider (USP) must take into account where costs could be shared by several USO eligible premises. BT is the USP for the UK (excluding Hull), and KCOM for the Hull Area. They are required to provide the USO and to report at six monthly intervals on delivery.[39]

BT's delivery of the broadband USO

So far, BT has received just under 1350 orders.[40] Each order may require network build that can serve multiple premises, and therefore these orders will lead to full fibre connections being built that can serve just under 6,500 premises that do not currently have access to decent broadband. These break down by Nation as shown in Figure 10.

Figure 10: USO orders and number of premises being built

	Number of USO orders	Total homes passed by resulting build
England	1100	5000
Northern Ireland	57	439
Scotland	84	288
Wales	108	689

Source: Ofcom analysis of BT data.

BT published its latest delivery report in October 2021.[41] These reports show that to date:

- it has received just over 20,000 requests to its USO Helpdesk;
- of these, around two-thirds were ineligible as a decent broadband product already existed from BT or another provider, or one would be made available within 12 months by a publicly funded scheme; and
- BT has connected just under 200 premises under the USO scheme. As stated above, network build may serve more than 1 premises. The build that has been completed may serve many more than these 200 premises. However, a connection is only provided once a customer places an order.

Shortly after the USO launched, we were concerned that BT may not be complying with the USO conditions correctly when it was calculating the excess costs for a given connection. This was potentially resulting in some customers receiving a quote for a connection that was higher than it should have been, leading to fewer people taking advantage of the USO. We opened an investigation

[38] In our statement of 6 June 2019 (para 5.1), we decided that an affordable service was one that cost £45 per month, rising annually by CPI. When the USO launched, this figure was £46.10.
[39] KCOM has received 1 request regarding the USO, which it found to be ineligible as a service meeting the decent broadband specification was available. KCOM does not consider any premises would be eligible for the USO because all customers can access either an affordable full fibre or a copper ADSL service. See Para 2.19, Ofcom, Statement: Compensating providers delivering universal services, 22 May 2020
[40] Data provided by BT to Ofcom includes orders up to 14 October 2021. BT's public reporting, up to 30 September 2021, indicates 1288 orders.
[41] BT, BT report on progress against the Broadband USO, [accessed 29 October 2021].

into BT's approach to calculating quotes for excess costs in October 2020.[42] In November 2021, we closed the investigation and amended the conditions imposed on BT so that: [43]

- BT would have to share costs appropriately amongst premises where the cost per premises was below £8,400 (£5,000 above the reasonable cost threshold), and would have to start build immediately after the first customer placed an order; and
- BT could wait until it had agreement to recover all the shared network costs of a build, where the cost per premises was higher than £8,400, to ensure that where excess costs are high BT will recover these costs given fewer customers might be prepared to pay these higher amounts.

Some premises may not get connected under the USO

Data analysis by BT indicates that in many cases, the costs to connect these remaining premises will be high so that many customers are likely to receive excess cost quotes above the £3,400 threshold. Those premises that are the most expensive to connect may need alternative solutions.

Satellite services may be an option for customers in poorly served areas

Satellite remains an option for a fixed broadband connection, particularly for premises without the alternative of a fixed provider. However, the number of customers accessing satellite services remains low in comparison with traditional broadband provision.

Geostationary (GSO) satellites orbit the earth at around 36,000km, and can be used to provide satellite broadband to premises across the UK, including the most remote premises, but the connection's performance can be limited by its latency, and by data caps that are commonly imposed on satellite broadband connections. But newer GSO services may offer improved services for consumers. For example, Konnect states that its satellite covers around 75% of the UK and offers commercial services on a 24/7 basis direct to consumers with download speeds between 30Mbit/s and 100Mbit/s, with upload speeds averaging 3Mbit/s.

We are beginning to see the introduction and deployment of Low Earth Orbit (LEO) satellite constellations that offer residential and business broadband to UK consumers. These services will have lower latency, because the satellites are closer to Earth, so they are more likely to provide better broadband services. However, the throughput that a customer receives will also depend on the number and capacity of satellites and available spectrum, which will be shared between users of the service.

SpaceX's Starlink service has been launched and is currently in beta trial. It offers direct to consumer services on a 24/7 basis in most of the UK with future coverage for the whole of the UK planned. Starlink indicates that users can currently expect to see 100 to 200 Mbit/s or greater download speeds and upload speeds of 10 to 20 Mbit/s with latency of 20ms or lower in most locations.

[42] Ofcom, Investigation into BT's compliance with its obligations as a broadband universal service provider, October 2020.
[43] Ofcom, Statement: Approach to high excess costs under the broadband universal service, 11 November 2021.

Other LEO services include OneWeb, which aims to provide 24/7 coverage of the entire UK by the end of 2021, with services available via distribution partners in 2022. We understand it will have a focus on backhaul and services for businesses initially.

We plan to conduct broadband performance measurements on satellite connections to understand in more detail the performance that can be delivered on these networks.

Private and public sector investment play a role in building faster networks

Supporting investment in faster networks across the UK is a key priority for Ofcom. While commercial and public sector investment has delivered at least superfast services to most of the UK, not every part of the UK has the same access to faster speed services. Therefore, we are continuing our work to both improve access to better broadband services in the hardest to reach locations, and support investment in new gigabit capable networks.

Investment in telecoms network infrastructure increased by 9% to £6.3bn in 2020

Over half of network investment in 2020 was in fixed network infrastructure, including full fibre

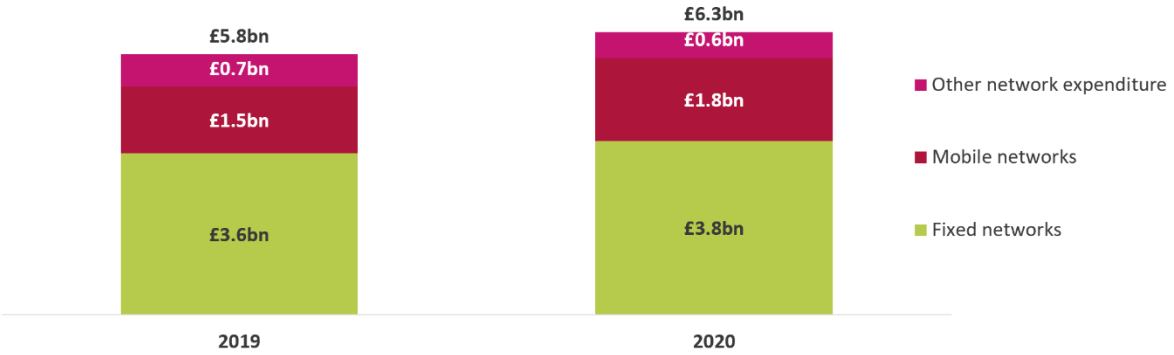
We collected network capital expenditure (CAPEX) data from over 30 of the UK's largest fixed and mobile telecoms providers to help us understand how telecoms providers are investing in network infrastructure.[44]

The information is collected from telecoms providers and relates to their annual financial reporting periods. As financial reporting periods can differ from provider-to-provider, we have pro-rated the data to estimate network investment in the calendar years 2019 and 2020.

The figures shown below include any public funding provided to support the rollout of better fixed and mobile connectivity, such as UK Government funding, funding provided via the governments of the devolved nations and local authority funding.

[44] Only capital expenditure required to provide and operate network infrastructure in the UK is included: figures exclude VAT and expenditure on retail activities (e.g. retail billing or marketing systems). Figures include capital expenditure on tangible and intangible assets, including capitalised staffing and labour expenditure, and expenditure on assets in the course of construction (AICC). Figures exclude expenditure on assets that have been added to a balance sheet through adoption of the IFRS16 accounting standard, on assets held for sale and the costs of maintenance contracts purchased alongside hardware. Expenditure associated with asset transfers and leasing follows the same guidelines the Office for National Statistics provides when requesting information in its quarterly acquisitions and disposals of capital asset survey. While the figures shown have been rounded, any percentage changes shown are calculated using the unrounded data.

Figure 11: Telecoms network capital expenditure: 2019 and 2020



Source: Ofcom / operator data.
Note: Adjusted for CPI (2020 prices).

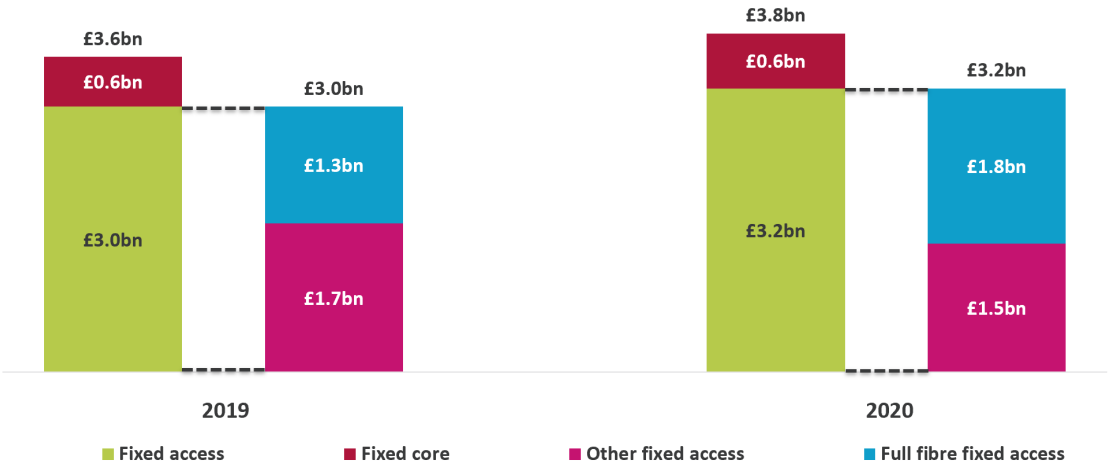
Expenditure on fixed telecoms network infrastructure increased to £3.8bn in 2020

Data collected from more than 25 of the UK's largest fixed telecoms providers suggest that UK telecoms providers invested £3.8bn in fixed network infrastructure in 2020, a £0.3bn (7%) increase in real terms compared to 2019. In addition to this, £0.6bn was invested in infrastructure that is used to provide both fixed and mobile telecoms services in 2020.

Investment in access network infrastructure accounted for most fixed network investment during the year, (£3.2bn, or 84% of the total), with fixed core and backhaul networks accounting for the remaining £0.6bn (16% of the total). These proportions were unchanged from 2019.

Gigabit-capable full fibre access network investment totalled £1.8bn in 2020, a year-on-year increase of £0.4bn (32%). In addition, a proportion of the £1.5bn that was spent on other fixed access services may also support deployment of gigabit-capable networks where this relates to upgrades to physical infrastructure (such as fibre deployments for fibre-to-the-cabinet) that could be re-used in future.

Figure 12: Fixed telecoms network capital expenditure: 2019 and 2020



Source: Ofcom / operator data.
Notes: Adjusted for CPI (2020 prices); the split of full fibre access and other fixed access investment for 2019 data has been updated to reflect operator restatements.

Public sector investment has a key role in delivering connectivity

Governments across the UK continue to supplement commercial rollout by investing in faster speeds for the hardest to reach areas. While subsidy schemes designed to bring superfast speeds continue to operate, governments are also now using public funding to support gigabit-capable connectivity.

The UK Government has set a target of at least 85% gigabit coverage by 2025, alongside an ambition to get as close to 100% as possible. To help achieve this, the Government has committed £5 billion in investment as the UK Gigabit Programme, with at least £1.2bn available by 2025, to provide connectivity for the hardest to reach areas. The first procurement rounds have now commenced, with the first contracts likely to be awarded in 2022 with build commencing thereafter.

Examples of ongoing government schemes to support faster speeds in hard to reach areas include:

- Alongside the UK Gigabit Programme, the UK Government provides vouchers including through the Gigabit Broadband Voucher Scheme for individual eligible customers to contribute towards the installation of faster connections using gigabit-capable infrastructure.
- The Welsh Government awarded its Superfast Cymru successor scheme contract to Openreach, which is expected to provide full fibre to 39,000 premises, in three lots across Wales by June 2022. This will be achieved with £56m of public subsidy from the Welsh Government and EU funding. This contract is already known to have completed 31,531 premises. It is focused on tackling premises in the final 4% of Wales that can't yet access speeds of 30Mbit/s.
- In Scotland, the Scottish Government has committed to ensuring every home and business in Scotland can access superfast broadband. This commitment will be delivered through the Reaching 100% (R100) programme via three key strands of activity – the £600 million R100 contracts (North, Central and South), the Scottish Broadband Voucher Scheme (R100 SBVS) and ongoing commercial deployment. Contracts for R100 in all three lots have been signed with BT and will go beyond the original commitment to provide superfast broadband by providing a significant number of gigabit-capable and full fibre connections.[45] Work is now underway in all three lots and the Scottish Government is working with Openreach to identify opportunities to accelerate this where and when possible.
- In Northern Ireland, Project Stratum is utilising £165m of public funding to target premises that can't get a service capable of delivering a download speed of 30 Mbit/s (Superfast). 76,000 premises were included in the project, and in August 2021, the Department for Digital, Culture Media and Sport allocated an additional £25m towards bringing an additional 8,500 premises into the project. The first premises were connected in Coalisland, Co Tyrone in March 2021, with over 19,000 premises expected to be passed by the end of 2021.

More information about schemes run by the devolved governments is available in the individual nations reports.

Working with the UK and devolved governments, Ofcom will continue to focus on ways to deliver decent connectivity to all. In particular, the UK government consulted earlier this year on the

[45] Scottish Government, Improving broadband access, 2 September 2021.

premises in the hardest to reach locations where even the broadband USO and other public schemes will not reach,[46] and we will work with the government as it develops its policy in this area.

More consumers are upgrading to higher speed packages

More people are taking up full fibre

Having discussed coverage, and the investment in improving the availability of networks, we now report on take-up. The benefits of increased coverage of broadband networks able to support higher speed services cannot be realised if consumers do not take advantage of these services when they are available.

We estimate that the take-up of services using full fibre at any speed, where fibre is available, is around 24%.[47] Our reporting of full-fibre take-up may appear lower than expected because, whilst networks are being deployed at pace, take-up is likely to lag behind coverage. This occurs because the new fibre services may not be advertised until the network is available so that there is a lag in awareness of availability, and consumers may need to wait until their existing service contract ends before they can migrate to a new fibre service. But, in absolute terms, take-up is increasing rapidly with the number of full fibre connections increasing by at least 750,000 in the year to September 2021.[48] Figure 13 below provides a breakdown of full fibre take-up as a percentage of premises where full fibre services are available.

Figure 13: Estimated full fibre take-up as a percentage of premises where full fibre services are available: 2020 and 2021

	2021	2020
UK	24%	25%
England	25%	27%
Northern Ireland	19%	11%
Scotland	22%	25%
Wales	24%	22%

Source: Ofcom analysis of provider data.

Customers taking a full fibre broadband service can usually choose from a range of speeds. Approximately half take a package that delivers a download speed of up to 100Mbit/s. Take-up of gigabit speed services is still low, with around 7% of full fibre customers taking these higher speed services.

[46] GOV.UK, Improving broadband for Very Hard to Reach premises [accessed 3 December 2021].
[47] This take-up figure refers to the underlying technology; customers can often choose a range of speed tiers over full fibre technology.
[48] Our estimate of 750,000 is based on take-up data from a subset of providers offering full fibre. These are the largest providers and so will account for the majority of customers. We have not estimated take-up of smaller providers that have not submitted take-up data to us.

