Ofcom
making communications work
for everyone

Connected Nations 2022

UK report

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1. Overview

Ofcom's objectives include delivering internet we can rely on through ensuring fast and reliable connections and services for everyone, everywhere. In this annual Connected Nations report, we measure progress in the availability of broadband and mobile services in the UK, including the roll-out of gigabit-capable, full fibre and 5G networks.

We have published separate reports on broadband and mobile availability in each of the UK's nations. Our interactive report allows people to easily access data for different areas of the UK and specific services. We are also releasing the International Broadband Scorecard 2022, which compares the UK's recent position on broadband availability with a number of other European nations.

What we found

- **Full-fibre broadband is available to 12.4m homes (42%):** this is 4.3 million more premises (14 percentage points higher) than a year ago, and for the second year running represents the highest year-on-year increase since full fibre started being rolled out in the UK.
- **Gigabit-capable broadband is available to 20.8m homes (70%):** this includes full fibre and upgraded cable networks that are capable of delivering download speeds of 1 Gbit/s or higher.
- **The number of premises without access to decent broadband continues to fall:** factoring in coverage from both fixed and fixed-wireless networks, nearly 80,000 homes and businesses (0.3%) still do not have access to decent broadband. We estimate that around 15,000 of these will be covered by publicly funded roll-out schemes in the next 12 months.
- **5G rollout has rapidly increased**: the level of coverage provided outside of premises by at least one mobile network operator is now at 67-77% (up from 42-57% last year). This coverage is supported by 5G deployments on a total of around 12,000 sites, almost double the amount we reported last year.
- **We have seen some small improvements in 4G coverage:** the four mobile network operators (EE, Virgin Media O2, Three and Vodafone) each estimate they provide 4G outdoor coverage to c.99% of premises. Their coverage of the UK's landmass ranges from around 80-87% (up from 79-86% last year), with similar small improvements in Scotland, Wales and Northern Ireland. These improvements are partly as a result of initiatives such as the Shared Rural Network (SRN), with more than 150 new sites deployed directly to meet the SRN coverage commitments.
- **The storms last winter had a significant impact on communications services:** this was primarily because of lengthy power outages, which led to communications services becoming unavailable in impacted areas. It initially took providers longer than expected to recover from these impacts, which has highlighted the need for better co-ordination across the communication and energy sectors. Improvements are already being made in this area and we urge industry and others to continue this progress.

Faster, better networks are increasingly available across the UK

Full fibre and gigabit-capable broadband coverage continues to improve

Just over 12m (42%) of UK homes now have access to full fibre connections – an increase of over 4m premises in the past year. This is the largest year-on-year increase in full fibre coverage we have seen so far and represents a nearly seven-fold increase over the last five years.

Gigabit-capable broadband – able to provide broadband speeds of 1Gbit/s or higher – can be delivered over full fibre networks and the latest version of cable networks. Gigabit speeds are now available to just under 21m (70%) homes. This has increased by 23 percentage points (7m homes) over the last year. Full fibre and gigabit-capable availability is highest in urban areas in Northern Ireland, and lowest in rural Scotland.

5G rollout is expanding

EE, Virgin Media O2, Three and Vodafone have continued to extend their 5G networks across the UK, and we are reporting individual mobile network operator (MNO) coverage for the first time, based on the High to Very High Confidence range which we established in 2021. These ranges cover an increasing probability that the coverage predicted by MNOs will translate into coverage on the ground. As noted above, the level of coverage provided outside of premises by at least one mobile network operator across this range is now at 67-77% (up from 42-57% last year). The coverage provided outside of premises from individual MNOs ranges from 39-58% at High Confidence, with a range of 31-45% at our Very High Confidence level. Though most 5G sites are focused around busy urban areas - providing additional capacity to existing mobile data services - we're now seeing coverage extending into smaller towns and other high footfall locations. The distribution of this investment remains broadly similar to last year, with 86% of sites in England, 8% in Scotland, 4% in Wales and 2% in Northern Ireland.

Good connections are available to most people across the UK

Superfast broadband (with speeds of at least 30Mbit/s) is now available to 97% of UK homes (an increase of one percentage point from last year). We estimate that around 73% of premises that are able to get superfast broadband actually take it. So, although most people have superfast broadband available to them, some do not always choose the fastest speeds.

Mobile operators provide a high level of 4G coverage outside of premises, with coverage from each individual mobile network in the vicinity of c.99% premises. Indoor coverage from each MNO covers a range (from the MNO with the least to the most coverage) between 92% and 95% of all premises. However, coverage levels remain lower in rural areas, and across the extent of the UK landmass. Individual operator coverage ranges between 77% and 85% of the rural landmass, slightly below the overall UK coverage figures (80-87%, as noted above). Alongside this view of coverage, we also present emerging findings from our work towards a new approach for reporting on the quality of mobile networks.

We continue to support investment in new networks

We are supporting investment in the deployment of competing gigabit-capable networks to provide customers with a choice of fast and high-quality services. Last year we 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 rolling out full fibre and gigabit-capable services. This is largely driven by deployments from the larger fibre providers, including Openreach which has committed to pass 25m homes with its full fibre network by 2026, Virgin Media O2, which plans to upgrade its cable network to full fibre by 2028 (having already upgraded to gigabit capable speeds last year) and and CityFibre, who plan to pass up to 8m premises by 2025. At the same time, a large number of smaller network providers are also increasingly deploying full fibre, with many targeting underserved communities and regions across the UK.[1]

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. We continue to engage with, and report on the progress of, the Shared Rural Network programme, which is seeking to expand the provision of 4G mobile coverage across the UK. We will undertake an initial compliance assessment against MNOs' 88% landmass coverage targets in 2024.

As the UK focuses on deploying new networks, we are closely monitoring the transition from the legacy fixed public switched telephone network (PSTN) - which is used to deliver traditional landline and other services - and 3G (and eventually 2G) mobile networks to ensure that disruption is minimised and customers are protected, particularly those that are more vulnerable. The first 3G network switch-off is starting next year and we are working closely with the mobile operators to ensure a smooth transition.

A small, but decreasing, number of UK properties still cannot access decent broadband

Around 80,000 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. Some of these premises may be eligible to be connected under the universal broadband service.[2] Since its launch in early 2020, there have been around 1,850 orders for the universal service that will result in full fibre connections being available to almost 9,500 premises that previously had no access to decent broadband.

We expect that many of the remaining premises will be in particularly remote areas, so households will have to contribute to the costs of building a connection. For a significant number of these,

[1] We recently published our first forward looking report about planned network deployments of full fibre. Ofcom, Planned Network Deployment, November 2022.

[2] 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.

connection costs will be very high, which means they may need alternative solutions. The UK Government is continuing to look at options for these very hard to reach premises and has recently launched a trial to see whether satellite can be used to deliver high speed connections in more than a dozen hard to reach locations across the UK.

We estimate that there are around 30,000 UK premises that cannot access either a decent broadband service, or good 4G mobile coverage.

The UK's communications networks were severely impacted by the storms last winter

Towards the end of 2021 and in early 2022 the UK was hit by several severe storms, starting with storm Arwen in November 2021, followed by storm Barra in early December and storms Malik and Corrie in late January 2022. In February 2022 there were three further storms in the space of a week – storms Dudley, Eunice and Franklin.

These storms had a significant impact on communications services. This was primarily because of lengthy power outages which caused communication services to become unavailable in impacted areas, for several days in some cases. For example, during storm Arwen, thousands of mobile cell sites were disrupted by power outages, and this affected all four MNOs. On the fixed networks, the largest impact was due to customers losing power to equipment in their homes (e.g. broadband routers).

The recovery process following the storms, particularly after storm Arwen, took longer than expected due to the volume and scale of the power outages. This highlighted the need for better co-ordination and information sharing between the communication and energy sectors. Improvements have already been made to these processes, which helped reduce recovery times during the later storms. We are continuing to work with industry and government to act on lessons learnt during the storms and help ensure improved resilience of the networks in future.

A new framework for telecoms security

The new Telecoms Security Act came into force on 1 October this year. It imposes new, strengthened duties on communications providers to implement network security measures as appropriate for the purposes of identifying and reducing the risk of security compromises, and preparing for when they do occur. It also requires communication providers to take specific security measures, as well as giving Ofcom extended powers and duties to monitor and enforce compliance against these new obligations. The Government has recently published a Code of Practice for communications providers on its preferred approach to demonstrating compliance with the new requirements. In future we will report on the extent to which communications providers comply with their new duties, as part of our Connected Nations reports.

2. Fixed broadband and voice

Introduction

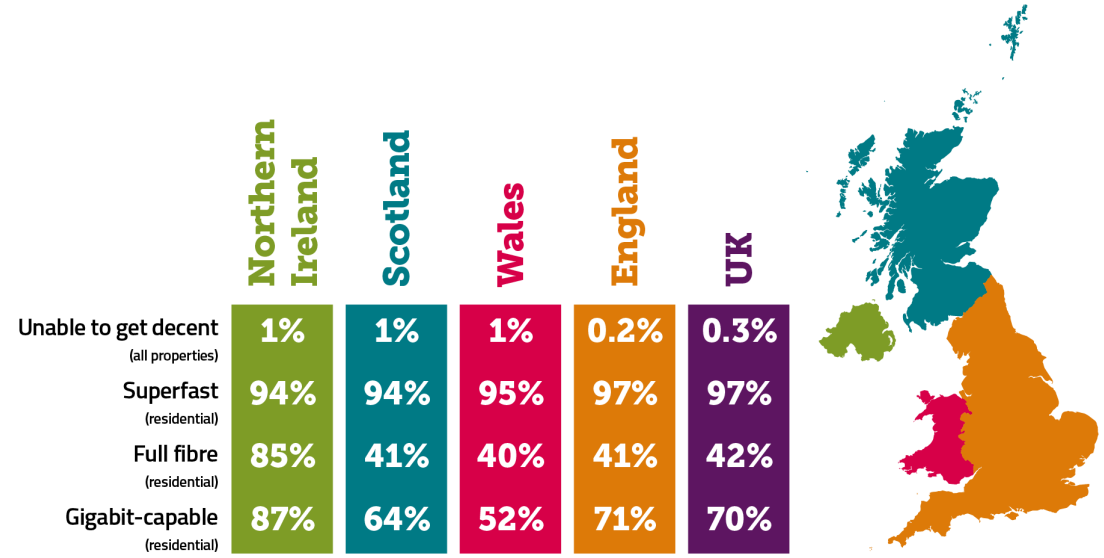
High speed networks are rapidly expanding, bringing fast and reliable voice and broadband services to homes and businesses across the UK. In this section we provide an update on the roll-out of these networks over the last year, as well as the remaining numbers of premises that still do not have access to decent broadband.[3] We also update on the deployment and performance of fixed wireless and satellite networks, that are also delivering broadband connectivity. We then cover take-up of fixed broadband and voice services, as well as the migration away from traditional voice services and the changes in data traffic use on broadband networks since last year.

Highlights

- **Coverage of high-speed networks continues to grow rapidly**. Full fibre is available to 42% / 12.4m of premises – an increase of 14 percentage points / 4.3m premises over 2021. Gigabit-capable broadband covers 70% / 20.8m of premises. Superfast coverage has increased to 97%.
- **The number of premises without access to decent broadband continues to fall.** It is now around 0.3% / 80,000.[4] We estimate that around 15,000 of these premises will be connected via publicly funded schemes in the next 12 months.
- **The availability of low earth orbit satellite broadband services has increased**, offering a possible alternative for customers in poorly served areas, including some areas where customers are otherwise unable to access decent or better broadband.
- **Customers are increasingly taking up the higher speed services that are now available to them**. Over 73% of consumers that have access to superfast broadband have upgraded to a superfast service. We estimate that around 25% of premises that are able to get full fibre are actually taking it, with take-up increasing by at least 1.4 million premises since last year.
- **Average monthly data use has grown this year** to 482 GB per connection compared to 453 GB last year.

[3] We plan to report on the coverage of fixed broadband services to small and medium enterprises as part of our Spring 2023 update.
[4] Unless otherwise specified, coverage figures for decent broadband count all UK premises (residential and commercial). Coverage for other speed tiers count residential premises only.

Figure 2.1: Summary of broadband coverage at a fixed location across the UK and Nations



Source: Ofcom analysis of provider data (September 2022).

The UK has a variety of available fixed broadband services

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

- **Copper (ADSL)**[5] – 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, and it consumes more energy than newer broadband technologies.
- **Fibre to the cabinet (FTTC)** – There is 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)[6]. As with ADSL, actual speeds diminish with distance, and the network can be affected by poor weather and is susceptible to faults.

[5] Asymmetric Digital Subscriber Line.
[6] 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. However, the signal degrades more quickly so the customers able to get ultrafast speeds are limited to those closest to the cabinet.

- **Hybrid fibre coaxial cable (HFC)** – The cable TV network[7] uses fibre to a street cabinet and coaxial cable from the street cabinet to the premises. There is decreased signal loss compared to the use of copper, 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.[8] The latest standard of cable technology, DOCSIS 3.1, is capable of delivering gigabit speeds, although 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.[9]
- **Full fibre or 'fibre to the premises' (FTTP)** – The connection from the exchange to the premises is provided entirely over 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. It is also more efficient as it consumes less energy whilst transmitting the same amount of data.[10] Most full fibre implementations utilise Passive Optical Network (PON) approaches where capacity in the downstream and upstream direction is shared. 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 download and 1 Gbit/s upload, to 10 Gbit/s in both directions, and future generations will expand this further. Some providers are already deploying 10Gbit/s XGS-PON and it can co-exist with earlier versions which minimises upgrade costs.
- **Fixed 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 must 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 mostly use license exempt or lightly licensed spectrum and we are beginning to see some use of 5G technology.[11] Due to the frequencies where this spectrum is available, performance may be limited by line-of-sight issues although use of 5G spectrum alleviates some of these issues.

[7] Most cable broadband in the UK is provided by Virgin Media O2.
[8] DOCSIS: Data Over Cable Service Interface Specification.
[9] Virgin Media O2 is in the process of upgrading its cable network to full fibre to deliver further enhancements to its services. Virgin Media O2, Q3 2022 Earnings Release, November 2022.
[10] FTTP consumes less energy than traditional broadband technologies because it does not require active, powered equipment such as amplifiers or powered splitters between the exchange and the premise due to the use of passive street cabinets. There is also a reduced energy consumption at the exchange per user.
[11] Quickline, UK's First Broadband Provider to deliver 5G SA Cloud-Native Open RAN solution, August 2022.

Table 2.2: Summary of characteristics of different types of fixed broadband

Type of broadband	Speed	Use cases	Fixed broadband technologies that can provide this service
Decent[12]	10 Mbits/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 15 mins, or a 1 hour HD TV episode in 8 seconds. Likely to be more reliable and future proofed.	HFC Cable (when upgraded to DOCSIS 3.1) Full fibre

FWA (both that provided by MNOs and by WISPs) can also provide decent and superfast speeds and, under certain conditions, may be gigabit-capable, 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 42% of premises, with gigabit-capable broadband available to 70%

Full-fibre (FTTP) broadband is now available to 42% / 12.4m premises

Full fibre roll-out is growing quickly, with 42%/ 12.4m premises in the UK now served by full fibre, a growth of 14 percentage points and 4.3m additional premises in the past year. This is a nearly seven-fold increase compared to just five years ago.[13] This is primarily driven by deployments from the larger fibre operators (Openreach, Virgin Media O2 and City Fibre) but supported by a number of smaller providers across the UK which are increasingly included within our data gathering programme.[14] These new providers tend to be smaller and often target their rollout in underserved

[12] 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 currently deemed necessary for consumers to participate in a digital society.
[13] In 2018 we reported that 1.8m premises had access to full-fibre broadband. Ofcom, Connected Nations 2018.
[14] This year we have included data from over 60 full fibre communications providers (compared to around 40 last year).

communities and regions. As such, they do not significantly alter the national figures, but they are important in providing full fibre coverage at the local level.

Gigabit-capable broadband is now available to 70% / 20.8m premises

Our data shows rapid expansion of gigabit-capable networks. By September 2022, 70% / 20.8m residential premises had access to gigabit-capable broadband, compared to 47% / 13.7m residential premises in 2021. This significant growth has been driven by the continued rollout of full-fibre broadband by many network operators, as well as Virgin Media O2's now completed upgrade programme.[15]

Some of these premises have access to more than one gigabit-capable network; around 16% / 4.9m residential premises have access to more than one gigabit-capable broadband service over both cable and full fibre technology, 7% / 2.1m residential premises have a choice of two or more full fibre networks, and 21% / 6.4m residential premises have a choice of two or more gigabit-capable networks.

Table 2.3: Residential gigabit-capable and full fibre coverage

	Gigabit-capable			Full fibre		
	Total	Urban	Rural	Total	Urban	Rural
England	71% (17.6m)	76% (16.5m)	37% (1.1m)	41% (10.1m)	42% (9m)	34% (1.1m)
Northern Ireland	87% (0.7m)	96% (0.5m)	65% (0.2m)	85% (0.7m)	94% (0.5m)	65% (0.2m)
Scotland	64% (1.7m)	72% (1.6m)	26% (0.1m)	41% (1.1m)	44% (1m)	24% (0.1m)
Wales	52% (0.8m)	58% (0.6m)	34% (0.1m)	40% (0.6m)	41% (0.5m)	33% (0.1m)
UK	70% (20.8m)	76% (19.3m)	37% (1.5m)	42% (12.4m)	43% (11m)	35% (1.4m)

Source: Ofcom analysis of provider data (September 2022).

The table above illustrates that while there has been an increase in gigabit-capable coverage in both urban and rural areas, there has been a greater increase in urban areas.

The largest percentage increase in full fibre roll out has been in Northern Ireland and Scotland, both of which saw total coverage increase by 14 percentage points. There has been rollout in both urban and rural areas, but urban areas continue to have greater access to full fibre due to some providers (e.g. Virgin Media O2) tending to focus their roll-out on these areas.

[15] Virgin Media O2, Virgin Media O2 completes gigabit upgrade in boost for Britain's broadband target, December 2021.

Roll-out of gigabit-capable and full fibre networks

Availability of full-fibre and gigabit-capable networks is expected to continue to increase over the next few years, with different providers continuing to take different approaches to their business models for deployment:

- 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 premises with full fibre by December 2026. This includes 6m homes in harder to reach areas by 2025.[17]
- Having completed the upgrade of its cable network in December 2021,[18] Virgin Media O2 has this year been progressing with a fibre upgrade across its existing network with the aim of offering full fibre across its network footprint by 2028.[19] In July 2022, Virgin Media O2's shareholders (alongside an investment firm) announced a new joint fibre venture which plans to pass up to 7m premises with a wholesale full fibre network, including an initial focus on 5m homes not currently served by Virgin Media O2's existing network;[20]
- CityFibre plans to pass up to 8 million premises (both residential and business) across 285 towns and cities by 2025. It recently announced it has now passed 2m homes, completing 25% of its target. It uses a partnership model, with over 30 retail providers offering full fibre services to customers over its network.[21]
- 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.

