Connected Nations

UK Report 2023

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Section

1. Overview

In this annual Connected Nations report, we provide an update on the availability of broadband and mobile services in the UK, including the rollout of fixed full-fibre networks and mobile 5G networks.

Alongside this report, we have published separate reports for each of the UK's nations on broadband and mobile availability. We have also updated our interactive report which allows people to access data about different services and across different parts of the UK. In addition, we are releasing the International Broadband Scorecard 2023, which compares the UK's recent position on broadband availability with a number of other nations.

These published reports support our objective of making communications work for everyone, including to promote reliable, widely available, and high-quality networks. It also fulfils Ofcom's legal duty to report on the status of the UK's telecommunications infrastructure and services.

Significant investment in full-fibre and 5G networks is delivering fast paced deployment of both

Full-fibre and gigabit-capable broadband coverage is expanding

Full-fibre broadband is now available at more than half of UK residential premises (57%), sharply up from 42% last year. Gigabit-capable broadband coverage levels now exceed three-quarters (78%) of UK residential premises, up from 70% last year.

The availability of 5G services is growing rapidly

The level of 5G coverage provided outside of premises by at least one mobile network operator (MNO) rose from 67-78% in 2022 (across a range covering Very High and High Confidence levels of availability) to 85-93% in 2023.

As of September 2023, there were more than 18,500[1] 5G deployments in place across around 81,000[2] sites in the UK, up from around 12,000 5G deployments reported in 2022.

Adoption of new networks is gathering pace

Take-up of services on full-fibre networks is increasing

We saw 1.7 million new full-fibre consumer connections in the year to May 2023, out of a total of 4.6 million full-fibre connections. This means that just over a third of all full-fibre connections have been taken up in the twelve months to May 2023. As a proportion of premises where it is available, take-up rose by three percentage points from 25% last year to 28%. Take-up varies significantly across nations, between urban and rural areas and local authorities; for example, in local authorities with at least 20% full fibre coverage, take-up as a proportion of premises with full fibre coverage ranges from 6% to 64%.

[1] It should be noted that these deployments do not necessarily equate to a total of individual sites across all MNOs. For example, two MNOs may be offering coverage from the same site. In addition, this encompasses the various mobile 5G deployment types i.e. 5G NSA, 5G SA and dynamic spectrum sharing (DSS).
[2] We note that some of these sites are duplicates where one site might be shared by more than one operator or infrastructure of more than one operator is co-located.

There has been fast paced growth in 5G capable devices and traffic

5G traffic has shown around 140% growth, rising from 63 PB in 2022 to 151 PB in 2023. This data traffic was generated from devices, of which at least 43% are 5G capable handsets (up from around 20% in 2022).[3] Traffic on 5G capable handsets represents around 17% of total mobile traffic, up from around 9% in 2022.

Most people can access superfast broadband services and 4G mobile services

Superfast broadband is available at the vast majority of homes

Ninety-seven per cent of residential premises are able to access at least superfast broadband (with speeds of at least 30 Mbit/s). Take-up of superfast services as a proportion of all UK premises rose marginally to 72%.

4G remains the main mobile network for most users, while the switch off of 3G networks has begun

4G coverage provides the backbone of mobile services and has remained largely consistent with last year. The proportion of UK landmass covered by at least one MNO is now at 93% (+1 pp on 2022). 4G continues to carry the vast majority (81%) of mobile data traffic.

Individual MNOs have continued to incrementally extend their networks, partly reflecting the work they are undertaking to deliver their Shared Rural Network obligations to achieve 88% coverage of the UK landmass by 2024. We are preparing to assess MNOs compliance with these obligations in 2024.

Meanwhile, the MNOs have started switching off their 3G networks. The number of customers using devices reliant on 2G or 3G connectivity has fallen sharply, from approximately 5.5 million reported last year to 2.4 million this year,[4] of which just over half a million are residential customers with a 3G device. Less than 3% of all mobile data traffic is now carried on 3G networks, with 3G data traffic having decreased by an average of 44% year on year.

The number of premises without access to decent broadband has fallen to 61,000

Taking account of coverage from both fixed line and fixed wireless networks, we estimate that only around 0.2% of premises in the UK do not have access to a decent broadband service.[5] This figure has reduced by approximately 18,000 premises since last year to 61,000 this year.

Meanwhile, there are more customers taking up broadband services delivered via low Earth orbit satellites – these offer high-speed and lower latency services relative to traditional geostationary

[3] The methodology for calculating total number of devices varies across MNO making this figure an approximation rather than an exact figure. Additionally, we note that not all 5G capable devices may be enabled with a 5G subscription.
[4] Slight changes to reporting methodologies for device totals in 2022 and 2023 make it difficult to make a precise comparison between the two years.
[5] A decent broadband connection is defined as connections that provide at least 10Mbit/s download speed and 1Mbit/s upload speed.

satellites, and provide near-universal coverage across the UK, including in rural areas. Satellite services are a potential approach for reaching some of the remaining premises that do not have access to decent broadband via more traditional technologies. There are around 42,000 customers of Starlink's LEO satellite service in the UK, with the majority in rural areas.

We are monitoring network security, reliability and resilience

We are monitoring industry compliance with the Telecoms Security Act, starting with asking providers about measures they are taking to secure their management and signalling planes.

We have also started to collect data on the relative reliability of fixed network access technologies. From this initial analysis, we have found that the Openreach and KCOM fibre networks experience a materially lower fault rate compared to their respective copper networks, whereas there is limited difference between the fault rates on Virgin Media O2's FTTP network when compared to its cable network.

We continue to monitor resilience incident reports and found the total number of reported incidents has remained broadly in line with last year. Hardware failures continue to account for over half of all reports, alongside a rise in the number of incidents with the legacy public switched telephone network (PSTN).

Climate change and the transition to net zero are important context for the telecoms sector

As with all sectors, climate change has implications for the telecoms sector. More frequent and intense extreme weather events are impacting telecoms networks and other industries that depend on connectivity. Providers need to prepare their networks to reduce the impacts of potentially disruptive events.

For the first time, we are reporting on some of the actions that some UK providers are taking to reduce their own carbon footprints and the net zero commitments they have made ahead of the UK-wide 2050 deadline. We also discuss the role the telecoms industry plays to facilitate the use of technology to deliver net zero solutions and enable significant emission reductions in other sectors.

2. Fixed broadband and voice

Introduction

High-speed networks are rapidly expanding, bringing fast broadband services to homes and businesses across the UK. In this section, we present our findings on the rollout of full-fibre and other fixed line networks over the last year, as well the latest numbers on take-up of different technologies and speeds. We also provide an update on the deployment and take-up of fixed wireless and satellite networks, which provide alternative methods for broadband connectivity.

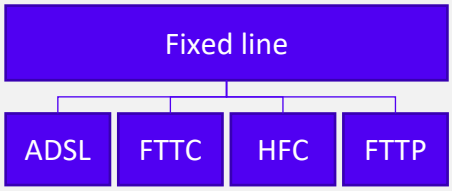
While the majority of residential premises in the UK are benefitting from these new high-speed networks, a small minority still do not have access to decent broadband. We provide the latest data on this, and information on the government schemes to establish or improve broadband connections for hard-to-reach premises. We also cover updates on migration from the traditional telephone network, towards voice services delivered over broadband.

Highlights

- **The majority of residential premises now have access to full-fibre networks.** Full fibre is available to 57% or 17.1 million premises, an increase of 15 percentage points or 4.6 million premises compared to 2022. Coverage in each of the four nations has also risen above the halfway point for the first time. Gigabit-capable broadband covers 78% or 23.2 million premises.
- **Take-up of services on full-fibre networks by residential and business customers is rising.** There was an increase of three percentage points in take-up as a proportion of premises where full fibre is available, from 25% reported last year to 28% this year. This equates to an increase of 1.7 million new full-fibre connections in the year to May 2023, for a total of 4.6 million connections available. Take-up of services on gigabit-capable broadband networks, as a proportion of premises where they are available, also increased from 38% to 42%.
- **Take-up of superfast broadband from fixed lines is now at 75% of premises where it is available.** Superfast coverage remained constant at 97%. Superfast take-up as a proportion of all UK premises is now at 72%.
- **There are more broadband options delivered over wireless and satellite networks**. We estimate that Fixed Wireless Access (FWA) services delivered via mobile networks are available to 95% of UK premises, while FWA services via wireless ISPs are available to 7% of UK premises. Additionally, nationwide low Earth orbit (LEO) satellite broadband coverage is now offered by Starlink. Relative to UK premises as whole, premises using a Starlink satellite broadband connection are more likely to be in a rural area, and less likely to have access to a decent fixed line or FWA broadband service.
- **The number of premises unable to access decent broadband has fallen, but around 61,000 still don't have access.** This is a fall from the 80,000 premises we reported last year that were unable to access decent broadband from either fixed line or fixed wireless networks. We estimate that around 11,000 of these premises will be connected via publicly funded schemes by September 2024, leaving only about 50,000 premises without access to decent broadband.
- **Consumers are moving from legacy voice services towards Voice over Internet Protocol (VoIP)**. As the switch-off of the legacy public switched telephone network progresses, customers are increasingly being migrated to managed voice services delivered over broadband by their provider. PSTN connections now account for less than half of all landline connections (41%). Other consumers are giving up their landline altogether and taking broadband-only packages.

Background to fixed line broadband technologies

Fixed connections provide broadband access at specific locations, such as residential or business premises. Fixed line broadband technologies can be broken down into different technology types.



There are four primary types of **fixed line connections** for fixed broadband access:

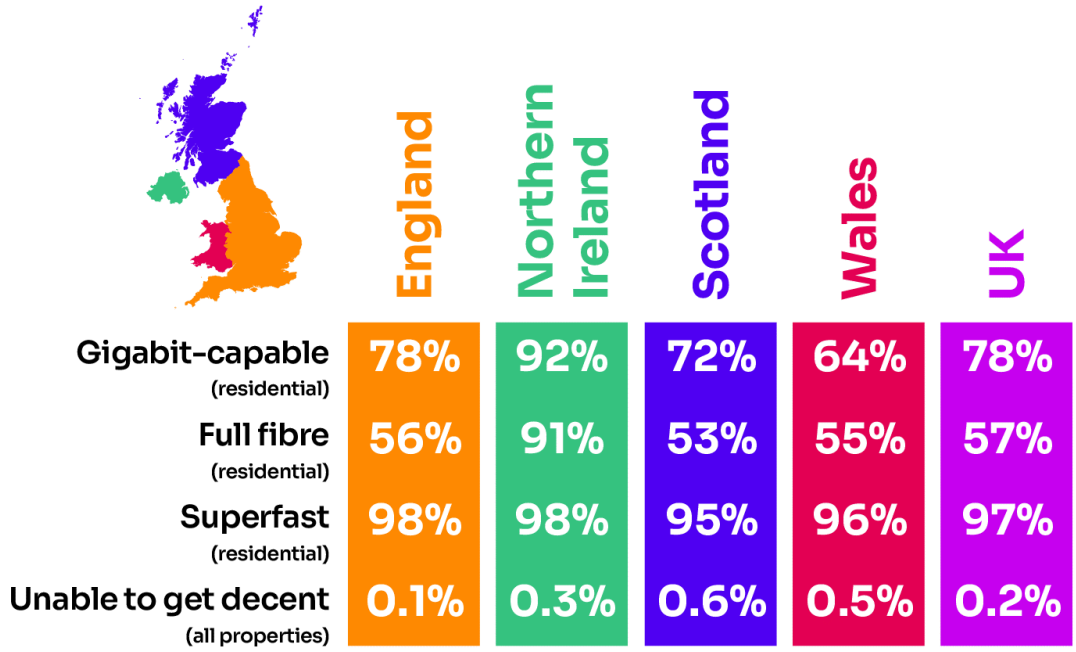
- **ADSL**[6] – Copper (telephone) cables are used to connect the exchange to each premises. Maximum download speed is up to 24 Mbit/s. Actual speeds delivered diminish with length of cable to the premises.
- **Fibre to the cabinet (FTTC)** – FTTC involves fibre to the street cabinet, with copper cables connecting the cabinet to the premises. FTTC uses 'very high-speed digital subscriber line' (VDSL)[7] technology. As with ADSL, speeds diminish with length of cable, but as cabinets are generally located close to premises, maximum download speed is normally up to 80 Mbit/s.
- **Hybrid fibre coaxial (HFC) cable** – With HFC, there is fibre to a street cabinet and coaxial cable from the cabinet to the premises. Because there is decreased signal loss compared to copper, HFC can deliver higher speeds over longer distances. Cable broadband in the UK is provided by Virgin Media O2, and its cable network can deliver gigabit speeds.[8]
- **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 can deliver gigabit speeds.[9]

We categorise fixed broadband connections based on the download speed they can provide:

- **Decent** – can provide at least 10 Mbit/s download and 1 Mbit/s upload speeds.[10] It can be delivered by ADSL, FTTC, HFC cable or full fibre. Decent broadband provides sufficient speeds for making a high-definition video call. Over minimum decent broadband, downloading a one-hour HD TV episode (1 GB) would take almost 15 minutes.
- **Superfast** – can provide download speeds of at least 30 Mbit/s and can be delivered by FTTC, HFC cable or full fibre. Superfast broadband provides sufficient speed for one person streaming 4K/UHD video. Downloading a one-hour HD TV episode would take under four and a half minutes and several devices can work simultaneously.
- **Gigabit-capable** – are able to offer download speeds of 1 Gbit/s and above. It can be delivered by HFC cable or full fibre. With gigabit-capable broadband, it is feasible to download a full 4K film (100 GB) in under 15 mins, or a one-hour HD TV episode in eight seconds.

[6] ADSL: Asymmetric Digital Subscriber Line.
[7] Another technology known as G.fast is also sometimes deployed at, or near, a limited number of cabinets offering higher speeds than VDSL.
[8] Cable broadband access networks are shared between a large number (usually hundreds) of premises.
[9] Most full-fibre access networks utilise Passive Optical Network (PON) approaches where capacity in the downstream and upstream direction is shared between around 30 to 60 users.
[10] The UK Government defines the characteristics of Decent broadband. This is the level of connection currently deemed necessary for consumers to participate in a digital society.

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



Source: Ofcom analysis of provider data (September 2023).

The coverage and take-up of full-fibre and other gigabit-capable networks continues to increase

Full-fibre broadband is now available to 57% of residential premises, with gigabit-capable broadband available to 78%

Full-fibre broadband is now available to more than half of UK residential premises

The availability of full-fibre networks is growing quickly. As of September 2023, 57% or 17.1 million residential premises had access to a full-fibre broadband network (Table 2.1). This is an increase of 15 percentage points, or 4.6 million premises, compared to last year. Coverage in each of the four nations has also risen above the halfway point for the first time.

There are differences in full-fibre coverage between rural and urban areas, with residential premises in urban areas across the UK more likely to have access to full-fibre networks (59%). Two in five residential premises in rural areas are able to access full fibre.

Northern Ireland has the highest level of full-fibre coverage at more than 90%. Northern Ireland has led other nations on the rollout of full-fibre networks, passing the 50% mark in 2020, when coverage in other nations was still below 20%. England follows with the second highest level of coverage. In the last year, England and Wales both saw increases of 15 percentage points in full-fibre coverage, while there was a 13 percentage points increase in Scotland.

Increased access to full fibre continues to be driven both by the major deployments of the larger network operators (Openreach, Virgin Media O2, and CityFibre) and new build from many smaller operators across the UK, some of which focus on previously underserved communities and regions.

Table 2.1: Residential full-fibre and gigabit-capable network coverage

	Full fibre			Gigabit capable		
	Total	**Urban**	**Rural**	**Total**	**Urban**	**Rural**
England	56% (14.1m)	59% (12.7m)	42% (1.3m)	78% (19.6m)	83% (18.2m)	45% (1.4m)
Northern Ireland	91% (0.7m)	95% (0.5m)	82% (0.2m)	92% (0.8m)	97% (0.6m)	82% (0.2m)
Scotland	53% (1.4m)	58% (1.3m)	32% (0.2m)	72% (1.9m)	80% (1.8m)	34% (0.2m)
Wales	55% (0.8m)	59% (0.7m)	41% (0.1m)	64% (0.9m)	71% (0.8m)	41% (0.1m)
UK	**57% (17.1m)**	**59% (15.2m)**	**43% (1.8m)**	**78% (23.2m)**	**83% (21.3m)**	**45% (1.9m)**

Source: Ofcom analysis of operator data (September 2023).

Gigabit-capable broadband is now available to 78% of residential premises

Gigabit-capable broadband can be delivered over both full-fibre and HFC technologies; therefore, the increase in full-fibre coverage has also resulted in an increase in the number of premises able to access gigabit-capable broadband. By September 2023, 78% or 23.2 million residential premises had access to a gigabit-capable broadband network. This is an increase of seven percentage points or 2.3 million residential premises compared to last year.[11]

An increasing number of premises have access to more than one gigabit-capable network. As of September 2023, this was 10.5 million residential premises, or 35% of all residential premises. This is a substantial increase from last year when 16% or 4.9 million residential premises had access to more than one gigabit-capable network. Additionally, 7% of all residential premises have a choice of three or more gigabit-capable networks.

Small and medium-sized enterprises increasingly have access to full-fibre and gigabit-capable networks

Access to high-speed broadband is vital for many small and medium-sized enterprises (SMEs). In the last year, we have seen increases in availability of both full-fibre and gigabit-capable broadband for SMEs; however, these coverage levels are still lower than for residential premises.

As of September 2023, 51% of SMEs in the UK had access to a full-fibre network (Table 2.3), which represents an increase of eight percentage points from January 2023. Seventy-four per cent of SMEs in the UK had access to a gigabit-capable network, an increase of four percentage points from January 2023.

[11] The share of gigabit-capable broadband delivered over full fibre is likely to be impacted by Virgin Media O2 upgrading its HFC network to full fibre by 2028. Virgin Media O2, Virgin Media O2 bolsters future network with fibre upgrade plan. 29 July 2021.

Consistent with the Connected Nations Spring 2023 update, coverage remains highest for micro businesses, which are often based in residential areas and can make use of residential services. Our coverage data does not include networks deployed specifically for businesses, such as leased lines, so coverage may be higher than indicated by the table below, particularly for medium-sized businesses.

As with residential broadband, SMEs in Northern Ireland had the greatest availability of full-fibre and gigabit-capable networks, followed by England (Table 2.3).

Table 2.2: SME full-fibre and gigabit-capable coverage by size of business

	Full-fibre availability		Gigabit-capable availability	
	January 2023	September 2023	January 2023	September 2023
Micro (1-9 employees on site)	43%	52%	72%	75%
Small (10-49 employees on site)	38%	45%	60%	65%
Medium (50-249 employees on site)	35%	42%	56%	61%

Source: Ofcom analysis of operator data (September 2023).

Table 2.3: SME full-fibre and gigabit-capable coverage by nation

	Full-fibre availability			Gigabit-capable availability		
	Total	Urban	Rural	Total	Urban	Rural
England	51%	52%	42%	75%	79%	45%
Northern Ireland	83%	85%	79%	86%	91%	79%
Scotland	45%	48%	28%	64%	72%	30%
Wales	50%	53%	40%	57%	64%	40%
UK	**51%**	**53%**	**43%**	**74%**	**79%**	**45%**

Source: Ofcom analysis of operator data (September 2023).

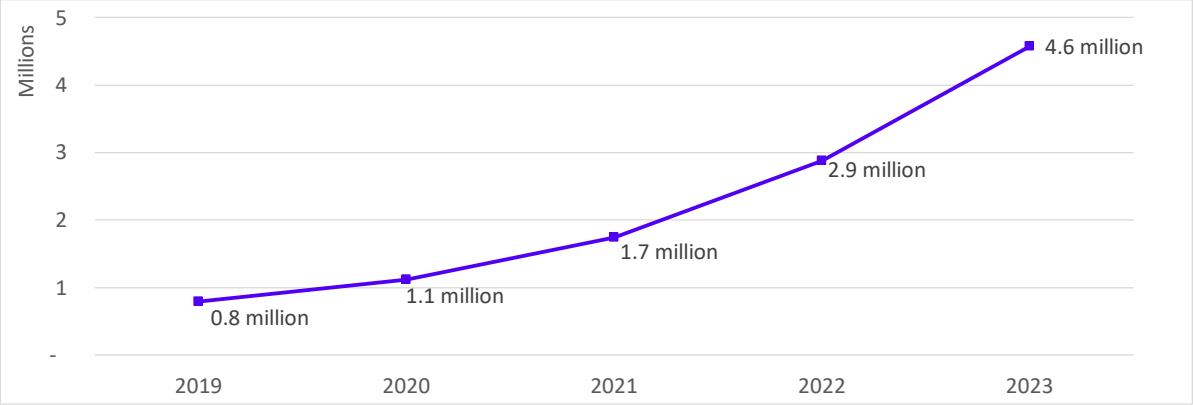
Take-up of services on full-fibre networks is increasing

As the rollout of full-fibre networks progresses, more customers are using services that are available on this network technology.

We estimate that in May 2023 take-up of services on full-fibre networks at all premises (residential and commercial) where available was 28% or 4.6 million premises (Figure 2.2, Table 2.4). Last year we reported that across the UK, approximately 25% of premises where full fibre was available had taken it up. This is an increase of three percentage points in take-up over the last year and equates to an increase of 1.7 million new full-fibre connections in the year to May 2023.

While take-up rates are rising, we note the rate of growth is suppressed somewhat by the rapid deployment of full fibre in the last year, which in the short-term tends to reduce take-up rates as a proportion of an expanding number of premises where full fibre is available.

Figure 2.2: Estimated total full-fibre broadband connections, 2019-2023



Source: Ofcom analysis of provider data (May 2023).[12]

Meanwhile, we estimate that take-up of services on gigabit-capable networks, where they are available, is now at 42% - meaning that more than two in five of all premises that have access to faster networks are using them. There has been an increase of four percentage points in take-up from 38% reported last year.

Full fibre take-up rates are lower in England and in urban areas

Across the four nations, take-up of services on full-fibre networks is lowest in England (27%) and Scotland (28%) while Northern Ireland leads the nations at 39%.

Some nations have seen larger increases than the UK average in the past year; Northern Ireland has seen an increase of 14 percentage points in take-up (up from 25%) and in Scotland, there has been an increase of five percentage points (up from 23%).

Table 2.4: Estimated full-fibre broadband take-up as a percentage of premises where full-fibre networks are available: 2021-2023

	2021	2022	2023
England	25%	25%	27%
Northern Ireland	19%	25%	39%
Scotland	22%	23%	28%
Wales	24%	28%	31%
UK	**24%**	**25%**	**28%**

Source: Ofcom analysis of provider data (May 2023).

We also find that the take-up of full fibre is considerably higher in rural areas than in urban areas so far. Of premises with access to full fibre, 49% of premises in rural areas have taken full fibre, compared to 25% in urban areas.

[12] In previous Connected Nations reports we have reported on the number of new full-fibre connections in the year as of September. Here we instead use data as of May in each year; therefore, the year-on-year increase in full-fibre connections will be different than those we have reported previously.

As a proportion of all premises in the UK (including those that do not yet have access to full-fibre networks), full fibre take-up is now 14%. Northern Ireland has the highest proportion of all premises taking up full fibre at 34%.

Take-up rates differ across local authority areas

We analysed differences in take-up rates at the local authority level, which can provide some insight into variations.

Of the 332 local authorities where at least 20% of the residential premises have a full-fibre network available, we see a large range in take-up levels.[13] As a proportion of premises with full-fibre coverage, take-up levels currently vary from 6% to 64%. The ten local authorities with the highest levels of take-up, as a proportion of premises with access to full fibre, are in Table 2.5 below. Kingston upon Hull has the highest take-up, followed by the Isle of Anglesey, Test Valley, City of London and Cornwall. We note that several of the local authorities on this list are largely rural. Additionally, Kingston upon Hull and East Riding of Yorkshire are areas where full-fibre broadband has been available for some time.