Take-up of superfast broadband has increased to over two-thirds

Overall, we estimate that for those premises that are able to take superfast broadband or a higher speed (96% of all premises in the UK), around 69% of them do so. This is an increase from around 60% last year. Take-up of superfast broadband or faster is highest in Northern Ireland; take-up has increased in all nations in the last year.

Figure 14: Estimated superfast take-up as a percentage of premises where superfast services are available: 2020 and 2021

	2021	2020
UK	69%	60%
England	69%	61%
Northern Ireland	73%	65%
Scotland	68%	57%
Wales	66%	55%

Source: Ofcom analysis of provider data.

Getting connected to full fibre networks depends on timely installation

Customers can only take advantage of the increasing coverage of new full fibre networks where connections can be provided in a timely fashion.

The coverage information we publish, both in this report and our associated maps and open data, shows where connections at the speeds indicated are available. For broadband services using the telephone line, such as standard broadband, the connection usually already exists to the property. However, in the case of full fibre connections, the network provider may have installed network close to the property but still needs to install the final connection to a property in order to provide service.

We asked full fibre providers the length of time it would take to make this connection. We found that there was a broad range of installation times. For those providers that provide fibre networks to new-build and campus developments, connections are built into the fabric of the properties, and hence connection times are effectively instantaneous. In general, we found that almost all operators are able to provide connections within 28 days of a customer order. In some situations, longer connection times may arise, either because of the geography (such as accessing very rural communities) or due to gaining necessary permissions to access private land.

This year we also asked a subset of full fibre providers about how often they complete a new physical connection within their respective standard connection provision time in order to gauge whether the providers were meeting their expected targets. More often than not, the full fibre providers were able to meet their targets. Where the full fibre providers were unable to meet their targets, the most common reason stated by the providers was when the customers requested them to arrange the appointment for a later date. However, other issues mentioned to us included complex construction challenges, engineering resource constraints and delays incurred between access network build completion and the operational ability to offer retail services to customers.

Networks need to make sure they have capacity to connect new customers

In some circumstances it is not possible to provide a broadband service to a new customer even though there is network coverage. This can arise because the network in the area is reaching the limits of its capacity, and therefore requests for service at the desired speed cannot be met. It may also arise if additional connections exceed the physical number of ports on equipment in the access network (such as a street cabinet or exchange equipment).

Similar to our 2020 report, we have again estimated that across the UK, fixed access networks had the capacity to meet additional demand from users 99% of the time. The underlying reasons for capacity constraints remain consistent, with more network providers reporting some, albeit low levels of capacity limitations.

To investigate the 1% of cases where demand could not be met, this year we also asked providers about the length of time they were unable to accept additional customers due to such capacity constraints and the reasons for this. This varied considerably, from a few days to many months, depending on the specific solution used to implement additional capacity. Other factors such as permission to carry out the work and resource constraints played a role as well, with one provider highlighting the impact of Covid-19 on their ability to carry out upgrades. Openreach mentioned that port limitations within its FTTC street cabinets are often mitigated by customers being able to upgrade to FTTP or G.fast, rather than by adding new capacity. Based on the responses we estimate that most capacity constraints are resolved within two months. However, in a very small number of cases, they have remained in place for much longer.

Helping customers choose the right broadband service

Consumers will be best placed to decide which service most suits their needs if they understand the range of options available to them. Ofcom has work underway to help consumers understand their broadband choices, and to see the potential benefits that faster connections may give them. Ofcom seeks to help consumers understand the broadband choices available to them, and to understand the additional benefits of a faster connection.[49] Our coverage checker also shows the network providers that are available at a particular location.[50]

We have also worked to help consumers know when their contract period is coming to an end, and what their options are when it does. Since February 2020, providers have been required to issue End of Contract Notifications (ECNs), which tell people when their contract is coming to an end, what they will pay when it does, the best deals their provider can offer them (as well as any prices only available to new customers), and that they have the choice to switch providers at the end of their minimum contract period if they wish.[51] Additionally, providers are required to issue Annual Best

[49] How to get more from your broadband
[50] View broadband availability
[51] Ofcom, Companies must tell customers about their best deals, 14 February 2020. Providers were required to send ECNs from February 2020, and ABTNs within 12 months from then for contracts that were already in force at that date – in effect this means that most providers began sending ABTNs from February 2021.

Tariff Notifications (ABTNs) to their out of contract customers, telling them that they are out of contract and the best tariffs they can offer.[52]

Consumers can find it difficult to choose their broadband service among the different offerings and we believe that it is important they have the right information to make informed decisions about their broadband. In June 2021, the taskforce convened by the UK Government to drive consumer take-up of gigabit speed internet connections ('GigaTAG') published its final report. [53] The report included the recommendation that Ofcom and industry should develop common terminology to describe broadband services and a core set of use cases and benefits to be used by providers. We have already started to engage with providers and consumer groups to develop a set of common standards for consumer information on broadband services.

The UK's traditional telephone network is also being replaced

It is not only the UK's fixed broadband networks that are changing – traditional landline services are also undergoing a substantial transition. Network providers such as BT, Virgin Media O2 and KCOM, that offer traditional telephony services, are in the process of retiring their legacy systems (referred to as the Public Switched Telephone Network, or 'PSTN') and replacing them with modern systems.[54] In particular, BT and Openreach plan to retire BT's PSTN network and the Openreach wholesale services that deliver that capability by the end of 2025. To make sure that landline services continue in future, providers which currently use the legacy telephony networks will deliver landline calls over a digital technology called Voice over Broadband (VoBB), which uses Voice over Internet Protocol (VoIP) over a broadband connection.

Analysis of provider data shows that around 15% of landline services are now delivered over broadband, up from 8% last year. Increasingly, customers have their landline service moved to VoBB when they change provider or upgrade their phone and broadband package. In addition, BT and Virgin Media O2 have started to migrate existing customers. We are monitoring the migration and continue to engage with providers to help ensure consumers are protected and disruption is minimised.

At the same time, broadband customers can choose a 'broadband-only' package, where they are no longer required to take a phone service. Broadband-only packages – with or without the option to add a landline service – are offered by most full fibre providers, and are increasingly being offered for copper-based broadband as well. With landline usage falling, we anticipate that adoption of these packages will grow significantly in the coming years, with a corresponding decrease in the number of landlines. [55] We also note consumers are using mobile phones to replace or complement fixed connections.

The migration from the legacy telephone network also brings certain challenges. We discuss these challenges in more detail in the Security and Resilience chapter.

[52] Ofcom, Helping customers get better deals: a review of the impact of end-of-contract notifications and pricing commitments by broadband and mobile providers, 30 November 2021.
[53] GigaTAG, Gigabit Take-up Advisory Group: Final Report, [accessed 7 December 2021].
[54] In the case of BT, PSTN services are provided by Openreach in terms of access connectivity and BT for calls services. Openreach's WLR withdrawal site gives more information.
[55] Ofcom's Communications Market Report 2021.

Data usage over fixed connections continues to grow

Access to higher speed networks offers the opportunity for consumers to access faster, more bandwidth heavy services.

Consumers continue to use more data over their fixed connections as more people use broadband for data-heavy activities such as streaming. Average monthly data usage now stands at 453 GB per connection, up from 429 GB last year and 315 GB in 2019.[56]

During 2021, nationwide lockdowns, and subsequent restrictions, due to the Covid-19 pandemic have continued, meaning many people have been using their home broadband connections for work and school, for keeping in touch with friends and family, for accessing essential services, and for leisure.

Overall, the growth in average monthly download traffic has slowed this year to around 5%, but peak download traffic (in the period 6pm to midnight) has grown more, by around 13%. The figures for this year were recorded during May as the UK eased lockdowns, with different Nations taking different approaches.[57] This compares to last year, when the data was gathered in June at a time when the initial very strict lockdown had eased but strict restrictions were still in place and many people were still working from home due to the Covid-19 pandemic.

To understand how traffic has changed over the last year, we again requested data spanning the period from February to July. This captures the period from full lockdown to when these restrictions were being lifted. This was the same period as we looked at last year.

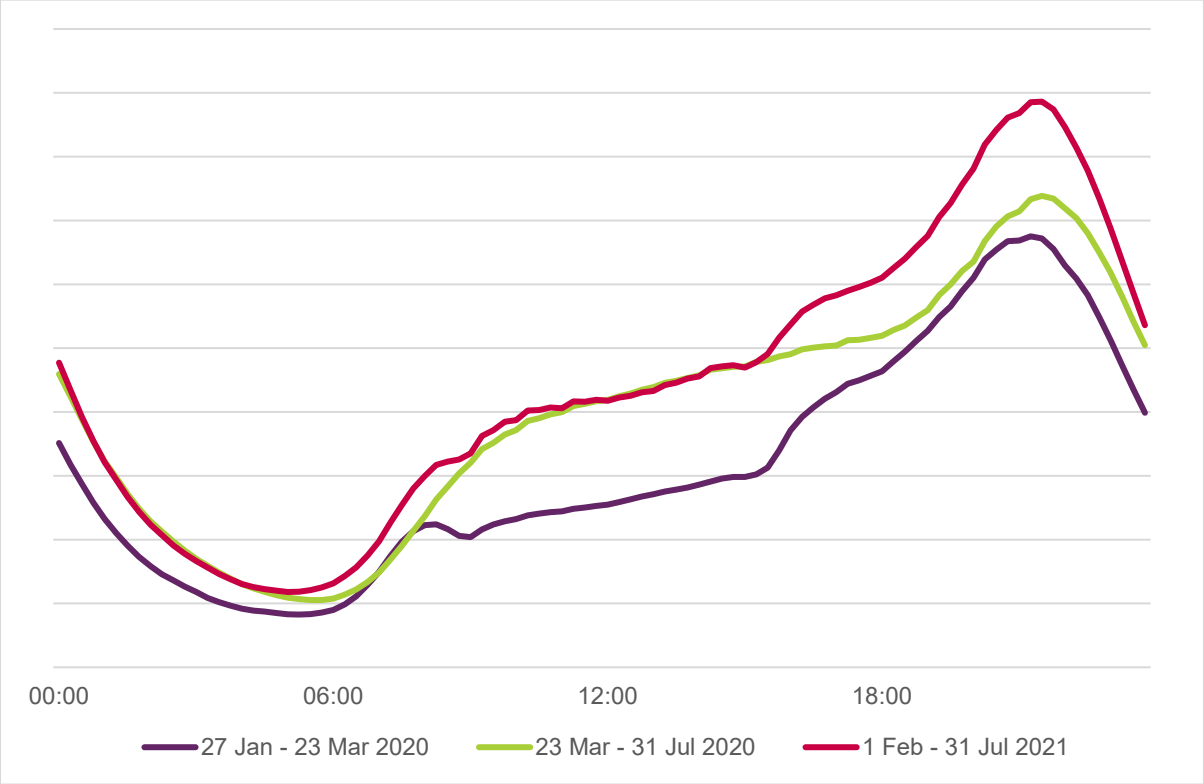
Some communications providers were able to provide detailed reports covering the entire period, whereas others had higher level analysis, or data for only part of the requested period. Figures 15 and 16 show the typical traffic profile for weekdays and weekends for three periods:

- Prior to national lockdown in 2020;
- The period of lockdown from late March to July 2020; and
- The period of lockdown from Feb to July 2021.

[56] These figures include connections not assigned to a specific location within the UK; equivalent figures in Nations reports include only connections assigned to addresses in that Nation. The UK average given here therefore includes data for premises not included in the figures given for each individual nation in the Nations reports.

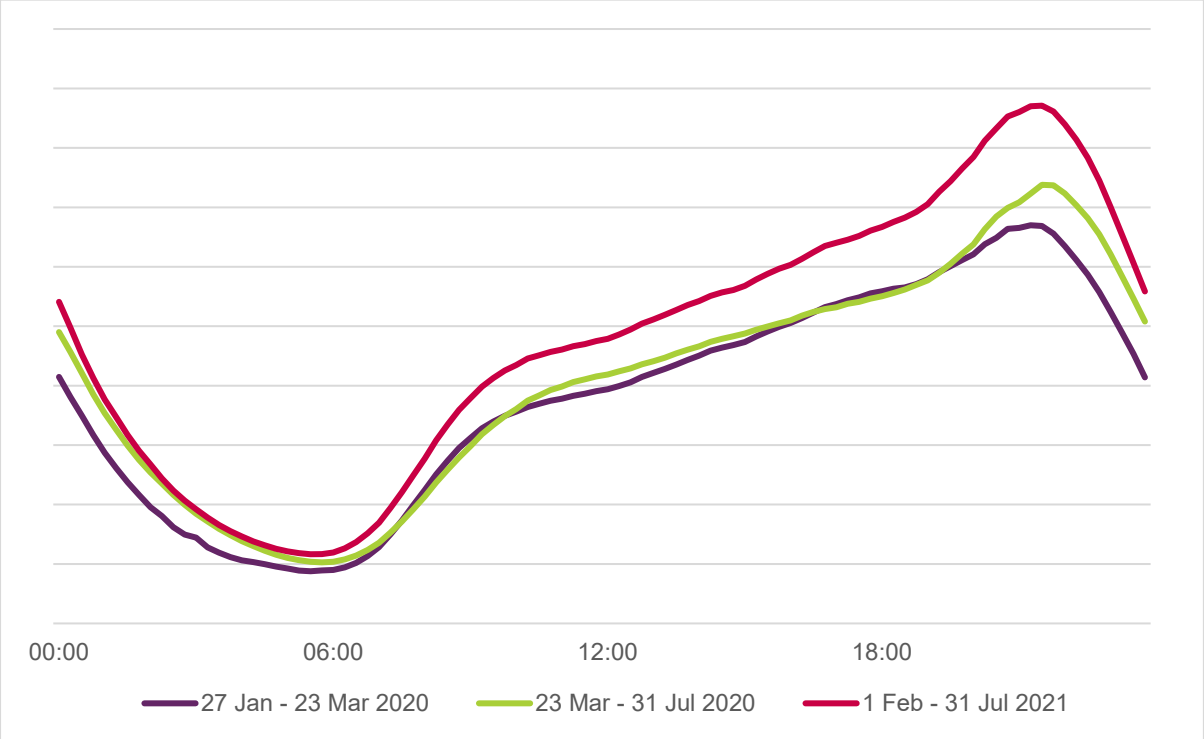
[57] At this time, many people were still working from home on a permanent or regular basis. Entertainment venues such as pubs were open to different degrees and with different rules in different Nations.

Figure 15: Average traffic profile (Gbit/s) on weekdays before national lockdown (27 Jan to 22 March), during national lockdown and subsequent restrictions in 2020 (23 Mar to end July), and during national lockdown and subsequent restrictions in 2021 (1 Feb to end July)



Source: Ofcom analysis of provider data.

Figure 16: Average traffic profile (Gbit/s) on weekends before national lockdown (27 Jan to 22 March), during national lockdown and subsequent restrictions in 2020 (23 Mar to end July), and during national lockdown and subsequent restrictions in 2021 (1 Feb to end July)



Source: Ofcom analysis of provider data.