In addition to these publicly available statements on network roll-out, we have gathered data on the deployment plans of network operators over the next three years, including privately funded and publicly supported interventions. We recently published this data in a separate report[22] - see also the summary in a later section below.

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.480,000km of duct and c.4.1 million poles. Since 2019, our rules have allowed easier access to Openreach's physical infrastructure (PIA). As of the end of September 2022, 154 providers

[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. KCOM, KCOM unveils £100m vision to deliver full fibre future for region, September 2022.
[17] BT Group, BT to increase and accelerate FTTP build to 25m premises by the end of 2026, May 2021. Openreach, Openreach focuses broadband build plans on upgrading millions more rural homes, May 2021. BT's latest quarterly report (30 September 2022) indicates it has FTTP build to over 8.8m premises, including 2.8 in rural areas.
[18] Virgin Media O2, Virgin Media O2 completes gigabit upgrade in boost for Britain's broadband target, December 2021.
[19] Virgin Media O2, Q3 2022 Earnings Release, November 2022.
[20] Virgin Media O2, New £4.5bn investment to extend Virgin Media O2's fibre footprint to 80% of the UK, July 2022.
[21] CityFibre, CityFibre network passes 2 million homes on its march toward 8 million, September 2022.
[22] Ofcom, Planned Network Deployment, November 2022.

had registered with Openreach as customers of PIA, and over 83% had already built network using PIA or have placed orders to do so. Providers have ordered c.112,000km of duct (20,000km of which has been delivered) and c.810,000 poles (134,000 of which have been delivered) to deploy networks.

The UK Government has continued its work to ease the administrative burden required when agreeing access to private land for operators looking to roll-out gigabit-capable (and 5G) networks. The new Product Security and Telecommunications Infrastructure Act (PSTI),[23] as well as addressing security issues, will include a number of telecommunications infrastructure measures. This will include making changes to the Electronic Communications Code[24] to support gigabit-capable and 5G network rollouts which will encourage collaborative negotiations between site owners and telecommunications operators, ensure expired agreements can be renewed more easily and enable telecoms providers to gain access to certain types of land more quickly in circumstances where a landowner repeatedly does not respond to access requests. We will be supporting this work through consulting on changes to the Electronic Communications Code of Practice.

Coverage of superfast broadband remains high, with most UK homes having access to a superfast broadband connection

Superfast broadband is now available to around 97% / 28.7m of UK premises, an increase of one percentage point, and about 600,000 homes compared to last year.

Figure 2.4: Residential superfast coverage

	Superfast	Urban	Rural
England	97%	98%	88%
Northern Ireland	94%	99%	82%
Scotland	94%	99%	76%
Wales	95%	99%	84%
UK	97%	98%	86%

Source: Ofcom analysis of provider data (September 2022).

As discussed above, providers are now heavily focused on deploying gigabit-capable networks and, in the future, will mainly deliver increased availability of full fibre. As such, we expect future increases in superfast broadband coverage to continue to be modest.

[23] UK Parliament, Product Security and Telecommunications Infrastructure Act, December 2022.
[24] Ofcom, Electronic Communications Code.

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

Fixed wireless access (FWA) on mobile networks

Of the four mobile network operators (MNOs) in the UK, only Virgin Media O2 does not offer FWA services. Based on information from the MNOs about their coverage levels, we estimate that 95% of UK premises have access to an MNO FWA service. This is an increase of one percentage point from last year. [25]

FWA services offered over the MNOs 4G and 5G networks, 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. This means that there may be areas of high mobile demand where a reliable FWA service cannot be offered.

We carried out some research this year on the performance of FWA services delivered over mobile networks (similar to the research we carried out last year on the speeds offered by WISP networks – see below). Our results show that FWA packages are offering similar capabilities to fixed connections, except in relation to latency. Specifically we found that: [26]

- two of the MNO 5G FWA packages that we tested delivered higher average broadband speeds than some packages on fixed technologies. These packages delivered average download speeds of over 140 Mbit/s and upload speeds of over 24Mbit/s;
- average packet loss for FWA services was similar to average packet loss for fixed broadband services; and
- latency of the FWA services we measured was higher than on fixed broadband technologies.

Fixed wireless access via wireless ISPs (WISPs)

These FWA services are delivered over networks that communicate via a wireless link between a provider's mast site and an external antenna fixed to a customer's premise. They mostly use license exempt or lightly licensed spectrum, and due to the range of frequencies being used to deliver this service, performance may sometimes be limited by line-of-sight issues. We are beginning to see some use of 5G technology, which alleviates some of these line-of-sight issues.

We have further expanded our collection of WISP data this year to now include 26 providers. Based on estimates from these providers, around 7% of UK premises have coverage from a WISP network, which is the same as last year.

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[25] 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.

[26] See our interactive report for more information. Note that the fixed broadband data included in this report was collected in March 2022. The FWA (and other wireless technology data) was collected in September 2022 and is not weighted to a representative sample for the UK. The analysis is therefore limited to the individual connections used in the study, which are spread across local regions across the UK and the majority of which are from remote or rural areas.

Table 2.5: Coverage of MNO and WISP FWA networks with at least decent broadband (residential premises)

	MNO FWA	WISP FWA
England	96%	7%
Northern Ireland	85%	0%
Scotland	95%	2%
Wales	93%	32%
UK	95%	7%

Source: Ofcom analysis of provider data (September 2022).

There continues to be a small number of premises that cannot access decent broadband

Excluding fixed wireless access coverage, 98% of UK homes and businesses have access to at least decent broadband on a fixed line connection. This means around half a million premises do not have access to decent broadband via a fixed connection – a drop from around 650,000 premises last year. Most of these premises are in rural areas of the UK.

As discussed above, MNOs and WISPs can offer a decent broadband service and can provide an alternative network technology for the premises that cannot currently access decent broadband from a fixed connection. Based on the coverage estimates from FWA providers, we estimate a significant proportion of those premises that do not have access to a decent broadband service could have access via an FWA network.

Table 2.6: Premises without access to a decent broadband service from either a fixed or wireless network

	Remaining premises without access to decent broadband
England	40,000
Northern Ireland	9,000
Scotland	21,000
Wales	10,000
UK	80,000

Source: Ofcom analysis of provider data (September 2022).

This leaves around 0.3% / 80,000 premises in the UK that still do not have access to a decent broadband service via either a fixed or wireless network. This figure continues to decrease year on year (down from 123,000 last year). This reduction is likely due to a combination of factors, including

the increased number of smaller fibre network and FWA providers from which we have gathered data, and the increasing roll-out of some publicly funded schemes.

When we analyse the 80,000 premises against 4G indoor mobile coverage data (reported in the next section), we estimate that around 30,000 premises cannot access either a decent fixed broadband service, or good 4G indoor coverage (of at least 2Mbit/s).

Some of the 80,000 premises will be due to receive a decent broadband service under a publicly funded scheme within the next 12 months. We discuss the publicly funded schemes further below but based on the data we have gathered on these schemes, we expect around 65,000 premises will still be left without access to decent broadband. These remaining premises may be able to have a new connection built under the broadband universal service obligation.

The broadband universal service obligation (USO)

The broadband USO provides everybody with the right to request a broadband connection with a download speed of at least 10 Mbit/s and an upload speed of 1 Mbit/s (as well as a number of other specific technical characteristics).[27]

Where an affordable service[28] with these characteristics is not available, or due to become available in the next 12 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 customer agrees to pay the excess.[29] 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.[30]

BT's delivery of the USO

As of October this year, BT had received 1851 orders.[31] Each order requires network build that can serve multiple premises, and therefore will lead to full fibre connections being built that can serve just under 9,500 premises that do not have access to decent broadband. These break down by Nation as shown below.

Table 2.7: USO orders and number of premises built

	Number of USO orders	Total homes passed by resulting build
England	1488	7099
Northern Ireland	85	702

[27] In particular these are: a contention ration 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 a month.
[28] When the USO was launched (in March 2020), we specified in the USO conditions that an affordable service was one that costs £45 per month, rising annually by CPI. This has now risen to £48.90 per month in line with CPI.
[29] 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.
[30] BT Group, A Universal Service Obligation - Keeping the UK connected.
[31] BT's public reporting shows a slightly lower number of total confirmed orders, this is because it only covers orders prior to, and during, network build, whereas the 1851 figure also includes orders made once build has completed.

	Number of USO orders	Total homes passed by resulting build
Scotland	110	583
Wales	168	1096

Source: Ofcom analysis of BT data.

BT's latest delivery report shows that of the c.25,000 requests to its USO helpdesk received to date, two-thirds were ineligible as a decent broadband product already existed from BT or another provider, or would be made available within 12 months by a publicly funded scheme.[32]

There are still some premises that may not get connected under the USO

Data analysis by BT indicates that there are a number of premises where the costs to connect them are likely to exceed the £3,400 cost threshold in the USO. In these cases customers will receive excess cost quotes that may be quite high in some cases. Those premises that are the most expensive to connect and are likely to need alternative solutions.

The availability of satellite services is increasing and may offer an alternative option for customers in poorly served areas

Satellite broadband services have been available in the UK for some time but take-up of these services has remained low compared to traditional broadband services.[33] The technology for delivering satellite broadband has evolved significantly in recent years, and continues to do so, with an increasing number of satellite constellations now being launched.

Geostationary (GSO) satellites, which orbit the earth at about 36,000km, have traditionally been the primary way of delivering satellite communication services. GSO providers[34] can provide satellite broadband to most premises across the UK, including some in the most remote areas, but the connection's performance can be limited by its higher latency and by data caps, which may mean the service is not suitable for all customers. However, newer GSO services offering higher speeds and unlimited data are becoming increasingly available.[35]

Low Earth Orbit (LEO) satellite constellations are now also available offering residential and business broadband to UK customers. LEO satellites can deliver lower latency services due to their lower orbit (below 2,000 km), enabling a more seamless use of applications like two-way video calling and gaming. Starlink launched its LEO satellite broadband service in the UK last year and it now provides coverage across the UK (excluding the top two thirds of the Shetland Islands).[36]

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[32] BT Group, BT report on progress against the Broadband USO, October 2022.
[33] We report in the 2022 Communications Market Report that there were 25,500 fixed broadband satellite connections at the end of 2021. This figure represents data collected from a non-exhaustive list of UK satellite service providers (excluding Starlink).
[34] For example ViaSat's KA-SAT and EutelSat's We Konnect services.
[35] We Konnect offers broadband in the UK, Europe and Northern Africa using GSO satellites. They state that average download speeds of 20 to 75 Mbit/s are available on plans ranging from about £38-£48 per month. Konnect.
[36] See Starlink's online coverage map. In September, Starlink expanded its coverage further north, reaching up to around the bottom third of the Shetland Islands, with the rest planned to follow in the first quarter of 2023. ISPreview, Starlink Expand UK Coverage to Include Part of Shetland Islands, 27 September 2022.

OneWeb also recently launched LEO satellite services in the UK and have partnered with BT to offer connectivity services. Its initial service trials have focused on satellite's role as a supplementary backhaul solution to sites where additional capacity or a back-up connectivity solution is required, and to deliver improved resilience for business customers.[37]

Starlink is therefore currently the only direct to consumer LEO satellite broadband service in the UK. We have recently carried out our own performance measurements of Starlink's services based on a small sample of individual connections spread across the UK (the majority of which were in remote or rural areas).[38] Our results confirm that Starlink customers on average receive download speeds of almost 100Mbit/s in peak hours, as well as upload speeds of around 14 Mbit/s. Whilst the latency of the service is higher than for fixed broadband, it was equivalent, or lower, than the FWA services that we also measured as part of the same study.

As of October 2022, approximately 13,000 customers have opted for a broadband service from Starlink and, based on our analysis of Starlink's data, at least some of these customers are based in areas which do not have access to traditional decent broadband services. These services are currently more expensive than traditional broadband services (Starlink's broadband is priced at £75 a month, plus a £460 one-off installation fee)[39] but may offer a good alternative option for customers in hard to reach areas who would otherwise face very high costs to install a traditional fixed broadband connection. The UK Government has recently announced a new trial, initially supported by Starlink, which aims to see the extent to which LEO satellites can deliver high-speed broadband connections to more than a dozen very hard-to-reach locations across the UK.[40]

There is a limitation on the number of customers both GSO and LEO services can currently provide services to due to the number and capacity of existing satellites, as well as the available spectrum which is shared between users. These capacity constraints can lead to Starlink occasionally suspending availability of its service to new customers in certain areas, meaning services are not immediately available and customers must instead sign-up to a waiting list.[41] As the number of operational satellites in orbit grows, so too will network capacity. We are releasing more spectrum which will offer more options for increased capacity in future.[42]

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[37] OneWeb, OneWeb and BT sign agreement to explore rural connectivity solutions in the UK and beyond, June 2021. BT Group, BT secures industry-first global partnership with OneWeb, November 2021. BT Group, Our Space Strategy, April 2021.

[38] Note that this sample was not weighted to be representative of the UK, and is limited to the individual connections involved in the study. See our FWA measured performance interactive report.

[39] Starlink.

[40] UK Government, Broadband beamed from space to isolated areas under plans to boost countryside internet connections, November 2022.

[41] For example in August 2022, Starlink reported it was temporarily suspending service offerings to new customers in two areas, south Manchester and southeast London. However, at the time of publication, Starlink's online coverage map now shows all areas in the UK as available for new customers.

[42] Ofcom, More spectrum for satellite connectivity – extending access in the Ku band, August 2022. Ofcom, Space spectrum strategy, November 2022.

Both private and public sector investment are continuing to play a role in building faster networks

Our planned network deployment report indicates how roll-out of full fibre could progress over the next three years

We recently published our first forward looking report about planned network deployments of full fibre.[43] This report is based on the stated deployment plans of network operators as of March 2022 up to three years in advance, and it includes plans that are privately funded as well as those that are supported through public funds/intervention that were known at the time the data was collected in May 2022.[44]

Some of our key findings were that, if all network deployments are realised as planned, the number of properties covered by full fibre could reach nearly 84% / 25m premises, with gigabit-capable coverage reaching up to 92% of premises. Up to 66% of premises are expected to receive gigabit-capable service from two or more providers.[45] For further details on our findings see the full report.

While this data sets out the operators plans, as opposed to achieved build, we have considered how their plans might change some of the measurements we report on in Connected Nations. For example, we have estimated how this expected deployment of full-fibre broadband services is likely to reduce the number of properties that cannot get decent broadband from either a fixed or fixed wireless connection over the next three years. Specifically, our estimates indicate that there will be 52,300 properties which will continue to be without access to decent broadband, and which may therefore be eligible for the broadband USO. Table 2.8 shows how this estimate breaks down by Nation.

Table 2.8: Estimate of remaining premises unable to access decent broadband by March 2025[46]

	March 2025
UK	52,300
England	29,400
Northern Ireland	3,300
Scotland	12,200
Wales	7,500

Source: Ofcom analysis of provider data (March 2022).

[43] Ofcom, Planned Network Deployment, November 2022.
[44] The report only takes account of communications providers planned deployments (whether privately or publicly funded), and therefore does not account for any aspirations or plans by public authorities, whether national or local, to roll out networks in their geographical areas.
[45] These estimates include coverage for plans across all planning stages (including those for which financial approval had not yet been obtained) as detailed in the Planned Network Deployment report, see page 4.
[46] This analysis is based on all premises (residential and commercial) and takes account of current FWA coverage. It does not include the coverage of future FWA deployments as the necessary coverage modelling has not taken place.

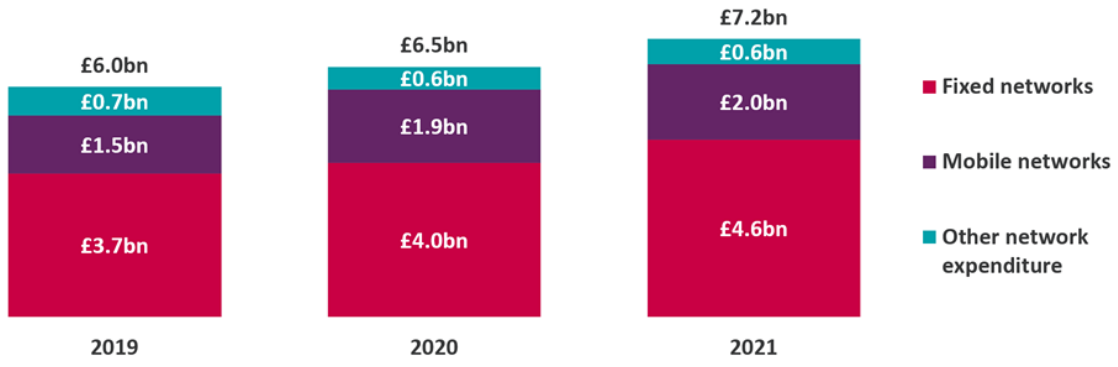
Expenditure on telecoms infrastructure increased to £7.2bn in 2021

In order to understand how telecoms providers are investing in network infrastructure, we collect network investment data from over 30 of the UK's largest fixed and mobile telecoms providers.[47] The information collected from providers relates to their annual financial reporting periods, which can differ between providers. To take account of this, we pro-rate the figures received to estimate network investment in each calendar year.

The figures below include 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. Further information on mobile network expenditure can be found in the mobile section of this report.

Our analysis suggests that, in total, UK telecoms providers invested £7.2bn in network infrastructure in 2021, a £0.7bn (11%) year-on-year increase in real terms (i.e. adjusted for inflation). During the year, fixed network investment totalled £4.6bn (64% of the total) with mobile network investment accounting for a further £2.0bn (27% of the total). An additional £0.6bn related to 'other network expenditure' (investment in infrastructure that is used to provide both fixed and mobile services).

Figure 2.9: Telecoms network capital expenditure: 2019 to 2021



Source: Ofcom analysis of provider data. Note: Adjusted for CPI (2021 prices).