Table 2.5: Ten local authorities with highest levels of take-up, as a proportion of premises with access to full fibre

Local authority	Nation	Coverage of full fibre (% of all premises)	Take-up (% of all premises with full-fibre coverage)
Kingston upon Hull	England	98%	64%
Isle of Anglesey	Wales	24%	61%
Test Valley	England	25%	59%
City of London	England	50%	57%
Cornwall	England	42%	55%
Ceredigion	Wales	34%	52%
West Lancashire	England	48%	49%
Powys	Wales	32%	49%
East Riding of Yorkshire	England	78%	49%
East Hertfordshire	England	22%	49%

Source: Ofcom analysis of provider data (May 2023).
Excludes local authorities where full-fibre coverage is <20%.

When we look at take-up levels amongst the ten local authority areas with the highest coverage of full fibre (Table 2.6), we see a range of take-up rates as a proportion of all premises from 21-63%.

Kingston upon Hull has both the highest level of coverage (98%) and the highest level of take-up (63%) as a proportion of all premises, of all the local authorities in the UK.

Some of the local authorities on this list with comparably lower levels of take-up are in urban areas, such as Belfast (26%), Worthing (21%) and Coventry (32%). Some of the more rural local authorities

[13] We exclude local authorities where fewer than 20% of premises have access to full-fibre networks, as network deployment in these areas may be very recent or skewed to specific circumstances where take-up is very high, e.g. new building developments.

on this list have comparably higher levels of take-up, such as Ards & North Down (44%) and Mid & East Antrim (40%).

Table 2.6: Full fibre take-up in the ten local authorities with the highest levels of coverage

Local authority	Nation	Coverage of full fibre (% of all premises)	Take-up (% of all premises)
Kingston Upon Hull	England	98%	63%
Coventry	England	95%	32%
Ards and North Down	Northern Ireland	91%	44%
Antrim and Newtownabbey	Northern Ireland	90%	35%
Lisburn and Castlereagh	Northern Ireland	90%	35%
Newry, Mourne and Down	Northern Ireland	90%	37%
Milton Keynes	England	90%	42%
Belfast	Northern Ireland	90%	26%
Mid and East Antrim	Northern Ireland	89%	40%
Worthing	England	89%	21%

Source: Ofcom analysis of provider data (May 2023).

Differences in full-fibre take-up could be driven by several factors

As set out above, we see variation in take-up levels across nations, between rural and urban locations, and local authority level. There could be various reasons why take-up rates vary, including, for example:

- **The length of time full fibre has been available** – it may take some time after a network is deployed for consumers to become aware of new networks. Even when potential customers are aware, they may need to wait for their existing contract to come to an end before taking up services on a full-fibre network.
- **The type of technology available to consumers before full fibre was deployed** – where consumers already have access to superfast broadband, for example, this may already meet their needs.
- **The extent to which providers are actively encouraging customers to migrate to newer networks** – some retail service providers may be actively encouraging customers to move from their services on copper networks to the services they now offer on full-fibre networks. Moreover, some may not offer services on legacy technologies to new customers.
- **The demographics of a given area** – for example, take-up may be influenced by average age or income levels in an area.

The length of time fibre is available increases likelihood of take-up

We have examined all properties that have taken up services on full-fibre networks and compared with when fibre was first made available to the premises. Our analysis finds that the longer fibre has been available, the more likely it is to have been taken up (Table 2.7). For example, if full fibre has been available at a property for more than four years, then there is a 55% probability that services on a full-fibre network will have been taken-up. By contrast, if full fibre has only been available for one year or less, there is only a 9% probability of take-up.

Table 2.7: Likelihood of full fibre take-up with respect to length of time it has been available

Years full fibre has been available at the property	Probability that the property has taken full fibre
One year or less	9%
Greater than one year, up to two years	22%
Greater than two years, up to three years	36%
Greater than three years, up to four years	43%
Greater than four years	55%

Source: Ofcom analysis of provider data (May 2023).

There is variation in speed packages taken by customers on full-fibre networks

For customers that have taken up full-fibre broadband, 14% are taking a package with download speeds of at least 900 Mbit/s, as shown in Table 2.8. Nearly three quarters (71%) of customers are taking a package which delivers at least 100 Mbit/s.

While increasing numbers of customers are moving from older broadband technologies to full fibre, not all customers taking up services on full-fibre or gigabit-capable networks will need or want the packages that offer the fastest speeds that these networks can offer. For example, we find that 4% of customers are taking a speed package with a download speed of at least 30 Mbit/s but less than 50 Mbit/s.

Table 2.8: Take-up of services on full-fibre networks by advertised download speed

Advertised download speed	Percentage of customers taking a package in this band
>=30 & <50 Mbit/s	4%
>=50 & <100 Mbit/s	25%
>=100 & <300 Mbit/s	39%
>=300 & <900 Mbit/s	18%
>=900 Mbit/s	14%

Source: Ofcom analysis of provider data (May 2023).

Increases in superfast coverage and take-up are plateauing for households and SMEs

Coverage of superfast broadband remains very high, with most UK residential premises having access

The vast majority of residential premises in the UK have access to superfast broadband – defined as a broadband connection that can provide download speeds of at least 30 Mbit/s. Our latest data show that the proportion of residential premises that have access to superfast broadband stands at

97%, or roughly 29.1 million UK residential premises (Table 2.9). This includes the 23.2 million premises that have access to faster, gigabit-capable networks as is discussed above.

There has been a modest increase in the number of residential premises able to access superfast broadband, from 28.7 million residential premises reported last year. Northern Ireland saw an increase of three percentage points, while Scotland, Wales, and England saw increases of less than a percentage point.

Table 2.9: Residential superfast coverage by nation, September 2023

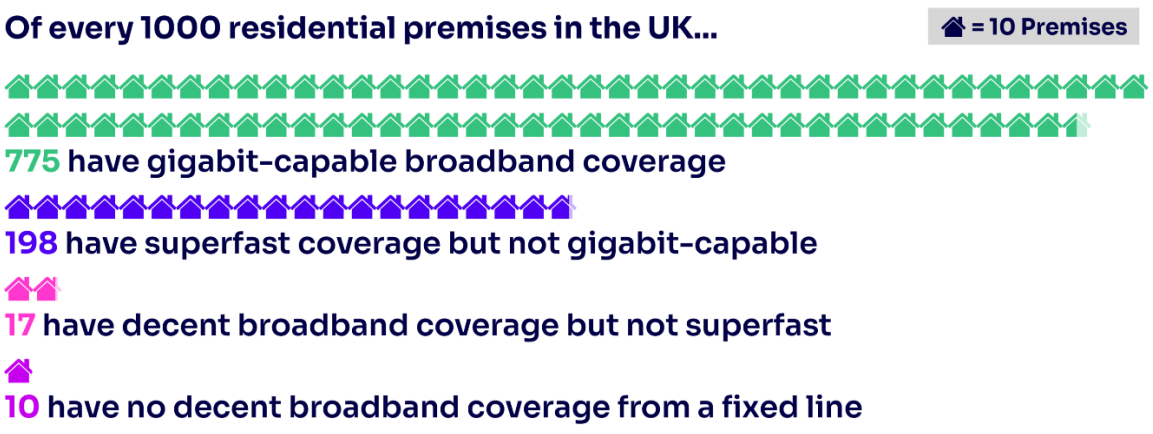
	Total	Urban	Rural
England	98%	99%	89%
Northern Ireland	98%	99%+	93%
Scotland	95%	99%	79%
Wales	96%	99%	86%
UK	**97%**	**99%**	**88%**

Source: Ofcom analysis of operator data (September 2023).

While full-fibre deployment continues at pace, this is not reflected in the growth of superfast coverage, as operators are mainly focusing full-fibre deployment in areas that already have superfast broadband. Growth in superfast broadband coverage is constrained in part due to the difficulty of connecting or upgrading the remaining residential premises without access to superfast broadband. There are various government schemes that aim to improve broadband coverage for these hard-to-reach premises which are outlined below in the section on public sector investment.

Looking at all fixed line coverage for residential premises (Figure 2.3), around 775 in every 1,000 premises in the UK have gigabit-capable coverage, while around an additional 198 premises have superfast but not gigabit-capable coverage. Of the remaining residential premises, 17 have decent broadband but not superfast, while 10 do not have access to decent broadband connection from a fixed line.

Figure 2.3: Residential fixed line broadband availability in the UK



Source: Ofcom analysis of operator data (September 2023).

Superfast coverage also remains steady for SMEs

As with residential premises, the availability of superfast broadband is very high for SMEs. Compared with the January 2023 data, there were marginal increases in coverage in Northern Ireland and Scotland (Table 2.10). Overall coverage has remained steady at 95% across the UK for all SMEs. Northern Ireland has overtaken England to have the highest SME superfast coverage of the four nations.

Table 2.10: SME superfast coverage by nation, September 2023

	Superfast availability		
	Total	Urban	Rural
England	95%	97%	84%
Northern Ireland	96%	98%	92%
Scotland	92%	96%	73%
Wales	92%	97%	78%
UK	**95%**	**97%**	**83%**

Source: Ofcom analysis of operator data (September 2023).

Take-up of superfast broadband has increased to 75% of premises where it is available

We estimate that for those premises in the UK that have access to superfast broadband or faster, around 75% of them take a broadband package that offers at least superfast speeds (Table 2.11). This represents a modest increase from 73% reported last year. As a proportion of all UK premises, the take-up of superfast broadband in May 2023 was 72%.[14]

Take-up of superfast broadband increased in all four nations in the 12 months up to May. England and Northern Ireland remain the nations with the highest take-up of superfast broadband.

Table 2.11: Estimated superfast take-up as a percentage of premises where superfast broadband is available: 2021-2023

	2021	2022	2023
England	69%	73%	75%
Northern Ireland	73%	73%	74%
Scotland	68%	71%	73%
Wales	66%	71%	73%

[14] Under the Communications Act 2003, Ofcom is likely to be issued with a direction to review the broadband USO if it appears to the Secretary of State that, on the basis of information we have published, take-up of superfast broadband has reached at least 75% of all UK premises.

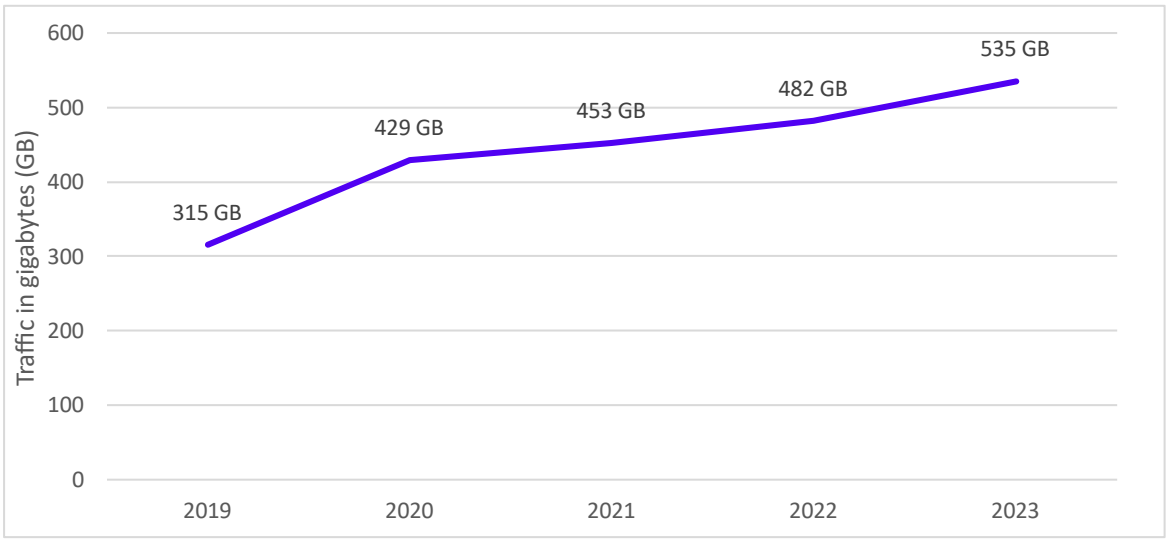
	2021	2022	2023
UK	69%	73%	75%

Source: Ofcom analysis of provider data (May 2023).

Data use over fixed broadband continues to grow

We continue to see growth in fixed data traffic. Average monthly traffic rose to about 535 GB per connection (Figure 2.4). This is an increase of 11% from last year, when on average data use was around 482 GB per connection per month.

Figure 2.4: Average monthly data use per connection (gigabytes), 2019-2023



Source: Ofcom analysis of operator data (May 2023).

There are more broadband options delivered over wireless and satellite networks for UK households and businesses

Background to wireless networks and satellite services

In addition to the fixed line connection technologies described above, it is also possible to receive fixed broadband via wireless networks and satellite.

Fixed Wireless Access (FWA) can be delivered by:

- **Mobile network operators (MNOs)** – 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.
- **Wireless internet service providers (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 spectrum under licence exemption or light licence authorisation. We are beginning to see some use of 5G technology specifically for fixed services, which is enabling WISPs to provide superfast and above speeds much more widely. 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.[15]

Fixed broadband can also be delivered over satellite. There are two types of satellite services:

- **Geostationary (GSO) satellites** – These orbit the earth at about 36,000 km and have traditionally been the primary way of delivering satellite communications services. GSO providers 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.
- **Low Earth orbit (LEO) satellites –** These 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.

FWA (both that provided by MNOs and by WISPs) and satellite fixed broadband connections 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.

[15] Ofcom introduced its Shared Access framework in 2019 to support local spectrum access for local networks. The framework includes the 3.8-4.2 GHz band and part of the 26 GHz band that are suitable for the provision of high-speed networks based on 5G technology.

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

Fixed wireless access via mobile networks

Fixed wireless access (FWA) services from the MNOs are provided primarily over 5G networks and advanced 4G networks (LTE-A). Based on information from the MNOs[16] about their coverage levels, we estimate that 95% of all UK premises have access to decent broadband through an MNO FWA service (Table 2.12), in line with the coverage we reported last year.

FWA services offered over 4G and 5G networks share the network capacity with mobile users, meaning that capacity has to be carefully managed between the demands of existing mobile users and FWA customers. As such, there may be areas of high mobile demand where a reliable FWA service cannot be offered, and elsewhere the reliability of FWA services may fluctuate as demand for mobile services does. The availability of higher spectrum frequencies provides the capability to support higher speeds, although the range of coverage that can be achieved is reduced, necessitating a greater number of masts to achieve coverage at higher speeds. At the same time, advances in the technology are allowing more dynamic use of the spectrum.

Fixed wireless access via wireless internet service providers

This year we collected data from 21 wireless internet service providers (WISPs).[17] Based on estimates from these WISPs, around 7% of all UK premises (residential and SME) have decent broadband coverage from a WISP network (Table 2.12), with no change on the previous year.[18] In Wales, WISP FWA services are already available to 31% of premises.

Fixed wireless access provided by WISPs has been primarily over the 5 GHz band. The availability of the 3.8-4.2 GHz band, primarily considered to be a 5G band, is allowing WISPs greater flexibility in the deployment of higher speed services over 5G standard equipment. This is still nascent and has historically been hampered by a lack of availability of 5G technology with the appropriate spectrum. This technology is now becoming available with features like MIMO (a Multiple Input, Multiple Output system which has multiple antennas and multiple radios[19]) and 'beamforming'.[20] This may allow for the availability of higher speed services in places where fibre has not yet been deployed, and where fixed wireless access services may be more cost effective than satellite services.

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[16] Our reporting here is based on data from EE and Three – see the annex for further information on the methodology.
[17] See the annex for further information on the methodology.
[18] The analysis for WISPs includes SME and residential users.
[19] A MIMO system transmits the same signal over multiple paths, each path having a different time delay. Multiple instances of a single transmitted symbol arrive at the receiver at different times, so that the message can be pieced together based on fragments received at different antennas. This can either increase the data rate at a given range or increase system range for a given data rate.
[20] Beamforming is an antenna technology that allows control of the directionality of the transmission/reception of a signal from an antenna array. It provides a better signal-to-noise ratio (SNR). In conjunction with other antenna technologies, such as smart antennas and MIMO, it boosts cell range and capacity.

Table 2.12: Coverage of MNO and WISP FWA networks with at least decent broadband (all premises)

	MNO FWA	WISP FWA
England	96%	7%
Northern Ireland	85%	3%
Scotland	95%	2%
Wales	93%	31%
UK	**95%**	**7%**

Source: Ofcom analysis of provider data (September 2023).

Ofcom analysis also shows year-on-year increases of fibre backhaul to masts that deliver mobile and FWA services. Such masts have the potential to support higher speed FWA services in the future.

Fixed wireless access case study: Quickline

Quickline is an internet service provider building a hybrid network to the rural North of England which combines full fibre and 5G fixed wireless broadband technology.

Previously they provided coverage in rural areas using wireless technologies in the shared 5 GHz band. They are now deploying 5G standalone technology and building their network using Open RAN technology, developed in partnership with Mavenir, to deliver very high-speed broadband services.[21]

The use of 5G technology enables stable performance with minimal packet loss. In addition, the potential to significantly improve downlink speeds using 5G technology allows multiple users to benefit from high speed, stable connections. Use of Open RAN may provide both cost improvements and resilience in supply chains.

At the end of October, Quickline had nearly 100 5G masts live across rural Yorkshire and Lincolnshire. Quickline states that these masts offer coverage to homes and businesses across hundreds of communities that have poor broadband speeds.

Due to the remote locations of its target customer base, the network has been designed to deliver the 5G wireless signal to an outdoor antenna, optimising the signal received at that location. This requires an engineer visit for installation.

Quickline currently offers packages of 50, 100 and 200 Mbit/s to customers on their 5G SA network. Further product development is underway with a target to achieve 400 Mbit/s and ultimately to launch gigabit speeds and even greater reach. Quickline has reported achieving download speeds of 350 Mbit/s and 50 Mbit/s for upload at a distance of 17 km from the mast site using the N77 spectrum band.

[21] 5G SA, or 5G Standalone, refers to a network using a 5G core as well as 5G radios. This and Open RAN is explained further in section 3 of this report.

The take-up of satellite services is increasing and may offer an alternative option for some customers in poorly served areas

Satellite technologies continue to evolve rapidly, and low Earth orbit (LEO) satellites particularly could potentially help to serve parts of the UK which are harder to reach through more traditional technologies. LEO satellites can offer high-speed, lower latency services relative to traditional geostationary (GSO) satellites. Steps are being taken to support the expansion of the satellite broadband market. For example, in 2022 we refreshed our Space spectrum strategy to optimise opportunities and improve use of space to better support businesses and households, including to connect harder to reach premises. We are also expanding the spectrum available to satellite operators through Satellite gateway[22] and Earth Station Network licences.[23] The UK Government is supporting trials to deliver high-speed connections to harder to reach locations and in August 2023 it announced proposals for a Connectivity in Low Earth Orbit scheme (CLEO), which would be designed to help industry develop new constellations.[24]

The LEO retail market is at an early stage of development and take-up has so far been low compared to terrestrial broadband services. This year we have collected data on LEO satellite provision. Starlink currently offers the only direct-to-consumer LEO service in the UK through its retail 'plug and point to the sky' product.[25] This delivers nationwide broadband coverage, including in harder to reach areas. The market is likely to evolve as we note proposals for new business-to-consumer services as well as ongoing trials of business-to-business services.[26]

The data provided to us by Starlink indicates that over 42,000 connections (up from 13,000 last year) in the UK currently make use of LEO satellites for their broadband service. This includes both residential and business packages, and our analysis of Starlink customer connections suggests that:

- the majority of these customers are in rural areas.
- 2-6% of these premises are in areas with no decent broadband, compared to 0.2% of premises in UK overall with no decent broadband.
- 15-20% of these premises have access to full fibre.

Relative to UK premises as whole, premises with a Starlink satellite broadband connection are therefore more likely to be in a rural area, and less likely to have access to a decent fixed line or FWA broadband service.

Although satellite services such as Starlink do not always guarantee any minimum speeds on their packages, Ofcom home broadband performance measurements published as part of Connected Nations 2022 suggest measured speeds on its network average around 100 Mbit/s download and 14 Mbit/s upload.

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[22] Ofcom, Consultation: Expanding spectrum access for satellite gateways in the 28 GHz band, 18 August 2023.
[23] Ofcom, Statement: More spectrum for satellite connectivity – extending access in the Ku band (14.25-14.5 GHz), 10 November 2022.
[24] DCMS, Broadband beamed from space to isolated areas under plans to boost countryside internet connections, November 2022. DSIT, Boost for broadband and 5G coverage revolution rollout as government explores plan to open £160 million satellites fund, August 2023.
[25] For information on residential services, see Starlink for homes. Services include a 'Standard' package for £75/month and a range of 'Priority' services priced at £80-£300/month, with hardware options priced from £449 on Starlink Service Plans.
[26] Plans for other consumer satellite services have also been announced, such as Amazon's 'Project Kuiper', while other business-to-business services have been trialled, such as BT and OneWeb's partnership. GSO-based services are also available, such as We Konnect.

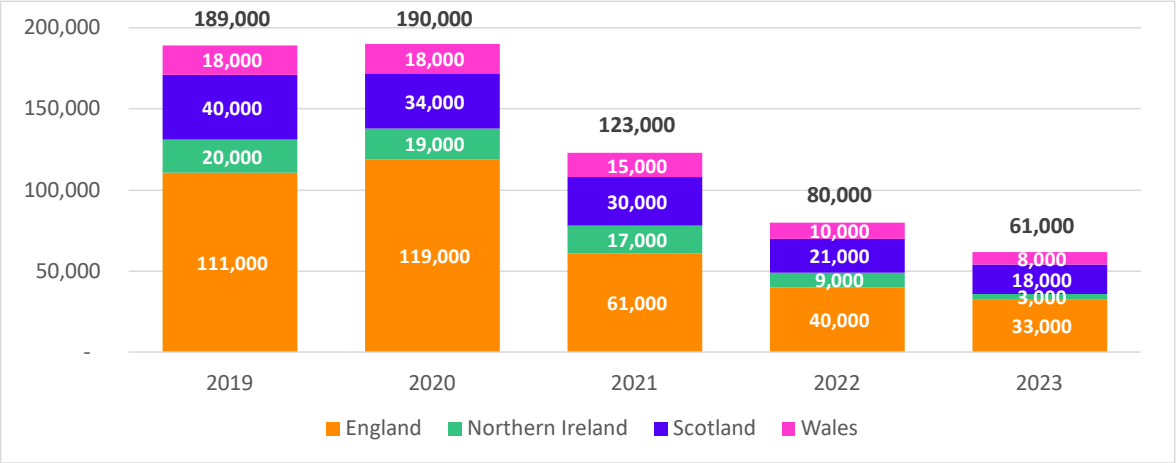
Some premises still cannot access decent broadband

The number of premises unable to access decent broadband has fallen, but around 61,000 still do not have access

We estimate that 1% of all UK premises, residential and commercial, cannot access decent broadband from a fixed line connection, which is defined as connections which provide at least 10 Mbit/s download speed and 1 Mbit/s upload speed. This is around 410,000 premises, a drop of 114,000 since last year, when we reported that around half a million premises did not have decent broadband via a fixed line.

Of those premises that do not have decent broadband via fixed lines, some will be able to access decent broadband via FWA services offered by MNOs or WISPs. Taking account of the coverage available from FWA, we estimate that this leaves around 0.2% or 61,000 premises in the UK without a decent broadband service from either fixed line or FWA (Figure 2.5). The remaining premises without access to a decent broadband service has fallen by around 18,000 from the approximately 80,000 premises we reported last year. These figures have dropped significantly in the past five years, from nearly 190,000 in 2019 to less than a third of that figure in 2023.