The charts show that:

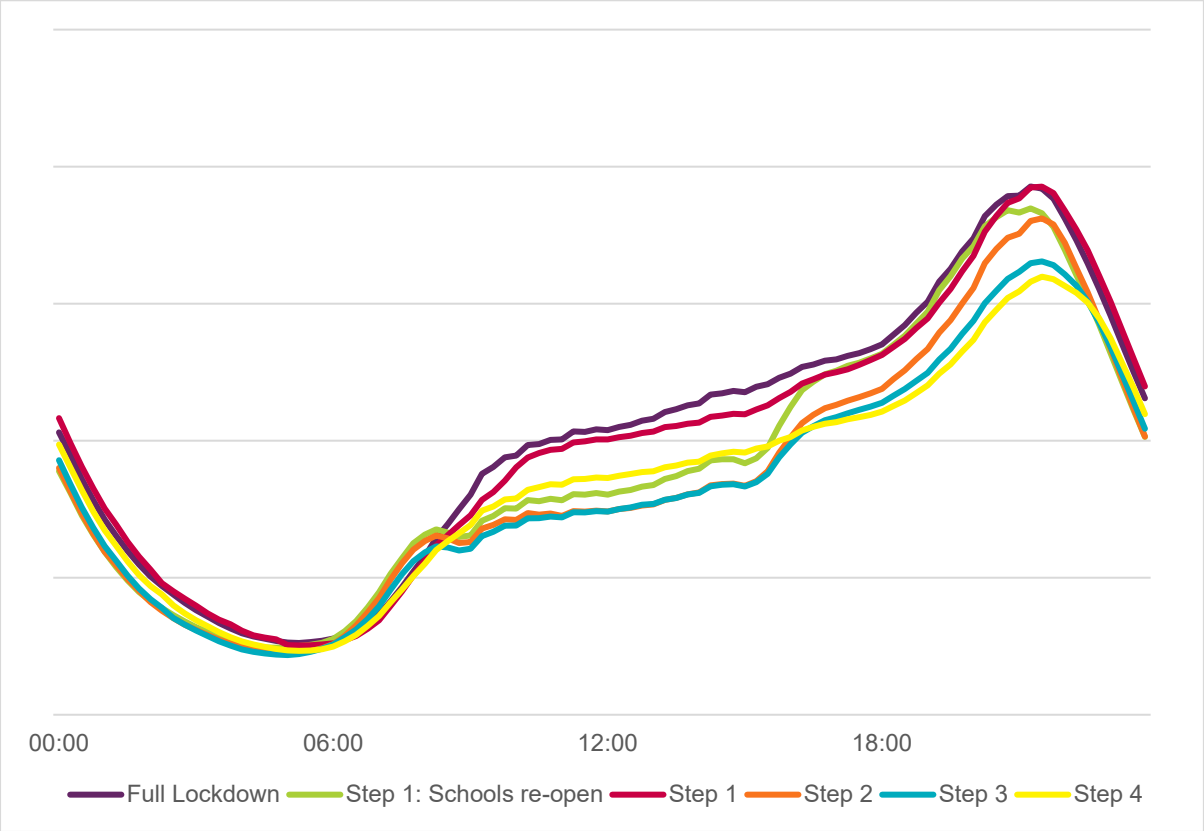
- peak traffic remained in the evening; and
- the significant increase in traffic during the weekday once nationwide lockdowns were introduced continued.

Whilst the above chart overall shows a higher peak in 2021 than 2020, several providers reported that increases in the peak were lower at the end of the period year on year (i.e. year on year growth from June/July 2020 to June/July 2021 was lower than in earlier months). However, we note that peak traffic does continue to grow and is likely to be driven by video streaming and gaming. Video streaming of live events can also lead to unexpected and/or volatile traffic peaks (for example, streaming of sports events can drive significant demand).[58]

The weekday data for 2021 shows an increase in traffic around 4pm. This is consistent with the peak seen pre-Covid restrictions and represents an increase in traffic as children finish school. Figure 17 below shows, for 2021, the weekday profiles for different stages of lockdown in England.[59]

[58] See for example: Openreach on Twitter: "Crouch. Bind. Stream. Last week was the busiest week of network traffic for the last six months. The spike was due to fans streaming the Rugby Autumn Internationals online over the weekend. Autumn is in full swing #WeAreOpenreach #AutumnInternationals"
[59] We note that lockdown steps were different in different Nations. The data shown is for the UK and will be driven by usage in England as the largest Nation.

Figure 17: Average traffic profile (Gbit/s) on weekdays by step of lockdown easing in England



Source: Ofcom analysis of provider data.

Where: Full lockdown is the period from 1 Feb to 7 Mar; Step 1: Schools re-open is the period from 8 Mar to 28 Mar; Step 1 is the period from 29 Mar to 11 April; Step 2 is the period from 12 April to 16 May; Step 3 is the period from 17 May to 18 July; and Step 4 is the period from 19 July to 31 July.

From Figure 17 we note that:[60]

- Weekday traffic was highest during full lockdown up until 7 March. This was particularly true during the day, but also in the evening.
- When schools returned, daytime traffic fell until around 4pm when traffic increased as children finished the school day.
- Higher daytime traffic was seen as schools were on holiday during the two week period from 29 March when Step 1 measures other than schools opening were implemented.[61]
- Each step easing lockdown saw an overall reduction in traffic.

As last year, networks have coped with the additional demand as a result of the lockdown. Providers plan their networks to have spare capacity to cope with year on year traffic growth and spikes associated with especially busy events. This has provided sufficient headroom to cope with any increased peak demand during the pandemic.

[60] Some of these steps cover different periods (for example Step 1 covers only 2 weeks. As such caution should be taken in placing too much weight on these specific charts, which are presented for illustrative purposes.
[61] Daytime traffic during Step 4 from 19 July is higher. This is consistent with usage during school holidays starting late July and with some children having finished school after exams.

Sustainability

As the UK progresses towards its net zero target,[62] it is vital that we all consider how we live and work from an environmental sustainability perspective. Meeting this target will include reductions in businesses' own greenhouse gas (GHG) emissions, greater use of renewable energy and consideration of embodied carbon. Businesses have a crucial role to play, and it is encouraging to see many fixed and mobile services providers commit to reducing their own environmental impacts.

The telecommunications services sector's CO2 equivalent emissions, on a consumption basis was estimated to be 0.08% of the UK's total in 2018, at 471,000 tonnes. The sector's CO2 equivalent emissions on a production basis was estimated to be 0.06% in 2019, equating to 308,800 tonnes.[63]

Providers have responded in a range of ways such as signing up to net zero pledges, integrating environmental sustainability principles into business decisions, championing schemes to reduce waste, and working with supply chains to reduce wider impacts. For example, during the 2021 financial year, some MNOs invested in energy efficiency and on-site renewable projects for their base station sites and technology centres, as well as energy efficiency management programmes, resulting in savings in energy consumption and running costs. Beyond reducing their own emissions, communications providers have a crucial role to play in enabling the UK to become more efficient and productive, empowering people and businesses to tackle their environmental impact. Communications can help society reach net zero by reducing GHG emissions, through networks, goods and services, such as smart buildings, smart logistics, smart grids or reducing travel by shifting to virtual meetings.[64]

As the regulator, we want to see investment in the latest technologies. But if these investments are to benefit consumers in the long term, they need to be sustainable financially and in terms of their wider impact on society. We will continue engaging with our industry stakeholders to understand their approach to running their businesses sustainably. All firms in the sector will need to understand how they affect the environment, how technologies can enable emission reductions in other sectors, and what actions could help achieve the UK's future net-zero carbon target.

[62] The International Panel on Climate Change (IPCC) defines net zero as that point when "anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period." https://www.ipcc.ch/sr15/chapter/glossary/ [accessed 7 December 2021]

[63] Consumption figures (2018) are from: UK's carbon footprint (www.gov.uk). The consumption carbon footprint refers to emissions from the worldwide production of goods consumed in the UK as well as goods produced in the UK and emissions directly generated by UK households. Production figures (2019) are from the Office of National Statistics [accessed 9 December 2021]. The production emissions are compiled on a residency basis, covering emissions from UK residents and UK-registered businesses regardless of whether they are in the UK or overseas. Greenhouse gases under the Kyoto Protocol: carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, perfluorocarbons, nitrogen trifluoride, sulphur hexaflouride.

[64] https://www.itu.int/rec/T-REC-L.1471-202109-I [accessed 7 December 2021]

Mobile, data and voice

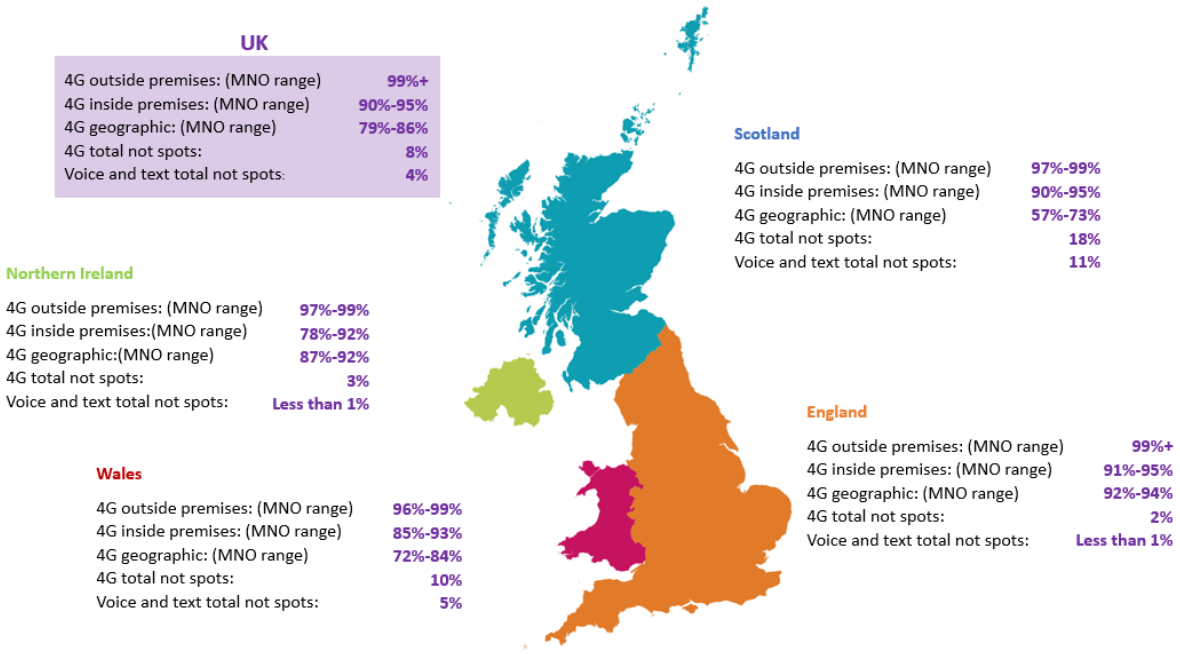
Introduction

Mobile services play an ever-increasing role in people's lives. In this chapter, we report on the availability of mobile coverage, outside and inside premises, across the UK's landmass and on roads. We provide an update on developments in the rollout of 5G over the last year, and provide a first view of how extensively 5G is available. We also address investment in, and the take up of mobile services, as reflected in the continuing growth of mobile traffic. Finally, we also report on the availability and use of 'Internet of Things' devices and services.

Key highlights:

- 5G is available from at least one MNO in the vicinity of c42-57% of UK premises (with a higher reliability of receiving a service at the lower end of this range). 5G remains largely focussed on adding capacity in urban areas, and this coverage represents only a small part of the UK landmass.
- 4G continues to underpin mobile experience in the UK, especially coverage for data services. 2021 has seen BT EE's geographic coverage rise 1 percentage point to c86%, alongside smaller increases from other Mobile Network Operators (MNOs), as the early impact of the Shared Rural Network and ongoing rollout to support the Emergency Service Network take effect.
- As consumer uptake of 5G enabled handsets increases (now c10% of devices) more traffic is being carried over 5G, rising from 1% of total traffic in 2020 to 3% this year. 4G traffic continues to grow, and remains the dominant technology for mobile traffic.
- Operators continue to manage dynamic behavioural changes resulting from Covid 19, as some but not all traffic returns to urban cores. Operators have met this challenge by deploying additional capacity in new places, particularly hotspot holiday locations.
- Internet of Things (IoT) connections grew substantially over the last year, with connections on MNO networks alone rising to more than 10 million. Although the overall volume of IoT data traffic remains less than 1% of all traffic, total IoT traffic has more than doubled year on year.

Figure 18: Summary of mobile coverage across the UK Nations



Source: Ofcom analysis of operator data, September 2021.

5G rollout and adoption is evolving

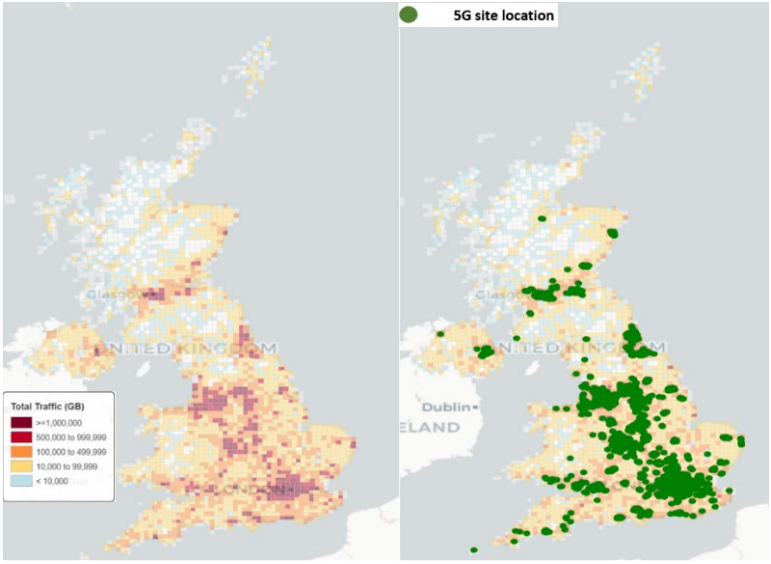
5G deployment has continued at pace in 2021, and now stands at more than c6,500 5G mobile sites across the UK, up from c3,000 in 2020. 87% of these sites are in England, 8% in Scotland, 3% in Wales and 2% in Northern Ireland.

Consumer take up remains relatively modest, but has increased substantially, with around 800,000 active 5G devices across all mobile operator networks in the UK in 2020 rising to more than 6 million handsets in September 2021. For MNOs this represents c10% of all active devices.

5G in the UK has been commercially rolled out initially in Non-Stand-Alone (NSA) mode, relying on a 4G core network, and using 4G for signalling and network control functions. This means that user services can be delivered over 5G, or a combination of 4G and 5G, which can place constraints on some of the full capabilities of 5G.

5G continues to be deployed to provide additional capacity in already busy areas, and is present on roughly half of the UK's 3,000 busiest sites (in terms of total traffic carried). Dense urban deployments of the high capacity 3 GHz spectrum (auctioned in 2018 and early 2021) predominate, however these are beginning to be supplemented with deployments in hotspot suburban areas and around transport corridors. Around 20% of sites in urban areas now have 5G deployed on them, compared with around 5% in suburban areas.

Figure 19: UK monthly mobile traffic (left) in relation to 5G site deployments (right)



Some of the locations highlighted above include areas where UK operators are deploying dynamic spectrum sharing (DSS) to roll out lower frequency 5G to suburban areas.[65] Where DSS is in commercial use by MNOs it represents on average c16% of 5G enabled sites in their portfolios, and offers a potential route to rapid further deployment of 5G. However, since it utilises existing spectrum it does not offer the same capacity gains as dedicated 3 GHz deployments. Available capacity across 5G deployments can further vary and be boosted to different degrees by the use of different MIMO antenna configurations, with a range of approaches being used by MNOs. [66]

What 5G means (alongside 4G, 3G and 2G) for consumers and businesses

Throughout this chapter, we report on the coverage available through more established 2G, 3G and 4G technologies, as well as the traffic carried upon them, alongside 5G. These technologies continue to underpin the service upon which the majority of consumers (at least 90%) rely. Indeed, notwithstanding the uptick in 5G handset availability and significant growth in deployment, 5G carries only 3% of the total UK mobile traffic, indicating that this remains a relatively small part of the mobile experience for most consumers.