Expenditure on fixed telecoms network infrastructure increased to £4.6bn in 2021

Data collected from the UK's largest providers suggest that UK telecoms providers invested £4.6bn in fixed telecoms network infrastructure in 2021, a £0.6bn (15%) increase in real terms compared to

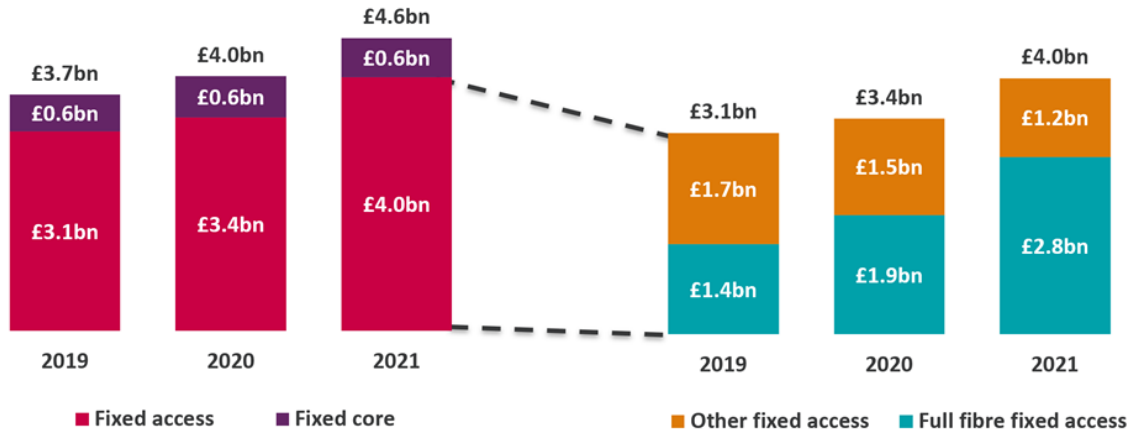
[47] Only capital expenditure required to provide and operate network infrastructure in the UK is included: figures exclude VAT and expenditure on retail activities (e.g. retail billing or marketing systems). Figures include capital expenditure on tangible and intangible assets, including capitalised 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.

2020. In addition to this, £0.6bn was invested in infrastructure that is used to provide both fixed and mobile telecoms services in 2021.

Investment in access network infrastructure accounted for most fixed network investment during the year, (£4bn, or 87% of the total), with fixed core and backhaul networks accounting for the remaining £0.6bn (13% of the total). The proportion of total fixed network expenditure that related to access networks increase by 3 percentage points in 2021, while there was a similar drop in the proportion relating to fixed core networks.

Gigabit-capable full fibre access network investment totalled £2.8bn in 2020, a year-on-year increase of £0.9bn (49%). In addition, a proportion of the £1.2bn that was spent on other fixed access networks may also support deployment of gigabit-capable networks where this is related to upgrades to physical infrastructure (such as fibre deployments for fibre-to-the-cabinet) that could be re-used in future.

Figure 2.10: Fixed telecoms network capital expenditure: 2019 to 2021



Source: Ofcom analysis of provider data. Note: Adjusted for CPI (2021 prices).

Public sector investment has a key role in delivering connectivity, particularly in harder to reach areas

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, primarily full fibre services.

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, it has committed, under Project Gigabit, to invest £5 billion to bring high speed broadband to hard-to-reach areas considered too difficult or expensive to connect under industry commercial plans. Its latest report on progress indicates that it has now launched procurements totalling over £780m which aim to cover up to 545,000 premises.[48]

[48] UK Government, Project Gigabit Delivery Plan - autumn update 2022, 30 November 2022.

The first contract was awarded under Project Gigabit in August this year, with three further contracts awarded since.[49]

Other examples of ongoing government schemes to support fast speeds in hard-to-reach areas include:

- The UK Government provides vouchers through the Gigabit Broadband Voucher Scheme for individual eligible customers to contribute towards the installation of faster connections using gigabit-capable infrastructure. In November 2022, the UK Government announced that over 79,000 vouchers had been used to connect premises to gigabit-capable broadband under the scheme.[50] It also increased the value of vouchers from £1,500 and £3,500 for homes and businesses respectively, to £4,500 for all beneficiaries. In July, the UK Government also announced an £82 million investment to help connect up to 3,000 schools in England to gigabit-capable broadband over the next three years.[51]
- The Welsh Government's £56m full fibre roll-out with Openreach will conclude in March 2023 serving around 39,000 premises that would not otherwise have been connected to full-fibre broadband. The Local Broadband Fund supports local authorities and social enterprises to deliver broadband to whole communities. The fund has provided grant funding to schemes across Wales including in Monmouthshire, Cardiff and Gwynedd. The Access Broadband Cymru grant scheme provides a broadband safety net though funding of up to £800 to connect individual homes, businesses and third sector premises.[52]
- The Scottish Government is making substantial investments in Scotland's digital infrastructure. Building on the work of Digital Scotland Superfast Broadband, the Reaching 100% (R100) programme is made up of three strands of activity –the £600 million R100 contracts (North, Central, and South), the R100 Scottish Broadband Voucher Scheme (R100 SBVS) and ongoing commercial deployment.[53] All three R100 contracts are delivering connections and going beyond the original superfast commitment by providing increased gigabit-capable and full fibre coverage. Over 14,300 premises have been connected through the R100 contracts with a further 2,600 connections delivered through the voucher scheme. Island communities in Scotland will also benefit from gigabit-capable broadband following the deployment of 16 R100 subsea cables that were laid during Summer 2022.[54] . In August 2022, a further £36 million of funding was jointly announced by the Scottish and UK Governments, which will see an additional 2,637 premises receive access to gigabit-capable speeds.[55]
- In Northern Ireland, the Department for the Economy secured additional capital funding of £32 million[56] in order to bring an extra 8,500 premises, including 2,500 hard-to-reach premises, into its broadband intervention scheme, Project Stratum. The inclusion of these additional premises

[49] UK Government, Work begins on first major broadband upgrade under £5 billion Project Gigabit, 30 August 2022.
[50] UK Government, Project Gigabit Delivery Plan - autumn update 2022, 30 November 2022.
[51] UK Government, Thousands of rural primary schools to get huge broadband upgrade, 1 July 2022.
[52] Welsh Government, Update on Digital Connectivity in Wales, 8 July 2022.
[53] Digital Scotland, R100 - Access for all.
[54] Digital Scotland, R100 subsea deployment.
[55] Digital Scotland, Delivering faster internet, 19 August 2022.
[56] The Department for Digital, Culture, Media and Sport provided £22.3 million, while the Department for Education and Department of Agriculture, Environment, and Rural Affairs will each provide £4.85 million. Fibrus Networks, which is delivering Stratum, is making an additional contribution of £2 million.

will bring the total number of premises to benefit from Project Stratum to 85,000. The deployment of the new full fibre network to reach all 85,000 premises will continue across four extended quarters of network build, with Fibrus Networks expected to complete deployment by March 2025. [57]

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

Earlier this year the UK Government published its response to its consultation on premises in very hard to reach locations, which the current public schemes will not reach. [58] It plans to use the evidence gathered from the consultation to produce a set of policy proposals to address the needs of these premises. [59] We will continue to work with the UK Government as it develops its policy in this area.

More people are upgrading to higher speed services and new technologies

Take up of full fibre and gigabit-capable services is increasing

It is important to understand whether consumers are benefiting from higher speed and more reliable broadband 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 25%. Take-up of gigabit-capable networks is higher at around 38%.

Our reporting of full fibre take-up may appear lower than expected because networks are deploying at pace and take-up lags behind coverage. This could occur because there is a lag in awareness of availability or consumers need to wait until their existing service contract ends before they can migrate to a new service. However, take-up is increasing with at least 1.4 million new full fibre connections in the year to September 2022.

Table 2.11: Estimated full fibre take-up as a percentage of premises where full fibre services are available: 2021 and 2022

	2021	2022
UK	24%	25%
England	25%	25%
Northern Ireland	19%	25%

[57] Department for the Economy, Project Stratum – extension to include 8,500 additional premises.
[58] UK Government, Improving broadband for Very Hard to Reach Premises: Government response, 25 May 2022.
[59] As noted earlier in this section, the UK Government is also currently trailing the use of satellite to deliver high speed connections in a more than a dozen UK very hard to reach locations. Following the trial, it intends to consider the feasibility of using satellite broadband to connect very hard to reach residences and business across the UK. UK Government, Broadband beamed from space to isolated areas under plans to boost countryside internet connections, 30 November 2022.

	2021	2022
Scotland	22%	23%
Wales	24%	28%

Source: Ofcom analysis of provider data (May 2022).

Customers taking a full-fibre broadband service can usually choose from a range of speeds. Approximately 9% of full fibre customers take a service at the highest available speed.

Take-up of superfast broadband has also increased

Overall, we estimate that for those premises that are able to take superfast broadband services (97% of all premises in the UK), around 73% of them do so.[60] This is an increase from around 69% last year. Take-up of superfast broadband is highest in England and Northern Ireland, however, take-up has increased in all nations in the last year.

Table 2.12: Estimated superfast take-up as a percentage of premises where superfast services are available: 2021 and 2022

	2021	2022
UK	69%	73%
England	69%	73%
Northern Ireland	73%	73%
Scotland	68%	71%
Wales	66%	71%

Source: Ofcom analysis of provider data (May 2022).

Helping customers choose the right broadband service

Customers will be best placed to decide which broadband service is most suitable for their needs if they understand the available options. We are continuing with a range of work to help customers understand their broadband choices, and to see the benefits that faster connections may give them.[61] Our coverage checker shows the estimated fastest speeds and network providers that are available at a particular address.[62] We also recognise that customers need the right information to make informed choices about their broadband services. Earlier in the year, we paused the work of the industry working group on developing a common terminology for broadband services,[63] as the

[60] For all UK premises, the take-up of superfast broadband is slightly lower, at 70%. Under section 72B of the Communications Act, the Secretary of State must give Ofcom a direction to review the broadband USO if it appears that, on the basis of information we have published, take-up of superfast broadband has reached at least 75% of all UK premises.
[61] Ofcom, How to get more from your broadband.
[62] Ofcom, Mobile and broadband checker.
[63] Which?, Gigabit Take-up Advisory Group report, June 2021.

group was not able to reach a consensus at the time. Instead, to progress this work, we commissioned research on consumer understanding of the different kinds of terminology used to describe broadband technologies, and whether further, consistent information on these would be useful to consumers. We plan to report on the research next year, along with a consultation on next steps if appropriate.

The affordability of broadband services will also have a significant impact on customer choice – particularly in the current context of wider cost of living pressures on households and rising retail prices. Our latest affordability research shows an increasing number of households reporting affordability issues (6% of customers reported an affordability issue with their fixed broadband service).[64] Social tariffs can help ensure that fixed broadband services remain affordable. As part of our work on affordability we are monitoring the take-up and availability of social tariffs, as well as seeking to address barriers to help increase take-up of social tariffs among eligible customers.

The migration of the UK's telephony network to digital is gradually progressing

The UK's traditional landline services are undergoing a substantial transition as network providers retire their legacy systems (referred to as the Public Switched Telephone Network, or 'PSTN') and replace them with modern systems. BT and Openreach aim to retire BT's PSTN network and the Openreach wholesale services that deliver PSTN by the end of 2025, with Virgin Media working on a broadly similar timescale. To make sure landline services continue in the future, providers currently using 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 27% of landline services[65] are now delivered over broadband, up from 15% last year. Increasingly, customers have their landline service moved to VoBB when they change provider or upgrade their phone and broadband package. Last year, BT and Virgin Media also began migrating some of their existing customers, known as managed or provider-led migrations. In the year to August 2022, around 1.6m customers migrated to a VoBB service, with just over half resulting from a managed migration.

In March, BT announced it had temporarily suspended its programme of managed migrations of existing customers, noting it had underestimated the disruptive impact the upgrade would have on some customers. It aims to re-start the programme once it has key solutions in place.[66]

We are continuing to monitor the migration closely and engage with providers to help ensure customers are protected and disruption is minimised. The migration from the legacy telephone networks also brings certain challenges with respect to the resilience of landlines in the event of power cuts. We discuss this further in Section 3 on Network Security and Resilience.

Customers can also choose a 'broadband-only' package, where they no longer take a phone service. Broadband-only packages – with or without the option to add a landline service – are offered by

[64] Ofcom, Affordability of communication services, September 2022.
[65] This figure relates primarily to residential and SME voice lines, although not all operators were able to provide SME data.
[66] BT Group, We're pausing our Digital Voice plans for Consumers, while we work on a more resilient rollout, 29 March 2022.

most full fibre providers and are increasingly being offered for copper-based broadband as well. In the year to August 2022, over half a million customers dropped their landline in favour of a broadband-only service. This is more than double the number that did the same last year. With landline usage falling,[67] we anticipate that adoption of broadband-only packages will continue to grow in the coming years.

Data usage over fixed broadband continues to grow

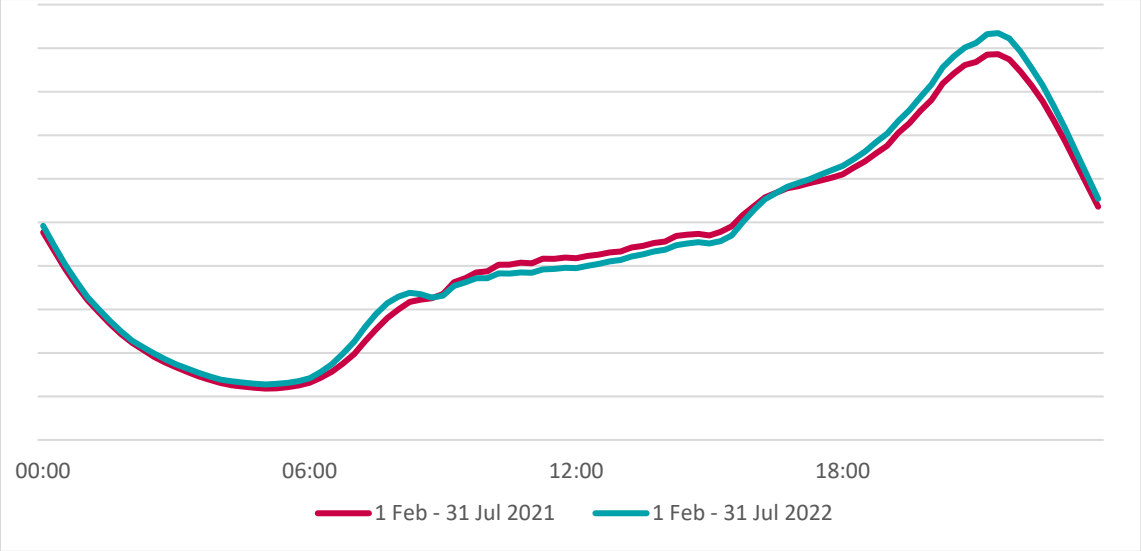
Fixed data traffic continued to increase this year, but the level of growth was slower in line with last year's trend. Average monthly traffic rose by 6% to about 482 GB per connection. This is up from 453 GB last year, which represented a 5% increase over 2020. Whilst this is a similar level of growth to last year, it is noticeably lower than the significant c.30% growth in 2020, largely as a result of the impact of Covid-19. Peak download traffic grew in line with overall usage, increasing by around 7% this year (compared to 13% last year).

We also obtained information and analysis on data traffic from some providers for the months of February to July this year. Some providers gave detailed reports covering the entire period, while others had higher level analysis, or limited data. Figures 2.13 and 2.14 show the typical traffic profile for weekdays and weekends for:

- the period from February to July 2021, when there were still Covid-19 restrictions in place, including national lockdowns;[68] and
- a similar period during 2022, when Covid-19 restrictions had lifted in England and begun easing in other Nations.

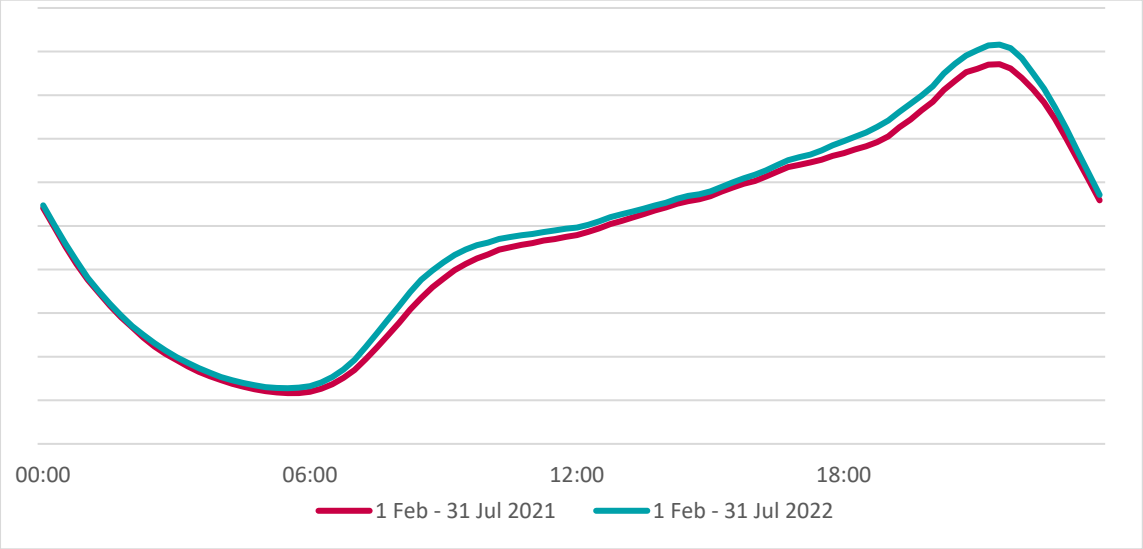
[67] Ofcom, Communications Market Report 2022, 18 July 2022. Fixed voice call volumes fell by 14% in 2021.
[68] At this time, many people were still working from home on a permanent or regular basis. Entertainment venues such as pubs were open to different degrees and with different rules in different Nations.

Figure 2.13: Average traffic profile (Gbit/s) on weekdays in 2021 and in 2022



Source: Ofcom analysis of provider data.

Figure 2.14: Average traffic profile (Gbit/s) on weekends in 2021 and in 2022



Source: Ofcom analysis of provider data.

The slight reduction in daytime, weekday traffic indicates lower broadband traffic during traditional working hours, potentially because of a return to in-office work after pandemic restrictions lifted. Otherwise, apart from this slight shift, the overall pattern of usage has remained similar to last year suggesting that overall usage patterns developed during the pandemic are here to stay. The growth in peak traffic indicates customers continue to use their fixed broadband connections for bandwidth heavy activities, such as streaming and gaming. Data from the operators from across this period indicated that overall usage levels were at their highest in February, with a trend towards decreasing usage in the spring and summer months.

3. Mobile, data and voice

Introduction

Mobile services continue to play an ever more central role in people's lives, from on-the-go calls and internet access to wireless connectivity for smart meters. In this chapter, we provide an update on the progress operators are making with their 5G rollout plans, while continuing to report on the broader availability of mobile coverage outside and inside premises, across the UK's landmass and on roads.

This chapter also provides early insights from our work to provide additional perspectives on the quality of mobile network performance. We then report on investment in, and the take up of mobile services, as reflected in the continuing growth of mobile traffic. Finally, we also update on the availability and use of Internet of Things (IoT) devices and services.