Figure 2.5: Approximate number of premises without access to a decent broadband service from either a fixed or fixed wireless access network, 2019-2023[27]



Source: Ofcom analysis of provider data (September 2023).

We estimate that around 11,000 of these premises will be connected via publicly funded schemes in the next twelve months, meaning that the number of premises remaining without decent broadband in September 2024 could be around 50,000.

Later in this section, we provide estimates of how many premises could continue to be without access to decent broadband in May 2026 and therefore may be eligible for the broadband USO.

[27] All figures have been rounded to the nearest 1,000.

The broadband universal service obligation (USO) is one mechanism for connecting those without decent access

The broadband USO provides all premises 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).[28]

Where an affordable service 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.[29] Where the costs are above £3,400, the customer has the option to pay the excess costs to get a USO connection. BT is the universal service provider 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]

As of October this year, BT had received a total of nearly 2,000 USO orders since the launch of the USO in March 2020.[31] Each order requires network build that can serve multiple premises, and therefore these orders will lead to full-fibre connections being built that can serve nearly 9,800 premises that do not have access to decent broadband.

Table 2.13 below shows the total of USO orders and premises passed by nation, and the map (Figure 2.6) shows how these USO orders are spread across the UK by local authority area (as a proportion of premises). The map shows that the USO has delivered connections all across the UK, with certain areas in South-West England and West Wales receiving the highest number of connections.

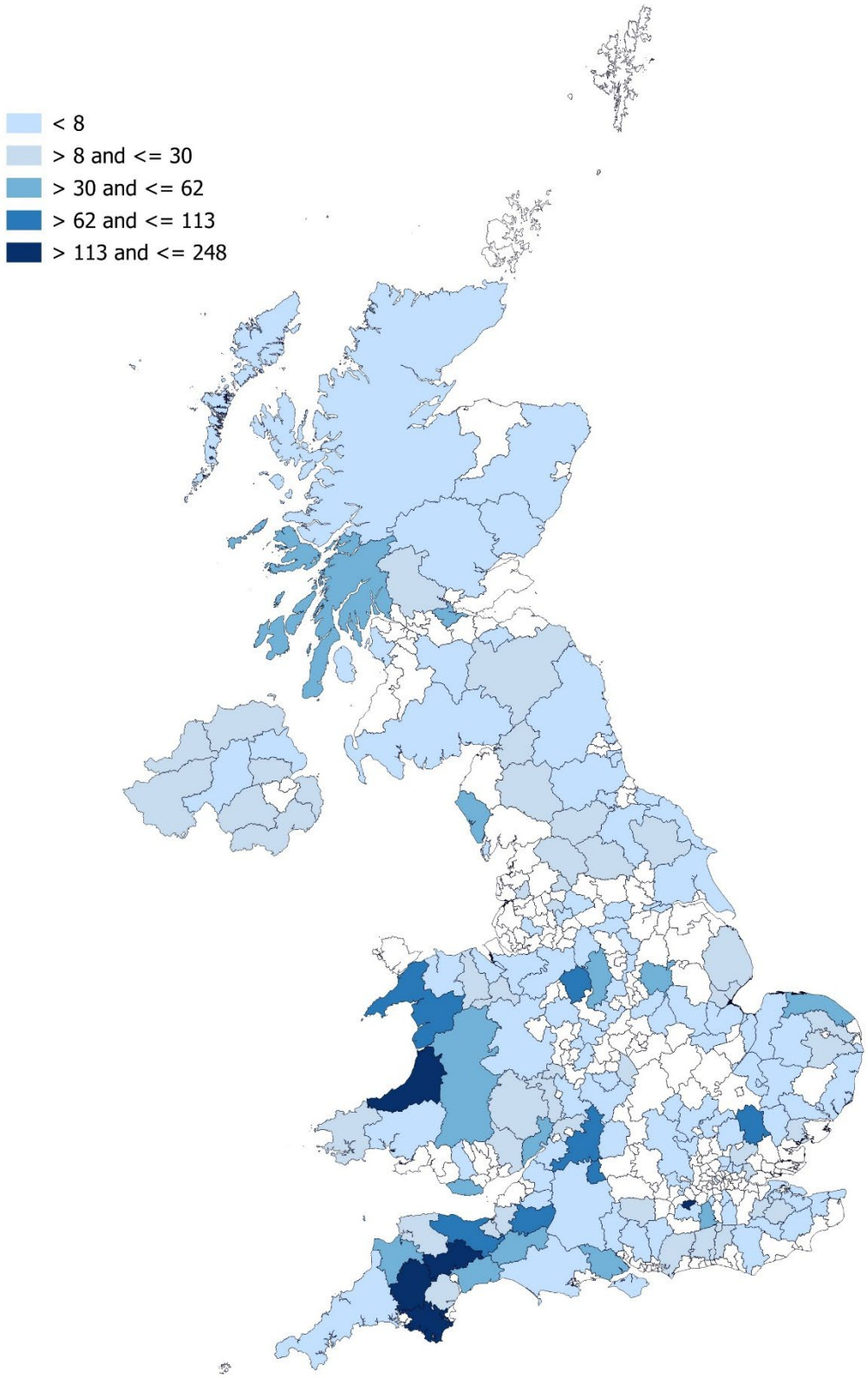
Table 2.13: USO orders and number of premises built[32]

	Number of USO orders	Total premises passed by resulting build
England	1,532	7,272
Northern Ireland	87	723
Scotland	112	528
Wales	241	1,313

Source: Ofcom analysis of BT data (September 2023).

[28] In particular these are: a contention ratio of no more than 50:1; latency which is capable of allowing the end user to make and receive voice calls effectively; and the capability to allow data usage of at least 100 GB a month.
[29] 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 £54 per month in line with CPI.
[30] BT, USO Reports. KCOM, USO Reports. To date KCOM has not received any eligible USO orders.
[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 2,000 figure also includes orders made once build has completed.
[32] While conducting final accuracy checks for the purpose of our report, BT informed us that the implementation of a new data model might have impacted on their reporting of total USO orders and premises passed by resulting build. We are following this up with BT and will publish corrected data if necessary.

Figure 2.6: Map of USO orders by Local Authority Area (per 100,000 premises)



Source: Ofcom analysis of BT data (September 2023) using 2021 Local Authority boundaries.

There was only a small increase in the number of USO orders this year (approximately 150 new orders)[33] compared to previous years (e.g. 500 in 2021), indicating a downward trend. Data analysis by BT indicates that nine out of ten of the remaining premises without access to decent broadband are likely to exceed the £3,400 cost threshold. In these cases, customers will receive excess cost quotes that may be quite high and, in most cases, unaffordable for customers. Those premises that are the most expensive to connect are likely to need alternative solutions.

The UK Government is seeking views on the broadband USO

In October 2023, the UK Government published a consultation seeking stakeholder views on what has worked well with the USO and what could be improved, including awareness, delivery, the cost threshold, funding mechanism, service requirements and eligibility. The consultation closed at the end of November and the Government will be reviewing responses to decide next steps. We are working closely with the Government as it progresses its work in this area.[34]

Private sector investment is driving rollout of faster networks, while public schemes support hard-to-reach areas

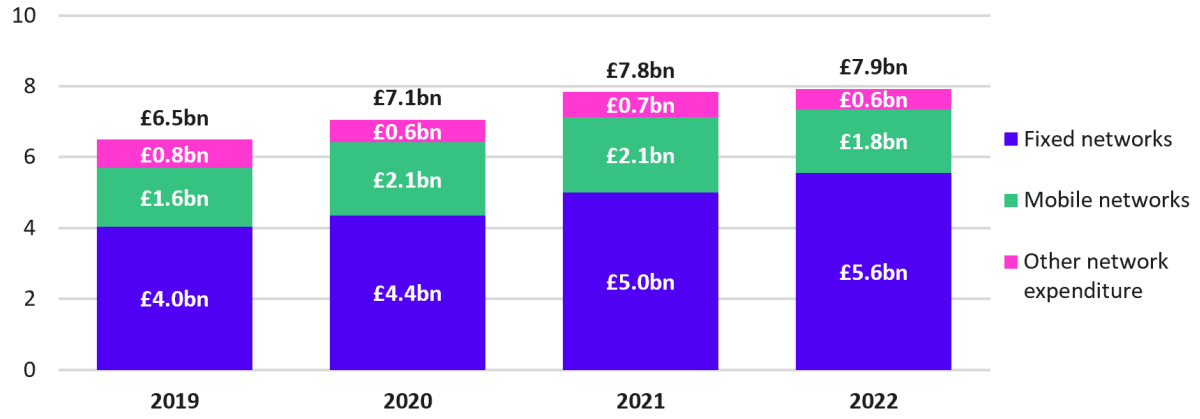
Expenditure on telecoms infrastructure increased to £7.9bn in 2022

We collect network investment data from around 30 of the UK's largest fixed and mobile telecoms network operators to understand how they are investing in network infrastructure.[35] The information collected relates to their annual financial reporting periods, which can differ between operators, and we pro-rate the submitted data to estimate calendar year figures. The figures 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 section 2 of this report.

We estimate that UK operators invested a total of £7.9bn in network infrastructure in 2022, a £0.1bn (1%) real-term increase (i.e. adjusted for inflation) compared to 2021 (Figure 2.7). Fixed network investment totalled £5.6bn during the year (70% of the total) with mobile network investment accounting for a further £1.8bn (23% of the total). An additional £0.6bn related to 'other network expenditure', i.e. investment in infrastructure used to provide both fixed and mobile services.

[33] Last year we reported that the total number of USO orders was 1,850.
[34] As mentioned above, under the Communications Act 2003, Ofcom is likely to be issued with a direction to review the broadband USO if it appears to the Secretary of State that, on the basis of information we have published, take-up of superfast broadband has reached at least 75% of all UK premises. Our data shows that, for all UK premises, the take-up of superfast broadband in May 2023 was 72%.
[35] 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, or assets held for sale and the costs of maintenance contracts purchased alongside hardware. Expenditure associated with asset transfers and leasing follows the same guidelines the Office for National Statistics provides when requesting information in its quarterly acquisitions and disposals of capital asset survey. While the figures shown have been rounded, any percentage changes shown are calculated using the unrounded data.

Figure 2.7: Estimated telecoms network capital expenditure: 2019 to 2022



Source: Ofcom analysis of operator data.
Note: Adjusted for CPI (2022 prices).

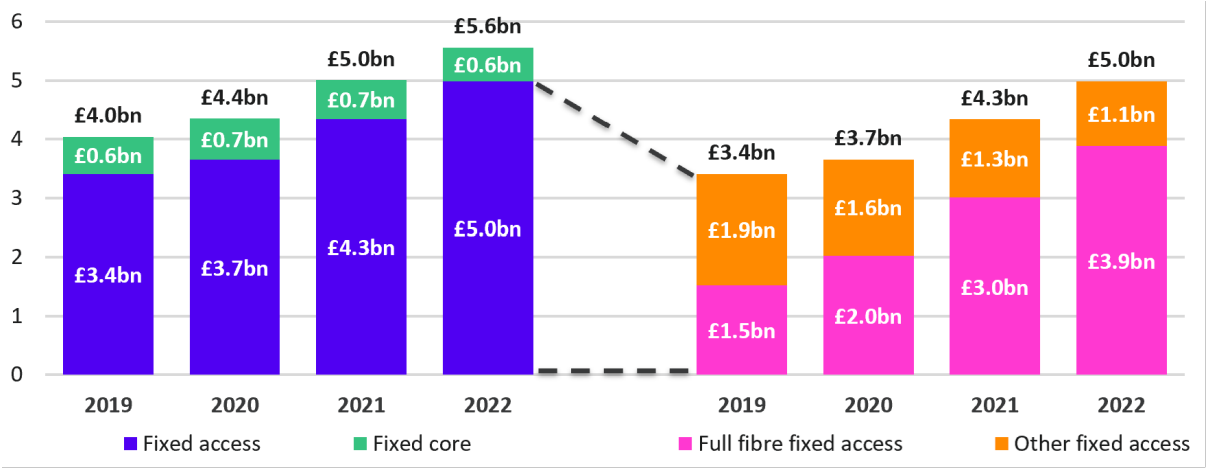
Fixed telecoms network infrastructure expenditure increased to £5.6bn in 2022

We estimate that UK operators invested £5.6bn in fixed telecoms network infrastructure in 2022 (Figure 2.8). This was a £0.6bn (11%) year-on-year increase in real terms.

Investment in access network infrastructure accounted for most of the fixed network investment in 2022 (£5.0bn, or 90% of the total) with the remaining £0.6bn (10% of the total) being investment in fixed core and backhaul networks. The proportion of total fixed network expenditure that related to access networks increased by three percentage points in 2022, and there was a similar decline in the proportion relating to fixed core and backhaul networks.

Investment in full-fibre access networks was an estimated £3.9bn in 2022, an increase of £0.9bn (29%) year-on-year in real terms. In addition, some of the £1.1bn that was spent on other fixed access infrastructure may also support the rollout of full-fibre networks where it relates to upgrades to physical infrastructure (such as fibre deployment for FTTC networks) that could be re-used in the future.

Figure 2.8: Estimated fixed telecoms network capital expenditure: 2019 to 2022



Source: Ofcom analysis of operator data.
Note: Adjusted for CPI (2022 prices).

Network operators are continuing to progress plans for the rollout of full-fibre networks

The availability of full-fibre and gigabit-capable networks is expected to continue to increase over the next few years. A range of network operators plan to continue deploying new infrastructure, using varying business models.

- Openreach is the incumbent wholesale infrastructure operator for almost all of the UK. It plans to reach 25 million premises with full fibre by December 2026. This includes six million homes in harder to reach areas by 2025.[36] Openreach reported in December 2023 that their full-fibre network had passed 12.5 million premises across the UK, with 3.5 million in rural areas.[37]
- Virgin Media O2 is rolling out full fibre through a combination of upgrades to their existing cable network and new network build through their joint venture, nexfibre. Through this, they plan to reach 80% of the UK with full fibre by 2028.[38] As of June 2023, Virgin Media O2 reported that their full-fibre footprint had reached three million homes.[39] Part of this footprint has been built by nexfibre, who reported having passed 500,000 premises as of September 2023.[40]
- CityFibre plans to pass up to eight million premises (both residential and business) across 285 towns and cities by 2025. In August 2023, it announced it had passed three million homes, completing over 37% of its target.[41] CityFibre uses a partnership model, with approximately 40 internet service providers offering full fibre to customers over the CityFibre network.[42]
- In the Kingston upon Hull area, KCOM is the incumbent operator. It committed to full-fibre deployment a number of years ago and availability in the Hull area is approaching 100%. As reported in September 2022, KCOM is also extending its full-fibre footprint beyond its traditional area of operation, targeting premises in East Yorkshire and Lincolnshire.[43]

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

In addition to the operators' own public statements on network rollout outlined above, we gather stated deployment plans of network operators, and in October 2023 we published our second forward-looking report on planned network deployment. This report is based on the stated deployment plans of operators within three years from May 2023, for both full-fibre and fixed wireless access networks, and for plans that are funded privately or supported through public funds.

As outlined in that report, the total number of residential premises expected to have full-fibre coverage in 2026 could be as high as 91% of all residential premises, and 94% of residential premises could have gigabit-capable coverage. However, when comparing plans from last year and this year,

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[36] Openreach, Openreach focuses broadband build plans on upgrading millions more rural homes, May 2021.
[37] Openreach, Celebrating getting next generation Ultrafast Full Fibre Broadband to 12.5 million homes and businesses, 7 December 2023.
[38] Virgin Media O2, Bringing our gigabit services to more areas with new fibre technology switch on, 29 June 2023.
[39] Virgin Media O2, Virgin Media O2 publishes Q2 results to 30 June 2023, 30 June 2023.
[40] Nexfibre, nexfibre announces its nationwide rollout plan, 7 November 2023.
[41] CityFibre, CityFibre's nationwide full fibre network rollout passes 3m premises , 29 August 2023.
[42] CityFibre, Full fibre broadband providers on the CityFibre network.
[43] KCOM, KCOM unveils £100m vision to deliver full fibre future for region, September 2022.

and actual deployment over the last year, we note that deployment has been lower than expected and future plans have been revised downwards. This likely reflects the market conditions faced by network operators in the previous year, and evolutions in the fixed broadband market, which we discuss below.

While these plans are forward looking and subject to change, we have also looked at how expected deployments of fibre and fixed wireless access networks might further reduce the number of premises (residential and commercial) that cannot get decent broadband over the next three years (see Table 2.14 for the current estimates of this). Our estimates indicate that there could be 25,000 premises that continue to be without access to decent broadband from fixed line or fixed wireless networks in May 2026.

Table 2.14: Estimated number of remaining premises unable to access decent broadband by May 2026

	May 2026
England	14,400
Northern Ireland	400
Scotland	5,000
Wales	5,200
UK total	**25,000**

Source: Ofcom analysis of operator data (May and September 2023).

Physical infrastructure access continues to play an important role in the deployment of new networks

Deploying new networks requires significant investment and engineering resources. Many providers can reduce the cost and timeframes for deployment if they roll out parts of their network using Openreach's network, which is made up of approximately 486,000 km of duct and 4.1 million poles. Since 2019, our rules have allowed easier access to Openreach's physical infrastructure (PIA). As of the end of September 2023, 169 providers had registered with Openreach as customers of PIA, and nearly 90% of these had already built network using PIA or had placed orders to do so. Providers have ordered around 160,000 km of duct (48,000 km of which has been delivered) and approximately 1.2 million poles (373,000 of which have been delivered) to deploy networks.

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 network deployment for the hardest-to-reach areas.

The UK Government has committed, under Project Gigabit, £5bn to bring gigabit-capable broadband coverage to 85% of premises in the UK by 2025. It is focusing on hard-to-reach areas that are not included in broadband network operators' rollout plans due to the difficulty and / or the cost of

building network in those areas. As of September 2023, the UK Government had launched 39 procurements representing over £2bn, aiming to cover 1.1 million premises.[44]

In addition, there are other government schemes to encourage rollout of faster broadband services in hard-to-reach areas:

- The UK Government's Gigabit Broadband Voucher Scheme provides vouchers worth up to £4,500 for eligible customers to contribute towards the costs of installing gigabit-capable broadband. As of September 2023, more than 100,000 vouchers had been used to connect premises to gigabit-capable broadband, and a further 21,800 vouchers had been issued, though not yet used.[45]
- The Welsh Government's Superfast Cymru programme has now concluded with the second phase connecting a total of 44,000 premises over four years at a cost of £57 million.[46] In partnership with Openreach, the four-year project has given access to full fibre connectivity to 44,000, exceeding the original target of 39,000. The rollout, with an original budget of £57 million, has been as a result of Welsh Government and EU funding, investment from Openreach and support from the UK Government.
- The Scottish Government's Reaching 100% (R100) Programme aims to enable superfast broadband connectivity (≥30 Mbit/s) to all premises, residential and commercial, in Scotland.[47] As of 30 September 2023, over 42,000 connections have been delivered through the R100 Programme, with over 3,500 of these connections delivered through the R100 Scottish Broadband Voucher Scheme (SBVS).[48]
- In Northern Ireland, the Department for the Economy's Project Stratum was developed to improve connectivity for premises unable to access broadband services of 30 Mbit/s or greater, primarily across rural areas of Northern Ireland. As a result of this public intervention, some 85,000 eligible premises will have access to gigabit-capable broadband. To date, 70,000 premises have been connected and the project remains on target to complete deployment to all 85,000 premises by March 2025.[49]

More information about schemes run by the devolved governments is available in our separate reports on each of the UK's nations.

The UK Government is also considering other ways to deliver better connectivity for rural and remote premises, including using satellite technology, which we discuss above. In 2022, it launched the Very Hard to Reach premises Alpha Trials to test the use of LEO satellite broadband as an alternative solution for delivering better broadband connections for very hard to reach locations.[50] The Government has also committed £8 million in funding to connect up to 35,000 remote properties to satellite internet[51] and a further £7 million for trials of hybrid satellite and FWA networks in rural areas.[52] The Government also launched a consultation in October 2023 on policy

[44] UK Government, Project Gigabit progress update, September 2023, 20 September 2023.
[45] UK Government, Project Gigabit progress update, September 2023, 20 September 2023.
[46] Welsh Government, Tens of thousands of homes and businesses can access gigabit capable speeds as rollout of full fibre broadband smashes targets, 6 December 2023.
[47] Digital Scotland, About R100.
[48] Digital Scotland, R100 Facts, October 2023.
[49] Department for the Economy, Project Stratum.
[50] UK Government, Very Hard to Reach premises: alpha trials, 2 October 2023.
[51] UK Government, New investment boosts UK's digital connectivity, 11 April 2023.
[52] UK Government, Government launches new drive to support rural communities, 6 June 2023.

options for improving broadband access for Very Hard to Reach premises.[53] We will continue to work with the UK Government as it develops policy in this area.

The fixed broadband market is continuing to evolve as a result of mergers and acquisitions among network operators

The landscape of network operators in the fixed telecoms space continues to evolve, with some mergers or acquisitions having taken place in recent years. This includes:

- In September 2023, Virgin Media O2 announced it was acquiring fibre operator Upp, which primarily serves premises in the East of England and East Midlands, to integrate with their fibre joint venture, nexfibre.[54]
- Full-fibre operator Trooli, which serves customers primarily in the South and South East, was acquired by Agnar UK Infrastructure Ltd in April 2023.[55]
- Fern Trading Limited announced in February 2023 that it was consolidating four retail and wholesale fibre brands, Jurassic Fibre, Swish Fibre, Giganet, AllPoints Fibre, into a single operating entity to create a national wholesale network.[56]
- In July 2022, Glide Group, a full-fibre operator that focuses on students, residential developers and businesses, acquired Velocity1, which built and managed fibre networks across Wembley Park for property developer Quintan.[57]

There have been a small number of operators going into administration in recent years. This includes Essex-based People's Fibre, which was put into administration in 2021, before being acquired by Swish Fibre.[58] Additionally, Broadway Partners, a fibre broadband operator building a network in Scotland and Wales, announced that it had been put into administration in June 2023, and has since been acquired by Voneus, a rural broadband operator.[59]

Current economic circumstances, including the recent period of high inflation and interest rate increases, alongside labour and supply chain challenges, could lead to further changes in the fixed broadband market, which Ofcom will continue to monitor.

Fixed providers are increasing their use of cloud services

Cloud computing, which is the provision of remote access to computing resources (such as storage and networking) on demand and over a network, is being rapidly adopted by businesses across the economy. It has become an essential part of how many digital services are delivered to consumers, including in the telecoms and broadcasting sectors.