Where a mobile site is not heavily loaded both 4G and 5G technologies can support most of the demanding use cases typically required by today's consumers. 5G has some unique features – for example, the potential to significantly reduce latency, which could enable the development and growth of certain newer applications (e.g. augmented reality or virtual presence) in the future. However, while our Mobile Matters report found that the latency of 5G connections was approximately 20% better than for 4G, this is unlikely to be noticed by today's smartphone user. [67]

[65] Dynamic spectrum sharing enables the parallel use of 4G and 5G in the same frequency band, as the technology determines the demand for 5G and 4G in real-time.
[66] MIMO, meaning multiple input multiple output antennas. We have seen MNOs adopt a range of approaches in 5G deployments, with around 44% of antennas found to be at either 32Tx32R or 64Tx64R (supporting the greatest capacity and throughput enhancements); around 45% at 8Tx8R; and the remainder at lower configurations (e.g. 2TX2R).
[67] Mobile Matters 2021, page 16 [accessed 7 December 2021].

The introduction of Stand Alone 5G may enable further improvements, where this is combined with more localised investment in data storage to achieve transformative experiences.

Figure 20: illustrative summary of use cases by mobile technology

Technology	Typical use cases (subject to demands on capacity)
5G Stand Alone (mid frequency & above)	Fastest connection speed, highest capacity, potential for ultra-low latency applications (and including 4G use cases)
5G NSA (mid frequency)	More capacity to support more people undertaking high data rate services e.g. higher volumes of demanding 4K video users (and including 4G use cases)
5G NSA (low to mid frequency)	General web browsing, social media, gaming, video streaming (and including 4G use cases)
4G	General web browsing, social media, gaming, video streaming (and including 3G use cases)
3G	Basic web browsing (and including 2G use cases)
2G	Voice calls, text, very low data rate applications

Although newer applications may become associated with Stand Alone 5G and the deployment of larger bandwidths (mid frequency and above), many such services are also likely to be possible on lower frequencies when there are fewer users in an area (for example in rural areas). Given the potential for different technologies to provide similar performance levels in the right circumstances, and the range of experiences that are possible (even on the same technology), we intend to develop new approaches to report in more detail on the quality of performance possible in different areas in the coming year.

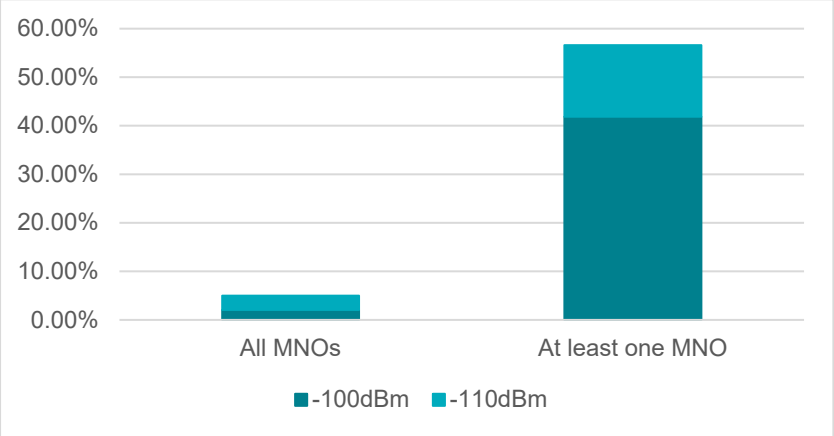
5G is available in many populated areas, although comprehensive coverage across MNOs is less extensive

5G rollout is evolving rapidly. We recognise that operators are still refining their 5G rollout plans, optimising their 5G networks and are still developing approaches to reporting on 5G (both to Ofcom, and directly to their customers). We therefore expect that further work in the coming months may yield refinements to these approaches and the data we collect. Nevertheless, more than two and a half years on from the commercial launch of 5G and with growing consumer take up, there is a significant interest in understanding how extensively 5G is available. Ofcom has worked with mobile operators to understand best practice for 5G reporting and seek a common reporting framework. This remains work in progress.

In light of this evolving picture and ongoing work, we are providing a view of where 5G is predicted to be available[68] from 'All MNOs', and from 'At least one MNO'[69], based on the information provided to us by operators, and informed by our own measurement work.[70]

Given the current level of 5G deployment, it is challenging to conclude on a single margin to define the reliability of a 5G service being available at this stage. Below we provide a view of 5G coverage availability outside premises across a range that provides increasing confidence of a reliable connection, from high confidence (-110 dBm) to very high confidence (-100 dBm).[71]

Figure 21: 5G coverage outside premises – by all and at least one MNO



Source: Ofcom analysis of operator data

The area where 5G coverage is available from all MNOs is significantly lower because this metric is constrained by the footprint of operators with the least coverage and localised differences in coverage coming from different site locations. It represents areas with maximum choice between MNOs, but provides a view of coverage that is lower than any 5G consumers would experience. Geographic 5G availability remains modest, with coverage from at least one MNO ranging between 6-10% of the landmass across these thresholds, reflecting the continued emphasis on 5G deployment in busier urban areas.

We are providing this perspective to give an indication of current 5G rollout. We are not able to report on individual mobile operator coverage for two main reasons:

- Although MNOs have undertaken some validation of their 5G predictions, this work remains ongoing. In addition, our own measurement work leads us to consider that while the above

[68] By Availability we mean where a consumer handset can reliably access a 5G network. We expect that where a handset can do this, a consumer will at least be able to access core services and in many cases significantly greater performance levels will be possible. We expect to report on quality of performance (for 4G and 5G) in the future.

[69] By 'At least one' we mean the total area in which 5G is potentially available from an MNO, although this service may be from one operator in one location, and another elsewhere.

[70] Our current measurement methodology for 5G (and 4G) is available on our website.

[71] In this approach, we have associated the signal strength which an operator predicts to provide (in dBm) with a confidence level for coverage being present on the ground. The higher signal level (-100 dBm) implies higher confidence. We set out our approach in more detail in Annex A
https://www.ofcom.org.uk/__data/assets/pdf_file/0023/229505/connected-nations-2021-methodology.pdf

ranges are appropriate, we are not in a position to be certain of this for individual MNO predictions; and

- The mobile operators currently have different views on what thresholds are appropriate for a high confidence of 5G availability. This may reflect both the ongoing nature of validation work on 5G, and evolving choices in network and traffic management strategies.

Ofcom will continue to work with MNOs to establish a more common approach to reporting, which should focus on providing consumers with information on coverage that is reliably available where it is predicted. This work will require MNO validation activity to be completed as soon as possible to ensure the accuracy of the information provided both to Ofcom and to consumers in MNO coverage maps. In addition, we will work towards an industry consensus on appropriate reliability margins for reporting coverage to avoid consumers receiving inconsistent coverage information from each MNO.

5G is also enabling MNOs and others to explore new private network opportunities

Last year, we highlighted the emerging opportunities for private networks enabled by 5G, as a result of its ability to afford organisations greater control over operational processes, with near instantaneous communications and the ability to guarantee quality of service. This remains an active and developing area, with the opportunity for a broader set of players to emerge as localised communications providers.

Over the course of 2021, there have been a number of announcements from organisations investing in private 5G networks:

- O2 launched a 5G private network development with Leonardo (a Ministry of Defence supplier) for a range of industry applications (e.g. next generation manufacturing);[72]
- Verizon and Nokia are developing a private 5G network for Associated British Ports in the Port of Southampton, enabling a more reliable and secure private wireless data network across areas in the Port;[73]
- Telent (whose clients include Transport for London, Highways England, BT/Openreach) launched its first 5G private network service and test facility.[74]

A number of schemes in operation are benefitting from the UK Government's Test beds and trials programme,[75] which in early 2021 announced £28 million to fund various use cases for 5G, including real time goods tracking at the ports of Felixstowe and Bristol, and testing 5G-powered cameras, drones and sensors for the construction industry in Scotland.[76]

Whilst MNOs are involved in this work, live commercial offerings of MNO private networks remain limited. As of September 2021, the number of fully operational commercial private networks run by

[72] WM5G, O2 UK partners with aerospace company to test private 5G networks, O2, 5G Private Networks and their role in transforming Defence and Manufacturing Industries.
[73] Verizon, Verizon signs its first European private 5G deal with Associated British Ports.
[74] 5Gradar, Telent launches new service to develop private 5G networks.
[75] The 5G Testbeds and Trials Programme, part of the DCMS, is exploring the benefits and challenges of deploying 5G with the aims of accelerating 5G deployments and maximising the benefits and opportunities of 5G for UK businesses.
[76] DCMS, £28 million to trial innovative new uses of 5G to improve people's lives, 13 January 2021 [accessed 7 December 2021].

mobile operators stands at 7, although a number of others are in the pipeline or at a trail stage. A number of these are operated on 5G, or a mix of 5G and 4G, although some are operated as 4G only networks.

Non-mobile operator players are also able to access mobile spectrum to provide services, and there is significant activity underway across a variety of players. They range from mobile equipment vendors, to system integrators and specialist ICT providers, all offering solutions to support digital transformation of industries.[77] Although we have not tracked all this activity for this report, Ofcom has issued more than 550 shared access licences since new rules were introduced in 2019, of which around half can be considered as supporting private network type solutions.[78]

Coverage of 4G, 3G and 2G remains largely stable, and extensive, but differences between urban and rural areas endure

Availability of mobile calls and data services

In this section, we continue to report on the availability of voice calls and data services across a range of metrics, as we have done in the past. This year, we are placing a particular focus on the range of 4G coverage available from individual MNOs, as this most closely matches the experience of most consumers. We continue to report on other metrics, including where all operators, or any one operator has coverage, both here but also in more detail in our online datasets.

The mobile coverage figures provided are based on predictions which the MNOs supply to Ofcom, with Ofcom undertaking regular testing to ensure the predictions provided are suitable for national and regional reporting. We take the accuracy of the data supplied to us seriously and we continue to monitor, through drive testing, the accuracy of all operators' coverage predictions. We note that operators continue to update and improve their prediction models and we continue to work with them to ensure appropriate validation is undertaken.[79]

Coverage outside premises remains high

As with last year, individual operators provide good 4G coverage outside more than 99% of UK premises.[80] In addition, c98% of premises have outdoor 4G coverage from all MNOs. Individual MNOs each provide coverage for outdoor voice calls in the vicinity of more than 99% of premises, whilst 99% of UK premises have coverage for outdoor voice calls from all MNOs.

Differences remain between coverage in urban and rural areas. Individual operators' 4G coverage outside of rural premises ranges between 93-97%, whereas each MNO serves more than 99% of

[77] There are also ongoing developments amongst cloud service providers. Amazon has recently announced a new 5G private network service, while Google and Microsoft have also entered into different partnerships internationally with telecommunications providers over the last 12-24 months.
[78] More information about the shared access approach is available on our website.
[79] In last year's report, we noted that new predictions had been received from O2 and that validation was ongoing. O2 has shared further data with Ofcom over the last year and is continuing to undertake work in this area.
[80] By coverage outside a premise, we mean coverage is predicted in a 100x100m area in which a dwelling is located, which can be seen as a proxy for outdoor coverage of populated areas.

urban premises. Outdoor voice coverage around rural premises ranges between 97-99% across MNOs, rising to more than 99% from each MNO for urban premises.

Coverage inside premises also remains high, with alternative solutions available for hard to serve locations

The coverage people receive indoors depends on a range of factors including: the thickness of walls, building materials used in construction and where in a building people are using their phone.[81] Consequently, there may be differences between operators' predicted indoor coverage data and the actual coverage available in some premises.[82]

For indoor 4G coverage, we find that the percentage of premises served ranges from 90-95% across the MNOs, with no substantive changes from last year. The availability of indoor voice calls is estimated to remain stable, ranging from 96-99% across the MNOs.

As with coverage outside premises, we continue to see a significant (and unchanged) difference between rural and urban areas for indoor coverage. Individual MNOs provide indoor 4G coverage to 69-80% of premises in rural areas, compared with 94-98% of urban premises. Indoor voice coverage is somewhat higher, ranging from 80-96% across the MNOs for rural premises, compared to a range of over 98-99% for urban premises.

Where indoor coverage remains poor, a number of alternative options are available to improve the experience. Tools include broadband-based calls on services such as Skype/WhatsApp, femtocells and Wi-Fi calling (the ability to make and receive a call and texts/SMS over a Wi-Fi network).[83] All UK MNOs offer Wi-Fi calling to consumers (though not all mobile phones are configured to support this feature). The percentage of calls made using voice over Wi-Fi by MNOs has remained relatively stable overall, between 2% and 16% per MNO (compared with between 2% to 18% in 2020).[84]

In addition, this year Ofcom has decided to expand the range of static indoor mobile repeaters that people can install themselves, without a licence. Such devices can boost the signals between a network operator's base station and a mobile phone, and so improve access to mobile services indoors. The new regulations will now allow 'provider specific' and 'multi-operator' repeaters to boost the signals of more than one MNO at a time, as long as they meet technical requirements.[85]

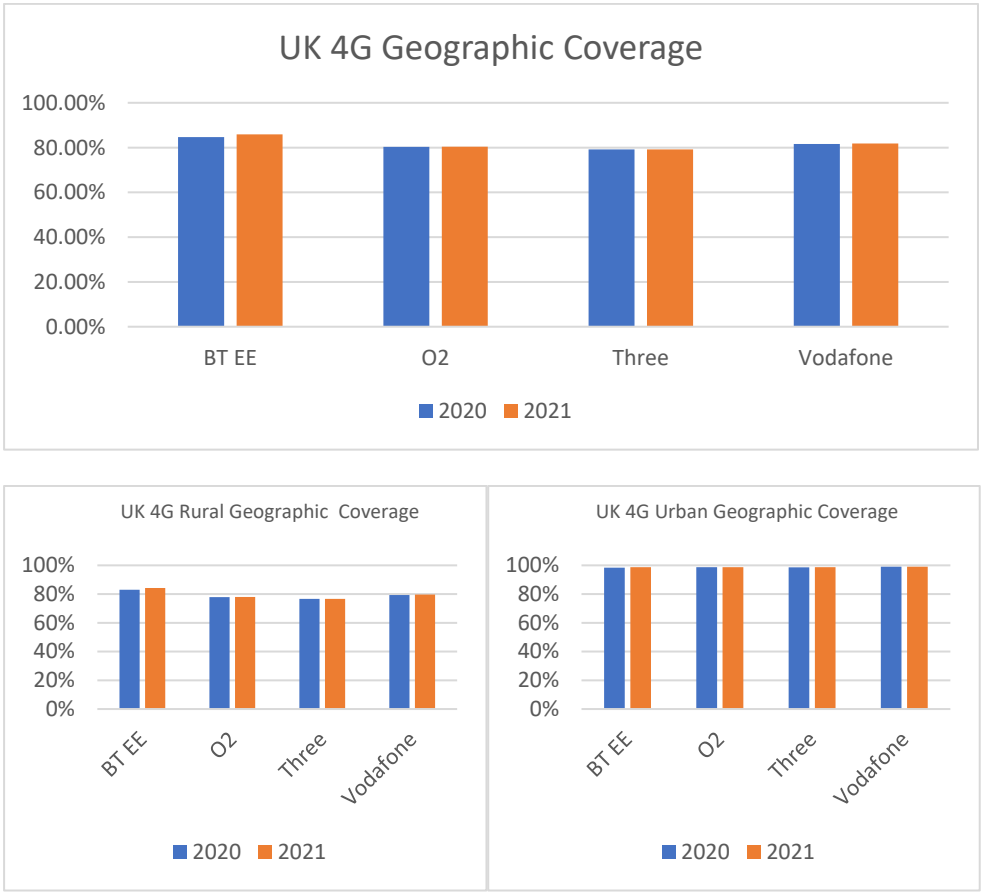
[81] Our online coverage checker provides additional information on the likelihood of there being indoor coverage in buildings at different locations and some of the factors that can affect a mobile signal indoors.
[82] We determine indoor coverage by applying an average building entry loss of 10dB across buildings. We acknowledge that this approach provides only a simplified view of what levels of indoor coverage might be, with the real experience in a building depending heavily on the types of building material and insulation in a given premises.
[83] We note that many of today's femtocells rely on 3G, and consequently some MNOs are placing less emphasis on this as a tool for improving indoor coverage.
[84] There are two types of Wi-Fi calling solutions: "cellular preferred", where the devices use Wi-Fi calling only if there is poor cellular coverage, and "Wi-Fi preferred" where all the calls are made via Wi-Fi, when Wi-Fi is available. This year, we have seen some of the UK MNOs move or revert to a "Wi-Fi preferred" solution.
[85] Ofcom, Statement: Mobile phone repeaters, 4 November 2021.