Highlights

- The availability of 5G services continues to grow rapidly, with the level of coverage provided outside of premises by at least one Mobile Network Operator (MNO) rising from 42-57% in 2021 (across a range covering Very High and High Confidence) to 67-77% in 2022.
- Our analysis of MNO 5G predictions indicates that Three has the most extensive 5G coverage outside premises at our 'High Confidence' level, at 58%; BT EE retains the most coverage at our 'Very High Confidence' level, reaching outside 45% of premises.
- 4G continues to carry the majority of mobile data traffic (accounting for 87% of total data traffic), with 4G coverage from at least one MNOs reaching 92% of UK landmass.
- Mobile traffic continues to grow, though we have seen slower growth this year, with traffic levels increasing c27% year on year, compared with a 37% rise between 2020 and 2021. However, it is too early to determine if this represents a trend.
- Data traffic carried over 5G has increased more rapidly, rising from 3% of all traffic in 2021 to over 9% this year, generated from a device pool which now includes c20% 5G capable handsets.
- We see continued evolution in non-consumer connectivity, with growth in private networks offered by MNOs, and by other players. Internet of Things (IoT) traffic also rose significantly, with a 20% growth in MNOs' IoT traffic.

Figure 3.1: Overview of voice and data coverage across the UK and UK nations [69]

	Northern Ireland	Scotland	Wales	England	UK
5G outside premises (MNO range)	14-26%	29-51%	10-46%	42-61%	39-58%
4G outside premises (MNO range)	98-99%	97-99%	96-99%	99%+	99%+
4G geographic (MNO range)	88-92%	57-75%	73-85%	92-94%	80-87%
4G total not spots	3%	17%	10%	2%	8%
Voice & text total not spots	>1%	10%	4%	>1%	4%

Source: Ofcom analysis of operator data (September 2022).

5G availability continues to grow, extending beyond the busiest urban locations

5G is within reach of a growing number of consumers, with around 20% of mobile handsets now 5G capable (up from c10% in 2021), and significant increases in coverage observed across the UK. [70]

The mobile coverage data in this report is based on predictions provided to us by the MNOs. To evaluate the accuracy of the information provided to us, we undertake regular testing to ensure the predictions provided are suitable for national and regional reporting. The development of 5G predictions has required new approaches from the MNOs, and in many cases relies upon new iterations of their modelling tools. We have therefore undertaken a 5G-focussed monitoring exercise before publishing these predictions, and we will continue to engage with MNOs, and undertake further monitoring, as networks are rolled out and models are updated. [71]

In 2021, we set out our approach to reporting on 5G availability across a confidence range covering High Confidence and Very High Confidence. These confidence levels reflect the likelihood of on the ground coverage for consumers in a particular location. We consider a High Confidence, associated with a signal strength (-110 dBm), to equate to at least an 80% confidence level, and a Very High Confidence - associated with a higher signal strength (-100 dBm) - to equate to a circa 95% confidence level. [72]

[69] The MNO ranges in this figure refer to the span between the MNO with the least coverage and that with the most coverage on a given measure. For 5G outside premises the MNO range is based on our 'High Confidence' measure, rather than the 'Very High Confidence' measure which we also use in this report.
[70] We note that not all 5G capable devices may be enabled with 5G subscriptions.
[71] Measurement data is collected as part of our monitoring activity on a regular basis. Ofcom, Mobile signal strength measurement data from our spectrum assurance vehicles, 26 July 2022.
[72] These signal strengths refer to control channel signals – for further detail see our Methodology Annex.

For 2022 we find that the area outside of premises[73] where 'At least one MNO' provides coverage is predicted to be between 77% for High Confidence and 67% for Very High Confidence.[74] This represents an increase of 20 percentage points and 25 percentage points respectively from 2021.

Figure 3.2: 5G coverage outside of UK premises by 'At least one MNO' (2021 and 2022)

Source: Ofcom analysis of operator data (May 2021 and May 2022).

The 'All' MNO footprint, representing the places where all 4 MNOs provide coverage, remains at a significantly lower level but has also increased, reaching outside 20% of premises at High Confidence, and 11% at Very High Confidence.[75]

These coverage increases have been driven by additional 5G deployments, with over 12,000 5G deployments now in place across the UK, up from the 6,500 reported in 2021.[76] Of these, 86% are located in England, 8% in Scotland, 4% in Wales and 2% in Northern Ireland, broadly in line with previous trends.

5G availability comes in different forms, and user experiences may vary

While this section focusses on 5G availability (i.e. the area in which a consumer can connect to a 5G network), it is important to recognise that there is a diversity of deployment strategies leading to potentially different consumer experiences within this coverage footprint.

Some areas that receive 5G may benefit from the deployment of new spectrum, released specifically to provide new bandwidth for 5G services, such as the 3 GHz and 700 MHz bands auctioned by

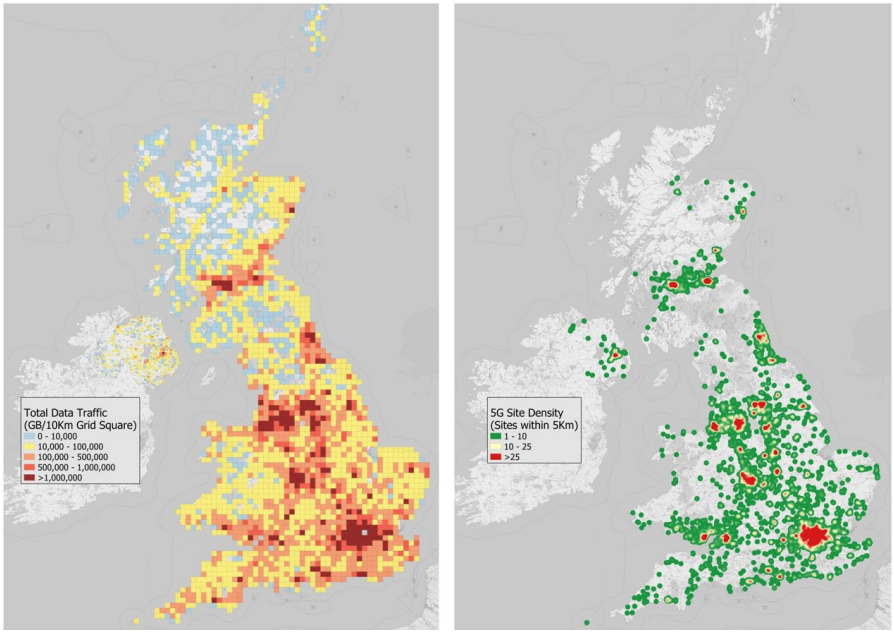
[73] By coverage outside a premises, we mean that coverage is predicted in a 100x100m area in which a dwelling is located, which can be seen as a proxy for outdoor coverage of populated areas.
[74] By 'At least one MNO' we mean the combined coverage that would be available if the total coverage of each MNO was included in an aggregated coverage footprint.
[75] All the 5G coverage reported here is currently provided on a Non-Stand Alone basis – although trials of Stand Alone 5G are underway. Non-Stand Alone 5G relies on a 4G core network and uses 4G for signalling and network control functions. Stand Alone 5G operates independently of the existing 4G layers.
[76] It should be noted that these deployments do not necessarily equate to a total of individual sites across all MNOs. For example, 2 MNOs may be offering coverage from the same site.

Ofcom in 2021. In other cases, MNOs are beginning to utilise pre-existing 4G spectrum holdings for 5G. Taken together, this provides MNOs with a range of 5G coverage and capacity options, with deployments typically influenced by the density of user demand.

The 3 GHz band offers very high capacity to support large numbers of demanding users across smaller areas, and consequently has to date been deployed predominantly in high traffic urban locations. Lower frequency bands such as 700 MHz may provide a more similar experience to existing 4G coverage – with additional capacity where fresh spectrum is made available – and are suitable for in-building and wide area coverage, so are increasingly present in both urban and more rural environments. Other bands previously used for 4G, such as the 2.1 GHz band, also offer a mix of coverage and capacity characteristics, without the need to deploy new spectrum. In some cases, this 5G coverage will be delivered through Dynamic Spectrum Sharing, where 4G and 5G services are carried over the same spectrum, which can help facilitate 5G rollout. [77]

Consequently, while 5G deployments continue to be focussed most intensively around more densely populated or regularly visited areas, 5G is increasingly available beyond city centres and can be found in smaller towns and along busy transport routes. Figure 3.3 shows how the density of these deployments remains most intense in the areas with greatest traffic (noting that the 5G capacity provided in these areas will vary, and is a product of both this site density and the available bandwidth). [78]

Figure 3.3: Intensity of total monthly mobile traffic per 10 km^2 (left) and density of 5G site deployments (right)



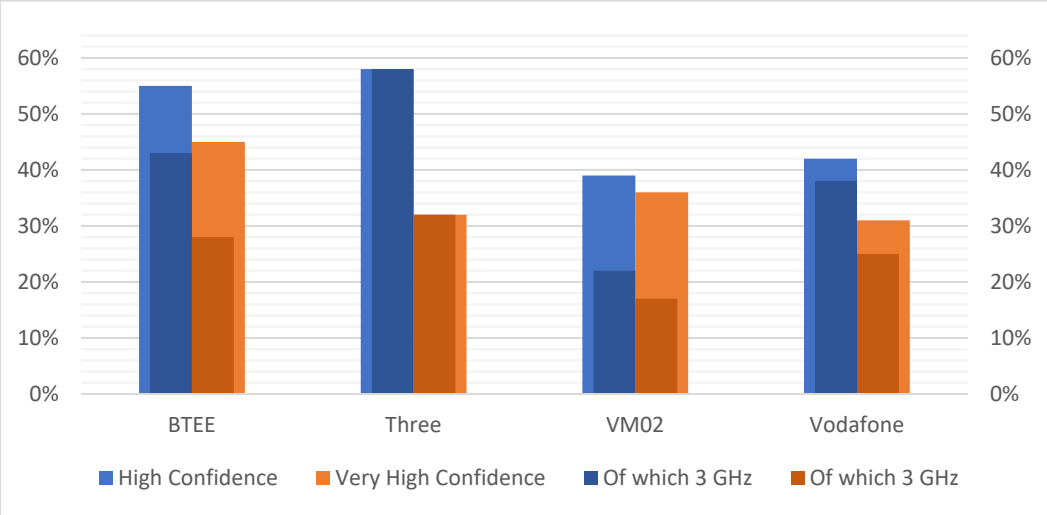
Source: Ofcom analysis of operator data (May 2022).

[77] Dynamic Spectrum Sharing is a process which enables operators to switch resource allocated to different technologies (i.e. 4G and 5G) in the same band dynamically, based on user demand, which allows MNOs to smoothly adjust the capacity provided to one technology or another depending on the number of devices in an area requiring 5G at the time.
[78] We note that where 5G and 4G are sharing the same spectrum, 5G is currently accounting for less than 4% of the total traffic in these shared bands.

Individual MNOs are now providing 5G outside a significant portion of UK premises

This year, for the first time, we are reporting on the 5G coverage of individual operators across the UK, and in each of the four UK nations. As shown in Figure 3.4, Three has the most extensive 5G coverage outside of premises at the High Confidence level, reaching to 58%, whilst BT EE retains the most extensive 5G coverage outside premises at the Very High Confidence level, at 45%. We have noted above some of the potential differences between the 3 GHz and other spectrum bands, and Figure 3.4 also highlights the extent to which outdoor 5G coverage for each of the MNOs is available on the 3 GHz band, as an indication of where the greatest increases in bandwidth have been seen.

Figure 3.4: MNO 5G coverage outside of UK premises, at Very High and High Confidence



Source: Ofcom analysis of MNO predictions (September 2022).

Landmass coverage remains at much lower levels across the UK, with coverage ranging across individual MNOs from 6% to 16% of the landmass at High Confidence, and 3% to 12% at the Very High Confidence level.

We note that predicted coverage can differ substantially across the High to Very High Confidence levels, reflecting the greater signal strength required to meet the Very High Confidence of coverage measure. The fact that some MNOs see smaller reductions in coverage, and others larger reductions, is likely to reflect different deployment choices. For example, it could be affected by the balance between more dense urban and more rural deployments, and also the point at which different MNOs have planned to hand coverage from one site to another. It could also reflect the extent to which deployments are focussed on higher frequency airwaves, which travel shorter distances and so see a more rapid decline in signal strength.

Differences in deployment strategies are also reflected in different coverage levels across the UK nations. Currently, 5G coverage outside of premises in each UK Nation ranges across individual MNOs as follows: 42-61% for England; 29-51% for Scotland; 10-46% for Wales; and 14-26% for Northern Ireland (all based on our High Confidence level).

Overall premises coverage

Even as 5G coverage increases, voice and data services continue to be most widely available (and accessed) via older technologies. In particular the 4G services offered by each of the MNOs continues to provide the fundamental backbone of most consumers' experience. We therefore highlight below the range of 4G coverage available from individual MNOs, alongside measures for voice coverage (where 2G and 3G also play a role).[79]

Outdoor premises coverage remains at a high level

As we have reported in recent years, individual operators continue to provide good 4G coverage outside more than 99% of UK premises.[80] In addition, 98% 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, while 99% of UK premises also have coverage for outdoor voice calls from all MNOs.

There continues to be a significant difference between coverage in urban and rural areas. Individual operators' 4G coverage outside rural premises ranges from 93-98% (up from 93-97%), while each MNO continues to serve 99+% of urban premises. Outdoor voice coverage levels remain unchanged from 2021, and ranges from 97-99% across individual MNOs for rural premises, rising to 99+% across individual MNOs for urban premises.

Indoor coverage continues to be high and other solutions are available for hard to serve locations

There are a number of factors which affect the coverage people receive indoors. These include the thickness of the walls, the building materials used in construction, and where in a building people are using their phone.[81] As a result, some premises may see differences between operators' predicted indoor coverage data and the actual coverage experience.[82]

For indoor 4G coverage, this year we find that the percentage of premises served ranges from 92-95% across individual MNOs. This is a slight change since last year (up from 90-95% across individual MNOs in 2021). The availability of indoor voice calls is estimated to remain stable, ranging from 96-99%+ across individual MNOs, in line with 2021 levels.

We continue to see a significant difference between rural and urban areas for indoor coverage, though there have been small improvements this year. Individual MNOs provide indoor 4G coverage to 71-81% of premises in rural areas (up from 69-80% in 2021), compared with 96-98% of urban

[79] 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.
[80] By coverage outside a premises, we mean that 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.
[81] Ofcom's Mobile Coverage Checker provides information on the likelihood of there being indoor coverage in buildings at different locations and explains more about the factors that affect mobile signal indoors.
[82] Ofcom determines indoor coverage by applying an average building entry loss of 10dB across buildings. We acknowledge this approach provides only a simplified view of indoor coverage and that the real experience depends heavily on the types of building material and insulation in a specific building.

premises (up from 94-98% in 2021). Indoor voice coverage is somewhat higher, ranging from 80-98% across individual MNOs for rural premises (up from 80-96% in 2021). This compares to a range of 99-99%+ for urban premises (from 98-99% in 2021).

Where indoor coverage is poor or unreliable, there are other solutions which can improve user experience. These include broadband-based calls on services such as WhatsApp, femtocells and WiFi calling.[83] All MNOs offer WiFi calling to their customers – although not all mobile phones are configured to support this feature. The percentage of calls made using voice over WiFi by MNOs has remained largely stable this year, ranging between 2% and 17% across individual MNOs (compared with between 2% and 16% in 2021).[84]

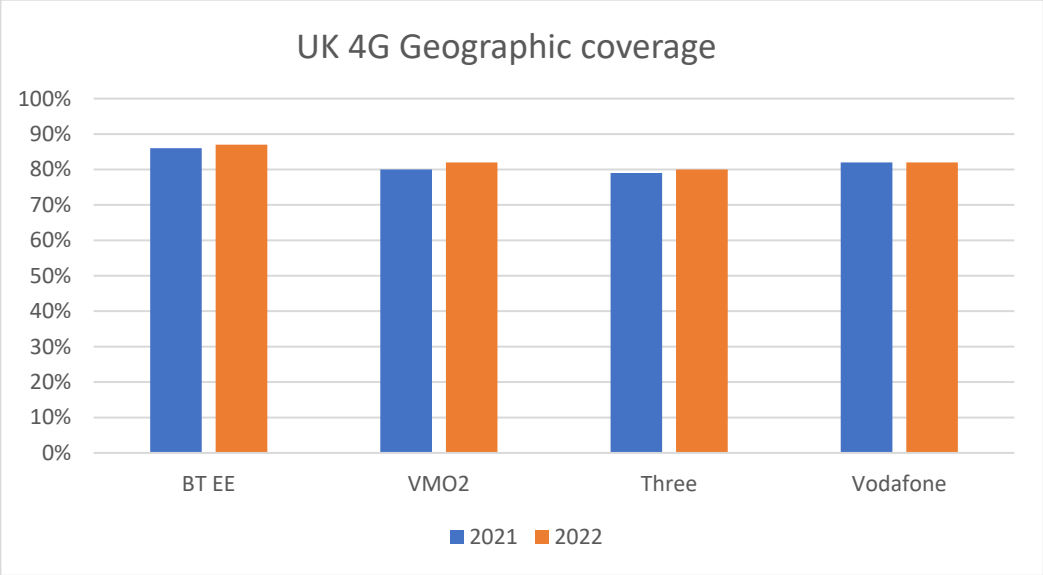
4G geographic coverage

The majority of operators have made small but notable improvements in their geographic coverage this year.

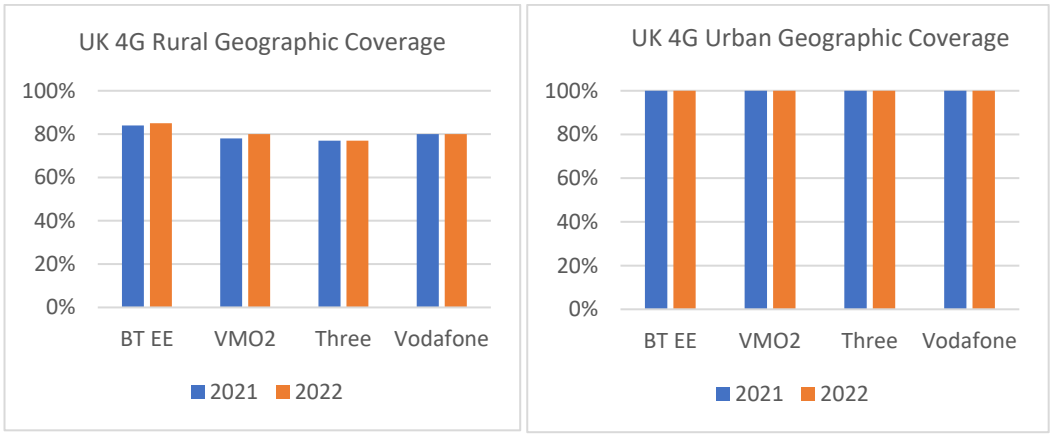
From the data reported to us, we can see that BT EE has increased its 4G geographic coverage by c1% to 87% of the UK; Virgin Media O2 has increased its coverage by c2% to 82%; and Three has increased its coverage by c1% to 80%.[85] Vodafone has also seen small incremental increases though its coverage remains statistically stable at 82%

Therefore, the UK landmass covered by individual MNOs ranges from 80-87% (up from 79-86% in 2021). As the majority of the UK landmass is rural, rural coverage levels are similar, with significantly higher urban geographic coverage.