We concluded our market study into the supply of cloud services in the UK in October 2023. In our study we observed that cloud services are changing how telecoms services are being produced and delivered to customers. We identified that both fixed and mobile providers are using cloud services

[53] UK Government, Improving broadband for Very Hard to Reach premises, 2 October 2023.
[54] Virgin Media O2, nexfibre acquires altnet Upp to accelerate fibre rollout by 175,000 homes in partnership with Virgin Media O2, 6 September 2023.
[55] Companies House, Notification of Agnar Uk Infrastructure Ltd as a person with significant control on 3 April 2023, 6 April 2023.
[56] Jurassic Fibre, Fern brings together its retail and wholesale fibre businesses to accelerate UK fibre deployment, 8 February 2023.
[57] Glide Group, Glide Acquires Velocity1, 13 July 2022.
[58] Comms Business, Swish Fibre snaps up People's Fibre, 4 January 2022.
[59] Macquarie, New funding and consolidation positions Voneus as UK rural broadband market leader, 25 September 2023.

to deploy specific network functions,[60] as well as for enterprise IT activities such as customer relationship management and enterprise resource planning (similarly to other businesses across the economy).[61]

Given the growing importance of cloud services to telecoms providers, as part of our work for Connected Nations we asked a number of fixed and mobile providers to tell us about their existing and planned use of cloud services for deploying network functions.[62]

Fixed providers told us that they have been making more use of cloud services in recent years, and they are predominantly using private cloud services for their network functions.[63] These included, for example, broadband core and voice core network functions. Some providers told us that they are also using private cloud for network monitoring and network element management. Looking ahead, providers told us about their plans to make greater use of private cloud, such as for elements of broadband control plane and for voice core evolution.[64]

The migration from legacy voice services to digital voice continues

The retirement of the legacy public switched telephone network is progressing

The UK's traditional landline voice services are undergoing a substantial transition as network operators 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. Other providers using the same legacy technology as BT are following a broadly similar timescale. As of 5 September 2023, Openreach has stopped new sales of the wholesale services that deliver the PSTN across the UK, an important step in the PSTN switch-off process.[65]

To make sure landline services continue to be available in the future, providers currently using legacy telephony networks will deliver landline calls over a digital technology called Voice over Internet Protocol (VoIP) over a broadband connection.[66]

Customers with landlines are increasingly using VoIP

A growing number of customers now have a VoIP landline service. This may be because their landline service was moved to VoIP when they switched provider or when they upgraded their

[60] Network function is a component of telecoms networks that delivers a specific function (e.g., router, switch, load balancer, firewall).
[61] See paragraphs 3.70 – 3.79 of Cloud services market study - Final report.
[62] This was done through a formal information request to support our Connected Nations reporting.
[63] Private cloud is a cloud deployment model where computing resources are dedicated to (as opposed to shared between) individual entities.
[64] Broadband control plane is an integral part of a fixed broadband network which controls and manages various functions and processes related to how data packets are forwarded in the network.
[65] Openreach, Openreach puts the stopper on copper.
[66] When discussing VoIP in this context, we are referring to managed voice services in which the voice service provider can control and manage the quality of the service over the broadband connection. This does not include general 'VoIP' calls made using personal online communication services such as Skype or WhatsApp, potentially over a range of different devices.

phone and broadband package with the same provider. Their existing provider may also have contacted them proactively to make the switch away from a PSTN service.

Our analysis of provider data (Table 2.15) found PSTN connections now account for less than half of landline connections (41%). Around 9.7 million landlines (residential and businesses) still use the PSTN.[67] Customers with a landline who are no longer on a PSTN line have either migrated to VoIP (8.1 million or 34% of landline connections) or have a service with a landline provider that uses a similar technology to the PSTN but does not rely on the PSTN, called Emulated PSTN (6.1 million or 25% of landline connections). Finally, some customers are ceasing their landline altogether, which we discuss in more detail below.

Table 2.15: Number and share of landlines by technology type

	Approximate number of lines	Share of total landlines
PSTN	9.7 million	41%
VoIP	8.1 million	34%
Emulated PSTN	6.1 million	25%
Total	**23.9 million**	**100%**

Source: Ofcom analysis of provider data (June 2023).

Some providers (BT, Virgin Media O2, Vodafone, KCOM and Zen) have been migrating some of their existing customers on to VoIP; this practice is known as provider-led or managed migrations.

In the year to June 2023, around 1.5 million residential customers who had a PSTN line migrated to a VoIP service, with 38% (583,000 lines) as a result of a managed migration.[68] The remaining 62% (935,000 lines) were as a result of customer-initiated migrations.

BT paused its managed migrations programme in March 2022 and restarted it in April 2023 with a trial of 'easier to migrate' customers who have low landline usage and no additional needs.[69] In the summer of 2023, BT started a regional rollout of migrations, focusing its engagement and communications activity in each region in turn.[70]

While migrating their landline service from a PSTN line to a VoIP line should be straightforward for most landline customers, some customers have more complex needs, such as telecare users, landline only users, customers with poor or no mobile reception, or other additional needs.

BT has announced a range of support for those customers with more complex needs. Notably, BT, which is the main provider of landline-only services, has recently said that customers without broadband will not be switched to a digital landline until they are able to. BT will install new

[67] The data used to calculate these figures was collected from a subset of providers, which combined cover the large majority of the UK voice and broadband connections. Whilst this provides a good reflection of the current profile of telephony technology in the UK it does not cover the whole market.
[68] The data we collect on migration only captures customers that migrate from PSTN to VoIP with the same provider (excluding those that switch from a PSTN service with one provider, to a VoIP service with another provider and consequently migrate to VoIP simultaneously). Therefore, we may underestimate the number of migrations that have occurred and may overestimate the proportion that occur as a result of a managed migration.
[69] BT, We're expanding our trials of Digital Voice for customers, 8 March 2023.
[70] BT, Digital Voice: Making progress with our customer led, regional rollout, 29 August 2023.

equipment in the local telephone exchange that will allow customers to use their phone in the same way as they do today, as a temporary solution until they are able to switch to a VoIP service.[71]

We are continuing to monitor the migration closely and engage with providers to ensure that disruption is minimised, and consumers are protected from harm. Our website provides advice to consumers about the move from landline phones to digital technology.

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.

The number of households using a landline service continues to fall

While some households are transitioning to new technology for their landline, others are giving up their landline altogether in favour of broadband-only packages. Broadband-only packages, with or without the option to add a landline service, are offered by most full-fibre providers.

In the year to August 2023, 486,000 households ceased their landline in favour of a broadband-only service. This is slightly lower than last year, when we reported that more than half a million households ceased their landline in the year to August 2022. As reported in our 2023 Communications Market Report, the total number of landline users has decreased by approximately three million between 2019 and 2022.[72]

As households cease their landline services, some consumers may be making use of personal online communication services (OCS), such as Skype or WhatsApp, to make voice and video calls. As we noted in our recent discussion paper on personal OCS, there has been a steady increase in call minutes made over OCS in the last decade, although call minutes on traditional services (landline and mobile) remain high.

Ofcom has a range of work to help customers choose the right broadband service

Customers increasingly have access to a greater variety of broadband services, at different speeds and over different technologies. Ofcom is continuing with a range of work to help customers understand these choices, the benefits provided by different technologies and make decisions about the broadband services that are most suitable for their needs.

Our broadband coverage checker shows the estimated fastest speeds and operators that are available at a particular address.

We recognise that consumers need the right information to make informed choices about their broadband services. We have recently published new guidance to ensure providers give customers information on the underlying technology of their broadband connection.

Ensuring people can access affordable fixed and mobile broadband remains a priority for Ofcom, and the affordability of broadband services will also have a significant impact on consumer choice, particularly given continued pressures on cost of living and rising prices we have seen in the past year. We have called on providers to offer and promote social tariffs, cheaper broadband and phone packages for people on benefits, and to make it easier for eligible customers to switch onto them. Our social tariffs webpage shows what social tariffs are available, the packages offered and how

[71] BT, BT announces regional rollout schedule for Digital Voice, 26 September 2023.
[72] Ofcom, Communications Market Report 2023: Interactive Data, 20 July 2023.

much they cost, to make it easier for consumers to find social tariffs. Our 2023 Pricing Trends report, published in December 2023, provides the latest figures on availability, awareness and take-up of social tariffs. We reported that, as of September 2023, 380,000 households were signed up to a social tariff, an increase of nearly 160,000 customers (72%) since February 2023.

In March and April 2023, many fixed and mobile providers implemented inflation-linked price rises for in-contract customers. In December 2023 we published a review of inflation-linked in-contract price rises, which considers their impact on consumers and on the functioning of markets. We are consulting on proposals to require companies, where they provide for any price rises during the customer's contract period, to set this out up-front at the point of sale in pounds and pence.

3. Mobile, data and voice

Introduction

In an increasingly interconnected world, mobile services continue to play an integral role in our daily lives, from on-the-go calls and internet access to wireless connectivity for smart devices. In this section, we provide an update on the progress mobile network operators (MNOs) are making with their mobile 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. In addition, we note the emerging role of neutral hosts in managing and providing infrastructure to support coverage.

We also provide insights into mobile network performance from our ongoing work on crowdsourced data. We report on investment in, and the take up of mobile services, as reflected in the continuing growth of mobile traffic, while also updating on the usage and availability of Internet of Things (IoT) devices and services, and private networks.

Highlights

- **The availability of mobile 5G non-standalone continues to grow rapidly.** The level of coverage provided outside of premises by at least one MNO increased to 85-93% in 2023, up from 67-78% in 2022 (across a range covering Very High and High Confidence levels). MNO 5G predictions indicate that Three has the most extensive outside premises coverage at our High Confidence level of 78% and BT/EE has the most coverage at our Very High Confidence level of 63%.
- **There has been some deployment of 5G standalone for mobile.** Last year, we reported that trials had begun, and this year we note the deployment of around 2,000 commercial mobile 5G standalone sites.
- **4G continues to provide the backbone of consumers' mobile experience.** Coverage for data services from at least one MNO reached 93% of UK landmass and 4G continues to carry the majority of mobile data traffic (accounting for 81% of total data traffic).
- **We are continuing to explore the use of crowdsource data** to offer better information on mobile coverage and performance and are providing performance maps as an initial view.
- **Mobile traffic continues to grow**, with overall traffic levels increasing by around 25% year on year, compared with a c.27% rise between 2021 and 2022. 5G traffic has shown the highest growth from 63 PB[73] in 2022 to 151 PB in 2023, a growth of around 140%.
- **MNOs have started switching off their 3G networks and have committed to switching off their 2G networks by 2033 at the latest.** The number of customers using devices reliant on 2G or 3G connectivity has fallen sharply to 2.4 million and the level of data traffic carried on 3G networks is less than 3%, on average, across all MNOs.
- **We see continued evolution in non-consumer connectivity,** marked by increased Internet of Things (IoT) connections from both MNOs and other players, alongside a 17% growth in MNOs' IoT traffic.

[73] 1 PB (Petabyte) is equivalent to 1,000,000 GB (Gigabyte). Additionally, traffic reported in this section except for MNO IoT traffic is rounded up to the nearest whole number.

Figure 3.1: Overview of voice and data coverage across the UK and UK nations[74]

	England	Northern Ireland	Scotland	Wales	UK
5G outside premises (MNO range)	51-81%	26-62%	39-70%	11-69%	48-78%
4G outside premises (MNO range)	99-99%+	98-99%	98-99%+	96-99%	99-99%+
4G geographic (MNO range)	92-95%	88-92%	59-76%	73-85%	80-87%
4G total not spots	2%	3%	16%	9%	7%
Voice & text total not spots	1%	1%	10%	4%	4%

Source: Ofcom analysis of MNO predictions (September 2023).

Background to mobile technologies

Mobile services described in this section include:

- **5G non-standalone (5G NSA)** involves deploying 5G radio equipment alongside existing 4G. This delivers an increase in capacity and allows MNOs to support demand as it continues to grow, without the congestion and degradation of service quality that would otherwise result.
- **5G standalone (5G SA)** involves the deployment of a new 5G core network. This could enable new use cases such as Augmented Reality (AR) /Virtual Reality (VR) and robotics, supported by the broader capabilities of 5G including ultra-low latency, advanced virtual network (slicing) functions, and potentially improved coverage.[75]
- **4G, 3G and 2G** are other generations of mobile standards with specified features. The introduction of 3G supported the use of data applications such as web browsing, while 4G has supported more data intensive activities such as streaming and gaming.

When reporting on mobile 5G availability predictions, we refer to confidence ranges[76] reflecting the likelihood of on the ground coverage for consumers as:

- **High Confidence** associated with a signal strength (-110 dBm), to equate to at least an 80% confidence level.
- **Very High Confidence** associated with a higher signal strength (-100 dBm), to equate to a circa 95% confidence level.

[74] 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.

[75] Augmented Reality (AR): an enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli delivered via technology. It overlays digital content, which could include a combination of sound, video, text, and graphics, onto a real-world environment using a headset or a device with a camera, such as a mobile phone.
Virtual Reality (VR): use of a headset to access a virtual experience, which could be digitally created or a captured 360° photo or video.

[76] Signal strengths refer to control channel signals – for further detail see our Methodology annex.

Mobile coverage

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.[77]

We have welcomed the emphasis placed on improving the accuracy of reporting of mobile coverage and performance in DSIT's wireless infrastructure strategy (WIS), as well as reporting on 5G standalone (SA) as it begins to be deployed in the UK. 5G in the UK has been commercially rolled out in non-standalone (NSA) mode. This means that user services can be delivered over 5G, or a combination of 4G and 5G, which can place constraints on some of the full capabilities of 5G. We are now beginning to see the transition to mobile 5G SA rollouts, moving from a trial phase reported last year to around 2,000 mobile 5G standalone sites commercially deployed this year.[78] We, however, note that we are still at an early stage in the rollout of mobile 5G SA, and we will continue to monitor progress in the years ahead.

5G availability is gathering pace, though it varies across MNOs

5G[79] availability is gathering pace though it varies by MNO and by geography. A notable increase in 5G coverage has been observed across the UK in 2023 and it now stands at 93% (High Confidence) and 85% (Very High Confidence), up from 78% and 67% respectively in 2022 for areas outside of premises where 'At least one MNO' provides coverage (Figure 3.2).[80] The 'All' MNO footprint, representing the places where all four MNOs provide 5G coverage, remains at a significantly lower level. But it has increased, reaching outside 25% of premises at High Confidence, and 16% at Very High Confidence, up from 20% and 11% respectively last year.

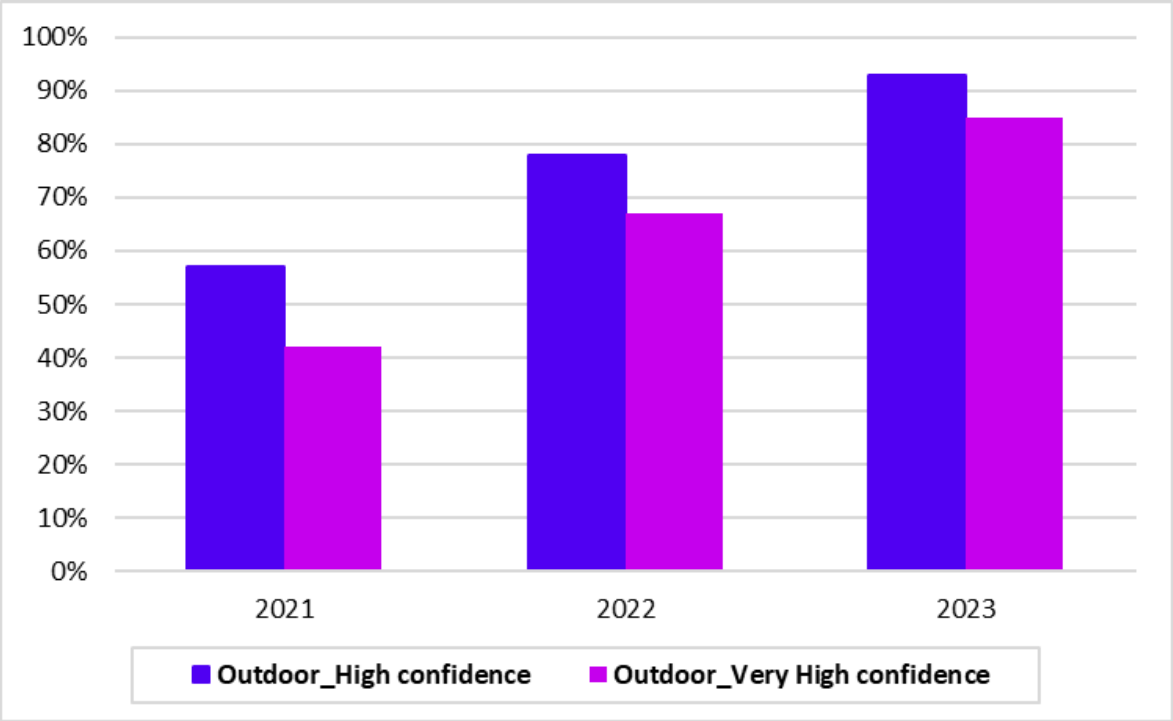
[77] For more information on this, please see the Methodology annex.

[78] To utilise a mobile 5G SA network, the user's device must be compatible with both mobile SA 5G and the operating frequency. As of November 2023, Android mobile phones compatible with mobile 5G SA services currently offered in the UK range from OPPO X3 and OPPO X5 to the Samsung Galaxy S21, S22 and S23 Series range (5G Ultra explained - Frequently asked questions -Which phones are compatible with 5G Ultra?). Apple IOS is available for mobile 5G SA with mobile phones such as iPhone 15 Pro, Model A310 and iPhone 15 Pro Max, Model A3106 in the UK market (5G and LTE. Find the iPhone that's right for your country or region).

[79] In this section, we mostly report on the availability of 5G on a NSA basis.

[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. 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.

Figure 3.2: 5G coverage outside UK premises by 'At least one MNO' (2021 - 2023)



Source: Ofcom analysis of MNO predictions (September 2023).

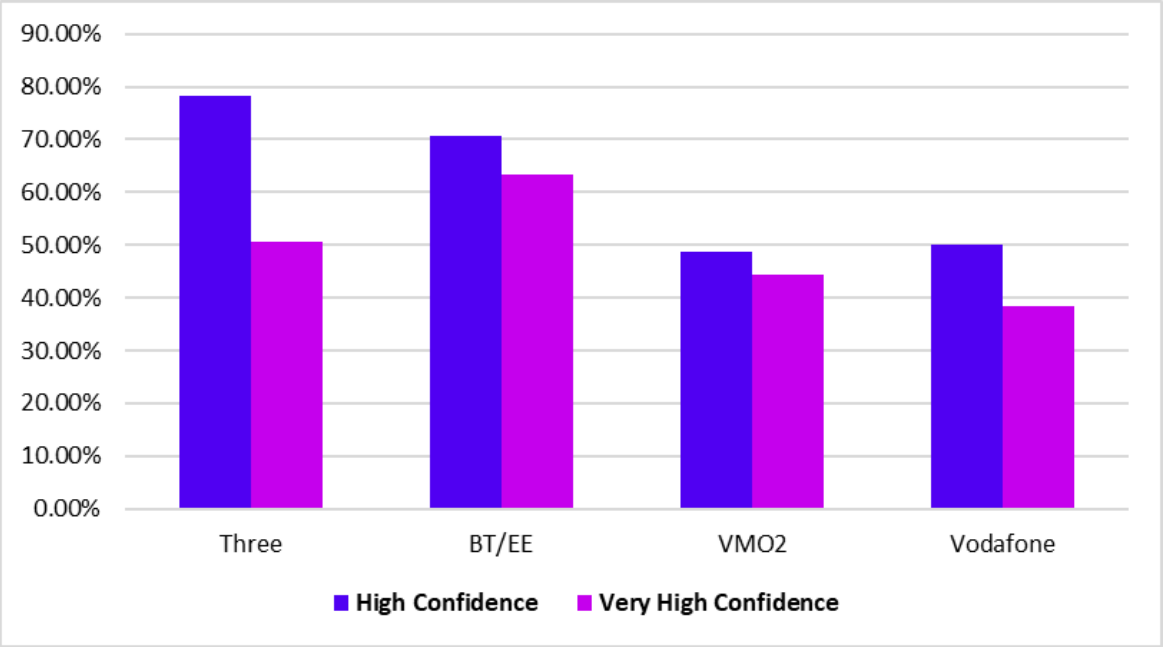
Landmass coverage for 5G across individual MNOs is steadily increasing; however, it still remains relatively low overall, ranging from 11% to 38% of the landmass at High Confidence, and 6% to 26% at the Very High Confidence level (up from 6% to 16% and 3% to 12% respectively last year).

These increases in coverage have been driven by additional 5G deployments, with more than 18,500 5G deployments now in place across around 81,000 sites in the UK, up from around 12,000 5G deployments reported in 2022.[81] Around 34% of sites in urban areas now have 5G deployed on them, compared with around 20% and 10% in suburban and rural areas respectively. Of these, 85% are located in England, 9% in Scotland, 4% in Wales and 2% in Northern Ireland, broadly in line with previous trends and reflecting national distribution of all mobile traffic across the UK.

BT/EE retains the most extensive 5G coverage at the Very High Confidence level, reaching over 26% of the UK landmass and with outside premises coverage extending to at least 63%. Three retains the most extensive 5G coverage at the High Confidence level, reaching over 38% of the UK landmass and with outside premises coverage extending to more than 78%.

[81] It should be noted that these deployments do not necessarily equate to a total of individual sites across all MNOs. For example, two MNOs may be offering coverage from the same site. Also, this encompasses the various mobile 5G deployment types I.e. 5G NSA,5G SA and Dynamic Spectrum Sharing (DSS).

Figure 3.3: MNO 5G coverage outside UK premises, at Very High and High Confidence levels



Source: Ofcom analysis of MNO predictions (September 2023).

Across individual MNOs, 5G coverage outside premises varies across UK Nations as follows: 51-81% for England; 39-70% for Scotland; 11-69% for Wales; and 26-62% for Northern Ireland (all based on our High Confidence level).

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

While this section focuses on 5G coverage (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 coverage footprints.

In addition to using existing spectrum bands to deliver 5G, more spectrum has been released to provide additional bandwidth for 5G services, such as the 3 GHz and 700 MHz bands auctioned by Ofcom in 2021. The 3 GHz band offers high capacity to support large numbers of demanding users across smaller areas, and consequently has to date been deployed predominantly in high traffic locations with at least 61% of 3 GHz site deployments in urban areas. Lower frequency bands such as 700 MHz may provide a similar experience to existing 4G coverage – with additional capacity where such spectrum is used – and is suitable for in-building and wide area coverage, so is increasingly present in both urban and more rural environments.

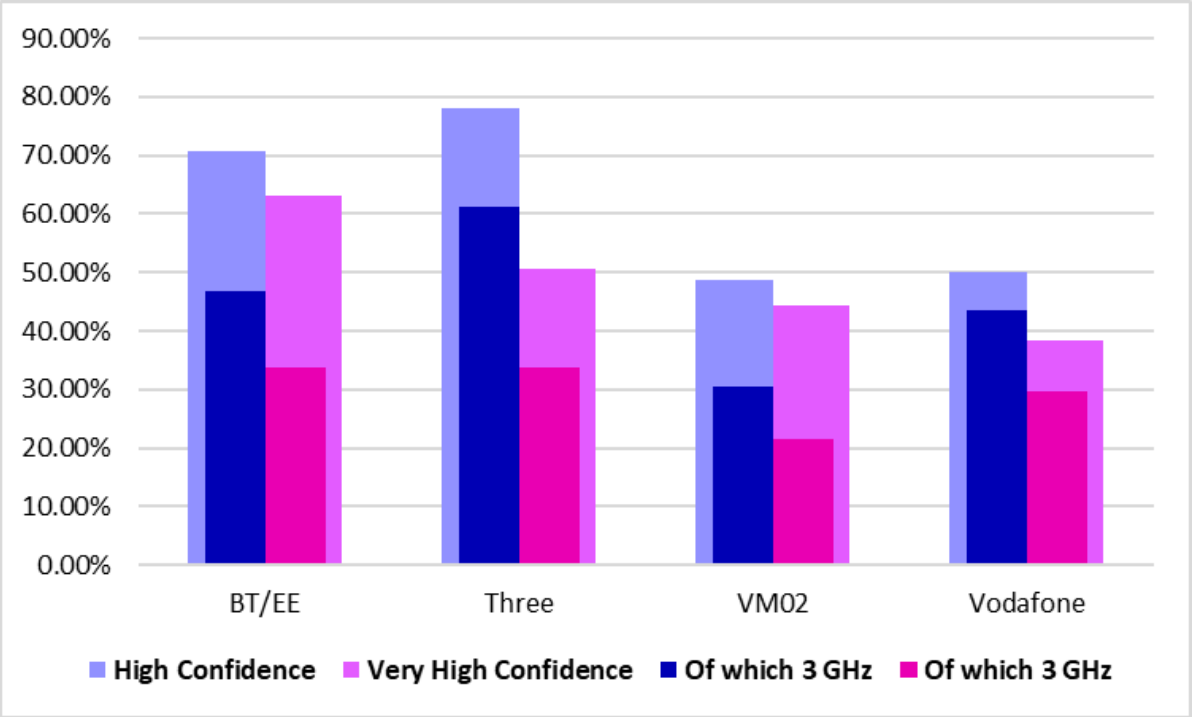
In other situations, MNOs deliver 5G through Dynamic Spectrum Sharing,[82] where 4G and 5G services are carried over the same spectrum, which can help facilitate 5G rollout.