Geographic coverage remains largely stable, with slight improvements in the reach of 4G services

Although we continue to see limited year on year changes in geographic coverage percentages, some incremental improvements by individual operators have taken place.

From the data reported to us, we can see that all operators' coverage levels are slightly higher than those found in September 2020. BT EE has increased its 4G geographic coverage by c1 percentage point to about 86% of the UK, the most of any MNO. For other MNOs these increases are not observable as a percentage of the landmass.[86] Consequently, the UK landmass covered by individual MNOs ranges from 79-86%. Since the majority of the UK landmass is rural, rural coverage is closely aligned with these levels, with significantly higher urban geographic coverage.

Figure 22: UK geographic coverage, broken down by total UK, rural and urban geographic areas



Source: Ofcom analysis of MNO predictions, September 2020 and 2021.

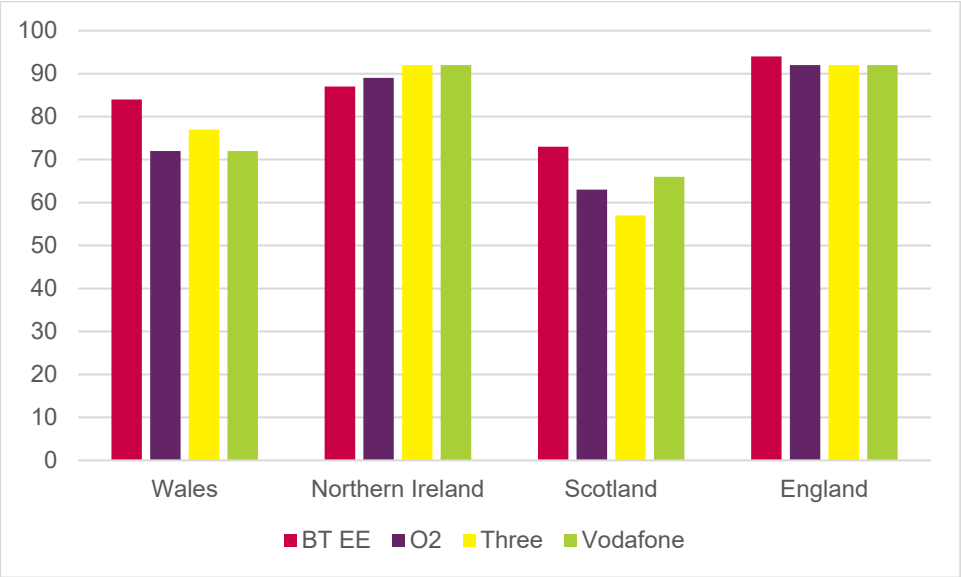
Differences across the UK nations

There continues to be significant differences in geographic coverage across the UK nations, although progress is also observable in each. As of September 2021, MNOs provided 4G geographic coverage ranging from: 92-94% in England; 87-92% in Northern Ireland; 57-73% in Scotland; and 72-84% in Wales. Coverage increases from BT EE mean that the top end of these ranges increased by 1

[86] As this would equate to c2500km2 of coverage, smaller increases may still reflect real improvements for some locations.

percentage point for England and Wales, and 2 percentage points in Scotland, alongside a 1 percentage point increase to the lower bound for Northern Ireland compared with last year.[87]

Figure 23: Differences in 4G geographic coverage in Wales, Scotland, Northern Ireland and England



Source: Ofcom analysis of MNO predictions, September 2021.

Initial SRN deployments are underway, although on the ground delivery remains at an early stage

The Shared Rural Network (SRN) project was agreed between the UK Government and the UK mobile operators in March 2020, as a key plank in improving UK mobile coverage and to support the Government's ambition of achieving 95% coverage of the UK landmass by 2025. Under the agreement, each MNO committed to reaching 88% coverage of UK landmass by 2024, and 90% of the landmass within 6 years from 2020 (subject to certain conditions), with an expectation that this will see the 'at least one operator' footprint reach 95% of UK landmass by 2025.[88] Ofcom is responsible for assessing operators against the 88% and 90% targets (including specific targets for each UK nation), which have been added to spectrum licences to make them binding.

2021 has seen MNOs begin to make progress towards the 88% target, which they are delivering though their own investment. As noted above, whilst this has crystallised in a percentage coverage point gain for BT EE alone, we have observed small increases from other MNOs. In 2020, we were only able to report a single early deployment as part of this commitment. Today, we can report that 46 fresh sites have so far been deployed to deliver on SRN commitments across all MNOs.[89] This includes 24 sites in England, 17 in Scotland and 5 sites in Wales.

[87] We also note that some areas without coverage are very remote - for example, 20% of Scotland was considered 'wild' by Scottish National Heritage. See Scottish Natural Heritage's (now NatureScot), Advice to Government, 16 June 2014.
[88] We note that MNO licences were amended in July 2021 to change the subsequent coverage deadline (relating to the 90% target) to January 2027. This reflects changes made to the Grant Agreement between the four mobile operators and Government in light of the current process for subsidy control.
[89] Other sites have been built over this period, which were in planning at the time of the SRN agreement and are not included in this figure, although they will provide significant coverage towards final SRN outcomes.

A key objective of the programme announced in March 2020 was a reduction in the number of partial not spots consumers experienced, where service was available from one MNO but not others. Since then, we have seen a two-percentage point decline in partial not spot levels, as parts of the UK begin to experience a more comprehensive service across all MNOs, as shown in Figure 24 below.

Figure 24: Partial Not Spots, Complete Not Spots and Full Coverage

	2019	2021
Complete Not Spot	9%	8%
Partial Coverage	25%	23%
Full coverage (All 4 MNOs)	66%	69%

Source: Ofcom analysis of MNO predictions.

Work to deliver the additional elements of the SRN that will secure the 90% and 95% coverage outcomes remains at an earlier stage. Component parts include deployment on the Extended Area Service (EAS) sites being built by the Home Office as part of the Emergency Services Network (ESN)[90], and the delivery of an additional 1% coverage in Total Not Spots (TNS) from sites shared by the 4 MNOs. In July, the Government completed its consultation on the target areas for investment, whilst the MNOs collectively published more localised plans highlighting areas likely to benefit from the programme.[91] Work to deliver this TNS commitment is continuing and remains focused on more detailed planning and procurement activities. We expect that the year ahead will see an increase in on the ground activity, although the planning and build lifecycle may mean more time is needed for coverage benefits to flow through.

Roads

4G coverage is predicted to be available inside vehicles on motorways and A roads in a range between 82-88% across the MNOs. This falls to 72-77% for B roads. Outside vehicles, 4G coverage ranges between 93-98% across MNOs for motorways and A roads (up 1 percentage point from last year for both Vodafone and BT EE), and 89-94% for B roads.

In-vehicle mobile voice services range from 90-97% of UK motorways and A roads across the MNOs. This falls to 80-91% of B roads. Voice calls outside vehicles on motorways and A roads remains stable, ranging from 98-99% across the MNOs, with voice calls outside vehicles on B roads ranging from of 94-97% across the MNOs.

[90] The Emergency Services Network (ESN) is a government programme to replace the current Airwave service used by the emergency services in Great Britain and transmit voice, video and data across a 4G network.
[91] Shared Rural Network, Forecast Coverage Improvements by Region [accessed 7 December 2021].

Rail

To gain a better understanding of the mobile signal on train routes, in 2019 Ofcom undertook a measurement campaign in partnership with Network Rail.[92] This highlighted that whilst predictions may indicate there is a good level of mobile signal present in the vicinity of rail corridors, this may not translate into a good experience on the ground because of the very specific challenges for mobile signals reaching into railway cuttings (on top of the challenge of getting the signal inside carriages).[93]

Given these challenges, solutions often require track side access, and so are not something MNOs can easily pursue on their own. Consequently, the last year has seen a number of significant announcements that reflect continuing efforts to address the challenge of delivering a service on-board trains across private and public sector players.

Case study: mobile coverage underground

In June, Transport for London announced it had agreed a 20 year concession with BAI communication to enable mobile coverage across the tube network. With 4G already available in parts of the network, this new plan means all stations and tunnels are expected to have coverage by the end of 2024.

The initial operational solution includes a Distributed Antenna System to provide connectivity along tracks and in ticket halls. It is forecast that more than 2,000 kilometres of cabling will be needed to deliver this, with an anticipated £1bn investment from BAI. As a neutral host model, BAI will provide the infrastructure and it will depend on commercial agreements with operators to provide seamless connectivity to consumers.

Meanwhile in Scotland, 5G RailNext, a Cisco led public and private consortium, undertook trials on Glasgow's Subway, with funding from the UK Government's 5G testbed programme, to explore the potential opportunities for 5G in busy underground environments.

[92] Ofcom, Mobile signal strength measurement data from Network Rail's engineering trains: information about the data files, 20 December 2019.
[93] For more detail on technical challenges in improving rail coverage see the report by Arup Alliance for the Department for Transport (Arup Alliance, April 2021, Mobile Connectivity in rolling stock – radio frequency attenuation characteristics.

Activity is also ongoing across several mainline routes. Another concessionary model was announced in March by Network Rail across the 51 miles of the Brighton Mainline, with Cellnex committing to provide mobile reception and fibre services across a 25 year period.[94] In the same month Network Rail and South Western Trains announced a new approach with Evo-Rail to deliver 'rail 5G' across 70km of track by 2025 (and starting this year) based on very high frequency Fixed Wireless Access providing track to train connectivity.[95] Other developments include announcements by BT EE of 65 new sites and 35 upgrades to improve rail connectivity across London, and a £45 million investment from Avanti to support a mix of upgrade and new build work across 200 sites and improved WiFi delivery along the West Coast Mainline.[96]

Emergency calls remain stable, with mobile increasingly used as a backup for fixed services

As we have explained in section one, traditional landline services are being retired and in future all fixed voice services will need to be delivered over broadband connections instead. However, in the event of a power cut, voice over broadband connections will not work, and therefore some fixed broadband providers are using mobile to provide backup services.[97] This increases the importance of indoor mobile coverage for emergency calls in the event of a localised power cut.

There are long standing arrangements that mean that a mobile handset making an emergency call will be able to do so through any network that is present, even if it is not the network the handset user subscribes to. Calls can also currently be made over 2G, 3G and 4G (via VoLTE) meaning that emergency calls are predicted to be possible inside almost all UK premises and across more than 95% of the UK landmass.[98]

On roads, emergency calls should be possible within vehicles for around 99% of motorways and A roads and 96% of B roads, rising to 99% of B roads outdoors (no change from last year).

We note, that as some network operators begin to consider reducing their 3G (and potentially 2G) deployments (see below), there may be a growing importance to the ability to roam onto another network to make an emergency call via VoLTE. Currently two of the UK's four MNOs offer emergency calling via VoLTE, with others relying on circuit switched fallback. More than 700,000 emergency calls were made via VoLTE in June 2021. Ofcom is monitoring the plans of the MNOs with regard to delivering emergency calling over VoLTE, including roaming onto other networks when necessary, to ensure there is no degradation in access as 3G and 2G services are withdrawn.

Switch off of 3G and (eventually) 2G services is on the horizon, and will need careful management

Over time, as 4G and 5G services reach an increasing number of households and businesses across the UK, mobile operators will be switching off their older 2G and 3G networks.

[94] https://www.cellnextelecom.com/content/uploads/2021/03/20210316-PR-Cellnex-UK-awarded-25-year-Network-Rail-contract-to-provide-connectivity-along-the-Brighton-Mainline-route_EN.pdf
[95] https://www.globalrailwayreview.com/news/119684/evo-rail-firstgroup-rail-5g/
[96] https://www.ispreview.co.uk/index.php/2021/05/ee-uk-boosts-mobile-coverage-across-londons-rail-network.html
[97] We discuss this further in the Network Security and Resilience chapter of this document.
[98] VoLTE meaning voice over long term evolution or 4G.

2G and 3G services first launched in the 1990s and 2000s respectively and while they continue to be important mobile services now, in coming years factors such as increasing operating costs and less efficient utilisation of spectrum and energy compared with newer generation technologies, are likely to result in the reduced use and eventual switch off of these networks.

Switching off these networks impacts a number of applications such as availability of mobile telephone calls, which rely on these legacy services. In addition, emergency voice calls and other applications such as smart meters and e-call services, could be impacted without careful implementation.

As things stand, the number of mobile sites where 2G and 3G is carried remains stable, with only a small reduction in the number of 3G sectors compared with 2020, as a result of spectrum being refarmed to other technologies.[99] This is in line with our expectation that typically 3G networks will be switched-off ahead of 2G networks. 4G services are now at a level of maturity where they can outstrip the data carrying capability of 3G in most places. However, based on data provided to us by MNOs, we estimate that more than 4m active devices continue to rely on 2G and 3G communications.[100] 2G will remain important, particularly for making voice calls, until more customers upgrade to 4G handsets.

Some MNOs are beginning to announce plans to switch off their 3G networks. For example, BT EE announced in July that it plans to phase customers off 3G by 2023.[101] The Government also announced on 8 December that mobile operators have confirmed that they do not intend to offer 2G and 3G mobile networks past 2033 at the latest.[102] Some operators will switch off their networks earlier than this date, and will announce their own plans, as BT EE have done.

We welcome the Government's commitment to work with network operators to ensure a smooth transition that meets the needs of consumers. It is important that as MNOs start to switch off these networks, adequate mitigation is in place to minimise the impact on users, including both customers with handsets and business users with systems reliant on 2G and 3G SIMs for IoT type communications.

Investment

Expenditure on mobile telecoms network infrastructure increased to £1.8bn in 2020

Data collected from providers shows that £1.8bn was invested in UK mobile network infrastructure in 2020, a £0.4bn (25%) real-term increase compared to 2019. In addition to this, £0.6bn was invested in infrastructure that is used to provide both fixed and mobile telecoms services in 2020.