Figure 3.5: UK geographic coverage, broken down by total UK, rural and urban geographic areas



[83] WiFi calling is the ability to make and receive a call and text/SMS over a WiFi network.
[84] There are two types of WiFi calling solutions: 'cellular preferred', where the devices use WiFi calling only if there is poor cellular coverage, and 'WiFi preferred' where all the calls are made via WiFi, when WiFi is available. The majority of MNOs currently use a cellular preferred solution.
[85] We note that over this period Virgin Media O2 has updated its coverage prediction model, so changes may reflect changes to that model as well as additional coverage deployments.

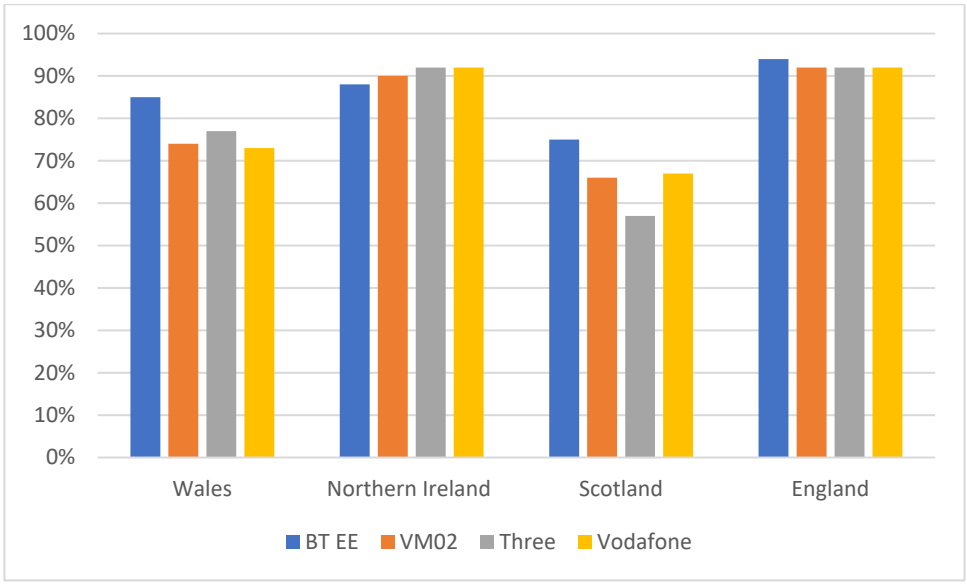


Source: Ofcom analysis of MNO predictions (September 2021 and 2022).

Differences remain in coverage across the UK Nations, but small improvements can be seen

There remain significant differences in geographic 4G coverage across the UK's nations. As of September 2022, MNOs provided geographic coverage ranging from 92-94% in England; 88-92% in Northern Ireland; 57-75% in Scotland; and 73-85% in Wales. This means that compared with 2021 the coverage range for England remains stable, with a 1 percentage point increase to the bottom end of the range in Northern Ireland, a 2 percentage point increase to the top of the range in Scotland, and 1 percentage point increases at both points of the range in Wales.

Figure 3.6: Differences in 4G geographic coverage in Wales, Northern Ireland, Scotland and England (2022)



Source: Ofcom analysis of MNO predictions (September 2022).

Public policy interventions, including the Shared Rural Network, continue to progress

The Shared Rural Network (SRN) was agreed between the UK Government and the MNOs in March 2020. Work has continued throughout 2022 on a range of fronts towards the delivery of the SRN, with operators' licence obligations to achieve good quality coverage across 88% of the landmass falling due in June 2024, and 90% of the landmass to be covered by January 2027. The UK Government also expects that as a result of this activity there will be good 4G coverage available across 95% of the UK landmass by the end of 2025 (based on the 'At least one MNO' measure).

Operators are committed to achieving the 88% target through their own investment, which includes a mixture of new site deployments, sharing and upgrades to existing infrastructure - and as noted above, we have seen statistically significant increases in coverage from 3 MNOs through the course of the year. MNOs have now deployed more than 150 new sites directly towards these SRN requirements (this excludes sites that were already planned at the time the SRN was announced, or built primarily to support the Emergency Services Network[86]). Many more sites have been upgraded. Taken together this activity has seen a small increase in the area where all MNOs now provide coverage. As a result of this activity, good mobile coverage from at least one MNO is now available across 92.2% of the UK, up from 91.9% in 2021.

Figure 3.7: Changes in partial and full coverage over time, and as represented in UK coverage today

	2019	2021	2022
Complete Not Spot	9%	8%	8%
Partial Coverage	25%	22%	22%
Full Coverage (All 4 MNOs)	66%	69%	70%

Source: Ofcom analysis of MNO predictions (September 2022).

On the publicly-funded side of the SRN, Digital Mobile Spectrum Limited is managing the programme and has continued to advance the required procurements which will underpin delivery of coverage in Total Not Spots.[87] Activity this year has included contracting for the acquisition, design and build

[86] The Emergency Services Network (ESN) is a UK Government programme to replace the current Airwave service, which is used by the emergency services in Great Britain, and will transmit voice, video and data across a 4G network. UK Government, Emergency Services Network: overview, 14 April 2022.

[87] Digital Mobile Spectrum Limited (DMSL) is a joint venture of all four mobile network operators which manages and runs the Shared Rural Network programme.

of the Total Not Spot sites and the managed services associated with this.[88] The sites delivered are expected to be shared by all 4 MNOs.

The process of enabling sharing of the Home Office Extended Area Service (EAS) masts is also progressing. Over 100 masts have been put into acquisition by Building Digital UK (BDUK) and are now with Home Office suppliers to start work. The number of sites acquired, built and then made available to MNOs will continue to grow into 2023. This includes the Home Office completing the passive build upgrades to around 28 sites by March 2023. This will be followed by a programme of works with the operators to activate commercial coverage. The arrangements which will enable the MNOs' access to these sites have been agreed and the first pilot site in Scotland is expected to be handed over to the MNOs for activation early next year.

This new coverage will sit alongside a range of other public policy interventions, including the Scottish Government's 4G infill programme, a £28.75m investment to tackle up to 55 Total Not Spots across rural Scotland. As of September 2022, 29 new mast sites had been activated, including in communities across the Highlands, Orkney and Aberdeenshire.[89]

Roads

4G coverage is predicted to be available inside vehicles on motorways and A roads in a range across individual MNOs between 83-88%. This falls to 73-79% for B roads (but with a 1 percentage point increase from H3G and 2 percentage point increase from BT EE within this). Outside vehicles, 4G coverage on motorways and A roads ranges between 94-98% across individual MNOs for (up 1 percentage point at the bottom of the range), and between 89-95% for B roads (up 1 percentage point at the top end).

In-vehicle mobile voice services on motorways and A roads range between 91-98% across individual MNOs (up 1 percentage point at both ends of the range). This falls to 80-94% of B roads (with a 3 percentage point increase at the top end of the range). Voice call coverage outside vehicles on motorways and A roads remains stable, ranging from 98-99% across individual MNOs, with voice calls outside vehicles on B roads ranging from of 94-98% across individual MNOs.

Rail

In 2019, we undertook a measurement campaign in partnership with Network Rail to gain a better understanding of the mobile signal on train lines.[90] This showed that, while predicted coverage may be present in the surrounding area, this often does not translate into a good experience on the ground, given the challenges for mobile signals reaching into railway cuttings and inside carriages themselves.

[88] Digital Mobile Spectrum Limited, https://srn.org.uk/shared-rural-network-publishes-contract-award-notices/, 8 July 2022.
[89] Scottish Government, Scottish 4G infill programme: progress update, 23 November 2022.
[90] Ofcom, Mobile signal strength measurement data from Network Rail's engineering trains.

In last year's report, we noted that solutions to these challenges will often require track-side access, and so are not something that MNOs can easily pursue on their own. Over the last year, there have been a number of developments around this approach.

Case study: Trackside Infrastructure Partnerships

One such solution is a project being led by Evo Rail, on behalf of South Western Trains and in partnership with Network Rail, which is installing new telecoms infrastructure along 70km of track between Basingstoke and London. It aims to deliver gigabit-capable connectivity and an enhanced onboard WiFi experience, and with much infrastructure now deployed is expected to offer services from early 2023.[91]

Throughout this year Network Rail has also been inviting companies to invest in upgrading its rail telecoms network in return for the right to commercialise spare capacity that might support improved services for consumers.[92] Network Rail uses its network for signalling, CCTV and internet for trains, depots and offices. In May 2022, it was reported that two groups – Neos Networks (bidding alongside Cellnex) and Virgin Media (bidding alongside Nokia and Jacobs) would be proceeding to bid in the auction.[93]

A significant development we highlighted in last year's report was Transport for London's 20-year concession partnership with BAI Communications to enable mobile coverage on the Tube network, including within the tunnels, by the end of 2024. This initiative uses a neutral host-led model.[94] This year has seen further progress, with the permanent enablement of mobile services on part of the Jubilee Line, and confirmation that all 4 UK MNOs will offer services to their customers as part of the solution.[95]

2G and 3G coverage, and switch-off

Plans for switch-off of 3G networks, and eventually 2G networks, are progressing

In December 2021, the MNOs confirmed to the UK Government that they do not intend to offer services on their 2G and 3G networks past 2033 at the latest.[96] 2G and 3G services launched in the 1990s and 2000s respectively, and running these networks alongside newer 4G and 5G services involves increased operating costs, as well as a less efficient use of spectrum and energy. Moving

[91] Evo-rail, evo-rail, South Western Railway, and Network Rail bringing new superfast Wi-Fi to train passengers, 25 October 2022.
[92] Network Rail, Network Rail invites £1bn private sector investment in telecoms, 26 April 2021.
[93] ISPreview, Neos and Virgin Media to Bid on British Rail's Trackside Cables, 10 May 2022. The Daily Telegraph, Privatisation plan to give commuters faster internet, 10 May 2022.
[94] BAI Communications, Mobile connectivity on the eastern section of the Jubilee Line made permanent, as BAI Communications completes first milestone of its rollout, 7 April 2022.
[95] BAI Communications, Customers of all major networks set to have access to high-speed mobile coverage across London Tube network, 8 July 2022.
[96] UK Government, 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 Diversification Strategy, 8 December 2021.

away from these older technologies will improve network efficiency and enable more spectrum to be used for 4G and 5G services.

MNOs are developing plans to switch-off their 3G networks first, with each MNO setting its own timetable. Vodafone is starting the switch off of its 3G network in early 2023, and has been contacting affected customers to advise them of the steps they need to take ahead of switch-off to ensure that their services are not disrupted. EE plans to start its 3G switch-off in early 2024, and Three expects to complete its switch-off by the end of 2024. Virgin Media O2 has yet to confirm a planned date for switch-off of its 3G network.

Vodafone, EE and Virgin Media O2 have not yet confirmed a date for switching off their 2G networks. We expect they will start making plans for this after their 3G network switch-offs are complete.

There are a range of users whose needs will require careful management

Ofcom is actively monitoring the implementation of switch-off and working closely with the MNOs to understand their progress and plans, in particular to ensure that affected customers and services are adequately informed. Early next year we plan to publish a document setting out our expectations of mobile providers as they implement switch-off, in particular the measures they should be taking to ensure that customers are protected and disruption is minimised.[97]

Based on the latest estimates from MNOs, there are likely to be nearly 5.5m[98] customers using devices reliant on 2G and 3G connectivity which will ultimately need to be upgraded or replaced.[99] Some customers will continue to be able to use these devices after 3G switch-off as they can carry on using the 2G network for voice calls in particular.[100]

In addition to mobile handsets, affected devices include those that offer machine-to-machine and Internet of Things (IoT) type applications, such as care alarms, security alarms and payment terminals. Many of these rely on roaming SIMs (non-UK SIMs which are used on a permanent basis in the UK and which roam to the best available network), where there may not be a direct relationship with a UK MNO and so will not be captured by the total device estimate above. Given this, raising awareness of upcoming switch-offs across all affected stakeholders will be essential. As part of our monitoring activity, we are engaging with government and other relevant stakeholders, such as service providers and equipment manufacturers, to help support a smooth transition.

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[97] Ofcom, Switching off the UK's 3G mobile networks: what you need to know, 3 August 2022.
[98] This number excludes 2G/3G Smart Meter devices supported by Virgin Media O2 in the southern half of England.
[99] Last year we reported an estimate of c.4m devices relying on 2G and 3G connectivity. This was an under-estimate and we consider the updated estimate this year is more accurate for a number of reasons, including: (i) MNOs have now undertaken a more detailed analysis to identify all the potentially affected devices; (ii) it now includes some devices that are 4G capable but not VoLTE-enabled and which are outside of the period of handset support for the software upgrades needed to enable VoLTE (therefore these devices will continue to be reliant on the 2G/3G network to make voice calls); and (iii) it also includes estimates relating to machine to machine devices reliant on 2G/3G – some MNOs did not include these in the figures reported last year. We are continuing to monitor this with MNOs and expect to see the overall number of devices decrease next year as more customers upgrade and update their devices ahead of upcoming 3G switch-offs.
[100] Three does not have a 2G network, so the network will not be able to offer native circuit switched calling once it switches off its 3G network, though roaming based solutions for emergency calling will still operate where other networks are present.

There is still a relatively significant level of ongoing 2G and 3G usage, particularly for voice traffic

The proportion of data traffic being carried over each MNO's 3G network is now relatively small, ranging from 2%-6%. In comparison, there is a higher proportion of voice traffic still using the 3G network, although the proportion varies significantly between the MNOs, with one MNO reporting 60% of its voice traffic using 3G, whereas for two other MNOs it is less than 15%. We would expect these percentages to decrease significantly over the coming years as 3G network switch-offs start being implemented and more customers upgrade and update their devices.

A much smaller proportion of MNOs' voice traffic is currently carried over 2G (around 4-5% for each MNO), although these percentages may rise as 3G networks switch-off. We expect MNOs to have plans in place to ensure their 2G networks have sufficient capacity so that customers do not experience degraded quality of voice calls once 3G networks are switched-off.

Our data has not yet shown a change in the levels of 2G or 3G coverage available across the UK, however we expect we will start to see a decline in 3G coverage levels from next year as the MNOs start to progress their plans. We will monitor this closely but envisage that any impact on coverage will be negligible, given MNOs are taking steps to ensure that their 4G coverage is improved ahead of switch-off, particularly in any areas which might be reliant on 3G currently. Three, for example, has committed that by the time 3G switch-off happens, it will have updated its 3G sites to 4G as a minimum, or ensured that coverage is provided from neighbouring sites. [101]

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

As we explain in Section 2, traditional landline services are being retired. Fixed voice services will in future be delivered over broadband connections instead. However, if there is a power cut, voice over broadband connections will not work where back up power is not provided. [102] Some broadband providers are using mobile to provide back up services in such situations. Where this is the case, it is increasingly important that people have indoor mobile coverage so that they can make emergency calls in the event of a localised power cut.

Longstanding arrangements mean that when making an emergency call, a mobile handset will be able to use any network that is available, even if it is not the network the handset user subscribes to.

Calls can currently be made over 2G, 3G and 4G (via VoLTE) and we predict that emergency calls are possible inside almost all UK premises and across 96% of the UK's landmass. [103]

On roads, emergency calls should be possible inside vehicles for around 99% of motorways and A roads, and 97% of B roads outdoors (up 1% on B roads from last year).

Emergency calling via 4G VoLTE, and the ability to roam onto another network using VoLTE, will become more important as 2G and 3G networks start being switched off by MNOs. As of June 2022, two of the UK's four MNOs were offering emergency calling via VoLTE (the same as in 2021). The

[101] Three, Our plans to switch off 3G.
[102] We explain this further in the Network Security and Resilience section of this report.
[103] VoLTE means voice over long term evolution on 4G.

number of emergency calls made via VoLTE on these networks was in the range of 243,000-756,000 in June 2022.[104] The two other MNOs expect to introduce emergency calling via VoLTE within the next few months. All MNOs will need to have implemented emergency calling over VoLTE, and the ability to roam onto another network using VoLTE for these calls, ahead of switching off their 2G networks (or 3G network in the case of Three).[105]

Developing insights into the quality of mobile network performance

While coverage is a prerequisite for connectivity, the quality of mobile connectivity is becoming increasingly important as services used by consumers become more demanding, and play an ever more important role in people's lives.

Network quality can differ between different mobile operators and technologies across different areas, due to both supply and demand factors. The supply is largely driven by network capacity and is affected by aspects such as the density of cell sites, the amount of spectrum deployed, and the technologies used. Demand is affected by the number of users on the network, the location of those users, and the impact of the applications they use.

We noted in our 2021 report our intention to develop new approaches to report in more detail on the quality of performance possible in different areas, particularly given the potential for different technologies to provide similar performance levels, and the range of experiences that are possible even while accessing a single technology (as touched on in our 5G coverage update above). We have explored a range of approaches to capture this experience and further inform consumers, and set out our initial approach and findings below, based on crowdsourced data.

Crowdsourcing can give a real-world view of network performance

Crowdsourcing is an approach that gathers network performance measurements from the user experience perspective, over many different devices, to build up a view of the network quality in an area. No single approach is likely to provide a perfect view of what mobile networks are capable of delivering, but we consider that data gathered in this way – via automated network tests – can provide meaningful insights into network quality. We have used performance data from an Opensignal dataset (which conducts such active background testing to measure network capability) to provide an initial view, which we will develop in the months ahead.[106]

To provide a view of overall performance, this approach combines measures for download speed, upload speed, latency, packet loss, jitter and time to first byte.[107] We then analysed results across a range of thresholds, to provide insight into where different performance levels are available.[108] We

[104] This year, we have not been able to calculate a total figure for emergency calls via VoLTE as one of the operators providing emergency calls via VoLTE has not been able to split the volumes of VoLTE and non-VoLTE emergency calls.
[105] Three already supports emergency calling via VoLTE.
[106] Active background testing conducts tests from the device across the MNO's network without needing user initiation.
[107] For more detail on these measures and their application see Annex 2 on Mobile Performance.
[108] A performance level is deemed as likely to be experienced if 80% of all measurement samples meet or exceed the relevant thresholds.