Last year, we reported on outside premises 5G coverage available on the 3 GHz band across MNOs. This year, in addition to updating on 3 GHz outside premises 5G coverage, we highlight the increasing 700 MHz outside premises 5G coverage as deployed by the MNOs that have access to this

[82] 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.

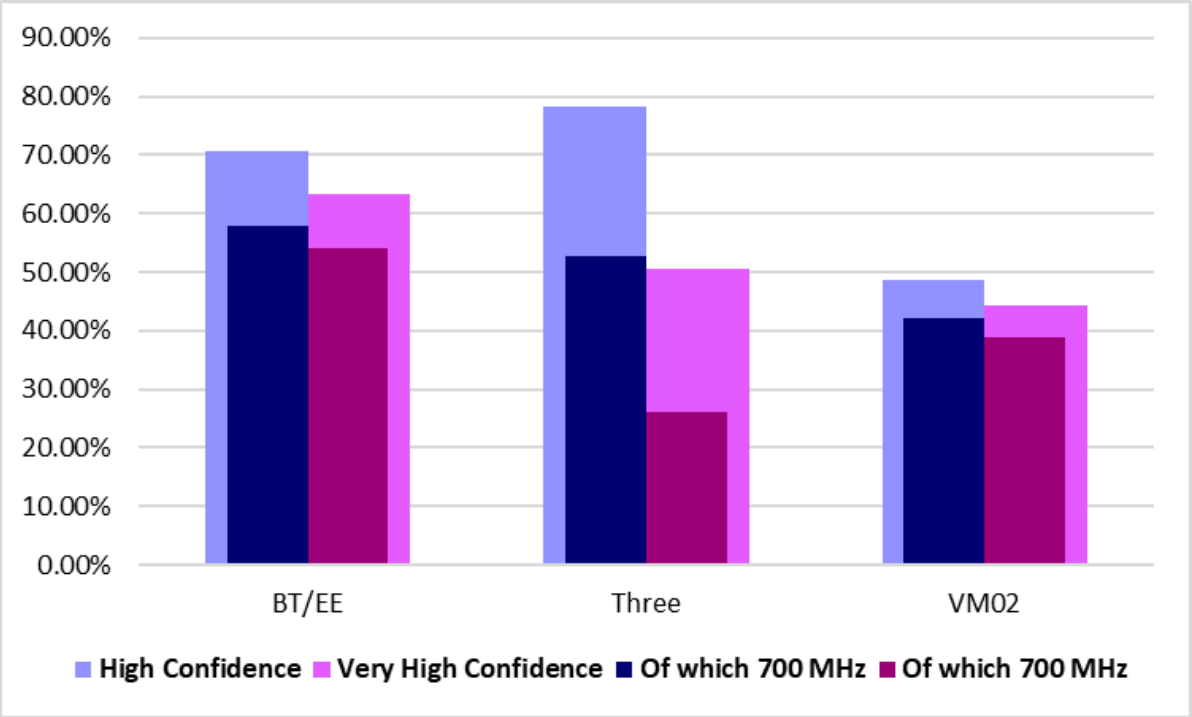
band. As mobile networks evolve, the mix of deployment strategies provide MNOs with a range of 5G coverage and capacity options, with deployments typically influenced by the density and nature of user demand.

Figure 3.4: MNO 5G coverage outside of UK premises with a spotlight on 3GHz



Source: Ofcom analysis of MNO predictions (September 2023).

Figure 3.5: MNO 5G coverage outside of UK premises with a spotlight on 700 MHz[83]



Source: Ofcom analysis of MNO predictions (September 2023).

Overall premises coverage

Alongside increasing 5G coverage, voice and data services continue to be most widely available (and accessed) through older technologies. In particular, the 4G services offered by MNOs continue to provide the fundamental backbone of most consumers' experience. We therefore highlight below the range of 4G coverage available from individual MNOs, alongside an update on 2G and 3G coverage and switch-off plans.

Outdoor premises coverage remains high

In line with recent years, individual operators continue to provide 4G coverage outside more than 99% of UK premises. In addition, 98% of premises have outdoor 4G coverage from all MNOs, which is unchanged from last year. Coverage for voice and text services is very high: MNOs each provide coverage for outdoor voice calls in the vicinity of 99%+.[84]

There continues to be a significant difference between coverage in urban and rural areas. Individual operators' 4G coverage outside rural premises ranges from 94-98% (up from 93-98% last year), while each MNO continues to serve 99%+ of urban premises. Outdoor voice coverage levels across the UK are at 99%+, unchanged from 2022.

Indoor mobile coverage is widely available

A number of factors affect the coverage people receive indoors, including the thickness of walls, building materials, and where in a building people are using their phone.[85] As a result, some

[83] Note that Vodafone does not currently hold a spectrum access licence for 700 MHz.
[84] The MNO's coverage is rounded up to the nearest percentage point.
[85] 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.

premises may see differences between operators' predicted indoor coverage and the actual coverage experienced.[86]

For indoor 4G coverage, the percentage of premises served ranges from 93-96% across individual MNOs. This is up by 1 percentage point at both ends of the range compared to last year (92-95% across individual MNOs in 2022). The availability of indoor voice calls is estimated to range from 96-99% across individual MNOs, compared to 96-99%+ in 2022.[87]

There continues to be a significant difference between indoor coverage in rural and urban areas as shown in Table 3.1 below:

Table 3.1: 4G and voice indoor coverage across MNOs in rural and urban areas

	4G		Voice	
	2022	**2023**	**2022**	**2023**
Urban	96-98%	96-98%	99-99%+	99-99%+
Rural	71-81%	73-82%	80-98%	81-97%

Source: Ofcom analysis of MNO predictions (September 2023).

Where indoor coverage is poor or unreliable, other solutions can improve the user's experience. These include broadband-based voice or video calls on services such as WiFi calling, online communications services such as WhatsApp, or femtocell.[88] All MNOs offer WiFi calling, although not all phones are configured to support this. The percentage of voice over WiFi calls reported by MNOs range between 3% and 16% across individual MNOs, aligning closely with the figures observed in 2022 (between 2% and 17%) and 2021 (between 2% and 16%).

4G geographic coverage

Overall, 4G geographic coverage across the UK has not increased substantially compared with 2022. From the data reported to us, we can see that percentage coverage by each MNO is 87% for BT/EE, 82% for Virgin Media O2, 80% for Three, and 83% for Vodafone.[89] Therefore, the UK landmass covered by individual MNOs remains consistent, ranging from 80-87% compared to the previous year's 80-87%.[90] As the majority of the UK landmass is rural, rural coverage levels are similar, with significantly higher urban geographic coverage.

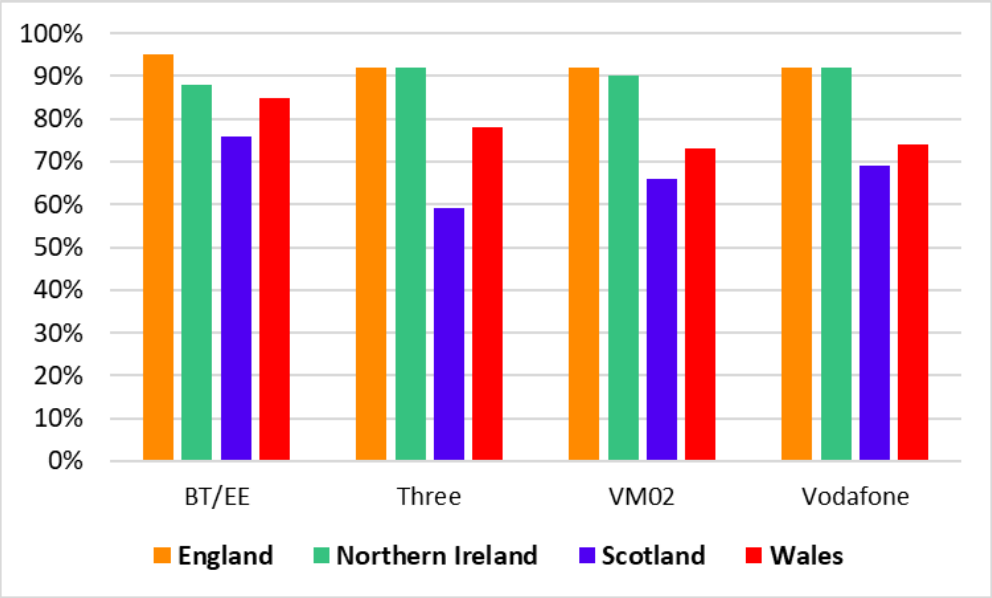
Significant differences remain in geographic 4G coverage across the UK's nations. As of September 2023, MNOs provided geographic coverage ranging from 92-95% in England; 88-92% in Northern Ireland; 59-76% in Scotland; and 73-85% in Wales (Figure 3.6). This means that compared with 2022

[86] 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.
[87] We note a reduction in voice coverage impacting indoor and roads voice coverage percentages, and we are engaging with MNOs to validate figures.

[88] WiFi calling is the ability to make and receive a call and text/SMS over a WiFi network. A femtocell is a small low-power cellular base station connected to the phone network over the internet.
[89] We note that Vodafone's total 4G coverage includes a small amount of incremental coverage from a new 4G coverage layer, which is subject to ongoing engagement and validation discussion.
[90] This coverage is reported to the nearest full integer (whole number), consistent with past publications. We note that in the Shared Rural Network section below, we report MNOs progress against their commitments to one decimal place, therefore providing a more detailed view of each MNO's level of progress for that purpose.

the coverage range for England is up 1 percentage point at the upper bound, up in Scotland by 1 percentage point at the upper and 2% at the lower bound, and consistent in Wales and Northern Ireland.

Figure 3.6: Differences in 4G geographic coverage in England, Northern Ireland, Scotland and Wales (2023)



Source: Ofcom analysis of MNO predictions (September 2023).

Roads

4G coverage is predicted to be available inside vehicles on motorways and A roads across individual MNOs in a range between 85-89%. This falls to a range of 74-80% for B roads. Outside vehicles, 4G coverage on motorways and A roads ranges between 94-98% across individual MNOs (similar to values reported in 2022), and between 90-95% for B roads (compared to 89-95% in 2022).

In-vehicle mobile voice services on motorways and A roads range between 91-97% across individual MNOs (91-98% in 2022). This falls to a range of 81-92% for B roads (80-94% in 2022). Voice call coverage outside vehicles on motorways and A roads ranges from 98-99% across individual MNOs, consistent with the coverage rates reported in 2022. Coverage for voice calls outside vehicles on B roads ranges from 94-97% across individual MNOs (compared to 94-98% in 2022).

The 3G switch-off has begun and plans for switching off the remaining 3G networks are underway

All MNOs have committed to switching off their 2G and 3G networks by 2033 at the latest, which will result in improved network efficiency and enable more spectrum to be used for faster 4G and 5G services. The MNOs are continuing to develop their own switch-off timetables for these legacy technologies and this year saw the initial stages of 3G retirement ahead of national 3G switch-off:

- Vodafone became the first network to switch off some of its 3G services, starting in Basingstoke and Plymouth in March 2023, followed by Glasgow, Hull and Oxford in July 2023. It expects to complete its switch-off in early 2024.
- BT/EE piloted its 3G switch-off in Warrington in July 2023 and is planning to switch off its national 3G network in early 2024, starting in January.

- Three expects to complete its switch-off by the end of 2024.
- Virgin Media O2 plans to switch off 3G services in 2025.

Vodafone, BT/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. Three does not operate a 2G service.

Numbers are decreasing, but there is still a residual level of ongoing 2G and 3G usage

Our latest estimates suggest that there are 2.4 million devices reliant on 2G or 3G networks. The number of these devices has, across the four MNOs, fallen from a previous estimate of 5.5 million reported last year.[91] Of the 2.4 million total, just over half a million are residential customers with a 3G device. Less than 3% of all mobile data traffic is now carried on 3G networks, with 3G data traffic having decreased by an average of 44% year on year.[92]

Although 3G is being switched off over the next two years, customers with a 3G device will still be able to use the 2G network for voice calls and texts and many devices will be able to access the internet through a WiFi connection. Ultimately, these older devices will need to be upgraded or replaced.

As Three does not operate a 2G service, it is particularly important for their customers using 3G devices to upgrade, so that they can continue to use voice and data services, as they will only be able to make emergency calls from their 3G device once Three switches off its 3G services.

Careful customer management and support will be necessary, particularly for vulnerable customers

Although the decision, timings and process for switching off 3G and 2G is being led by the MNOs, we want to make sure that consumers are treated fairly and can continue to access the services they need.

In February 2023, we published a document setting out our expectations of mobile providers during the switch-off process. This includes an expectation that MNOs minimise the impact of switch-off, so that customers experience the same level of coverage as before 3G and 2G switch-off.[93]

We also highlighted the importance of mobile operators contacting affected customers with sufficient notice, and providing advice to them on the steps they need to take to continue to use their mobile service. Vulnerable customers, and particularly those struggling financially, will need to be given additional support, and we continue to work with mobile operators to ensure that this support is in place.

We have continued to raise awareness through our communications and in 2023 updated our consumer guidance to help explain what 3G and 2G switch-off means to consumers. We have also

[91] Slight changes to reporting methodologies for device totals in 2022 and 2023 make it difficult to make a precise comparison between the two years.
[92] The total of 2.4 million devices includes 3G and 2G devices, both residential and business. Some customers with 4G/5G devices will also require VoLTE activation to continue using voice services once 3G is switched off.
[93] EE, Three and Vodafone made it clear to us that they plan to offer broadly the same level of coverage via their 4G networks as they currently offer via 2G and 3G. Once its plans have progressed, we expect VMO2 to offer a similar commitment (to ensure broadly similar coverage after switch-off).

worked with consumer groups to help promote awareness and to ensure any disruption is minimised.

Many devices, other than mobile handsets, will also need to be updated by service providers

In addition to mobile handsets, third party devices that could be impacted by 3G and then 2G switch-off include telecare alarms, security alarms and payment terminals. It is expected that many devices will still be able to operate on 2G networks once 3G is switched off, but it is important for service providers that have devices which operate on 2G, or will use 2G following the 3G switch-off, to start preparing a migration plan now to ensure continuity of service ahead of the 2G network switch-off in the coming years.

We have been engaging with sectors that could be impacted by the retirement of 2G and 3G, and in September 2023 published advice to support IoT/3rd party users of these networks. We note that some trade associations have also published guidance tailored to their specific sector and we are encouraging other industry sectors to do the same.[94]

The loss of 3G coverage might affect around 1-2% of the small number of telecare alarms that rely on 3G-only roaming SIMs, supplied by a provider outside the UK, and these will need to be upgraded to continue to work.[95] In this scenario, there may not be a direct relationship between the device supplier and a UK MNO. Ensuring continuity of service is of paramount importance, so we are working with telecare and other sectors to raise awareness.

The Government is also considering the requirements of key services ahead of switch-off, including smart meters and eCall.[96] The existing smart meters use 3G/2G mobile connectivity provided by Virgin Media O2, mainly in southern England and Wales. These will eventually need replacing, once 2G is switched off, and upgraded to 4G. For eCall, these devices currently rely on a 2G roaming SIM to make an emergency call and will need to transition to 4G in the future.

We will continue to work with government, as well as relevant trade bodies, service providers, and equipment manufacturers to help ensure a smooth transition and support the protection of vulnerable customers.

Emergency calls and messaging

As we explain in section 2, traditional landline services are being retired and in future all fixed voice services will 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. Some broadband providers are using mobile networks to provide back-up services in such situations.[97] Where this is the case, it remains important that people have mobile coverage so that emergency calls can be made in the event of a localised power cut. Additionally, alternative options such as satellite emergency services are being explored, as illustrated in the case study below.

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[94] Fire Industry Association, 3G is being switched off, 17 August 2023.
[95] Ofcom, Switching off 3G and 2G networks: advice for IoT and third-party device suppliers, 8 September 2023.
[96] eCall is a button in cars that can be pressed in the event of an emergency or can be automatically activated, for example, in the event of an incident when the airbags are deployed. Most cars and vans produced after 2018 have a 2G eCall system installed to meet vehicle eCall related type approval requirements.
[97] We discuss this further in section 4 on network security and resilience.

Long-standing 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 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.[98] On roads, emergency calls should be possible inside vehicles for around 99% of motorways and A roads, and 97% of B roads outdoors.

As MNOs begin phasing out their 2G and 3G networks, emergency calling via 4G VoLTE, and the ability to roam onto another network using VoLTE, are becoming increasingly important. By June 2023, all UK MNOs, except for VMO2, had already integrated emergency calling via VoLTE. The total number of emergency calls made via VoLTE on two of the UK MNOs reached around 433,800 in June 2023.[99]

Case Study: Direct to Device Satellite Connectivity

One potential solution for extending mobile coverage to some of the hardest to reach parts of the UK geography is direct-to-device satellite connectivity. Whilst satellite phones have been available for many years, the latest handset technology, and new satellite constellations mean that satellite connectivity could become a mass market proposition.

Several companies have launched direct-to-device satellite services, utilising existing constellations, enabling consumers to connect, via their handsets, when outside of terrestrial mobile coverage. For instance, Apple have partnered with Globalstar[100] to offer emergency messaging via satellite on its newer iPhones in the UK, for example to support users in remote rural areas or coastal waters. Meanwhile, other services such as Bullitt offer commercial messaging via satellite on its rugged smartphones or dongles.

Currently these services are limited to text messaging (in the case of some services, the messaging is limited only to emergency services) as the capacity provided by existing satellite constellations is limited, meaning that direct-to-device satellite connectivity is only used where there is no terrestrial coverage. Additionally, the current services are only supported by a limited number of premium devices and rely on a clear view of the sky and horizon.

We consider there are potential benefits for UK consumers, such as providing near universal access to emergency services across the UK and improving the resilience of mobile connectivity. We understand that the Apple service supported rescue efforts during the Hawaii wildfires in August 2023. However, it is important to note that, in cases where large numbers of users are attempting to connect from the same area, urgent traffic may need to be prioritised due to the capacity constraints of existing constellations.

The market for direct-to-device services to mass market handsets is nascent and unproven and we expect the technology and business models will continue to evolve. There is work in standards groups to support this type of connectivity and there have been several announcements of

[98] VoLTE means Voice over Long term Evolution and is the standard approach to deliver voice telephony services on 4G, using VoIP type technology to replace the systems used to deliver voice in 2G and 3G networks.
[99] 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.
[100] Apple, Emergency SOS via satellite on iPhone 14 and iPhone 14 Pro lineups made possible by $450 million Apple investment in US infrastructure, 10 November 2022.

commercial services being offered elsewhere (for example New Zealand,[101] the Cook Islands[102] and the Solomon Islands[103]). These services aim to utilise new satellite constellations to target existing, mass market legacy handsets.

Mobile network performance

As coverage improves, it is becoming increasingly important to consider the performance of the connectivity that people experience. Mobile network performance is affected by both supply-side factors (such as how many cell sites an MNO has in an area, the amount of spectrum deployed at each cell site, and how the network is configured) as well as the demand (the amount of network usage by users in the area).

In our work to obtain further insights into mobile network performance we are continuing to explore the role crowdsourced[104] data can play to inform our approach to mobile reporting. Crowdsource data has some limitations, but we consider that data gathered in this way – via automated network tests – can provide meaningful insights into network performance. In this section, we have used crowdsourced data from an independent 3rd party Opensignal to provide an initial view.

We have simplified the approach we established in Connected Nations 2022 by providing a view of performance focusing on the three primary metrics of download throughput, upload throughput and latency. These metrics represent what many consumers observe and understand when it comes to the quality of their connection. However, we will continue to review the metrics (and their thresholds) that we incorporate in our future approach. The thresholds we have used for this analysis are set out below in Table 3.2.[105]

Table 3:2: Performance metrics and thresholds

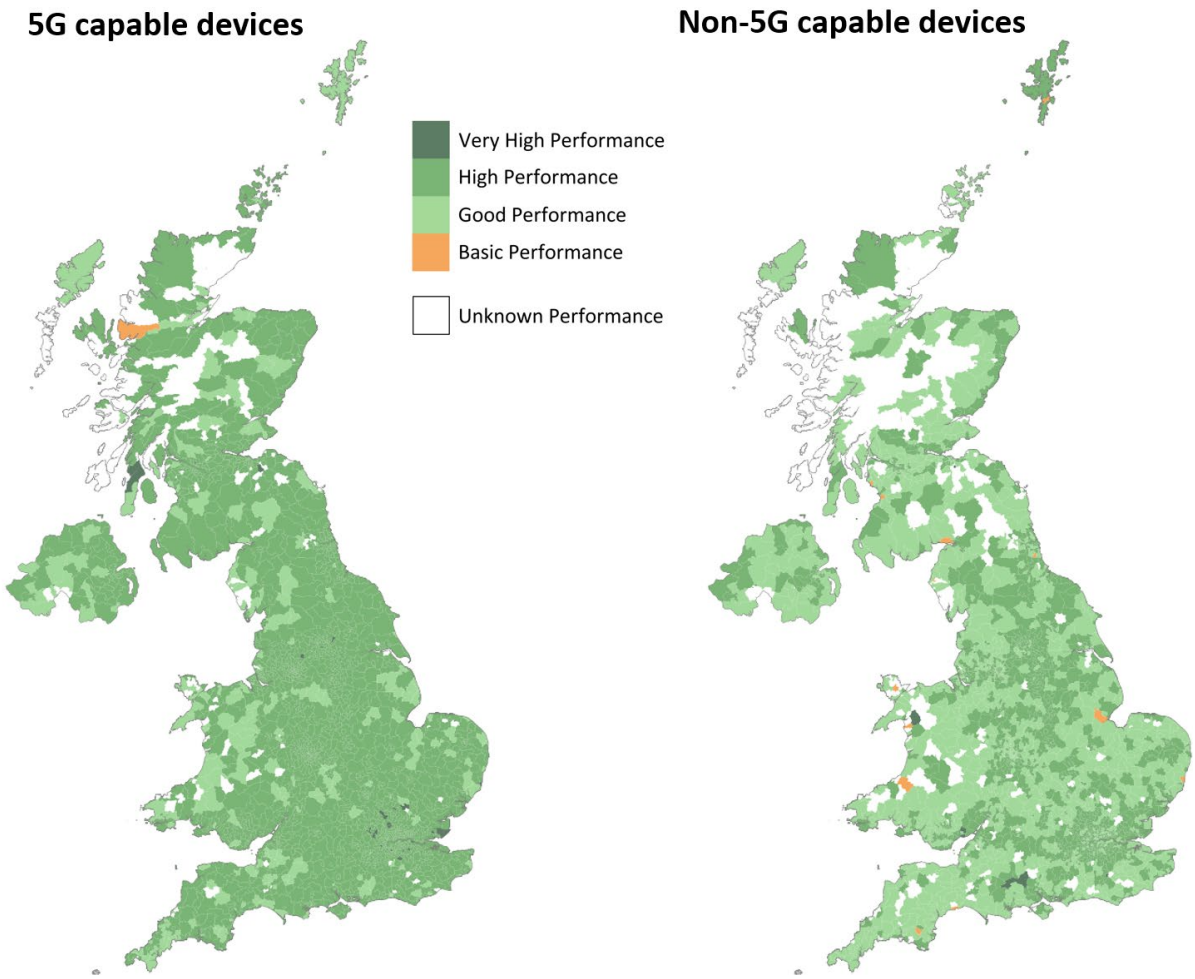
	Download speed	Upload speed	Latency
Good	**2 Mbps**	**0.5 Mbps**	**100 ms**
High	**5 Mbps**	**1 Mbps**	**50 ms**
Very high	**10 Mbps**	**2 Mbps**	**30 ms**

We have reported performance at a postcode district level, showing the performance that users have a good chance of experiencing. The colours denote the performance that a device in each area can typically expect to experience (where there is coverage available). These maps do not confirm the presence of coverage across each entire postcode district, nor do they confirm that a similar performance is available across confirm the whole of each postcode district, but rather that sufficient samples were recorded within the postcode district as a whole.