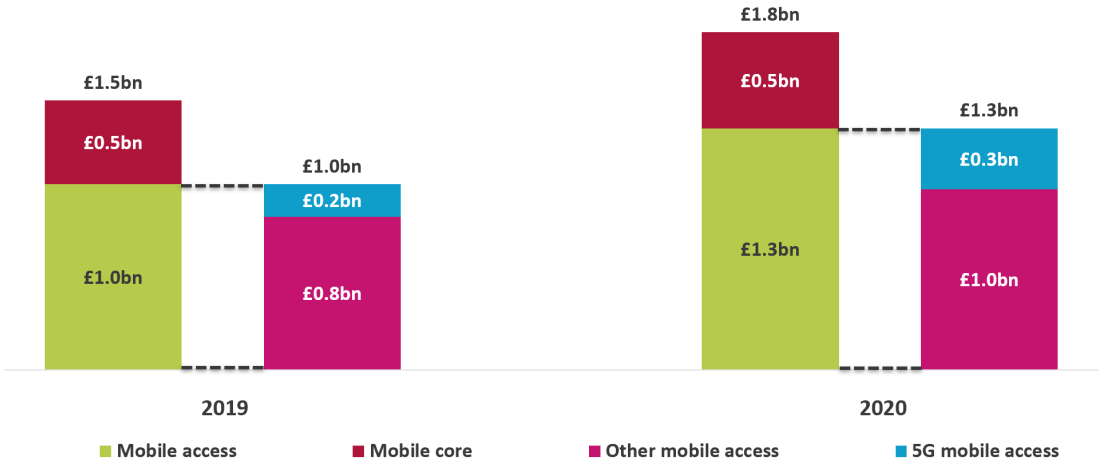
[99] Each technology on a mobile site may operate on several frequencies, and these can be divided into sectors (often three, but sometimes more), so there are many more sectors than sites.
[100] Based on aggregation of operator data supplied for June 20201.
[101] https://newsroom.bt.com/ee-to-offer-5g-solutions-across-the-entire-uk-as-bt-group-unveil-new-mobile-and-convergence-ambitions
[102] https://www.gov.uk/government/news/a-joint-statement-on-the-sunsetting-of-2g-and-3g-networks-and-public-ambition-for-open-ran-rollout-as-part-of-the-telecoms-supply-chain-diversificatio

Of the total mobile investment, £1.3bn (over 70% of the total) was investment in mobile access network infrastructure (including site acquisition, equipment and electronics). This was up by £0.3bn (30%) compared to 2019. The remaining £0.5bn was spent on mobile core and backhaul networks.

All four mobile network operators deployed 5G network infrastructure in 2020, when investment in 5G access networks totalled over £330m. This represented an increase of more than £150m (88%) compared to 2019.

Further information on how these figures have been compiled can be found in footnote 44 on page 21.

Figure 25: Mobile telecoms network capital expenditure: 2019 and 2020



Source: Ofcom / operator data. Note: Adjusted for CPI (2020 prices).

Adapting to the impact of Covid-19

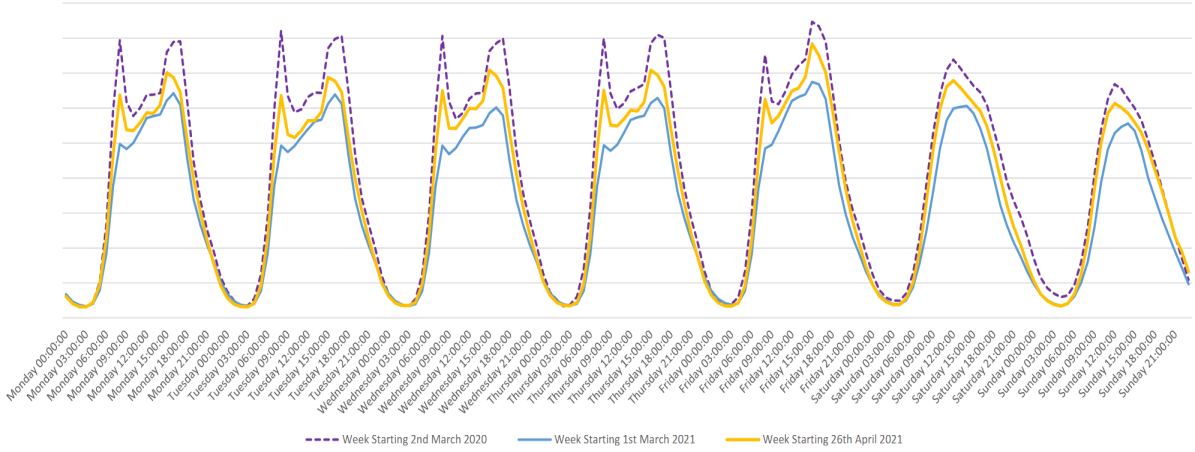
Last year we highlighted how mobile networks successfully adapted to the changing demands placed on them by Covid-19, as people came to rely ever more heavily on electronic communications services through periods of public health restrictions. In particular, we noted a shift in traffic from urban to more suburban areas.

This year we have found that some of the oscillations in network impacts resulting from changing consumer behaviour have smoothed out somewhat, but that for now at least some changes have become more enduring.

Operators continued to experience reductions in call handover volumes as new restrictions were introduced in January 2021, with commensurate increases as restrictions eased in April and May. [103] However, one operator found that user mobility was still significantly below pre-Covid 19 levels even as these restrictions eased, with more activity remaining in residential areas and city centre handover activity remaining at much lower levels.

[103] Call handovers occur as a user moves around and one site takes over from another as best placed to handle the call, usually based on proximity. As such, call handovers are a good indication of the overall mobility levels of a user base across areas.

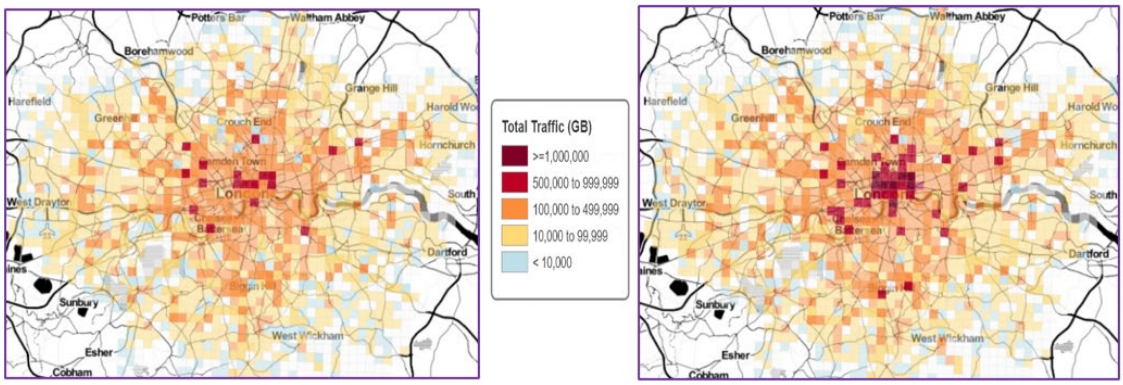
Figure 26: Call handover volumes between mobile cells for one operator, prior to the introduction of-Covid-19 related restrictions, and at two stages when restrictions were being eased



Source: confidential operator

Nevertheless, we have seen in our own analysis that traffic is to some degree returning to urban cores, with a significant increase in traffic volumes in dense urban areas such as central London, shown in Figure 27, below. This reflects a combination of the general increases in data consumption, as well as greater footfall in these areas over the 2021 measurement period.

Figure 27: Traffic density in London 2020 (left) vs 2021 (right)



Source: Ofcom analysis of operator data, June 2020 and May 2021.

One associated consequence of Covid-19 was an increased emphasis on UK holidays, which also led to increased demand in certain rural locations. Operators adapted to this change by deploying new sites and upgrading capacity to support increased consumer activities in these areas. As a result, some operators fast tracked key coastal towns for significant capacity upgrades, with at least 80 new deployments reported.[104] This should result in enduring improvements in service in these locations.

[104] Based on responses from two MNOs.

Mobile traffic

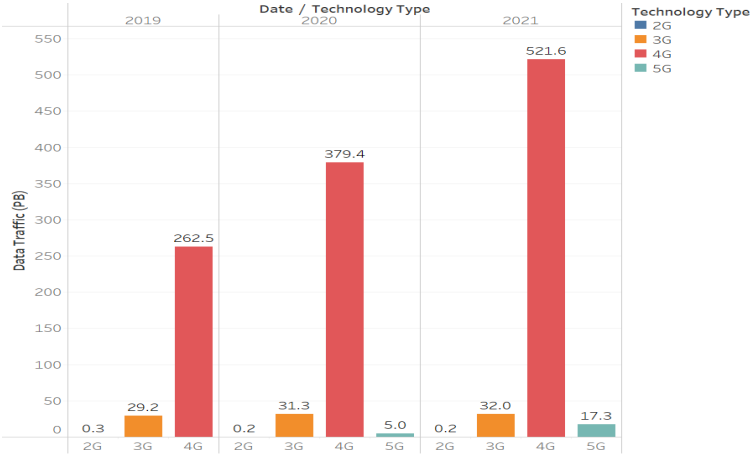
Mobile traffic continues to grow, with 5G making only modest inroads on the share carried by 4G

Mobile traffic continues to experience significant year on year growth, with the dominant share continuing to be carried across 4G networks.

From 2020 to 2021, we have seen an increase in our sample of total monthly data consumption of around 37% year on year, compared with a 42% increase from 2019 to 2020.[105]

4G traffic continues to predominate, representing 91% of all traffic (no change compared to 2020). 5G traffic is increasing more rapidly, and has grown from 5 petabytes (PB) to over 17 PB over the last year, a growth rate of 240%.[106] However, it continues to play a small role in absolute terms, representing only 3% of all traffic. 3G and 2G have seen negligible growth, and remain stable.

Figure 28: Monthly mobile traffic by technology, 2019-21



Source: Ofcom analysis of operator data (May 2019, June 2020, May 2021).

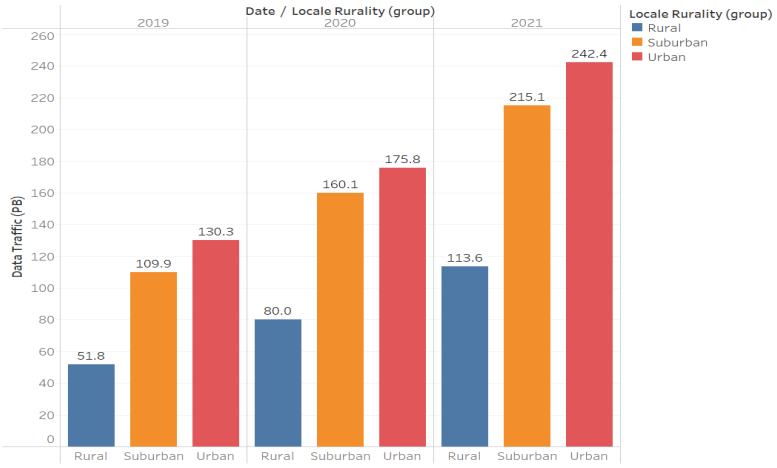
Data consumption continues to be divided between urban and rural areas in a way which largely reflects population distribution, rather than any significant difference in data consumption of a typical user in rural areas when compared.

This year we observe some small fluctuations, with a marginal increase in the share of data consumption in rural areas (almost 20%, up from just above 19%), while urban and suburban areas represent 80% of mobile data traffic.

As urban and suburban areas represent the majority of data use, its growth rate is closely tied to the national picture, up 36% on last year. In relative terms, it can be seen that rural usage continues to grow more rapidly (from a much lower base), up 42% on the previous year.

[105] Whilst this appears a slight decline in growth rate, we collected last year's data in June, and this year's data in May, suggesting a broadly equivalent growth rate overall.
[106] 1 PB is equivalent to 1,000,000 GB.

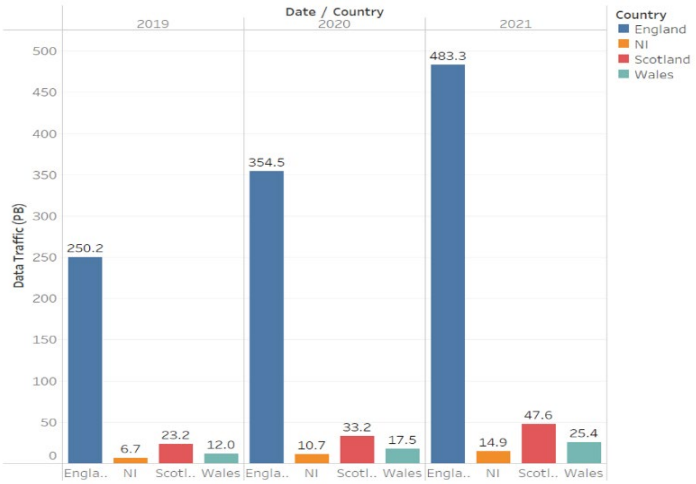
Figure 29: Monthly mobile data traffic in rural, suburban and urban areas, 2019-21



Source: Ofcom analysis of operator data (May 2019, June 2020, May 2021).

The relatively higher growth in rural data consumption, and different starting points, means that data growth looks different across the 4 UK nations. Whilst data traffic in England grew at 36%, just below the national average, and Northern Ireland saw growth of 39%, just above it, growth in Scotland and Wales was between 43% and 45% year on year.

Figure 30: Monthly mobile data traffic by UK Nation, 2019-21

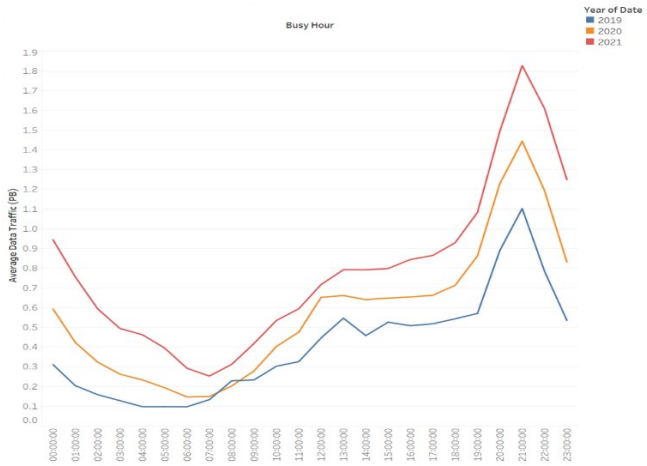


Source: Ofcom analysis of operator data (May 2019, June 2020, May 2021)

Mobile use in the home also continues to play an important part in traffic generated across the network, with our analysis showing that the mobile busy hour for data traffic continued to occur around 9pm, (in line with previous findings) at a time when restrictions remained on typical evening leisure activities.[107]

[107] Last year, we highlighted related analysis showing a significant decline in the number of sites experiencing their busy hour in the early morning, and an increase in sites which had their busy hour during the day and into the evening, as public health restrictions were introduced. Here we have instead focused on the cumulative busy hour traffic from sites whose busy hour falls within a given one hour window, showing that even as busy locations changed (as per previous analysis), overall traffic consumption trends and times of use have remained quite stable, apart from a small dip in morning rush hour consumption in 2020.

Figure 31: Mobile busy hour (daily average) calculated as traffic per sector at each sector's busiest hour



Source: Ofcom analysis of operator data.

As shown in Figure 31 above, traffic has increased substantially over the evening peak, up more than 25% on the last year from a level already well above typical day-time traffic. This aligns with wider trends also witnessed with fixed broadband traffic in the previous section, where we also highlighted the growth in fixed traffic during the already busy evening period over the last year.

Internet of Things

There has been a significant increase in the number of Internet of Things devices

The Internet of Things (IoT) refers to a network of devices and sensors capable of collecting and sharing data with humans or with other devices, and taking actions based on this. Operators use IoT and Machine-to-Machine (M2M) networks for a range of applications, including smart meters for utilities[108], travel and transport, environmental sensors and energy management solutions for smart buildings, car telemetry, video surveillance and pipeline monitoring for oil and gas companies. This year's report continues to provide qualitative and quantitative insights into public and private wide-area IoT networks.[109]

IoT Connectivity available from Mobile Network Operators

Low-power wide area networks (LPWAN)

Wide area IoT connectivity can be delivered via several technologies: traditional cellular (2G, 3G, 4G and 5G) and Low-Power Wide Area (LPWA) networks such as Narrowband IoT (NB-IoT), Long Term Evolution for Machines (LTE-M), Long Range Wide Area Networks (LoRaWAN) and Sigfox. NB-IoT and LTE-M have been standardised by 3GPP and they are now part of the 4G standard.