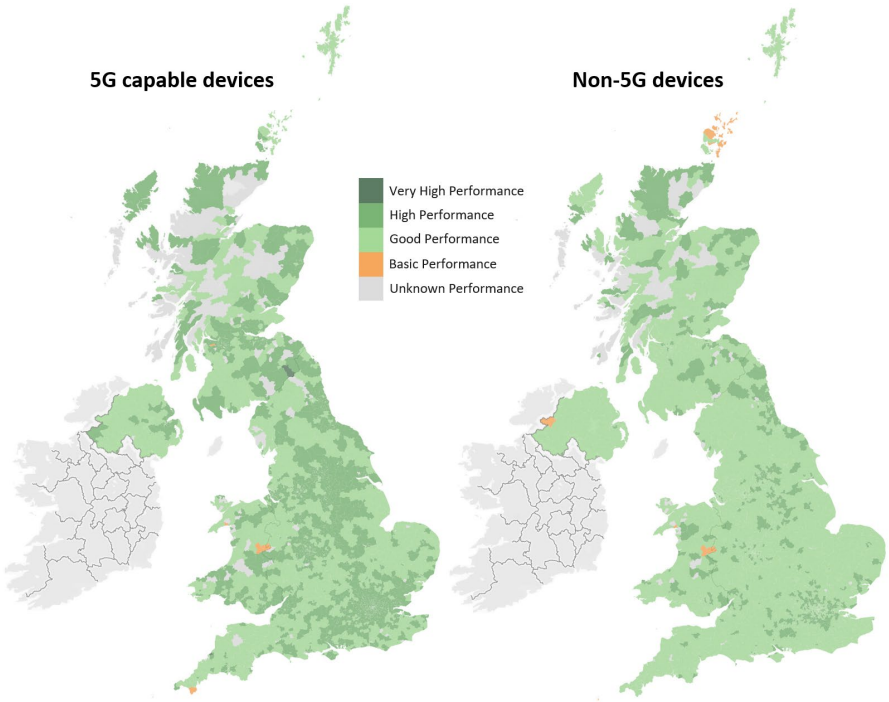
present this data using initial levels, but expect these levels may change over time as we develop our approach, and as we take account of how consumer expectations and service requirements change.[109] The thresholds used for this analysis are set out below, and a fuller explanation of this approach can be found in Annex 2 on Mobile Performance.

Table 3.8: Performance Key Performance Indicator technical thresholds

	Download speed	*Upload speed*	*Latency*	*Jitter*	*Packet loss*	*Time to first byte*
Good	*2 Mbps*	*0.5 Mbps*	*100ms*	*20ms*	*4%*	*1.2s*
High	*5 Mbps*	*1 Mbps*	*50ms*	*15ms*	*2%*	*0.8s*
Very high	*10 Mbps*	*2 Mbps*	*30ms*	*10ms*	*1%*	*0.5s*

For this year's report, we are providing an overview of the network quality provided in postcode district areas[110] based on composite data for all MNOs, showing the differences in experience that can be expected for those with a 5G capable device (whether connected to a 5G or 4G network) and those with a 4G device. The colours denote the performance that a device in each area can typically expect to experience (where there is coverage available). The maps do not confirm that coverage is available in the whole of each postcode district, but rather that sufficient samples were recorded within the postcode district as a whole.

Figure 3.9: Combined MNO performance for 5G-capable devices (left) and non-5G devices (right)



5G-capable devices may not always be connected to 5G and will also report results from areas where only 4G is available.

Source: Ofcom analysis of Opensignal data. Based on data provided by Opensignal, provided under a CC BY-SA 4.0 (Creative Commons) licence. Data may not be used for any commercial purpose.

[109] The Key Performance Indicator thresholds we use here are our own and are not those of Opensignal.
[110] Postcode district means a geographical area indicated by the (alphabetical) letters and numbers in a postcode preceding the space in the code e.g. SE1.

As can be seen, many more areas achieve a 'high performance' level where a consumer device is capable of accessing a 5G service, reflecting the impact of the newer technology and some of the capacity increases described above – although we note that even here, few areas meet the highest performance level. Areas of 'unknown performance' may well have coverage, but there were insufficient data samples for us to be confident of a meaningful result – and consequently we find slightly more areas of unknown performance for the smaller sample of 5G devices.[111]

In the coming months, we intend to make further information available to consumers based on this approach. This will include providing additional information on the performance of each MNO, and a more localised view of network performance via our coverage checker. This will enable the reported quality of mobile network performance across a local area to be accessed on a lookup basis, and compared between providers.

As noted above, we recognise that no single tool is likely to provide a complete view of mobile network performance that distinguishes all influencing factors. For example, this approach does not currently enable us to provide insights across the entirety of UK, given the limited samples available in the many rural areas. It also aggregates samples from different device locations at the time of the test (e.g. whether a device was indoors or outdoors) and whether the test was conducted at a very busy period or not, such that additional, more granular insight may be possible over time. We will consider whether and how our approach can be refined as we make greater use of crowdsourced data in the future.

Mobile traffic

Mobile traffic grows significantly, with 5G traffic growing most quickly

As a result of the increased coverage and take up of 5G described above, 5G traffic has grown substantially over the last year, more than trebling from 17 PB in 2021 to 63 PB in 2022.[112] This means that 5G now represents over 9% of the total mobile traffic, up from 3% in 2021.

The increasing share of traffic carried over 5G has the potential to be more energy efficient than use of previous technologies, when defined on a bits per Joule basis. This is because of changes in the air interface from 4G and 3G technologies, and can be further enhanced by application of sleep modes - enabling base stations to be put to sleep for longer periods of time when experiencing low traffic loads - and a capability to reduce transmission power levels during off-peak periods.[113]

While 5G traffic has increased rapidly, growth in mobile traffic as a whole has been slower, though absolute growth remains significant. Total monthly traffic has risen from 570 PB to 724 PB, an

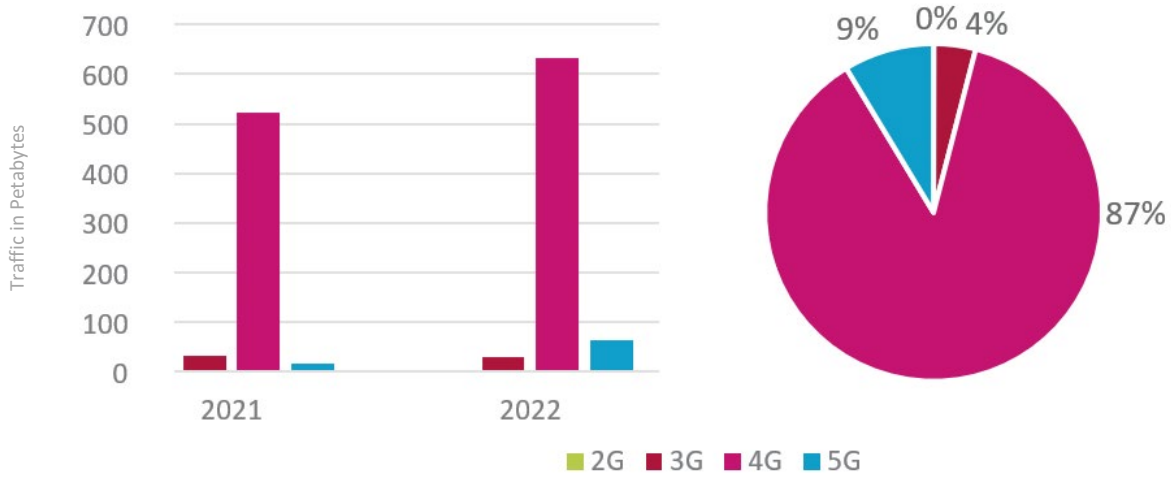
[111] This data comes from many different types of mobile devices, in different areas, in different locations (both indoor and outdoor) and at different times. To reduce any risk of biases in results where sample sizes are too low, we are only showing a view of performance where we have a good supply of data in a given area. A minimum of 100 different full measurements, a minimum of 15 different types of device, and a maximum margin of error of 10%. This is set out in more detail in Annex 2 on Mobile Performance.

[112] 1 PB is equivalent to 1,000,000 GB.

[113] It is important to note that despite this improvement in energy efficiency, we anticipate the total energy consumption of the mobile networks may continue to rise in the coming years, given increases in the volume of mobile data traffic being generated by consumer demand can exceed efficiency gains.

annual growth of c27%, compared to a c37% increase in 2021. This aligns with other reports on mobile traffic internationally over the last year, but it is too early to ascertain if it represents a trend, especially noting the variations between MNOs within this.[114] Possible explanations might include changes to population mobility (where more home-working might increase offload onto the fixed networks), or limitations on consumer demand (e.g. increased price sensitivity, or natural limits on data demands). We will continue to report on these traffic levels in future years to allow any long-term changes to be observed.

Figure 3.10: Total monthly traffic by technology (2021-2022) and percentage share (2022)



Source: Ofcom analysis of operator data (May 2021, May 2022).

In December 2021, the UK Government confirmed a target for 35% of mobile traffic to be carried over 'Open RAN' by 2030.[115] Such open architectures promise to offer additional resilience through the disaggregation of radio equipment suppliers. As of this period, Open RAN has been deployed on only a small number of sites (fewer than 20) with minimal mobile traffic carried over such architectures. We note that we are still at an early stage in the commercialisation of Open RAN, with the UK Government announcing a £250m Open Networks Research Fund this summer, and we will continue to monitor progress in the years ahead.[116]

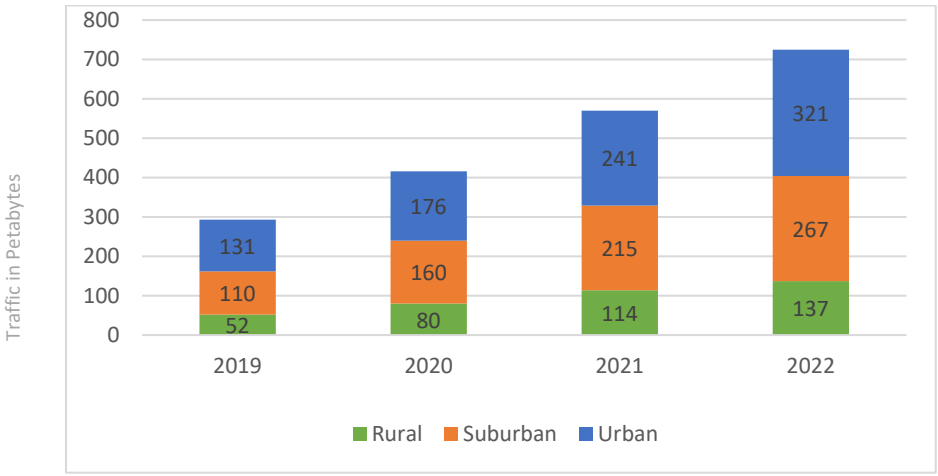
Distribution of mobile data traffic

In 2022, urban areas have seen mobile traffic growth higher than the average 27%, with a 33% year on year growth. Increases have also been seen in more rural and suburban locations, but are less pronounced, at 20% and 24% respectively. Conversely, we had seen slightly greater than average data growth in rural areas over the preceding years. This change may in part reflect population shifts back to urban areas as Covid-19-related public health restrictions were lifted. We note that the spread of data traffic continues to broadly reflects the population distribution, with the rural

[114] For example, see Tefficient's report on international trends in mobile data traffic. Tefficient, Further slowdown in data usage growth causes positive ARPU development to soften, 25 November 2022.
[115] Minister for Media, Data and Digital Infrastructure, Telecoms Diversification: Update Against Taskforce Recommendations, 8 December 2021.
[116] UK Government, Open Networks Research and Development Fund, 29 July 2022.

classification representing approximately 19% of all traffic, and a similar amount of the population.[117]

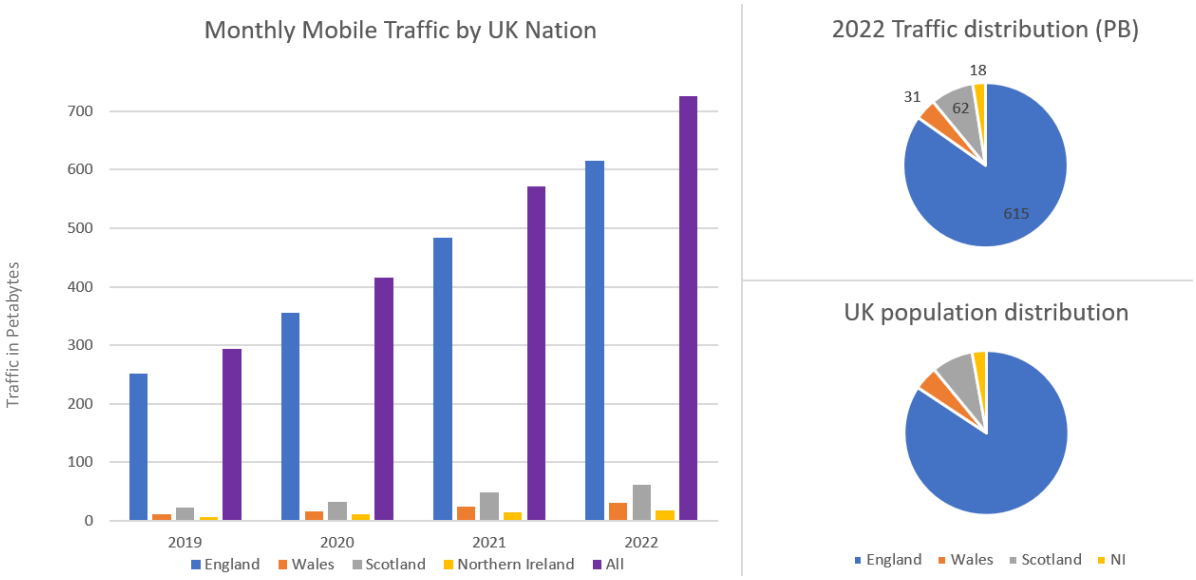
Figure 3.11: Total monthly mobile data traffic in rural, suburban and urban areas (2019-2022)



Source: Ofcom analysis of operator data (May 2019, June 2020, May 2021, May 2022).

Mobile traffic in the UK grew fastest in Scotland, with year-on-year growth of 29%, while Northern Ireland displayed the least growth at c20%. However, traffic in the UK continues to be distributed broadly in line with national populations.

Figure 3.12: Total monthly mobile data traffic by UK Nation (2019-2022)



Source: Ofcom analysis of operator data (May 2019, June 2020, May 2021, May 2022).

We note that this analysis includes the impact of all traffic across mobile networks, and therefore includes traffic generated by Fixed Wireless Access, where operators are offering domestic fixed

[117] The rural population of England, Scotland and Wales is estimated to be between 17-20%, with the rural population in Northern Ireland somewhat higher. UK Government, Rural population and migration, 28 October 2021. Scottish Government, Rural Scotland Key Facts 2021, 24 February 2021 Welsh Government, A Statistical Focus on Rural Wales, 2008. Northern Ireland Executive, Key Rural Issues: Northern Ireland 2021.

broadband services over their wireless networks. Where MNOs offer such a service, we estimate that on average it accounts for 13% of all traffic, with significant variation around this average.

Investment in mobile telecoms infrastructure

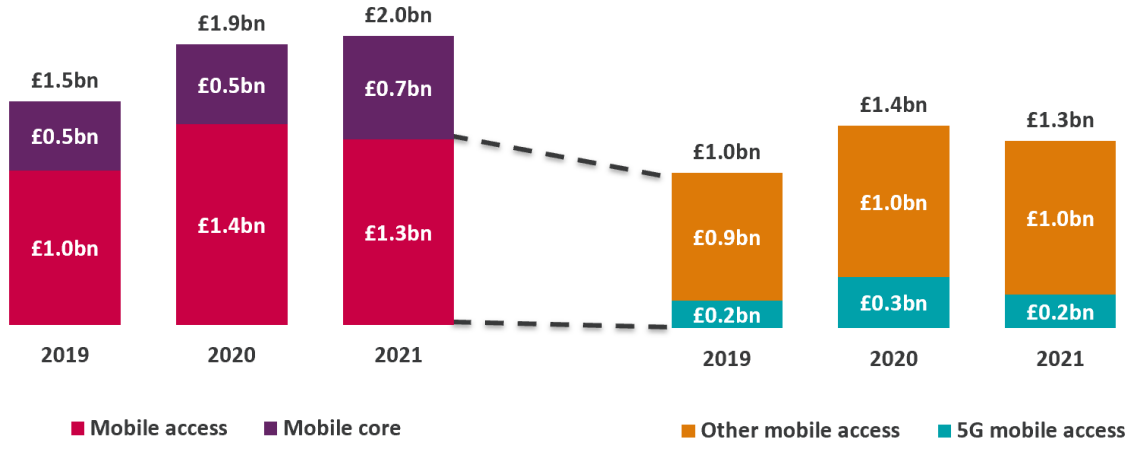
Expenditure on mobile telecoms network infrastructure increased to £2.0bn in 2021

The extent and quality of mobile coverage is influenced by investment in network infrastructure. Data collected from operators shows that £2.0bn was invested in UK mobile network infrastructure in 2021, a £0.1bn (3%) year-on-year real-term increase. In addition to this, £0.6bn was invested in infrastructure that is used to provide both fixed and mobile telecoms services in 2021.[118]

Of the total mobile investment, £1.3bn (64% of the total) was investment in mobile access network infrastructure (including site acquisition, equipment and electronics). This was down by £0.1bn (7%) compared to 2020. The remaining £0.7bn was spent on mobile core and backhaul networks.

All four mobile network operators continued to deploy 5G network infrastructure in 2021, when investment in 5G access networks totaled over £220m. This represented a fall of more than £110m (34%) compared to 2020. We note that this investment data lags behind some of the coverage gains we are reporting this year.

Figure 3.13: Mobile telecoms network capital expenditure: 2019 – 2021



Source: Ofcom analysis of operator data. Note: Adjusted for CPI (2021 prices).