[101] Capacity, Spark to launch satellite to mobile service, 7 June 2023.
[102] Mobile World Live, Lynk Global cooks-up second commercial launch, 8 August 2023.
[103] Developing telecoms, Bmobile launches Lynk satellite-phone service in Solomon Islands, 7 November 2023.
[104] 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.
[105] A performance level is deemed as likely to be experienced if 80% of all measurement samples meet or exceed the relevant thresholds for all three KPIs.

To ensure that our findings are representative, we only report performance in areas where the data meets certain thresholds for the minimum number of samples and the minimum number of devices that contributed those samples. Where the data does not meet these thresholds, we report the performance as unknown. Full details can be found in the Methodology annex.

Figure 3.7: Combined MNO performance for 5G-capable devices (left) and non-5G devices (right)[106]



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.

As we noted last year, many more areas achieve a 'high performance' level where a consumer has a 5G capable device reflecting the impact of the newer technology and some capacity expansion as described above – although we note that even here, few areas meet the highest performance level (Figure 3.7).

[106] Areas of 'unknown performance' may well have coverage, but the data did not meet the confidence criteria for us report a result – and consequently we find slightly more areas of unknown performance for the smaller sample of non-5G devices.

We have also reported the performance of each MNO (Figure 3.8). In areas where not enough crowdsourced data is available across all MNOs for statistical confidence, the postcode district is shown as white.[107]

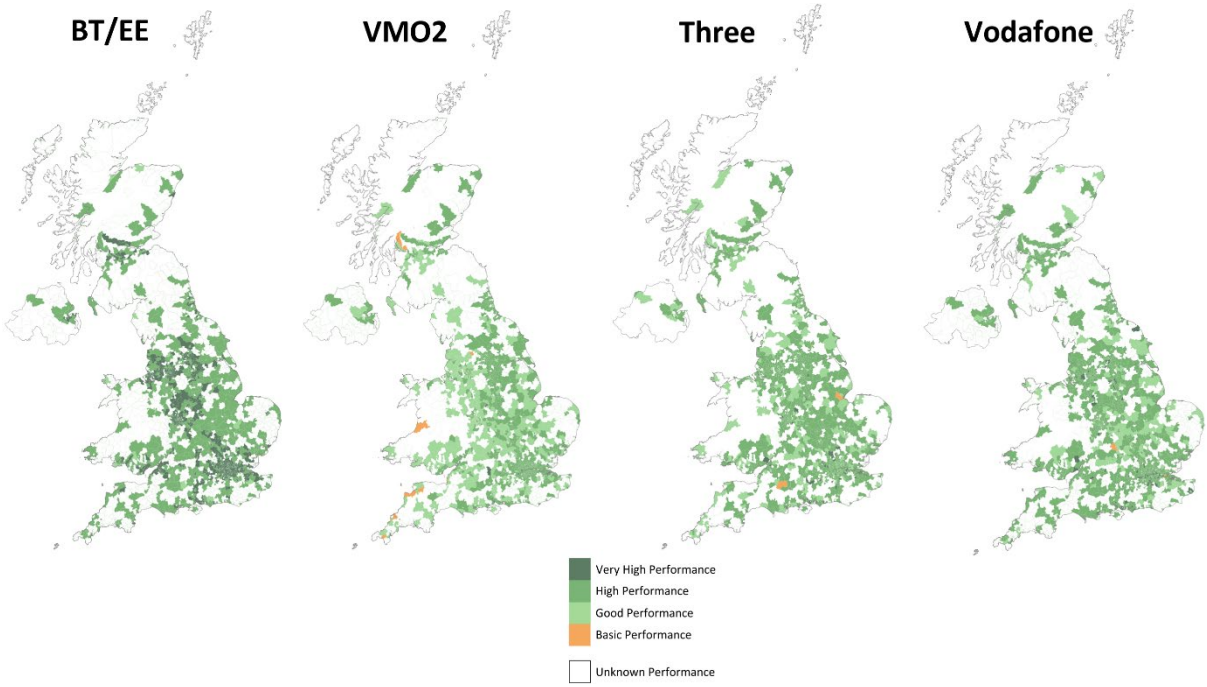


Figure 3.8: Performance of 5G capable devices across the UK

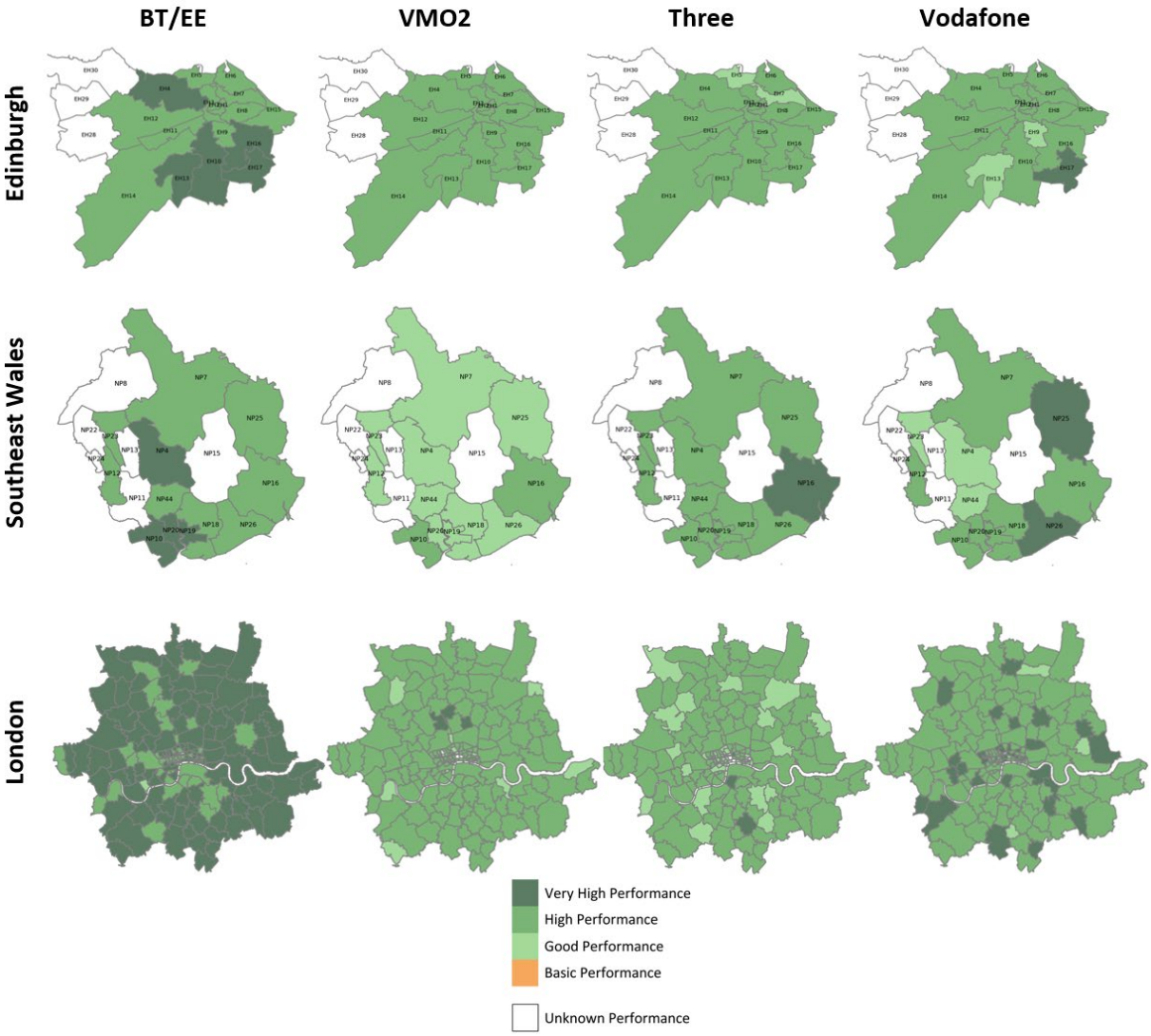
In areas where the performance of any of operators is classified as unknown, the area is shown as white across all MNOs.

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.

The following charts in Figure 3.9 show a more localised view of performance in three example locations.

[107] There are more areas where sufficient samples are not available for every individual MNO, than when we look at an aggregate all MNO perspective. More details on the approach taken can be found in the Methodology annex.

Figure 3.9: Performance of 5G capable devices in example locations



In areas where the performance of any of operators is classified as unknown, the area is shown as white across all MNOs.

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.

Crowdsourced data on performance has some limitations as the insight depends on the number of samples collected in a given area, in this case postal districts.[108] We also recognise that no single tool is likely to provide a complete view of mobile network performance that distinguishes all influencing factors.

We are continuing to analyse how the use of crowdsourced data might further support our work to improve the quality of information on mobile coverage and performance across the UK. We hope that additional, more granular insight may be possible over time.

[108] Due to the lower density of samples, crowdsourcing is inherently less comprehensive in areas where fewer people and devices go.

Public policy interventions, including update on the Shared Rural Network (SRN)

MNOs have continued with the programme of work towards their obligations to provide 4G coverage across 88% of the UK landmass (to be achieved by the end of June 2024). In total MNOs have now deployed more than 190 new sites since 2020 to meet their SRN targets, with 35 new sites added this year. They have also upgraded thousands of sites with a combination of additional spectrum and higher operating power.[109] Three of the four MNOs have added in the region of one percentage point of landmass coverage in the last year, and individual MNO's 4G geographic coverage now stands as: BT/EE (87.5%), Vodafone (83.3%), Virgin Media O2 (81.7%) and Three (80.5%).[110] As a result, 4G coverage from at least one MNO has reached 92.7%.[111]

Three MNOs still have substantial progress to make to meet their obligations in the coming months. We note reports that three MNOs have approached the UK Government to ask for an extension to their 2024 deadline. However, we continue to prepare to assess MNO compliance with the 88% threshold and associated nations obligations in summer 2024.

The UK Government-funded elements of the SRN - which is focussed on 'total not spot' areas (TNS) and is due to complete in early 2027 - are also progressing.[112] Digital Mobile Spectrum Limited (DMSL) is managing the programme and continuing to advance the required procurements which will underpin this. The MNOs and their suppliers are currently establishing where masts should go to deliver the best coverage by carrying out site suitability surveys. The first TNS planning application has been approved for a mast on South Uist in the Western Isles, with more applications starting to be lodged.

The process of enabling sharing of the Home Office Emergency Services Network's Extended Area Service (EAS) masts is also progressing, with 154 masts put into design & planning by Building Digital UK (BDUK).[113] 50 sites are now fully upgraded, making them structurally suitable for the SRN Programme. In May, BDUK announced that the first EAS mast upgrade for SRN was activated in Lockerbie, Scotland. Collaborative work continues between BDUK, the Home Office, DMSL and the MNOs to make further EAS sites fully available in 2024.

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. In October 2023, the Scottish Government confirmed that 54 of the 55 proposed sites for the programme had been built, marking progress from the 29 sites that were built and activated as of September 2022, with the remaining site in progress.

[109] By higher operating powers we mean bringing the transmit power of the site (which can impact both coverage and capacity) nearer to the limits authorised in operator's spectrum licences.
[110] Note that we are providing MNO coverage levels here to one decimal place, given the relevance of this greater granularity to understanding progress against SRN commitments, and that some of these coverage increases are not apparent where we are reporting to the nearest whole number elsewhere in this report.
[111] We are also providing detail of the 'at least one MNO' coverage to one decimal place in light of the SRN programme's stated objective to deliver 95% 4G geographic coverage on this measure by the end of 2025.
[112] A total not spot is a geographic area not covered by any MNO.
[113] BDUK is an executive agency sponsored by the Department for Science, Innovation and Technology.

Table 3:3: Total not spots across UK nations

	May-22	Sep-22	Jan-23	Apr-23	Sep-23
England	2%	2%	2%	2%	2%
Northern Ireland	3%	3%	3%	3%	3%
Scotland	17%	17%	17%	16%	16%
Wales	10%	10%	9%	9%	9%
UK	**8%**	**8%**	**8%**	**7%**	**7%**

Source: Ofcom analysis of MNO predictions (September 2023).

Mobile traffic

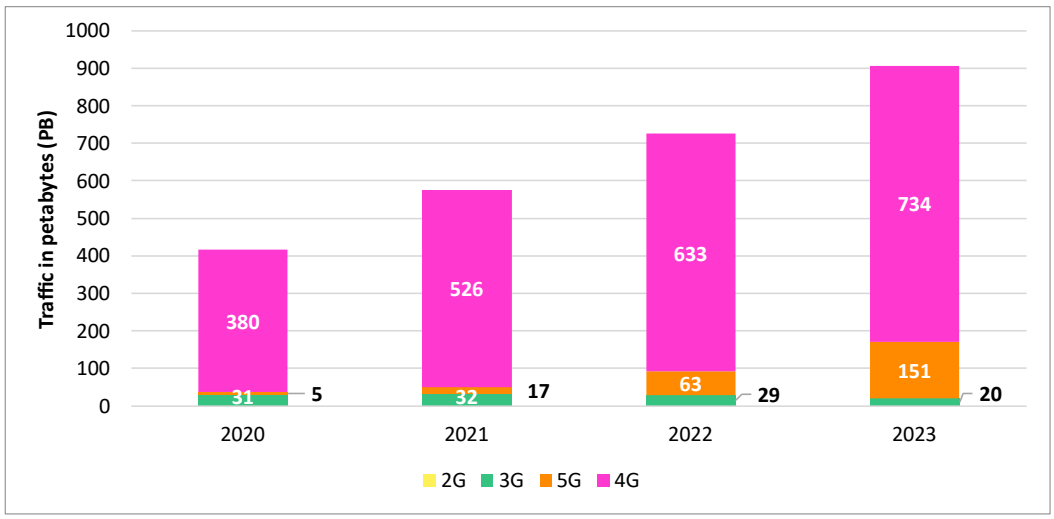
Mobile traffic continues to grow, with greater 5G traffic growth

Mobile traffic continues to experience significant year on year growth although the rate of this growth has been slower, with the dominant share (81%) continuing to be carried across 4G networks (Figure 3.10).[114] From 2022 to 2023, total monthly traffic has risen from 724 PB to 905 PB, an annual growth of around 25%.[115] Although this growth is lower than the c.27% reported last year, it aligns with other reports on mobile traffic growth internationally over the last year,[116] indicating a decline in global mobile traffic growth.[117] We will continue to report on these traffic levels in future years to allow any long-term changes to be observed.

5G traffic has shown the highest growth from 63 PB in 2022 to 151 PB in 2023, a growth of around 140%. This data traffic was generated from a device pool which now includes at least 43% 5G capable handsets (up from around 20% in 2022)[118] and represents around 17% of the total mobile traffic, up from around 9% in 2022.

[114] In comparison, less than 3% of data is now carried on 3G reflecting a long term downward trend, with 2G/3G voice also continuing to decline as voice traffic moves to 4G/5G VoLTE.
[115] The reported total monthly traffic includes all traffic across mobile networks, and therefore includes traffic generated by Fixed Wireless Access, where operators are offering domestic fixed broadband services over their wireless networks. All MNOs, except for one, offer FWA services with varying traffic splits, ranging from approximately 1% to 35%.
[116] Analysys Mason, Wireless network data traffic: worldwide trends and forecasts 2022–2028, 5 June 2023.
[117] Possible explanations to the decline in mobile traffic growth 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).
[118] Methodology for calculating total number of devices varies across MNO making this figure an approximation rather than an exact figure. Additionally, we note that not all 5G capable devices may be enabled with a 5G subscription.

Figure 3:10: Total monthly traffic by technology (2020-2023)



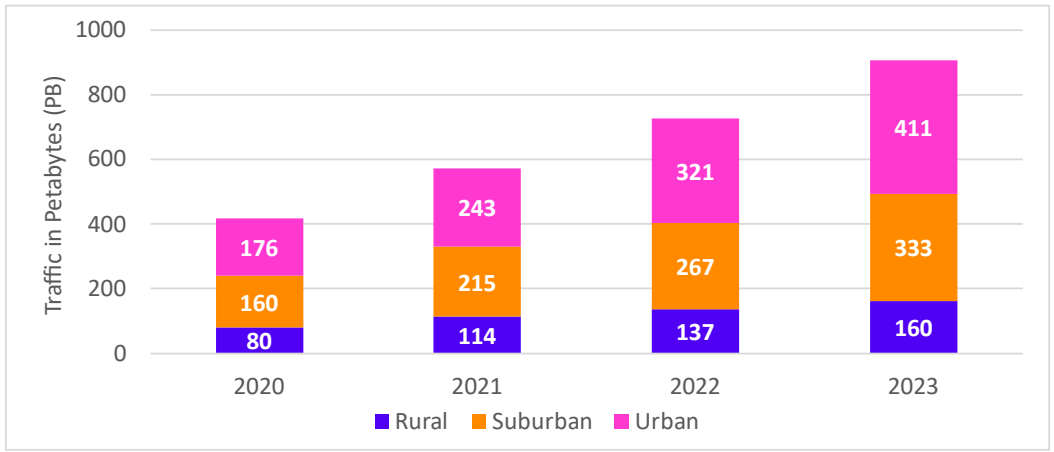
Source: Ofcom analysis of operator data (June 2020, May 2021, May 2022, May 2023).

Distribution of mobile traffic

Most of the mobile data traffic (c.82%) is generated in urban and suburban areas (Figure 3.11). Data consumption continues to be divided between urban and rural areas as well as across the various nations of the UK in a way which largely mirrors population distribution, rather than any significant difference in data consumption of a typical user in rural areas or any specific UK nation when compared.[119]

In 2023, urban areas experienced higher mobile traffic growth than the UK average (c.25%), reaching a 28% year-on-year increase. This growth, though lower than the previous year's 32%, aligns with the broader traffic trends observed. Meanwhile, suburban areas experienced a modest 25% rise, closely matching the UK average mobile growth. Rural areas also saw growth, but it was less pronounced, at 17%.

Figure 3:11: Total monthly mobile data traffic in rural, suburban and urban areas (2020-2023)

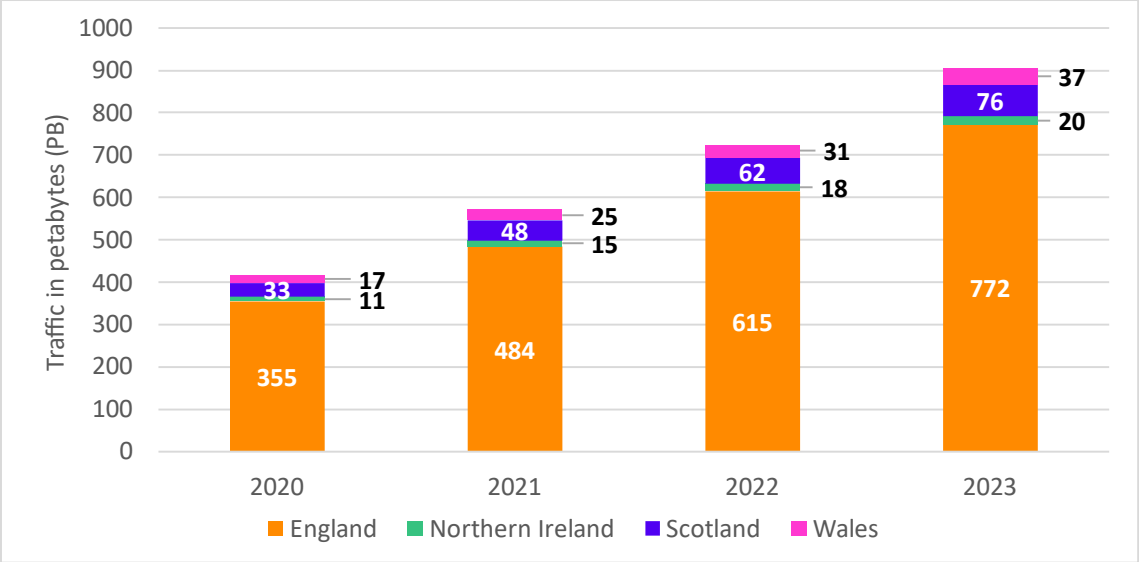


Source: Ofcom analysis of operator data (June 2020, May 2021, May 2022, May 2023).

[119] 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.

Across nations (Figure 3.12), mobile traffic grew fastest in England, with year-on-year growth of c.26%, just above the national average while Northern Ireland displayed the least growth at c.15%. Scotland and Wales also experienced significant year-on-year data traffic growth, with Scotland at c.23% and Wales at c.22%.

Figure 3.12: Total monthly mobile data traffic growth by UK nations (2020-2023)



Source: Ofcom analysis of operator data (June 2020, May 2021, May 2022, May 2023).

Open RAN Adoption

In September 2023, the UK Government, in collaboration with the four major UK MNOs reaffirmed the UK's shared ambition for 35% of network traffic, in aggregate, to take place over open and interoperable systems (Open RAN) by 2030.[120] Such open architectures promise to offer improved security and resilience of critical network infrastructure. Currently, Open RAN deployment remains limited, with around 40 sites reported this year compared to fewer than 20 last year. Similarly, mobile traffic carried over such architectures remains limited at around 78,600 GB.[121] We, however, note that we are still at an early stage in the commercialisation of Open RAN, and we will continue to monitor progress in the years ahead.

Expenditure on mobile telecoms network infrastructure

Expenditure on mobile telecoms network infrastructure fell to £1.8bn in 2022

Mobile network coverage and performance are determined by infrastructure investment. We estimate that MNOs invested £1.8bn in UK mobile network infrastructure in 2022, a £0.3bn (16%)

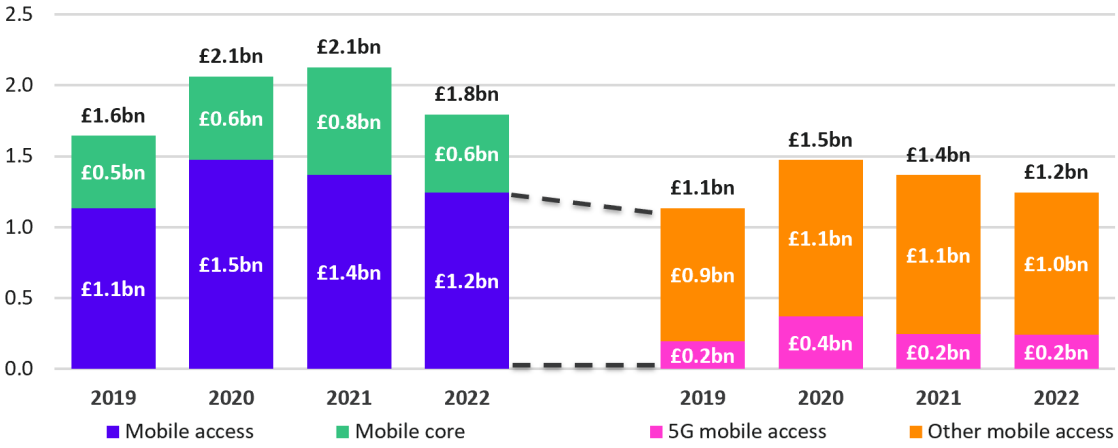
[120] Open Radio Access Network (Open RAN) is a network infrastructure that enables greater choice and flexibility in telecoms supply chains. It is considered to be one option that could allow the supply chain to be disaggregated with the use of "open" and "interoperable" off-the-shelf hardware, vendor-neutral protocols, and software-defined technology – Ofcom's article, What is Open RAN and why does it matter? provides further information on Open RAN.