[108] Arqiva Limited provides radio communications links between the smart meters and the energy suppliers in Scotland and the north of England while O2 provides the radio links in the rest of England and Wales.
[109] IoT can be delivered via other tech such as Wi-Fi, Zigbee, Bluetooth and several others. In this report, we focus only on IoT services delivered through traditional cellular technologies by MNOs and LPWAN technologies such as NB-IoT, LTE-M, Sigfox and LoRa.

LPWA technologies are designed for IoT applications and services that have low data rates, require long battery lives and can operate in remote and hard to reach locations. Furthermore, their extended range makes them better suited for in-building applications such as smart meters and smart car parks which may be located underground or in basements.

Today, IoT connectivity is delivered by UK MNOs using a mix of cellular technologies (2G, 3G, 4G and 5G) and Low Power Wide Area Networks (LPWANs) such as NB-IoT and LTE-M. Vodafone continues to provide NB-IoT coverage across the UK. While O2's LTE-M coverage remains available only in the eastern parts of the UK, it has now started offering commercial services on the network. BT EE is exploring proof-of-concept deployments using LoraWAN.

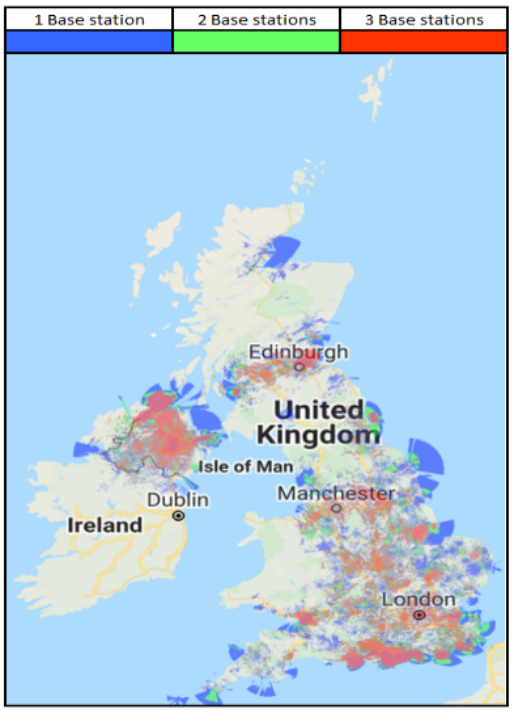
This year, the number of active IoT connections on MNO networks increased by 63% (more than double the year-on-year growth from last year) to 10.3 million. Although the overall volume of IoT data traffic across all UK MNOs increased by 55% to 1.26PB, it remains significantly less than 1% of overall data traffic.

IoT Connectivity available from non-mobile network operators

Sigfox

Within the past year, WND UK - the sole Sigfox network operator in the UK - has focused on developing a cost-optimised network that supports very low bandwidth applications with infrequent transmissions such as telemetry, metering, asset tracking, gas and water leak detection. Its network includes more than 1500 base stations, with population and landmass coverage of 83% and 54% respectively. Figure 32 below shows the coverage of WND UK's network, distinguishing between areas where more than one base station is providing service for increased reliability.

Figure 32: Map of WND UK's Sigfox coverage



Source: WND UK.

Public LoRaWANs

Public community LoRaWAN networks, which are open-source and largely free to use, allow users to connect devices to existing gateways (base stations) or add new gateways to increase overall coverage.[110] [111] They support developers, small and medium businesses and enterprises (particularly for Proof-of-Concept), government and public initiatives across the UK. Today, The Things Network (TTN) - one of the leading global providers of public LoRaWANs - has about 950 gateways in the UK serving 100 communities.

Private LoRaWANs

Private networks offer managed carrier-grade services with guaranteed availability, on a paid basis. We are aware of several private LoRaWAN providers operating in the UK, such as Comms365, Connexion, The Things Industries (TTI) and North limited. We estimate that these networks have at least 580 gateways (a 66% increase from the past year) between them serving about 37,000 devices (a 50% increase from the past year). Some of the services provided by these networks include intelligent lighting, smart building, flood and air quality monitoring, waste management solutions, soil moisture sensing and asset tracking.

IoT has the potential to play a growing role across a range of services

The increase in IoT devices and traffic suggests that businesses are increasingly utilising the services IoT can deliver.

As the Covid-19 pandemic has evolved, businesses are relying on a range of IoT devices to support the safe and secure return of employees to work. For example, some of these devices measure body temperature, building occupancy and social distance, with both Vodafone and Virgin Media O2 having launched suites of solutions for the delivery of such services.

The on-going PSTN switch-off planned for completion in 2025 has implications for a range of sectors which include domestic and business customers, with the potential for IoT to support enduring solutions in services such as security devices, telecare and utility network monitoring.

Businesses across various sectors and industries are also increasingly relying on IoT applications to support their sustainability goals. Remote monitoring and control of devices, for example, can enable businesses to reduce the need for human travel, thereby reducing their carbon footprint. Smart technology in cities (e.g. smart lights, smart bins and traffic management systems) could also minimise wastage and drive efficient use of resources and infrastructure.

There is an enabling environment for IoT to thrive in the UK

The increasing availability of 3GPP standardised technologies – such as 5G (Massive Machine-Type Communications or MMTC), NB-IoT and LTE-M – which are optimised for IoT applications, together with non-3GPP standardised technologies such as Sigfox and LoRaWan, support the continued adoption of IoT services.

[110] They are usually bound by fair use policies which restrict, for example, data rates, packet sizes, transmit time, and number of gateways/devices.
[111] The network servers are hosted by not for profit institutions like the Digital Catapult (UK) or companies which also offer private networks.

One historic obstacle has been the potential security limitations in certain consumer IoT devices, which in many cases have universal default passwords and are not updated against known security threats. However, in the UK, government has set out its intentions for proposed legislation to regulate the cyber security of such products with the overall objective of ensuring a 'secure by design' approach in the future.[112]

Furthermore, Ofcom recently introduced regulations which harmonise conditions for spectrum use by Short-Range Devices within the 870 to 874.4 MHz frequency bands.[113] These changes will make the band more suitable for IoT type applications such as smart metering and industrial automation. The decision also means the UK can benefit from economies of scale for IoT type devices which already operate in these bands in other territories.

[112] DCMS, Government response to the call for views on consumer connected product cyber security legislation, 21 April 2021.
[113] Ofcom, Statement: Decision on changes to the licence exemption for wireless telegraphy devices and on licensing equipment in 57 to 71 GHz, 29 April 2021.

Network security and resilience

Key highlights:

- Ofcom has been working closely with DCMS and the National Cyber Security Centre (NCSC) in preparation for the introduction of the Telecommunications (Security) Act, which will bring major changes to our existing regulatory regime.
- As part of providing a summary of network security & availability incidents reported to Ofcom this year, we identify the themes of the common causes of major outages. We highlight a trend of software related incidents impacting services for more customers and for longer periods of time compared to hardware and process/policy failures. Work to explore and address these causes is ongoing.
- The incidents reported to Ofcom this year do not suggest that the Covid-19 pandemic has resulted in a noticeable increase in telecoms outages, despite the increased demands on the networks.
- The landscape for resilience at customer premises is changing. New resilient broadband services have been launched which make use of 4G services as backup. Landline voice is evolving too. Engineering the new All-IP version of landline voice services securely and reliably remains important.

Security

New legislation will improve telecoms security and increase our role in monitoring and enforcement

In last year's report, we discussed the Telecommunications (Security) Bill[114] which DCMS had introduced at the end of 2020, with the objective of improving the security of the telecoms sector. The new legislation does this in two main ways:

- it imposes new, **strengthened security duties on public telecoms providers**, to be supported by detailed security regulations in secondary legislation, and technical Codes of Practice giving guidance on the measures to be taken. The Bill also gives Ofcom powers to monitor and enforce industry compliance with these duties and specific security requirements, and to impose financial penalties in the event that we find a breach; and

[114] Telecommunications (Security) Bill: overarching documents (gov.uk)

- it introduces new powers for the Secretary of State to set rules limiting the use of products and services provided by **High Risk Vendors (HRV)** where necessary in the interests of national security. Although not involved in its enforcement, Ofcom may be asked to monitor public telecoms providers' HRV usage.

The Bill has now become an Act, having received Royal Assent on 17 November 2021. The parts of the legislation related to HRV are now operational. It is expected that the DCMS Secretary of State will soon issue Designation Notices to some companies, which identify them as HRVs, and Designated Vendor Directions to some communications providers, which will set out restrictions and other requirements relating to their use of the equipment or services offered by companies which have been identified as HRVs. The Secretary of State may also then direct Ofcom to gather information from communications providers who have received a Designated Vendor Direction and report on their usage of relevant equipment or services.

The provisions in the Act relating to strengthened security duties, and Ofcom's new powers to monitor and enforce compliance with them, are expected to come into force in October 2022. Prior to this, the accompanying secondary legislation and any initial Codes of Practice will be consulted on and issued by DCMS. Ofcom will also consult on and publish procedural guidance, which will set out how we expect to exercise our functions under the new legislation. This will cover practical matters, such as arrangements for reporting security compromises and our approach to compliance monitoring.[115]

The new regime is a major change in the regulation of security in the telecoms sector. Providers are likely to have to make substantial improvements to their current security measures and processes to comply, and indeed this will be an ongoing process as security threats, and provider responses, evolve. It will also take time for Ofcom, using our extended powers, to build a detailed understanding of the security measures providers have in place, and to identify any compliance concerns. We will be including a summary of the extent to which providers are complying with their key security duties in future versions of this report.

Resilience

In the following sub-sections, we discuss the network and service affecting incidents reported to us by Communications Providers, as required under the Communications Act 2003. We highlight the trends of the reported incidents, which give an indication of the technology changes in the telecommunications landscape and how they impact networks and services.

We reflect on how residential connectivity and services resilience is changing, including the ability to make calls over mobiles and landlines, ongoing broadband and voice technology changes, and the resulting resilience approach for residential voice services.

We discuss how Ofcom has progressed work on network and service resilience in collaboration with industry bodies. We also discuss ongoing and future UK resilience initiatives related to the telecommunications sector.

[115] Until these provisions come into force, existing security duties under section 105A to 105D of the Communications Act 2003 and associated Ofcom guidance continue to apply.

Communications Provider incident reports

We have received reports from Communications Providers throughout the year describing the security and availability incidents that created a significant impact on their networks and services. We have published guidance for providers, explaining the types and sizes of incident we expect them to report to us in order for them to comply with their regulatory obligations.[116]

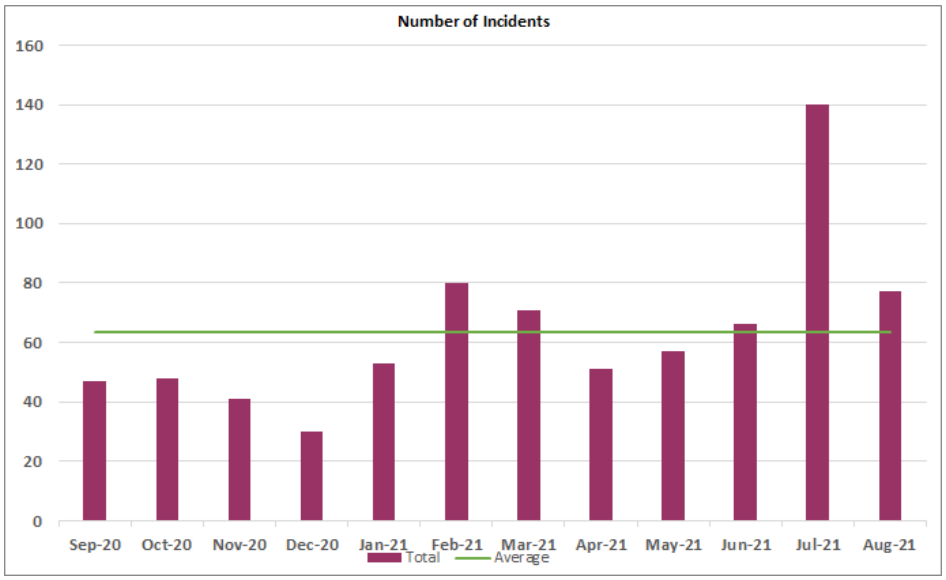
We received a total of 761 reports of relevant incidents from Communications Providers this year, and although this is an increase in the number of incidents reported in 2020 it is still within range of previously observed year-on-year variability.[117]

The number of fixed network incidents increased in relation to last year (426 in 2021 compared with 283 in 2020). The number of mobile network incidents reported was 335, which also represents an increase from the 249 mobile incidents that were notified in the previous year.

We have focussed on ensuring consistent reporting across both fixed and mobile operators in this period, and the increases identified above may be a reflection of progress in ensuring all relevant incidents are reported to Ofcom in line with our guidance.

The monthly breakdown of incidents in Figure 33 shows a degree of month-on-month variability as well as the average, which increased to 62 for 2021 from 43 in 2020. There were no obvious seasonal patterns with the exception of the single peak experienced during the summer months, which occurred in July this year.

Figure 33: Monthly number of incidents reported between September 2020 and August 2021



Source: Ofcom analysis of operator reported data.

[116] Ofcom, Ofcom guidance on security requirements in sections 105A to D of the Communications Act 2003, 18 December 2017.

[117] Note that our approach to incident reporting does not capture individual "line faults" in fixed networks affecting a single network connection. There is no evidence that there has been any significant change in this area, although, as fixed networks move away from copper to full fibre connections, they should reduce considerably.