Network infrastructure is provided by an evolving set of players

While MNO investment in infrastructure underpins much of the coverage and services we report on here, a range of third-party players also invest in and provide access to infrastructure which supports the public network. This ranges from remote rural lattice masts to sites on urban rooftops, and small

[118] We note that in our December 2022 *Future Approach to Mobile Markets and Spectrum – Conclusions Paper* we reported a higher figure for capital investments. That figure includes a range of non-network costs, including investment in property and non-network ICT systems upgrades.

cells on street furniture to indoor coverage solutions. As part of this, we are beginning to see the emergence of new 'neutral host' models to provide mobile coverage and capacity in busy locations – often indoors, where a majority of mobile traffic is generated. [119] Services such as WiFi also play an important role in picking up and supporting consumer demand for data generated over mobile handsets. [120] And there is the potential for this diversity of provision to grow in the future, with some satellite operators indicating that they expect to be able to support a limited set of mobile services (such as voice and text) on consumer mobile handsets in the future. [121]

In the UK, we estimate that just under 11,000 mobile sites are provided by third party providers, covering everything from macro cells, to street furniture, to small cell deployments indoors. [122] Of these, 82% are located in England, 11.5% in Scotland, 5% in Wales and 1.5% in Northern Ireland. A majority of sites host only 1 MNO, while fewer than 10% of sites host 3 or 4 MNOs.

Approximately 83% of such sites are macro tower structures, whilst 14% of these third party sites are based on street furniture deployments, typically on lampposts, bus shelters, traffic signals or CCTV poles. The vast majority of such street furniture sites currently support single MNOs. This may reflect load bearing limitations of the physical asset, or that some of these deployments are filling in small coverage and capacity gaps specific to a particular MNO.

The emerging picture for indoor solutions looks somewhat different. Deployment is at a relatively early stage and as of today accounts for only around 3-5% of the total third party deployments. [123] However, there are a number of additional players increasingly active in this space, as well as work amongst the operators to develop refined standards for neutral host in-building (NHIB) solutions. [124] Some approaches, such as BAI's London Underground deployment and Freshwave's provisioning of 22 Bishopsgate in London, build on existing Distributed Antenna Systems approaches, while Freshwave has also recently announced a partnership with Three to roll-out the newly specified NHIB small cells. [125] We find that almost half of third party indoor deployments are supporting 3 or 4 MNOs at the same time, indicating that there may be potentially greater synergies between different MNOs' coverage and capacity challenges indoors, and a potential for efficiently addressing these challenges through such shared mechanisms. We will continue to monitor these developments over the coming years to further understand these trends as the model matures.

[119] Estimates for mobile traffic generated indoors range up to 80% (Cisco Vision 5G) though have been shown to vary substantially by location (Ericsson, Planning indoor 5G coverage).
[120] Developments such as Wi-Fi Passpoint may facilitate seamless access, to increasingly enable MNOs to offload mobile traffic. Wi-Fi, Passpoint.
[121] T-Mobile, T-Mobile Takes Coverage Above and Beyond With SpaceX, 25 August 2022.
[122] This figure is based on responses from the following organisations: BAI communications, Britannia Towers, Cellnex, Freshwave and Wireless Infrastructure group. It excludes sites provided by CTIL and MBNL.
[123] This range encompasses differences in responses we have received from neutral host infrastructure providers and the MNOs.
[124] Recent developments include the development of a neutral host in building joint operator technical specification.
[125] Freshwave, Three UK partners with Freshwave on the operator's first JOTS Neutral Host In-Building mobile deployments, 20 September 2022.

Business Connectivity and IoT

5G and private networks

Mobile services are not only provided for the general public, they can also support business connectivity and device to device services as well. Private networks are playing an increasing role in the mobile market, with their ability to provide tailored connectivity solutions and meet stringent quality of service requirements. Taking advantage of the added capabilities of 5G, including its potential for ultra-low latency, they can provide monitoring of products and devices and real time connectivity between manufacturing equipment. Such networks are now playing a role in supporting the digital transformation of many sectors of the economy, from ports to airports, and from factories to smart agriculture.

As we noted last year, non-mobile operator players are now able to access mobile spectrum to provide services across localised areas of the country – authorisations are provided either for single base stations at a medium power level, or multiple lower power base stations authorised within a 50m radius.

Ofcom has issued around 900 shared access licences since new rules were introduced in 2019, up from the 550 we reported in 2021.[126] We continue to estimate that around half of this increased number can be considered as supporting private network type solutions. Around 91% of shared access licences are found in England, 4.5% in Wales, 3.5% in Scotland and 1% in Northern Ireland.

We have also seen evidence of increased MNO activity developing these solutions. Last year, we reported that only 7 MNO-led private networks were live in the UK. This year, that figure has risen to 26. These networks operate using 4G, 5G or a combination of 4G and 5G technologies, noting that none are currently delivered as a slice of the commercially deployed 5G network.

Internet of Things

The Internet of Things (IoT) refers to a network of devices and sensors which are capable of collecting and sharing data with people or with other devices, and taking action based on this information. IoT and Machine-to-Machine (M2M) networks support a range of uses. These include: connecting smart meters for utilities[127]; travel and transport; environmental sensors and energy management solutions for smart buildings; car telemetry; video surveillance; and pipeline monitoring for oil and gas companies.[128]

[126] Including legacy licences, there are over 1,600 active licences in the shared access bands.
[127] Arqiva Limited provides radio communications links between smart meters and energy suppliers in Scotland and the north of England. O2 provides the radio links in the rest of England and Wales.
[128] 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.

IoT connectivity available from Mobile Network Operators

IoT connectivity is delivered by both MNOs and other non-MNO players, often operating in a specific local area. MNOs use a mix of cellular technologies (2G, 3G, 4G and 5G) and Low Power Wide Area Networks (LPWANs) such as NB-IoT and LTE-M.

This year, the number of active IoT connections on MNO networks stands at just above 19 million.[129] While these connections typically generate much lower data volumes than consumer handsets, IoT traffic volumes continue to increase significantly up by 20% in the last year to 1.51 PB per month (from 1.26 PB last year). However, such volumes remain significantly less than 1% of overall data traffic.

IoT connectivity available from non-mobile network operators

Non-MNO players operate both private IoT networks and public community networks.

Public community LoRaWAN networks are open-source and generally free to use. Users can connect their devices to gateways (base stations) or add new gateways to extend coverage.[130] Public community networks support developers, small and medium-sized businesses, government and other public policy initiatives. The Things Network, a global provider of public LoRaWANs, currently has about 855 gateways in the UK serving 105 communities (a small increase in the total communities served from last year, whilst decreasing the total gateways they report in operation).[131]

Private networks offer carrier-grade services with guaranteed availability, for a charge. Several private LoRaWAN providers operate in the UK. These include Comms 365, Connexin, The Things Industries and North SV Limited. We estimate that these networks have at least 746 gateways (an increase from at least 580 gateways last year), between them serving about 100,000 devices (up from about 37,000 devices last year). 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 is playing a growing role across a range of services

The increase in IoT devices and traffic this year suggests that businesses are increasingly using the services IoT can deliver. One such benefit can be the capacity for IoT applications to support businesses in their sustainability goals. For example, they can enable businesses to reduce the need for travel, reducing their carbon footprint. Smart technology in cities – for example smart lights, smart bins and traffic management systems – can also help to drive the more efficient use of resources and infrastructure.

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[129] We note that we have made a methodological change to the information we now request from operators since we reported c10 million active connections in 2021. Based on information provided in 2021 and 2022 we consider that year on year active connections are broadly static.

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

[131] The Things Network, United Kingdom.

As noted above, the ongoing PSTN switch-off planned for completion in 2025, and 2G and 3G switch-off planned by the end of 2033, can have implications for a range of sectors, and for residential and business customers. IoT can also play a supporting role here, enabling future solutions and innovations in services such as security systems, telecare and utility network monitoring.

4. Network security and resilience

Introduction

The resilience and reliability of networks is critical. We rely on our connections at work, at home and on the move. Strong, secure networks that are resilient to outages and cyber-attacks are therefore essential. In this section we provide an update on new requirements for operators to implement network security measures and how we will be reporting on compliance in future. We also provide an update on how the storms last winter affected communications services, as well as an overview of the network and resilience incidents reported to us during the year. Finally, we also report on other developments in our network resilience work.

Highlights

- The new Telecoms (Security) Act 2021 came into force on 1 October. It revised the legislative requirements for providers to report the incidents which form the basis for much of this chapter. It also introduced new requirements, focussing particularly on cyber security. Our monitoring of compliance with the Act will be used for our security reporting in future Connected Nations publications.
- The storms last winter had a significant impact on communications services. This was primarily because of lengthy power outages which caused communications services to become unavailable in impacted areas; for several days in some cases.
- The recovery process following the storms (particularly after Storm Arwen) took longer than expected due to the volume and scale of these power outages. This has highlighted the need for better co-ordination and information sharing between the communication and energy sectors. Improvements have already been made to these processes.
- We are continuing to work with industry and UK Government to act on lessons learnt and help ensure improved resilience in future.
- There was a significant increase in the number of network and resilience issues reported to us this year, particularly for mobile where the total number of incidents doubled. One cause of this was the impact of the winter storms.

Security

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

In October 2022, the remaining provisions of the Telecoms (Security) Act 2021 (the "TSA"), as well as the accompanying Regulations[132], came into force. The TSA replaces section 105A-D of the Communications Act 2003. These are the provisions which, amongst other things, require providers

[132] UK Government, The Electronic Communications (Security Measures) Regulations 2022.

to report incidents to us, and it is these reports which form much of the basis for this chapter of the report.

We do not expect the reporting of resilience-related incidents to change significantly as a result of the TSA, as in this sense the new provisions are similar to the previous ones. However, the TSA does add a particular focus on the reporting of cyber security compromises, so we expect more reports on these in the future. It also adds requirements for us to report on the extent to which providers of public UK networks and services are complying with their duties under sections 105A-D[133]. We will be fulfilling this requirement in this section of Connected Nations.

As the new obligations only entered into force in October 2022, we do not, at the time of publication of this report, yet have information on compliance with them. We will instead explain our intended approach to building the knowledge on which we will base our future reports. We preface this with a brief introduction to the DCMS Telecommunications Security Code of Practice, which will play an important role in this work.[134]

DCMS Telecommunication Security Code of Practice

The intention of the TSA is to drive a change in the approach to security in the telecoms sector. Alongside the TSA itself, the Regulations do this by imposing a much more detailed set of security requirements than we have had in the past. However, translating these requirements into practical security measures that a provider should take in order to best achieve them, is challenging. To assist with this, DCMS has published the Telecommunication Security Code of Practice (the "Code"). This contains detailed technical guidance for large and medium-sized providers on the UK Government's preferred approach to demonstrating compliance with the requirements. Although the Code is not itself legally binding, we are required to take its content into account in determining whether a provider has met its legal obligations.

Our plans for monitoring compliance

We consulted on two draft documents related to the TSA earlier this year. One, known as our "procedural guidance"[135], covers our general approach to the exercise of our functions under the TSA, including the detail of how we will be monitoring compliance. The other, our "resilience guidance", focuses on how we expect providers to meet their requirements in relation to the network and service resilience aspects of the TSA. We have recently published the final versions of these documents.[136]

Demonstrating full compliance with the TSA will be a longer term journey. The Regulations and the Code are complex and for some providers will require significant changes in how networks and services are currently designed and secured. As such, the Code sets out timescales by which it is

[133] See s134A in combination with s134B(1)(ha) and s134B(2)(fa) Communications Act 2003.
[134] DCMS, Telecommunications Code of Practice, December 2022.
[135] Under section 105Y of the Communications Act 2003, as amended by the Telecommunications (Security) Act 2021, Ofcom has a duty to publish a statement of our general policy with respect to the exercise of our functions under sections 105I and 105M to 105V of the Communications Act 2003 Act.
[136] Ofcom, Guidance on resilience requirements imposed by or under sections 105A to D of the Communications Act 2003, December 2022.

expected that providers will reach full compliance with different sets of technical measures. These timescales span from 2024 to 2028. We therefore expect to see a gradual improvement in security, and the levels of compliance, over this time.

We are structuring our monitoring approach around a series of formal information gathering exercises with the large and medium-sized providers (or Tier 1 and Tier 2 in the language of the Code). We will use these to ask for information and evidence about the security measures the providers are taking, or are planning to take, and whether these follow or depart from those in the Code.

Due to the amount of measures in the Code, we expect it will take two or three years before we have formally requested information on all the measures in the Code from providers. At this point, some of the timescales for implementing the measures in the Code will not yet have passed, so we will still not have a complete view of compliance. However, at the end of this period we do expect to have a good baseline understanding, across all the elements of the TSA, of the providers' current levels of security and their improvement plans.

In parallel with this planned information gathering, providers have an ongoing obligation to report significant security compromises to us. In receiving these reports, and in following up or, if required, taking enforcement activity, we expect to further build our understanding of the extent of compliance with the TSA.

For next year's Connected Nations report, we will therefore only be part way through our information gathering exercises. We will not have gathered information about all the aspects of the Code, but we do expect to have received information on some of the most important and urgent matters. We will use this knowledge, and whatever we have gained from reported compromises, to inform next year's Connected Nations reporting on the extent of compliance with the TSA.

Network resilience

The winter storms led to significant communication network outages across the UK, largely due to sustained power losses

Towards the end of 2021 and in early 2022 the UK was hit by several severe and named storms starting with Storm Arwen in November 2021, followed by Storm Barra in early December and storms Malik and Corrie in late January. In February there were three further storms in the space of a week – Storms Dudley, Eunice and Franklin. A key feature of all these storms were gale force winds, reaching 100mph in some cases. Storm Arwen caused complete power outages for almost 1 million customers - 40,000 customers were without supply for more than three days, and nearly 4,000 customers were off supply for over a week.[137] Storm Eunice also caused a record power outage over a 24-hour period, with over 1.4m homes affected.[138]

[137] Ofgem, Final report on the review into the networks' response to Storm Arwen, 9 June 2022.
[138] BBC, Storm Franklin hits UK with flooding and high winds - BBC News, 21 February 2022.

These storms, in particular Storm Arwen, created major challenges for communications providers and led to multiple network outages, causing major disruption for customers.

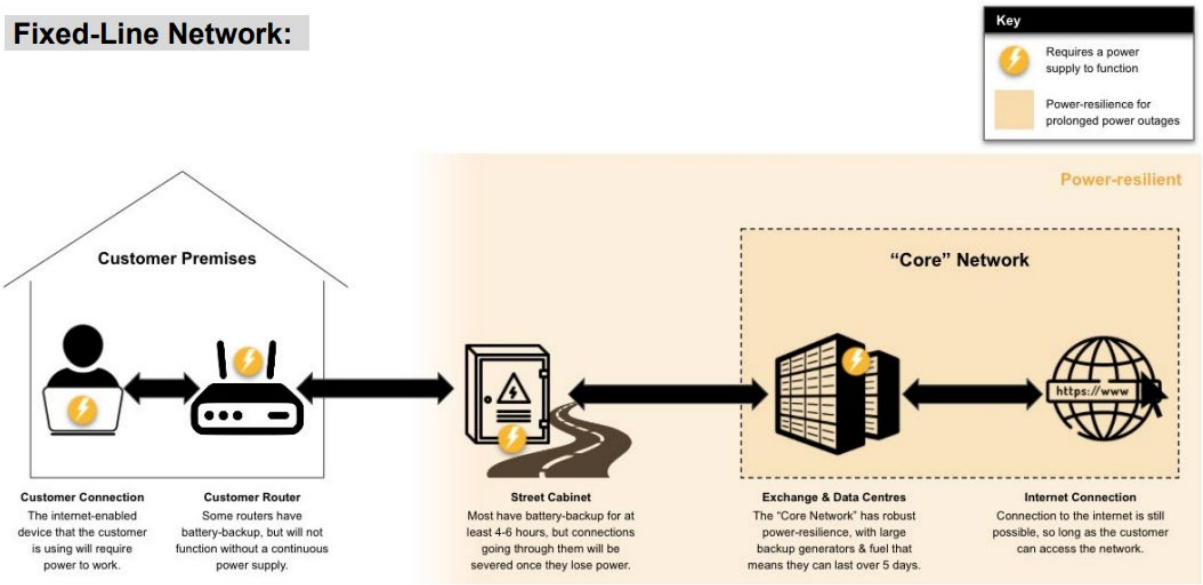
Impact on fixed networks

The storms caused considerable damage to Openreach's overground network. Some of its poles and overhead wiring were damaged by debris and falling trees. For example, storms Dudley, Eunice and Franklin destroyed more than 650 of Openreach's poles,[139] with South Wales, the South of England and parts of East Anglia worst affected. The impacts were more significant in rural areas where there is greater use of overground infrastructure. Urban areas have less overground access network cabling, and therefore experienced less of this type of damage.

While damage to fixed infrastructure was the cause of some services becoming unavailable, it was the loss of mains power which created the majority of broadband and fixed line outages. This impacted both customers of the larger fixed line providers, as well as smaller fibre network operators. Again, the impact was more significant in rural areas because of the prevalence of overhead power lines in these areas (in urban areas power lines are more routinely buried underground).[140]

The diagram below illustrates how fixed networks are dependent on power.

Figure 4.1: Power dependency in fixed access networks[141]



The largest cause of fixed line service loss during the storms was due to customers losing power to their homes. As illustrated above, fixed line services are dependent on power in the home – this

[139] Openreach has approximately 4m poles in total. Openreach, How recent storms have affected our network, 1 March 2022.
[140] Department for Business, Energy & Industrial Strategy, Energy Emergencies Executive Committee Storm Arwen Review Final report, June 2022.
[141] Diagram sourced from the Electronic Communications Resilience & Response Group (EC-RRG), 2021/22 Severe Storms Post-Incident Report, May 2022.

includes the broadband router, any connected devices including landline phones using VoIP, as well as any cordless landline phones[142] (which make up the majority, c.75% of landline phones).[143]

Core fixed networks remained operational throughout the power outages. This is because exchanges typically have integrated generator back-up which will typically hold fuel for up to five days. During the initial days of Storm Arwen, over 1,500 of Openreach's exchange sites were running on back-up power generators.[144] Fibre street cabinets also have battery back-ups fitted, which typically can withstand mains power loss of up to four hours – however because the storms caused prolonged power outages in some areas, this also meant some fibre street cabinets lost power.

Impact on mobile networks

During Storm Arwen, thousands of mobile cell sites were disrupted by power outages, and this affected all four mobile providers.[145] Storm Eunice also caused several hundred sites to be disrupted.

Some mobile mast sites are backed up with an on-site battery designed to last between 15 minutes and six hours. However, because many of the power outages were prolonged, and in excess of the battery capacity, it led to mobile cells ceasing to operate and customers losing access to their mobile services.

For example, one provider reported that over 1,500 of its mobile sites went down during Storm Arwen, and around 130 of these were down for more than 72 hours. Another provider reported that over 1,200 sites were impacted by Storm Eunice.