[121] Open RAN figures reported here are derived from only three MNOs, as one didn't provide Open RAN data.

year-on-year decline in real terms (Figure 3.13). In addition to this investment, £0.6bn was invested in infrastructure used to provide both fixed and mobile telecoms services in 2022.

Of the estimated mobile investment total, £1.2bn (69% of the total) was investment in mobile access network infrastructure (including site acquisition, equipment, and electronics). This was down £0.1bn (9%) year-on-year in real terms. The remaining £0.6bn was spent on mobile core and backhaul networks, a £0.2bn (28%) fall compared to 2021. All four UK MNOs continued to deploy 5G infrastructure in 2022, when investment in 5G access networks totalled over £240m. This represented a small (1%) real-term fall compared to 2021.

Figure 3.13: Estimated mobile telecoms network capital expenditure: 2019 to 2022



Source: Ofcom analysis of operator data.
Note: Adjusted for CPI (2022 prices).

Network infrastructure is provided by an evolving set of players

While MNO infrastructure underpins much of the coverage we report on here, a range of third-party players are increasingly contributing to the provision of infrastructure[122] which supports both public and private networks, from satellites highlighted earlier in the section to neutral host models. There tower structures from MNOs, enabling MNOs to transition capital expenditure to operating costs. These entities could subsequently lease access to the infrastructure to numerous tenants. Others focus on introducing new infrastructure solutions that support both public and private networks, offering a range of services, from passive infrastructure[123] to comprehensive active infrastructure [124] tailored for specific environments like office buildings, stadiums or underground train stations. Some models combine both approaches.

[122] This includes but not limited to remote rural lattice masts, urban rooftop sites, satellite constellations and street furniture with small cells to indoor coverage solutions and indicates a potential for this diversity of provision to grow in the future.
[123] Neutral host providers offer only the physical infrastructure required for network deployment, such as towers, antennas, and cables but do not manage the active components like radio equipment or the spectrum.
[124] Neutral host providers offer both the physical elements (passive infrastructure) like towers, antennas, etc., as well as the electronic components or elements of the network necessary for signal transmission and reception (i.e., active layer). For example, radio equipment.

In the UK, we estimate that the number of mobile sites provided by neutral hosts is at least 13,000,[125] an increase from under 11,000 sites reported last year.[126] The distribution across nations has seen minimal change from last year, with approximately 83% in England, 11% in Scotland, 5% in Wales and 1% in Northern Ireland. Of these sites, 65% host one public network, with just over 10% hosting three or more public networks. Approximately 84% of the sites primarily host MNOs, with the majority of neutral host offerings to MNOs consisting solely of passive infrastructure.[127] However, a small number of indoor sites are reported to offer both passive infrastructure and radio. Based on data provided by MNOs, we estimate that the total mobile traffic through neutral hosts sites is over 143 PB, c.16% of total UK mobile traffic.

Indoor deployment continues to make up a small proportion (around 3%) of the overall neutral host deployment. However, compared to other neutral host models, indoor deployments typically host more public networks per site, with c.88% hosting two or more public networks.[128]

Additionally, some of the neutral host providers are also facilitating coverage within Transport for London's underground tunnels and stations, hosting the four UK MNOs and delivering 5G[129] on a majority of the sites. There are additional deployments in progress,[130] in addition to collaborative efforts and expanding partnerships among key players in this space.[131] This indicates that there may potentially be greater synergies between different MNOs' coverage and capacity challenges, 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.

MNOs have invested in cloud services and have plans to make wider use of them in future

Given the growing importance of cloud services to the provision of mobile services, we asked MNOs to tell us about their existing or planned use of cloud services for deploying network functions.

MNOs told us that they are making extensive use of cloud services and are predominantly using private cloud services for their network functions. These included, for example, 4G core, 5G core as well as voice core network functions. MNOs are also using private cloud for network monitoring. Looking ahead, MNOs told us about their plans to make further use of private cloud by moving to

[125] This figure is based on responses from the following organisations: BAI communications, Britannia Towers, Cellnex, Freshwave and Wireless Infrastructure group. It includes macros bought from MNOs and excludes sites provided by CTIL and MBNL.
[126] Around 84% of all neutral host sites in the UK are macro tower structures, while 13% are based on street furniture deployments, typically on lampposts, bus shelters, traffic signals or CCTV poles. The vast majority of street furniture sites host one MNO. 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.
[127] Approximately 97% of MNO sites hosted by neutral hosts support 4G or 5G.
[128] MNOs are the only hosted public networks on c.44% of indoor sites.
[129] 5G is delivered using the 3 GHz band at underground stations and the 700 MHz band in tunnels.
[130] Transport For London, Mayor sets out next phase of 4G and 5G across the Tube network as first West End stations go live, 8 September 2023.
[131] Cellnex, Cellnex UK and Three UK to provide end-to-end connectivity along the Brighton Mainline route,10 January 2023.

containerised network functions.[132] This is the next step of an evolution pathway to bring the MNOs to cloud-native deployment.[133]

Business Connectivity and IoT

Mobile services extend beyond serving the general public; they play a pivotal role in supporting business connectivity and facilitating device-to-device communication. In today's digital landscape, many businesses rely on broadband services for the actual delivery of their products and services. Consequently, both mobile and non-mobile service providers are leveraging the capabilities of 5G technology (in addition to other technologies) to provide bespoke connectivity solutions across a wide array of sectors, including manufacturing, logistics, agriculture, automotive, energy, media and entertainment, and healthcare.

5G and private networks

With their ability to provide tailored connectivity solutions and meet specific quality of service requirements, private networks are playing an increasing role in the mobile market, supporting the digital transformation of many sectors of the economy, spanning from the enhancement of operations in ports and airports to the optimisation of processes in factories and smart agriculture initiatives.

With the emerging opportunities for private networks enabled by 5G capabilities, including its potential for ultra-low latency, private networks remain an active and developing area, with a diverse array of providers, encompassing both MNOs and non-MNO entities and the opportunity for a broader set of players to emerge as localised communications providers.

Whilst MNOs continue to be involved in this work, live commercial offerings of MNO private networks remain limited. As of September 2023, less than 20 fully operational commercial private networks were reported by MNOs, a decrease from the 26 reported in the previous year. These networks leverage a mix of 4G, 5G, or a combination of both technologies and operate across various frequency bands, including N77 (3.3-4.2 GHz), N78 (3.3-3.8 GHz), B40 (2.3-2.4 GHz), and B41 (2496-2690 MHz). Notably, eight of these private networks are deployed as 5G SA, and only one of all the reported private networks is currently delivered as a slice[134] of the commercially deployed 5G network.

Non-mobile operator players are also able to access mobile spectrum through the shared access licences framework to provide services across localised areas. Authorisations are provided either for single base stations at a medium power level, or multiple lower power base stations authorised

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[132] Containerisation is a virtualisation format currently dominating the cloud computing space offering better portability, reduced runtime, and higher resource utilisation compared to virtual machines by allowing multiple applications to share a single operating system instance.

[133] Cloud-native computing is a set of technologies that help in the development and operation of scalable and portable applications such as containerised micro-services that are dynamically managed and orchestrated by a platform to utilise the advantages of cloud computing. These techniques enable loosely coupled systems that are resilient, manageable, and observable. Combined with robust automation, they allow engineers to make high-impact changes frequently and predictably with minimal toil; Who We Are | Cloud Native Computing Foundation (cncf.io) (accessed October 2023).

[134] Network slicing is a feature of 5G SA networks. It allows an MNO to create multiple virtual networks (slices) on top of its common shared physical infrastructure. The virtual networks are then customised to operate with specific quality of service and meet the specific needs of applications, services, devices, customers or operators.

within a 50m radius.[135] There is significant activity underway across a variety of players. They range from mobile equipment vendors to system integrators and specialist ICT providers, all offering solutions to support the digital transformation of industries.

The number of shared access licences issued by Ofcom continues to rise, reaching over 1,500 from around 900 reported last year. Approximately 65% of the allocation falls within the 1800MHz band, while the 3800-4200 MHz band constitutes roughly 33% of the shared access licences. Of these 3800-4200 MHz licences, around 65% operate at medium power level. We continue to estimate that around half of this increased number can be considered as supporting private network type solutions, highlighting the increasing prevalence of private networks and the pivotal role shared access plays in bolstering these solutions. These licenses are distributed across the UK, with 88% in England, 6% in Wales, 5% in Scotland, and 1% in Northern Ireland, mirroring the 2022 distribution of 91%, 4.5%, 3.5%, and 1%, respectively.

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. Across the UK, IoT connectivity is delivered by both MNOs and other non-MNO players, often operating in a specific local area, utilising frequencies in the lower and mid-band ranges[136] that are either licence-exempt or authorised for use by MNOs.[137]

The rise of IoT adoption is evident in the growing number of connections and data traffic, with businesses and local authorities increasingly leveraging IoT services to support their sustainability goals and drive more efficient use of resources and infrastructure such as implementing smart buildings and technology in cities, including smart lighting, waste management, and traffic control systems. In 2023, these networks continued to expand, with a growing number of connections for existing applications, although there weren't any notable new use cases reported.

Beyond these applications, IoT's versatility extends to supporting future innovations in areas such as security systems, telecare, and utility network monitoring, a critical consideration given the planned phase-out of 2G, 3G, and PSTN networks. This evolving landscape underscores the pivotal role IoT plays in driving delivery improvements across a spectrum of sectors and services.

[135] Ofcom is currently consulting on steps to update this framework to support further sharing, especially in the popular 3.8-4.2 GHz band https://www.ofcom.org.uk/__data/assets/pdf_file/0017/272051/Consultation-Shared-Access-Licence.pdf

[136] Frequencies used by IoT services typically range from around 700MHz to 3800MHz.

[137] 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 MNOs

MNOs continue to offer IoT connectivity through their existing 2G, 3G, 4G and 5G networks, as well as through Low Power Wide Area Networks (LPWANs)[138] including LoRA[139], NB-IoT[140] and LTE-M[141].

Uses of IoT connectivity provided by MNOs include asset tracking, utility metering,[142] travel and transport, environmental sensors and energy management solutions for smart buildings, car telemetry and video surveillance.

This year, the number of active IoT connections on MNO networks stands at just above 24.9 million, a 31% increase since last year. While these connections typically generate much lower data volumes than consumer handsets, MNO IoT traffic volumes continue to increase, up by 17% to 1.77 PB per month (from 1.51 PB last year).[143] However, such volumes remain much 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, using licensed-exempt frequencies for their services. Public community LoRaWAN[144] 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. 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 896 gateways[145] in the UK serving 106 communities (which is one more than last year).

Private IoT networks offer carrier-grade services with guaranteed availability, for a charge. Several private IoT networks exist in the UK, offering a range of applications including smart metering, waste management, smart buildings, and environmental monitoring. These networks have grown steadily, with over 950 gateways reported this year (compared to 746 last year and 580 the year before), now connecting over 140,000 devices (up from about 100,000 last year).[146]

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[40] Low-power wide-area networks (LPWANs) are designed for IoT applications and services which have low data rates, long battery lives and, if required, can operate in remote and hard-to-reach locations. Furthermore, their extended range makes them better suited for in-building applications such as smart meters and smart car parks which may be located underground or in basements.

[139] LoRA, developed by the non-profit LoRa Alliance, is an open-source wide area network technology using license-exempt spectrum. It provides good coverage with very low transmission power and allows the building of an end-to-end private solution.

[140] Narrowband IoT (NB IoT) is a wide-area solution that supports massive deployment of IoT devices and is also optimised for a very long battery life. NB-IoT networks can be deployed in mobile bands and integrated on existing mobile base stations.

[141] Long Term Evolution for Machines (LTE-M), is a complementary technology to NB-IoT with the added capability of supporting IoT applications with higher data rates and lower latency requirements. It can also be deployed in mobile bands and integrated on existing mobile base stations.

[142] Virgin Media O2 provides the mobile network connectivity to smart meters in the south of England and Wales. Arqiva Limited provides radio communications links between smart meters and energy suppliers in Scotland and the rest of England.

[143] Overall, IoT traffic includes MNO and non-MNO traffic. However, non-MNO IoT providers were unable to provide traffic data.

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

[145] The Things Network, United Kingdom. Note that the number of gateways is correct as of 6 December 2023.

[146] This increase is despite Ofcom receiving data from fewer providers of private IoT networks this year.

4. Network security and resilience

Introduction

In this section, we set out our approach to monitoring the security of telecoms networks, including summarising our approach to monitoring compliance with the new telecoms security framework. We provide an update on the ongoing requirement for industry to report security compromises to us, and our work monitoring compliance with high-risk vendor requirements. We also set out some ways that we are maintaining a wide understanding of relevant security matters.

We then cover our work on network resilience, which includes summarising some analysis on the relative reliability of the main fixed network access technologies. We provide the latest summary of trends from the incident reports we receive from providers. We also discuss resilience risks relating to legacy technologies and extreme weather events, before noting the wider context on resilience.

Highlights

- **We have started monitoring industry compliance with the telecoms security framework.** We sent out the first of a series of formal information requests to large and medium-sized providers in June 2023.
- **Providers have ongoing obligations to report certain security compromises to us, which includes reporting both resilience and cyber related incidents.** We are reviewing how our cyber compromise reporting guidance has been working in practice and have started discussions with the largest providers.
- **This year we sent out our first set of information requests about high-risk vendors and submitted a report of to the Secretary of State based on the information that we gathered from the relevant providers.** This follows the responsibility we were given to assist Government in its compliance assessment with the new restrictions on certain providers' use of Huawei products.
- **On network resilience, we have gathered some insights on the relative reliability of the main fixed network access technologies**: full-fibre, copper twisted pair and co-axial cable. For those operators with two types of access network, fibre is experiencing a materially lower rate of faults compared with respective twisted copper networks, and a marginally lower level of faults compared to co-axial cable.
- **The total number of significant resilience incidents reported to us has remained consistent with last year**. We received 1,209 submissions this reporting year, compared to 1,281 last year. Hardware failures continue to account for over half of all reports. In terms of lost customer hours, network change activities caused the most serious cases, while hardware faults accounted for under a third of total lost hours.
- **There are resilience risks associated with legacy technologies and extreme weather events.** The closure programmes for the PSTN, 2G and 3G networks present certain resilience risks that need to be addressed, but so does the continued reliance on legacy technologies. For example, this year saw a 20% rise in the number of PSTN incidents reported to us and a 60% increase in the number of PSTN service hours lost. On extreme weather incidents, this year the number of outages has fallen overall, but certain events such as Storm Otto had an impact on telecoms networks, particularly in Aberdeenshire.

Security

Telecoms Security Act implementation has commenced

In October 2022, the Telecommunications (Security) Act 2021 ('the Security Act') and The Electronic Communications (Security Measures) Regulations 2022 (the 'Regulations') came into force. They place new, detailed, obligations on providers and give Ofcom powers to monitor and enforce compliance. In December 2022, the Telecommunications Security Code of Practice (the 'Code') was published by DSIT, which sets out the recommended measures providers should follow when securing their networks.

As we set out in our procedural guidance in relation to the new security framework, our approach to monitoring compliance will centre around a series of formal information requests to large and medium-sized providers (or Tier 1 and Tier 2 in the language of the Code). These requests will ask providers about the measures they are taking, or planning to take, in order to comply with their obligations, by reference to recommended measures in the Code.

We sent the first round of these requests in June, which focussed on understanding the networks, services and assets in scope, and some of the initial measures taken by the providers. Responses to the requests were due in late 2023, and we will analyse the information and work with the providers to address any outstanding queries in the coming months.

We expect to send out subsequent formal requests approximately every nine months, with providers having six months to respond. We will use the information requests to understand what each provider is doing, or plans to do, in relation to each security measure in the Code.[147]

For next year's Connected Nations report, we expect to share some of our findings from the first information request and provide an update on our second information request.

Cyber security compromises now need to be reported to Ofcom by communication providers

In parallel to our new monitoring regime, providers have an ongoing obligation to report to us security compromises that meet certain criteria. A security compromise has a broad meaning, and may cover both cyber-type security compromises such as those caused by hackers, and resilience-type security 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). We focus on cyber-type security compromises here and resilience-type security compromises further below.

Our procedural guidance sets out guidance to the industry on which security compromises to report, when and how to report them. In relation to resilience-related security compromise reporting, our guidance on incident reporting, which has been in place for around a decade, is largely based on quantitative customer impact thresholds, which providers can use to design their own reporting processes. In contrast, in relation to cyber security compromises, our guidance is new (since providers were not specifically required to report such incidents in the past) and is qualitative in nature as many reportable cyber security compromises may not necessarily result in any directly measurable customer impact.

[147] The detail of our information gathering approach will be refined over time and may need to be amended depending on specific factors, but we expect that it will take at least four subsequent formal requests to gather a reasonable level of detail about all Code measures.

This guidance on the reporting of cyber security compromises has been in place for just over a year, so providers have had some time to develop and operate their corresponding internal processes. We consider that now is therefore a suitable time to review how the guidance has been working. Accordingly, in the coming months, we will be meeting providers to understand more about the processes they have in place to monitor cyber security incidents and how they decide whether they should be reported.

So far, very few cyber security incidents have been reported to us, and we are keen to understand why this is the case. Reviewing reported compromises allows us to understand how providers are monitoring their networks and addressing issues that they detect, as well as spotting cross-industry trends to focus our attention on particular areas. One critical aspect of compromise monitoring and reporting is in the initial compromise phase, sometimes referred to as 'pre-positioning'.[148]

We have received a High-Risk Vendor monitoring direction

In October 2022, the DSIT Secretary of State placed restrictions on certain providers regarding the use of Huawei products within their networks and services.[149] In June 2023, DSIT issued a monitoring direction that requires us to collect information on whether providers are complying with the restrictions by certain due dates. We have published a redacted version of the direction on our website.

We sent out our first information notice in July this year and received responses in October. As required by the direction, we prepared and submitted to the Secretary of State a report based on the information which we have collected. At the time of publication, we are preparing our second report, which relates to the restrictions which are due to be implemented by the end of October this year. Additional sets of restrictions are due to be implemented by the end of December 2023, December 2025 and December 2027. We will follow the same process for each of these.

Ofcom is monitoring broader security topics relevant to our regulated sector

The companies we regulate face a wide and evolving set of cyber threats and, in light of the ongoing work we are carrying out to monitor the compliance of providers with their obligations under the Security Act and the Regulations, it is important that we maintain a wider understanding of relevant security matters. Some of the areas we have been focussing on this year are discussed below.

Mobile network signalling

A topic of concern is the security of signalling between mobile networks. Signalling is a critical control plane that is vital to the operation of mobile networks and the facilitation of the mobile service to the subscriber. Consequently, signalling access is highly sought after by malicious actors. There are few built-in security features within the SS7 signalling protocol,[150] making it an

[148] An example of such a situation would be where an attacker had gained access to a system, which they could have used to mount a further attack and cause significant effect. We are referring to incidents reportable under s105K(1)(b), and further information can be found in paragraph 5.14-5.15 in our procedural guidance.
[149] The Secretary of State may give a 'designated vendor direction' to a public communications provider if they consider that the direction is necessary in the interests of national security and proportionate (s.105Z1 of the Communications Act 2003).
[150] Signalling System No. 7 (SS7) is a set of telephony signalling protocols developed in the 1970s, which is used to set up and tear down telephone calls in most parts of the world-wide PSTN. The protocol also performs number translation, local number portability, prepaid billing, Short Message Service (SMS), and other services. See https://www.itu.int/rec/T-REC-Q.700/.

opportunity with the potential for an attacker to exploit, for example in order to geolocate handsets and intercept SMS/Calls/Packet data.

One area of particular concern is the extent to which malicious actors are able to obtain or purchase access to 'Global Titles' numbers/addresses, which are used by mobile operators for routing signalling messages between networks. We understand that some mobile operators, which have been allocated +44 mobile number ranges, are leasing access to their Global Title numbers (identified from within these ranges) to third parties. In some cases, these leased Global Titles may facilitate the invoking of malicious signalling attacks against other mobile operators around the world. The Telecommunications Security Code of Practice states that UK operators are responsible for the traffic that originates from any of their leased Global Titles. We note the GSMA has recently issued a Global Title Leasing Code of Conduct and we would encourage all operators to declare their compliance. In addition, we are considering if any regulatory interventions may be necessary to address potential security risks.

Threat awareness

We are enhancing our threat intelligence capability in addition to those provided by the National Cyber Security Centre (NCSC), including on specific areas such as signalling and vendor vulnerability information. We have noted the hesitance of some vendors to engage in this area and are working with them to encourage transparent reporting of vulnerabilities in their products. We intend to work with bodies such as other regulators, information assurance agencies, industry, and standards bodies in order to ensure we have the best possible understanding of the threats faced by telecoms providers which will feed into our compliance monitoring programme.

Artificial Intelligence (AI)

A hot topic in many contexts, AI and machine learning are becoming a greater focus in the cyber security sector too, both as tools used by attackers, and by providers in defending their networks and services. For example, AI tools are already being used to detect anomalous activity on networks, which may indicate that attackers have set up fake base stations to steal customer data, or are using customer accounts to conduct malicious activity. We plan to develop our understanding of how providers are intending to use these technologies as part of their security measures.

Standards and Vendors

We engage with various vendors of telecoms networking equipment, access management, virtualisation products, and cloud services to maintain a broader understanding of the telecoms ecosystem.

Meanwhile, the Government is setting up the UK Telecoms Lab (UKTL) which will "boost the security, resilience and performance of the UK's telecommunication networks."[151] The UKTL will provide testing facilities for vendor equipment as well as advice. Once setup, the UKTL will help identity risks and vulnerabilities in critical national infrastructure and also encourage innovation and growth. We will continue to engage closely with DSIT and other stakeholders as UKTL develops.

In addition to working with the vendors, we are increasing our interaction with standards bodies to ensure a better upstream view of trends and capabilities.

[151] National Physical Laboratory, UK Telecoms Lab to be operated by NPL on behalf of the Department for Science, Innovation & Technology (DSIT), 13 December 2022.

Quantum Computing and Cryptography

Today cryptography is at the heart of telecommunications as it is used by providers to secure their networks and services. This can be, for example, to protect the confidentiality and integrity of data, or to securely authenticate engineers attempting to make changes to a network.

Although it is possible in principle to 'break' cryptography with enough conventional computing power, it is usually accepted that this would be beyond the resources of most, if not all, attackers. However, quantum computers can tackle the required maths problems in a totally different way which might allow it to be 'broken' much more readily, if and when such devices move from the current status of cutting-edge research into practical tools. While that is expected to be many years away, progress is being made, and the role of cryptography is so fundamental it is important to think now about how the security industry should adapt to this risk. We expect to learn more about industry's activities in this area as our overall work on security develops.

Network resilience

We have collected some data on the reliability of different fixed line access network technologies

This year we have sought information and insights related to the reliability of the main fixed network access technologies: full fibre, part fibre, copper twisted pair and coaxial cable.

Many factors can impact the technology used in network access, from the network deployment type (overhead versus underground) to the environment (rural versus urban). Various aspects can also be factored in when considering the reliability of a network, for example fault rates and repair times, but also the consumer experience at the service layer underpinned by the technology type.

We have focussed on gaining an understanding of the relative performance of different types of access networks only, rather than a comparison of the reliability of the services from an end-to-end perspective from a given communications provider. We have therefore separated the reliability of the underlying technology from customer experience issues that may result from other wider factors.