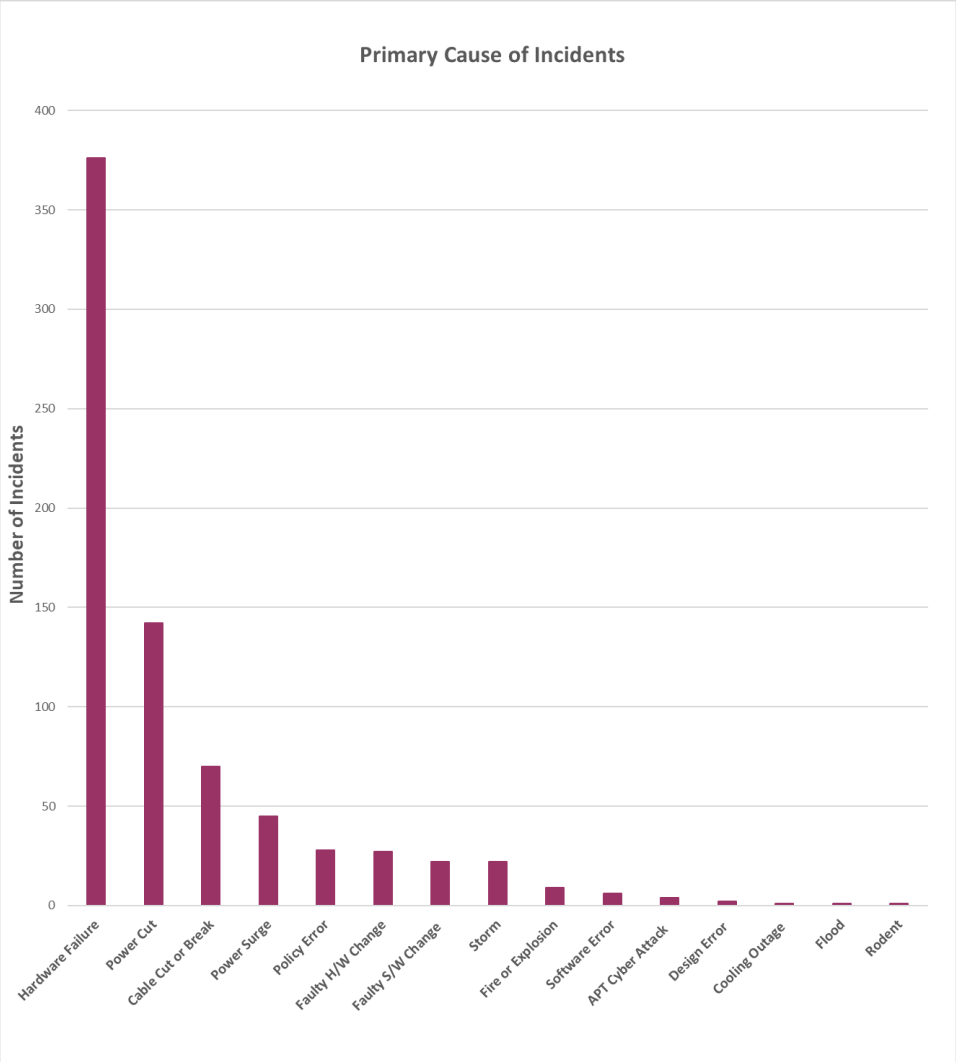
All networks have continued to cope well with the extended work-from-home period as a result of the Covid-19 pandemic. It is notable that despite the increased volume of traffic during this reporting period, including additional Covid-19 lockdown periods (with broadband traffic consistently 30% above average), we have not recorded any incidents directly attributable to changed working and behaviour patterns.

Equipment failure and power interruption remain the primary cause of incidents

During the previous reporting period, we changed the root cause categories used to classify the primary cause of each incident based on the information in the providers' reports. This has enabled a more granular approach to be adopted and has provided us with better information to understand the common factors behind a variety of incidents.

The most common causes of incidents are either hardware failures, cable damage or supply of stable power. The next group of incidents that occur most frequently are related to issues with change management processes or policy flaws within a Communications Provider's organisation. These are represented in the chart below.

Figure 34: Primary causes of incidents reported to Ofcom, September 2020 to August 2021



Source: Ofcom analysis of operator reported data[118]

In this reporting period we have particularly focussed on the Faulty Software Change category, as although the number of incidents is comparable with Faulty Hardware Change or Policy, Process and Procedure Errors, the hours lost by these incidents has been significantly greater as detailed in the following tables. The majority of these software incidents occurred in the first half of the reporting period, and we have worked with the relevant providers to address our concerns and have seen a reduction in both the number and impact of these events.

However, due to the disproportionate impact of these types of Incidents we will continue to work with the relevant providers and we may take action to review any further occurrence of these types of events using our information gathering powers.

[118] H/W – Hardware, S/W – Software, APT – Advanced Persistent Threat

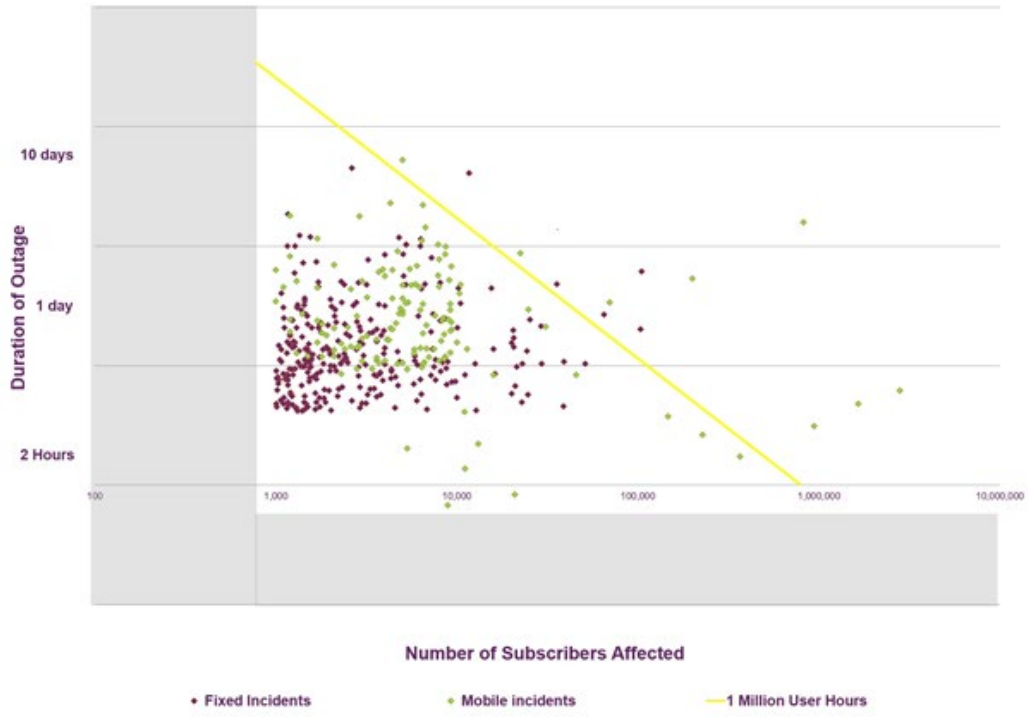
Figure 35: Users impacted / Service Hours lost by Hardware, Software and Procedural incidents

Type	Total Incidents	< 10K	10K - < 99K	100K - < 249K	> 250K
Hardware	27	20	6		1
Software	22	11	2	3	6
Process / Policy	28	23	5		

Type	Hrs Lost	< 1 Hr	1 - < 12 Hrs	12 - < 24 Hrs	> 24 Hrs
Hardware	5,663,726	2	19	5	1
Software	52,804,284	4	13	3	2
Process / Policy	759,131	2	23	3	

The new categorisation of faults not only allows us to better understand what is failing in providers' networks, but also to understand where in the architecture of the network a failure has occurred, and if there is any correlation between this and the scale of impact.

Figure 36: The impact of incidents reported between September 2020 and August 2021



Source: Ofcom analysis of operator reported data.

The chart above further categorises incidents by adding the duration of an outage to the number of users impacted. This provides a view of the total number of hours lost to users of the networks or services during an incident.

Each of the fixed and mobile points to the right of the yellow line indicate an incident that caused more than one million service hours to be lost for that incident.

Some of these incidents seem to be driven by "technology refresh" linked network transformation activities. We have aggregated our concerns under a number of themes below and set out how we have progressed our concerns with the providers involved.

We have progressed our work with industry on incident themes

Throughout the year, we have continued our work with communications providers to extend the correlation and analysis of incident themes. While there have been improvements within some of these areas as a result of the respective providers progressing mitigation actions, growth in the frequency and impact of events under other themes has also been observed:

- **Change management and testing:** as communications providers have continued their network upgrade or transformation activities during the period, we have seen an overall reduction in the impact of service-affecting events caused by poor practice in change management and testing. However, there are still a number of incidents caused by inadequate change management control, and some of these incidents have been attributable to the work that providers are conducting to prepare their networks for Network Functions Virtualisation (NFV). [119] We will continue to work with the affected providers to address this issue.
- **Mobile backhaul transport:** ongoing analysis of incidents affecting backhaul transport in mobile networks has confirmed that disruption at a single site continues to cause the loss of service availability at a large number of additional mobile sites. We will be considering use of our information gathering powers to ensure that the scope and scale of this issue are fully understood.
- **Fixed access and aggregation:** over the reporting period, exchange consolidation programmes have been implemented in coordination with FTTP deployments and we have started to observe single location incidents impacting significantly increased numbers of users. We will be considering use of our information gathering powers to obtain information on access and aggregation designs to identify any further impacts from the development of this trend. We may also consider guidance about what we consider to be appropriate levels of non-resilient concentration.
- **Interconnect:** the ongoing migrations from traditional PSTN & copper services towards fibre-only FTTP and fully IP-based services, along with new alternative FTTP access network provider rollout have increased the incidents affecting interconnect and other wholesale transit services. We will seek to work more closely with standards forums like NICC and industry groups such as the Comms Council UK to promote the adoption of best practice.

For all of the above themes, we will continue to analyse causes and mitigation actions so that they can be shared with other operators within each relevant sector. We will also seek to establish an industry working group to develop a trial procedure for the automated submission of incident reporting data.

[119] Traditional networks are evolving from Physical Network Functions to Virtual Network Functions based on cloud-native software principles, usually located within a provider's physical network estate. Network Functions Virtualisation across different technology domains (fixed, mobile, Wi-Fi, etc) presents convergence opportunities that allow further innovation and efficiencies.

Emerging customer premises resilience approaches

As technology changes and consumers and businesses become ever more reliant on communications services, providers are finding ways to enhance the resilience of their services.

Mobile backup for fixed broadband Internet:

Two providers have launched 4G mobile backup solutions to their fixed broadband Internet products. These services use enhanced capabilities of the broadband routers they supply to customers to automatically switch over to mobile access when a fault occurs on the fixed access connection.[120]

There is also standards work ongoing in the Broadband Forum Wireless Wireline Convergence group which could further develop such products to enable more seamless handover between, and the concurrent use of both fixed and mobile access technologies.

Landline voice

As set out in "*The UK's traditional telephone network is also being replaced"* on page *27*, BT and Openreach plan to retire BT's legacy telephony network and the wholesale services that underpin that network by the end of 2025. To ensure that landline voice services continue to be available, providers currently using the legacy telephony network will deliver landline calls using digital technology called Voice over Internet Protocol (VoIP) over the broadband connection, which is typically referred to as Voice over Broadband (VoBB).

In order to maintain a high quality, robust, and secure voice service, the largest consumer focussed communications providers have built their VoBB services entirely within their own infrastructure and securely separated it from the Internet. Such *non-Internet* VoBB services can be prioritised over the user's local area network (LAN) and the provider's access and core networks to ensure that it works consistently well during network congestion or on low-speed broadband connections and offers high levels of resilience.[121]

However, in the event of a power cut, customers using VoBB will lose the ability to make voice calls. Among other things, Ofcom guidance with regard to compliance with General Condition A3.2(b) provides that VoBB providers should provide at least one solution that enables access to the emergency services for a minimum of one hour in the event of a power outage.[122] The obligations in

[120] https://www.bt.com/halo and https://www.vodafone.co.uk/broadband/pro

[121] This assumes that the broadband service is functioning and that the customer's premise has power available to the broadband router which contains the VoBB client. Such services can be prioritised provided they meet the requirements for a 'specialised service' set out in Art 3(5) of retained Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015 laying down measures concerning open internet access and retail charges for regulated intra-EU communications and amending Directive 2002/22/EC and Regulation (EU) No 531/2012 (Text with EEA relevance).

[122] In addition: the solution should be suitable for customers' needs and should be offered free of charge to those who are at risk as they are dependent on their landline; providers should i) take steps to identify at risk customers and ii) engage in effective communications to ensure all customers understand the risk and eligibility criteria and can request the protection solution, and; providers should have a process to ensure that customers who move to a new house or whose circumstances change in some other way are aware of the risk

General Condition A3 and Ofcom's related guidance on them are technology neutral and providers are taking a variety of approaches to meeting the obligation, based either on offering battery back-up to the equipment delivering the service in the home, or relying on alternative connectivity over mobile networks. We will ensure that communications providers comply with these obligations as VoBB is rolled out.

Persistent attacks on Internet-based voice service providers

The UK community of smaller Internet-based "All IP" Voice Service providers have been subject to a persistent and sector-wide Distributed Denial of Service (DDoS) attack[123]; the objective of which has been to extort a fee from each of the operators who have been attacked, in order to secure relief from future attacks for a period of twelve months.

We have participated in an industry forum alongside Government and NCSC to support the response of the sector to this threat and we will continue to encourage the adoption of industry best practice to assist in mitigation.

Our work with the Electronic Communications Resilience & Response Group (EC-RRG) has continued

We have continued our work with the Electronic Communications Resilience & Response Group, known as the EC-RRG, and have contributed to updated *Resilience Guidelines for Providers of Critical National Telecommunications Infrastructure*[124] which were published in August 2021.

The updated guidelines include design and operations guidance for new areas such as Virtualisation and a methodology for the Measurement of Resilience as described in both ETSI and ITU publications. Criteria included in this methodology identified both service parameters and operational state.

The latest issue of the EC-RRG Resilience Guidelines has also identified design principles for resilience which include:

- Separation between Layers & Domains
- Redundancy for Systems & Paths
- Replication and Synchronisation of both Data and State
- Load Sharing and Balancing of Traffic

In the coming year, within the EC-RRG Resilience working group, we will collaborate with communications providers to encourage them to contribute their best practice design inputs to enhance or augment these design principles. We will also work with the group to ensure these

and protection solution available. For more information, see Ofcom, Guidance on General Condition A3.2(b) - Protecting access to emergency organisations when there is a power cut at the customer's premises, 10 October 2018.

[123] BBC, Cyber-attack hits UK internet phone providers, 26 October 2021.. Such attacks typically involve targeting network servers with high volumes of bogus messages from multiple sources so that services are degraded or fail completely.

[124] EC-RRG Resilience Guidelines for Providers of Critical National Telecommunications Infrastructure

principles can support the creation of a Resilience Assessment Framework - which will improve Ofcom's ability to assess and report on the resilience of the sector.

Our activities and guidance will adapt to the new legislative environment

Resilience and the Telecommunications (Security) Act 2021

The Telecommunications (Security) Act 2021 introduces significant changes to the Communications Act. It also changes the legislative framework in which broader network and service resilience is captured. Among other things, Ofcom will consult on and publish procedural guidance, which will set out how we expect to exercise our functions under the new legislation, including in relation to reporting security compromises, which encompass non-cyber-security aspects of network and service resilience. We will also review our existing guidance on security and resilience requirements[125] and consider issuing resilience guidance under the revised framework where appropriate.

Other network and service resilience issues

Reliability of Internet services

In addition to Incidents obliged to be reported to us, there were three incidents which were not subject to reporting requirements as they currently fall outside the scope of relevant Ofcom regulation, but which had a significant impact on the availability of services and applications used by the public. These incidents occurred in June and July of 2021:

- Fastly[126] - Content Delivery Network affecting Media, UK Government and Payment Websites
- Akamai[127] - Domain Naming Services affecting Banks, Gaming and TV Streaming Services
- Facebook[128] - Change Management issues affecting Messaging and Social Media applications.

Other UK resilience initiatives

- In May 2020 the National Infrastructure Council (NIC) published its report and recommendations on the resilience of specific sectors that support critical national infrastructure. It included a recommendation for the regulatory authorities of these sectors to develop resilience standards and report to Government on their effectiveness.
- Following the NIC Report, Government has identified the need for a National Resilience Strategy Review - and has already concluded a call for evidence for this strategy in September 2021. A number of the NIC recommendations informed the questions presented within the Call for Evidence, including the need for resilience standards. We will look to engage with the sector and Government on any relevant recommendations once they have been published in 2022.

[125] Ofcom, Ofcom guidance on security requirements in sections 105A to D of the Communications Act 2003, 18 December 2017.
[126] BBC, Websites begin to work again after major breakage, 8 June 2021.
[127] BBC, Major websites hit by global outage, 22 July 2021.
[128] BBC, Facebook, WhatsApp and Instagram back after outage, 5 October 2021.