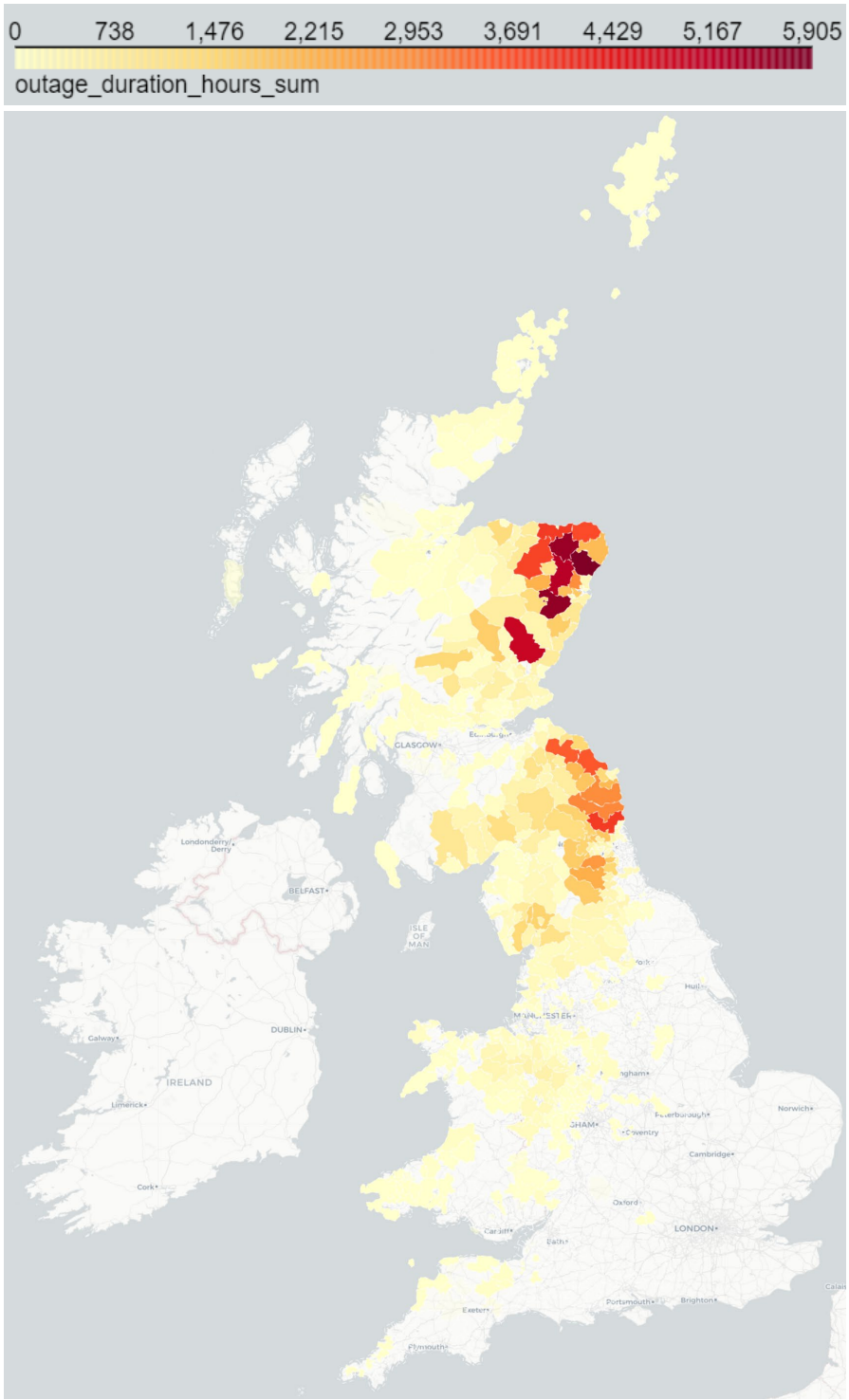
The combined impact across fixed and mobile services left some customers cut-off completely

The impact of the winter storms on communication services was particularly severe in those areas where mobile cell sites went down and the loss of power also affected customers' fixed line services. Some customers were left without any means to communicate, including for calls to the emergency services.

The most prolonged and consistent power outages during Storm Arwen were experienced in rural areas of Northern England and Eastern Scotland. The map below illustrates the extent of the power cuts during Storm Arwen. This shows the volume of mains power outage hours experienced in a postcode region; where clear means negligible hours lost and deep red is highly disrupted.

[142] Where a landline phone is corded, the power is provided by the PSTN exchange line so there is no requirement for additional mains power.
[143] Communications Consumer Panel, Quantitative research into the needs of landline telephony consumers, September 2022, page 10.
[144] EC-RRG, 2021/22 Severe Storms Post-Incident Report, May 2022, page 4.
[145] EC-RRG, 2021/22 Severe Storms Post-Incident Report, May 2022, page 5.

Figure 4.2: Power outage map of the UK on 26 November 2021 (Arwen Day 1)



Source: Ofcom analysis of data supplied by Ofgem.

The response to, and recovery from, the impact of the storms on communications networks took longer than expected

In some cases, portable generators were despatched to mast sites and street cabinets which were experiencing prolonged power outages. However, the use of this approach proved challenging

during the storms, given the limited number of generators available and the complex logistics involved in deploying them, particularly given the poor weather conditions.

Providers would typically prioritise the deployment of generators to the sites where they are most needed, in particular those sites where mains power restoration was likely to take longer and/or where battery back-up capacity was likely to be exceeded. However, during the storms, providers sometimes struggled to get clear and timely information from energy network distribution operators on power restoration plans, which made it difficult for providers to prioritise effectively and contributed to a longer than necessary recovery period in several areas. This highlighted the urgent need for improved co-ordination and information-sharing between the energy and communications sectors.

This was the first major incident across the newer fibre network which has less well-established (and tested) recovery processes compared to the copper network. Exacerbating this were delays to repairs caused by factors outside the providers' control (such as difficulties in accessing infrastructure due to fallen trees, limited daylight hours, getting permission to access private property and closed roads). There were also delays to recovery times because customers without power were unable to contact their providers in order to report faults. This is illustrated by the fact there was a dramatic spike in reported faults on the Openreach network in the second week after Storm Arwen. After Storm Arwen, whilst most faults were resolved within the first two weeks, fixed network infrastructure providers still took up to two months to reconnect all customers to their networks. This meant several hundred customers were left without telephone and internet services over Christmas.

Lessons have been learned from the impact of the storms and work is ongoing to ensure the industry is more prepared in future

Following the severe impact of Storm Arwen in particular, the communications industry identified a number of important learnings and were able to use this knowledge to help reduce the overall impact and recovery delays resulting from the later storms. These learnings included the need to scale-up fixed network management processes, taking a more proactive approach to fault identification in the networks, and improved engagement between energy and communications providers.

The Electronic Communications Resilience and Response Group (EC-RRG) published a post-incident review that outlined many of these learnings and set out an action plan to improve the sector's response and resilience to severe storms in future.[146] This is an important area of work, particularly as changing weather patterns from climate change may make these incidents more frequent in future. We are therefore continuing to work closely with the UK Government and industry to ensure that these learnings are taken on board, and action is being taken to improve the preparedness for future such events.

[146] EC-RRG, 2021/22 Severe Storms Post-Incident Report, May 2022.

Incident reports from communication providers

As in previous years, we continue to receive reports from communications providers throughout the year about any resilience incidents that created a significant impact on their networks and services. Our guidance for providers explains the types and sizes of incident we expect them to report to us in order for them to comply with their regulatory obligations.

As highlighted earlier in this section, we have recently updated this guidance to reflect changes to section 105A-D of the Communications Act 2003 implemented by the TSA, which introduced a new definition of 'security compromise'. [147] A 'security compromise' has a broad meaning, and covers both 'cyber-type' compromises such as those caused by hackers, and 'resilience-type' compromises such as outages caused by external factors (e.g. a flood or power cut) or internal factors (e.g. hardware failure, or operational process error). Our updated resilience guidance applies to the section 105A sub-category of security compromises relating to the resilience of networks and services, in terms of availability, performance, or functionality. It also provides some general observations and specific incident scenarios that will inform our approach to compliance, drawing on the changing nature of resilience risks and our experience of incident reporting and investigation.

Total number of reported incidents increased significantly this year, particularly for mobile

We received a total of 1,281 reports of relevant incidents from providers this year. This is a notable increase on the 761 reports we received in 2021.

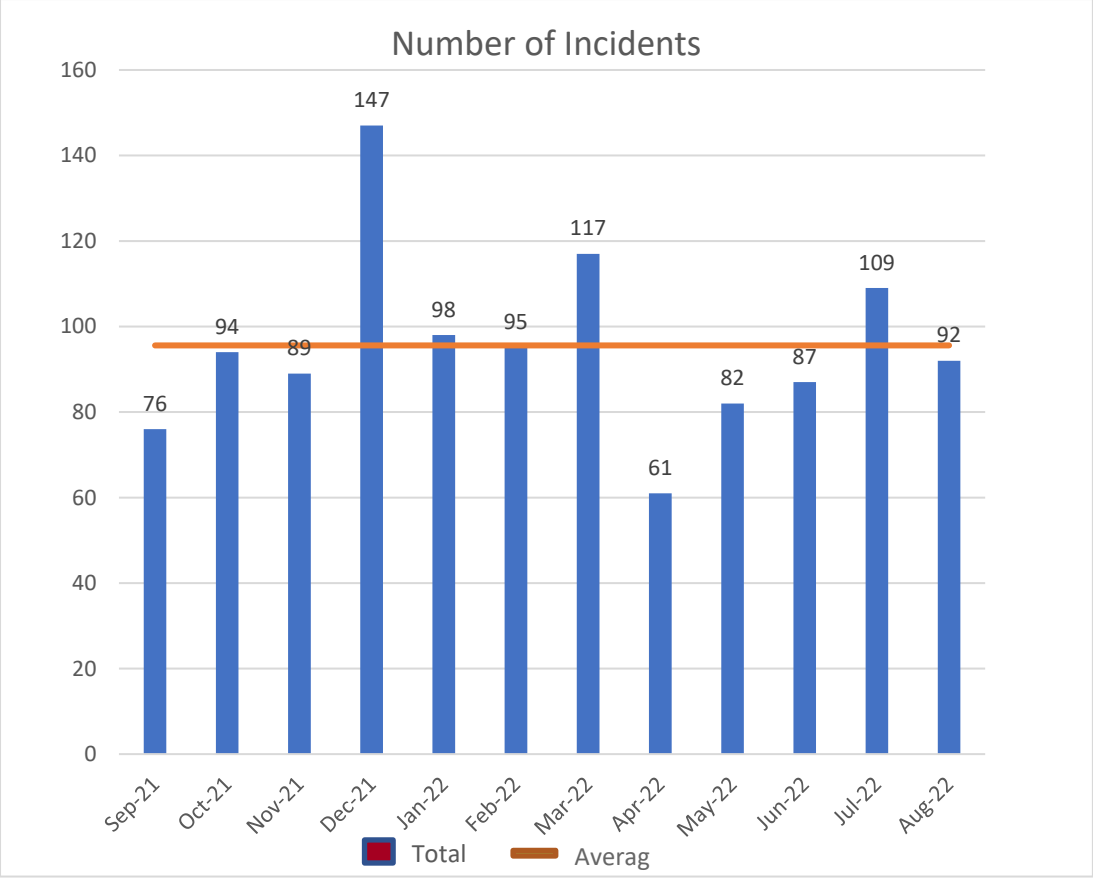
The increase in the number of fixed network incidents (545 in 2022 compared with 426 in 2021) was broadly in line with previous year-on-year variability. There was, however, a significant increase in number of mobile network incidents, more than doubling from 335 last year to 736 this year.

The monthly breakdown of incidents in Figure 4.3 shows the extent of month-on-month variability in the incidents as well as the average, which increased to 95 incidents each month in 2022, compared to 62 in 2021. The chart shows how the winter storms had a considerable impact on the number of reported incidents, particularly during December and March.

The overall increase in reported incidents is also likely to be due to our continued work to ensure consistent reporting across mobile and fixed providers, in accordance with our procedural guidance.

[147] Ofcom, Guidance on resilience requirements imposed by or under sections 105A to D of the Communications Act 2003, December 2022.

Figure 4.3: Monthly number of incidents reported between September 2021 and August 2022



Source: Ofcom analysis of provider data.

Equipment failure was the most common cause of reported incidents

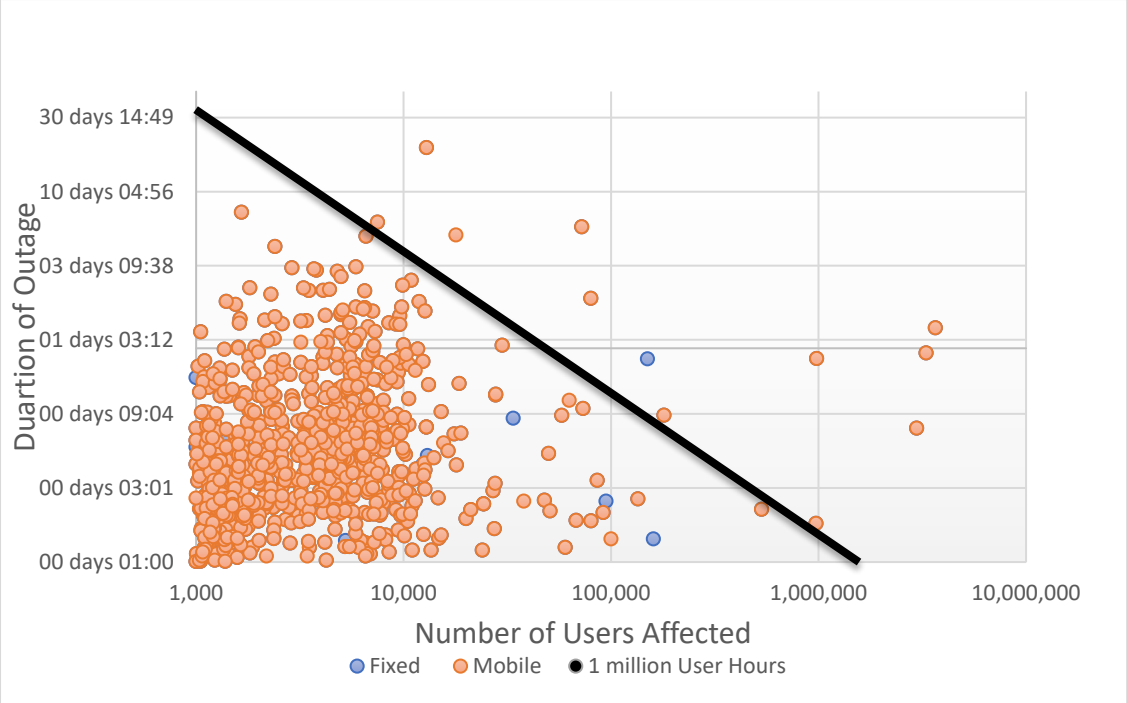
Over the last few years, we have made changes to the categories used to classify the cause of reported incidents based on the information included in providers' reports. These changes are helping us to look at how the type of incidents being reported to us is changing as technology evolves, and what this might mean in future as further developments are made.

Similar to previous years, hardware failures were the most common cause of outages this year, contributing over half of all incidents in the reporting year. This year, as discussed earlier, power issues were also more common as a result of the widespread power outages during the winter storms. We will continue to analyse causes and mitigation actions and work closely with industry to share our analysis and improve the accuracy and relevance of incident reporting to enable better learnings to be shared with stakeholders.

There were an increased number of mobile incidents which impacted a large number of users, and which lasted more than three days

The chart below sets out the duration of incidents and 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 black diagonal line indicates an incident that caused more than one million user hours to be lost for that incident.

Figure 4.4: The impact of incidents reported between September 2021 and August 2022



Source: Ofcom analysis of provider data.

The chart illustrates that the majority of incidents lasted less than one day and impacted less than 10,000 customers. However, there was an increase this year in the number of incidents, particularly for mobile, which lasted more than three days. Many of these incidents were driven by the impact of the winter storms. Within the incidents that exceed a million user hours there were no themes or patterns of which we have concerns.

Other network and service resilience issues

Service loss in Shetland

In October this year residents of the Shetland Islands were cut off from their mobile and fixed line services for approximately 16 hours.[148] This resulted from one of the Islands' subsea fibre link cables (which connects Shetland to Orkney and onto mainland Scotland) being damaged by a fishing trawler. A secondary fibre link subsea cable to the Island was already unavailable at that time due to damage sustained the previous week.

While the impact of this incident is still under investigation, we understand that PSTN landlines for voice remained largely available due to the presence of legacy low bandwidth microwave backhaul.

The damage to the south fibre cable meant that there was a loss of light through the fibres, and temporary restoration of the services was achieved by increasing power output at the source. Over the next ten days, repairs were carried out across both the primary and secondary fibre cables to the islands, leading to a permanent restoration of services.

[148] BBC News, Damaged cable leaves Shetland cut off from mainland, 20 October 2022.

As part of the R100 North Contract, the Scottish Government has laid 16 new subsea cables[149] which is connecting 15 Scottish islands to faster and more reliable broadband services.

Ongoing engagement with fibre network providers

Given the significant growth in the number of fibre network providers, we are keen to understand the approach these providers are taking to ensuring the resilience of their networks, and providing service assurance. To help meet this aim, we undertook a series of site visits with some of these providers over recent months. These visits have been useful and positive, and we have been encouraged by the careful consideration these providers have put into the expected growth of their networks and into ensuring the appropriate architecture is used to meet the resilience needs of their growing customer base in line with our guidance. We plan to continue this engagement next year to build our understanding and knowledge of resilience approaches across these providers.

Reliability around the world

In addition to incidents reported to us, we are also aware of incidents outside the scope of our regulation that have occurred worldwide. These incidents provide insight into the types of issues that can lead to network outages as technology evolves around the world and understanding the causes can help inform any future guidance and advice we may produce.

In particular there were a number of incidents last year which were reported in the media, including nationally in Japan[150] and Canada.[151] We are continually engaging with the national regulatory authorities in relevant countries where incidents occur to get a better understanding of the causes and any useful learnings that might be relevant for UK-based networks.

We note that a common theme in these incidents appears to involve large network transformation or change programmes where a specific action was taken that does not appear to have been tested, documented or planned sufficiently. The impact of this type of error was then compounded by the absence of appropriate back-out processes or recovery preparation. This is recognised as poor practice that should be avoided. While it is understood that unexpected events and failures can occur, rigorous testing processes should always be in place, as well as appropriate contingency plans. It is important that UK providers therefore also review and learn from incidents such as these to ensure they have appropriate testing and recovery procedures in place.

[149] Digital Scotland, R100 subsea deployment.
[150] Reuters, KDDI aims to restore service Sunday after 40 mln users affected, 3 July 2022.
[151] BBC, Canada's internet outage caused by 'maintenance', 10 July 2022.