We engaged with a small number of network operators to gather and understand information related to their fault rates and repair times. We collected data from three operators with two different types of network technology and compared the fault rates across the two network technologies for each of the operators. We are therefore able to present findings regarding the relative performance on fault rates across two network technologies for each of the single operators (rather than comparing faults rates across operators):

- Over the last three years, for the two operators with fibre and copper access networks (KCOM and Openreach), the fault rate (per 1,000 connections) on KCOM's copper access network (ADSL) and Openreach's copper access networks (ADSL / VDSL) was around 50% higher than the fault rate (per 1,000 connections) on their respective FTTP networks.
- Virgin Media's cable access network, based on coaxial cable, appears to have similar, but marginally higher, fault rates when compared to its FTTP network.

Given the rate and scale of deployment of fibre in recent years, we would expect that providers installing new full fibre services may have their fault rates affected by early life failures (ELFs)[152] which can reflect provisioning failures, rather than network reliability issues. Indeed, Openreach has provided data showing that the 'in-life' fault rate for its copper access network is more than twice as high as for its fibre access network, once ELFs are removed from the data.

Meanwhile, the data we collected on repair times suggests they are broadly similar across the different access network technologies. The data does not indicate a clear correlation between repair times and access network technologies.

More generally, we found though that there are significant differences in repair times across full-fibre operators, which may be partially explained by differences in operational approaches. It should also be noted that repair times are often influenced as much by the deployment environment, e.g. overhead versus underground and rural versus urban, as the access network technologies.

This was the first year that we collected specific data on fault rates and repairs times of fixed access network technologies, and we focussed on a small number of network operators. As fibre is deployed more extensively, we will further build our understanding of its reliability in future.

We continue to receive incident reports from communications providers

As in previous years, we continue to receive reports from communications providers throughout the year about resilience incidents that created a significant impact on their networks and services. Our procedural 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.

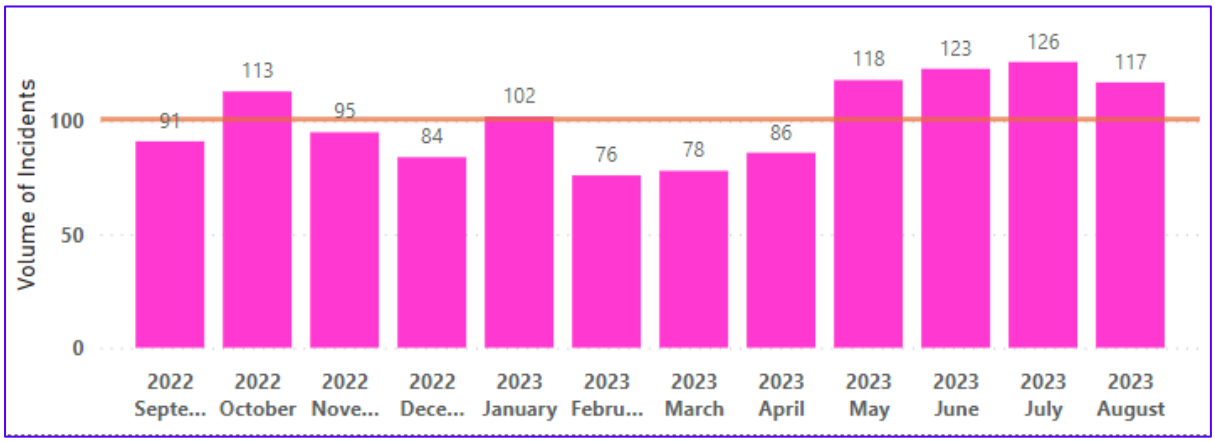
The total number of reported incidents has remained broadly in line with last year

We received a total of 1,209 reports of relevant incidents from providers during this reporting year (September 2022 - August 2023), which covers both fixed and mobile incidents. This is marginally lower than the 1,281 reports received in 2022.

Fixed network incidents increased from 545 in 2022 to 600 in 2023. The volume of fixed incidents, particularly relating to PSTN voice, has grown over a number of years due to the equipment being beyond its intended lifespan and reduced skills in this legacy area of technology. For instance, this year has seen a 20% increase in the number of PSTN incidents reported to us, with a 60% increase in the amount of service hours being lost for customers.[153] This means that these incidents are having a greater impact on consumers and occurring more regularly. Mobile network incidents decreased from 736 in 2022 to 609 in 2023.

[152] An Early Life Failure is a fault that takes place within 0-28 calendar days of provision.
[153] Lost Customer Hours is a metric calculated using the impact of an incident and its duration.

Figure 4.1: Volume of incidents reported to Ofcom each month

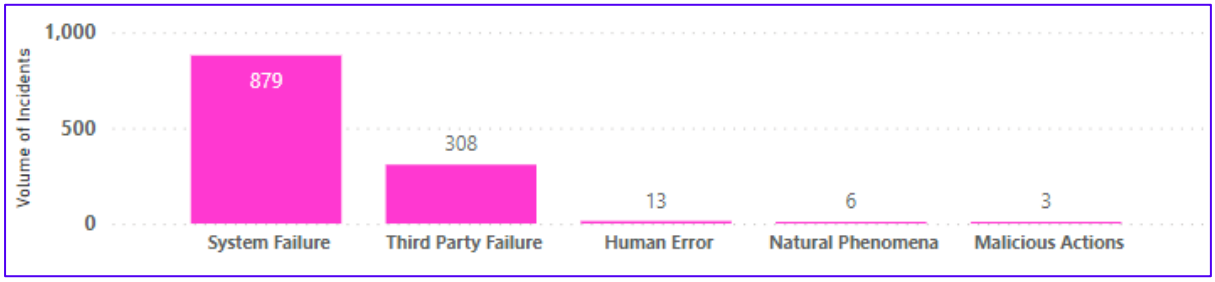


Source: Ofcom analysis of provider data (September 2022 - August 2023).

At a monthly average of 100 incidents, there is less variability between months than last year (Figure 4.1). We have seen a seasonal uplift in incidents occurring through the summer months, during which time there were widespread heatwaves, which may be a related factor.[154] In comparison to 2021/22, where winter storms had a significant impact, 2022/23 did not experience the same level of named storms, which is reflected in significantly lower incident volumes in the winter months compared to last year.

From the incidents that were reported to us over the period, we have seen that outages above the reporting thresholds impacted a total of 17.5 million customers, and there were approximately 107 million customer hours of service lost.[155]

Figure 4.2: Volumes of incidents by root cause of incident



Source: Ofcom analysis of provider data (September 2022 - August 2023).

The most prevalent root cause for the majority of reported failures was system failures, covering elements such as, for example, hardware failures, design errors, and faulty changes (Figure 4.2). However, third party failures, which cover items such as street works causing cable breakages or failed backhaul circuits from wholesale providers, has seen a steep increase from 84 last year to 308 incidents this year.

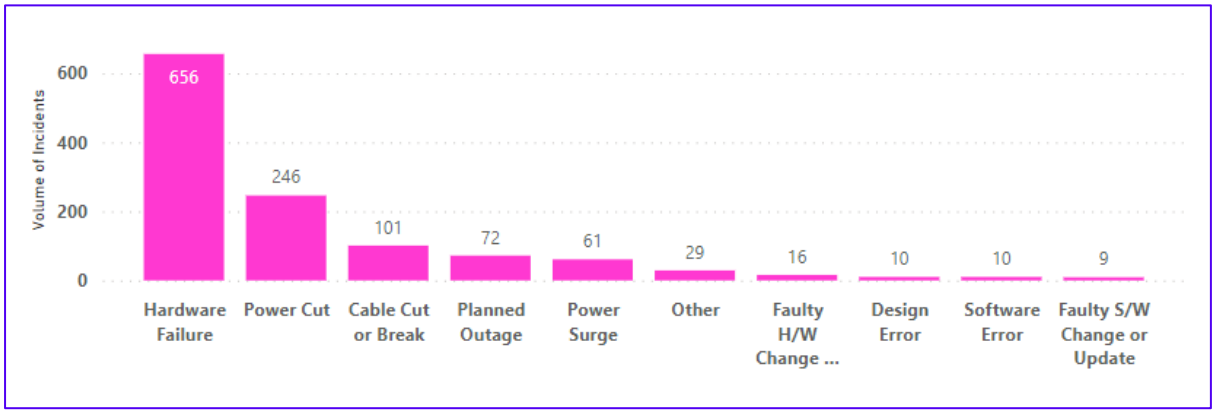
The volume of incidents related to natural phenomena has been lower this year. This appears to be linked to a lower incidence of storms, along with the reporting thresholds being higher than the impact that most natural events typically cause. Among the six incidents attributed to natural

[154] Met Office, Mixed conditions bring warm and wet summer for the UK – Met Office, 1 September 2023.
[155] Due to an established set of Causes and Threats we use ENISA categorisations. About ENISA - The European Union Agency for Cybersecurity — ENISA (europa.eu).

phenomena, three were related to storms, two to flooding or water ingress, and one was due to excess heat.

Failing equipment still generates the highest volumes of reported incidents

Figure 4.3: Volumes of incidents reported by primary cause of incident



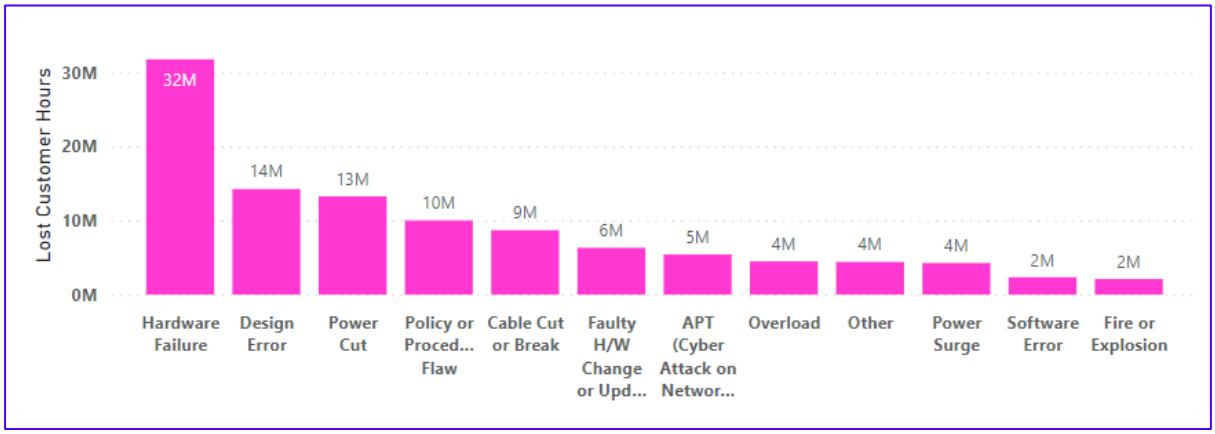
Source: Ofcom analysis of provider data (September 2022 - August 2023).

The root causes used to categorise incidents are quite broad. By looking deeper into the primary causes, we have a better insight into the specific factors that are driving customers to lose service (Figure 4.3, Figure 4.4).

As in previous years, hardware failures are the largest volume (656) of reported incidents when categorised by primary cause, exceeding over half of the reports received. This generated under a third of the total lost customer hours reported to us this year (30%).

This year we received 246 reports related to power cuts, leading to 13.3 million user hours being lost. There were a further 61 power surges reported, resulting in 4.3 million user hours being lost. This means that power incidents reported to us generated 25% of the total volume of incidents reported and approximately 16% of the reported total user hours lost. Most of these hours lost impacted mobile base stations or the associated backhaul transmission systems.

Figure 4.4 : Volume of lost customer hours by primary cause



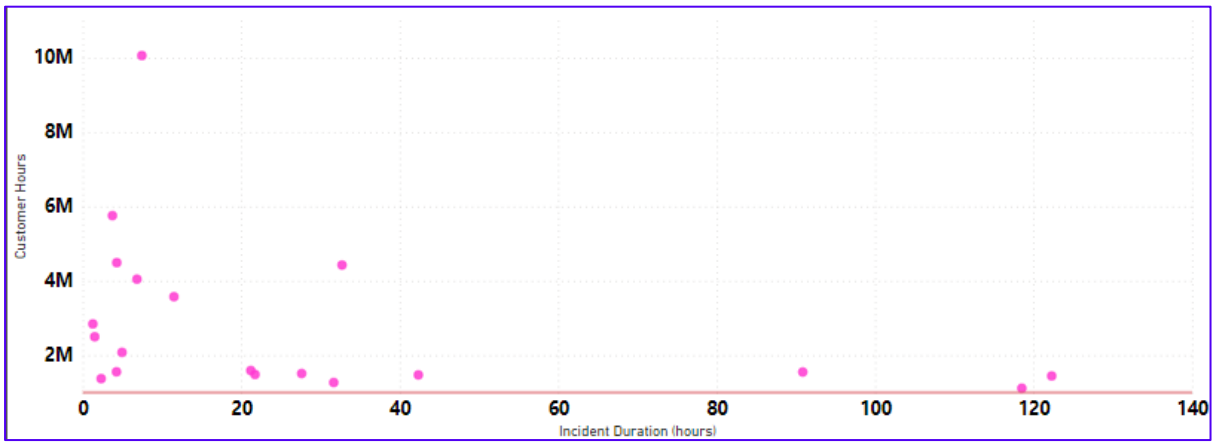
Source: Ofcom analysis of provider data (September 2022 - August 2023).

While not the most significant in terms of the volume of incidents reported (10), design errors contributed the second highest amount of lost customer hours (14 million). This means that these incidents have a high impact when they do occur. From the incidents reported to us that are related to errors with design, a common trend relates to implementing High-Risk Vendor (HRV) removal. Design errors occurred as part of migrations to new vendors, for example due to wider architectural context differences that had not been fully understood, adequately designed for or mitigated against. This sometimes led to issues with how network components interacted with each other, resulting in cascading failures in some instances.

Changes to networks are driving the highest impact incidents

Across this year, 20 incidents were reported to us with impacts exceeding 1 million user hours of lost service (Figure 4.5). Of these incidents, the top three have a root cause within change control and change management, including an incident that exceeded 10 million user hours of lost service. Furthermore, out of these 20 incidents over the million-user-hour mark, 11 were due to change activities. Change management is an area that regularly causes high impact incidents.

Figure 4.5: Customer hours lost against incident duration for reported incidents exceeding a million hours of customer impact



Source: Ofcom analysis of provider data (September 2022 - August 2023).

999 emergency call services disruption

On Sunday 25 June 2023, BT, who manages the emergency services call system experienced a disruption due to a software issue. During the disrupted period, BT provisionally identified that a total of 11,470 unique calls were unsuccessfully connected to 999.[156]

Following the incident, on 28 June 2023, we opened an own-initiative investigation into BT's compliance with General Condition A3.2 (GC A3.2) and sections 105A and 105C of the Communications Act 2003.[157]

[156] BT Group, BT Group review: 999 emergency call services disruption on Sunday 25 June 2023, 29 June 2023.
[157] Ofcom, Ofcom Investigation into BT following 999 emergency call service outage on 25 June 2023, 13 July 2023. GC A3.2 requires certain communications providers to take all necessary measures to ensure the fullest possible availability of voice and internet services provided over public electronic communications networks in the event of catastrophic network breakdown or in cases of force majeure, and uninterrupted access to emergency organisations as part of any voice services offered.

The investigation is ongoing and will seek to establish the facts surrounding the incident and examine whether there are reasonable grounds to believe that BT has failed to comply with its regulatory obligations.

We are monitoring emerging resilience risks for consumers

There are resilience risks associated with remaining on legacy networks[158]

We have seen advancements and adoption of newer technology with Voice over Internet Protocol (VoIP) for landline calls, and with 4G and 5G for mobile services.[159] These developments mean that the legacy networks that predated these advancements can be retired, provided that any disruption is minimised and consumers are protected from harm. Plans are progressing for the legacy PSTN to be switched off; BT has announced it intends to retire its PSTN by December 2025.[160] Similarly, the 2G and 3G mobile networks are also expected to be closed down by 2033 at the latest.[161] We outline progress towards the transition to VoIP in section 2 of this report and the first steps on the switch-off of 3G networks in section 3.

There are a number of potential benefits from migrating away from legacy networks, such as providing additional 4G/5G capacity and higher speeds through better use of the spectrum currently used by 2G/3G, and efficiencies in space and energy costs through the removal of PSTN equipment. The retirement of legacy systems also offers the potential to enhance supply chain resilience, particularly with mobile technology and 5G.[162] Attempting to maintain legacy 2G or 3G networks with a modern 5G-core has backwards compatibility challenges, and it could also prevent the development of a new more diverse set of supplier options.

However, the retirement of these legacy systems raises some potential challenges and risks for consumers, which must be managed carefully to minimise disruption and prevent harm. Alongside the transitional issues for customers with more complex needs,[163] some concerns have been raised regarding the lack of line power with VoIP services (in comparison to PSTN services) and the potential risks to consumers as a result. We recently concluded a monitoring programme to assess the availability of solutions to enable access to emergency services during power outages and did not identify any significant compliance concerns.[164] We engaged with the industry on advances in the availability of in-home battery back-up units and found that many providers are taking appropriate steps.[165]

For mobile, a resilience question associated with the eventual switch-off of 2G and 3G networks arises from most mobile telephony currently 'falling back' through to these networks when signal

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[158] UK Government, Managing legacy technology - GOV.UK (www.gov.uk), 21 February 2019.
[159] 'VoIP' is an umbrella term for any approach to Voice over the 'Internet Protocol', though in this context we are specifically referring to managed voice services in which the voice service provider can control and manage the quality of the service over the broadband connection (sometimes referred to as Voice over Broadband (VoBB).
[160] Ofcom, Moving landline phones to digital technology: what you need to know - Ofcom, 16 January 2023.
[161] Ofcom, 3G and 2G switch-off (ofcom.org.uk), 2 February 2023.
[162] UK Government, Open Networks Research and Development Fund – GOV.UK (www.gov.uk), 5 January 2023.
[163] Our website provides advice for consumers of landline phones on the transition to digital technology.
[164] Ofcom, Compliance monitoring programme into access to emergency services during power outages - Ofcom, 20 July 2023.
[165] Many battery back-up units which were designed to meet the nominal one-hour requirement can last for longer if usage is restricted, and industry are now developing and deploying solutions which can last several hours.

strength is poor or a 4G connection is not possible.[166] Given that the prevalent use of mobile devices is within the home, an alternative potential method for most consumers to make voice calls from a mobile phone when at home is by the use of WiFi calling. This is dependent on the fixed broadband service (and not 2G or 3G mobile networks) and so provides alternative resilience for mobile users, though not all phones are configured to support this.

These risks, and others related to the migration away from legacy systems, need to be managed carefully. However, there are other emerging risks related to using legacy systems beyond their serviceable lifespan, as the equipment in these networks is being used for far longer than it was designed for. This could lead to a situation where network faults are left unresolved for long periods of time as replacement parts no longer exist, network performance becomes erratic, and operators are unable to effectively manage the network. Other potential impacts are higher maintenance costs, limited scalability and an inability to service networks effectively.[167] As outlined above, the incident reports we receive from providers show a rising number of incidents associated with PSTN failures, and these types of incidents are on average having a greater impact. We expect the prevalence and impacts of failures to increase in the years ahead. There is also an increasing risk of a 'cliff edge' failure event that is unrecoverable.

Extreme weather events and preparedness

Many recent extreme weather events are likely to be as a result of the impact of climate change (see also section 5 on climate change and telecoms networks). As networks evolve, operators should be taking these risks on board and understanding how best to mitigate the threats these events pose to their infrastructure.

Wildfires this year caused devastation through many areas of Europe and Maui, destroying telecoms equipment, depriving the first responders of vital communication channels that impacted their ability to effectively respond.[168] The UK did not experience wildfires in 2023 to this extent, but providers should identify and address any hazards that might lead to the loss of communication channels for first responders in such a scenario.

This year, in comparison to last, has seen a lower incidence of outages in the UK related to extreme weather. However, in February 2023, Storm Otto had a pronounced effect across Scotland and Northern England, with the most significant impact felt in the Aberdeenshire area.[169] Debris from the storm had some direct impact on telecoms networks, though the main cause of telecoms outages was the loss of power. More recent events such as Storms Babet, Ciarán and Debi had relatively limited impact on the UK mainland. Openreach has told us that during Storm Babet it deployed the five step process which it developed following Storm Arwen to reduce recovery times.

The named storms of 2021/22 were discussed in detail within last year's Resilience section of Connected Nations, and multi-agency work has continued in this space (see also the update below on the Electronic Communications Resilience and Response Group). Given that mobile is becoming the telecoms network that most people rely upon during times of stress, we have worked in partnership with the MNOs to understand their winter preparedness. The aim was to recognise what

[166] Although extension of 4G coverage through the UK Government's Shared Rural Network programme, and voluntary commitments made by MNOs to address any 'not spots' caused by 3G switch-off, will alleviate this.
[167] UK Government, Guidance on the Legacy IT Risk Assessment Framework - GOV.UK (www.gov.uk), 29 September 2023.
[168] Fierce Wireless, Fires on Maui destroy telecom equipment, adding to emergency (fiercewireless.com), 9 August 2023.
[169] BBC, Power cuts and schools closed as Storm Otto hits - BBC News, 17 February 2023.

MNOs can do to resist, absorb, and recover from events through the winter, while they work to understand what adaptions and transformations will be required moving forwards.

Mobile network power resilience update

Mobile networks are dependent on electrical power, and power outages can cause service disruption for mobile customers. In this year's reporting window (September 2022 to August 2023), the impact for power issues was 13.3 million customer hours lost.

Mains power disconnections can impact mobile access networks. In severe cases, this can lead to outages affecting many mobile cell sites in an area at the same time, for several hours in some cases. This means that, unless overlapping coverage is available from mobile cell sites that are unaffected by a mains power outage or the mobile mast has battery back-up to provide power, customers on the relevant networks will be unable to use their phones for voice and data services until the power is restored.

As our reliance on mobile services grows, there has been an increasing focus and dependence on the resilience of mobile access networks. Last year we asked the four MNOs for an update on their power resilience situation.[170] The below data was accurate as of September 2022. Some MNOs may have developed their power back-up provision since this data was collected. In summary, we were told:

- EE provides extended battery back-up ranging from 6 hours to 5 days to certain sites. The majority of sites do not have mains power back-up.[171]
- Vodafone and VMO2 use a network access sharing agreement, with each managing shared sites in one half of the country, to generate UK coverage. Vodafone deploys power battery back-up at all of its sites, broadly speaking covering the west of the UK, including Wales. Over half of Vodafone sites have 1 hour of back-up (its hub sites also have 8 hours back-up for transmission traffic), the remaining sites have 15 minutes.[172] VMO2 manages sites in eastern areas of England, plus Northern Ireland and the majority of Scotland. A limited number of VMO2's sites (hub sites) have either roughly a day of back-up or 7 days of power back-up.[173] For the majority of sites, VMO2 will have battery back-up of a maximum of 15 minutes.
- Three does not provide battery back-up for any of its radio equipment as part of its standard deployments. Three says it provides a power back-up solution for a limited number of sites meeting certain criteria across its mobile access network.
- For all the MNOs, all of their sites with more than a day of back-up are protected by permanent re-fillable generators.
- We also note that mobile generators may be available for MNOs to deploy to cell sites, through contractual rental agreements.

This data from 2022 suggests that around 50% of all mobile radio sites (i.e. across all MNOs) have some power back-up to maintain functionality at the RAN, 15% percent of all sites are able to

[170] In addition, the migration of landline users from the PSTN to VoIP technology means that some consumers will become more reliant on mobile networks in the event of a power outage that affects fixed networks.
[171] These sites are a combination of hub sites which transmit data from smaller sites to core sites - as a power failure at these sites would potentially impact other surrounding sites - and sites where the topology of the energy distribution network leads to a particular risk of site outage (for example, due to overhead, exposed cables up a mountain).
[172] Transmission systems at a hub site connect smaller singleton or 'child' sites back to the network core.
[173] VM02 noted this back up is more focussed on hub sites with lots of 'child/grandchild' sites.

maintain an hour of functionality during a power outage, with 2% of all sites able to withstand a six-hour power loss (excluding battery back-up for transmission traffic).

Ofcom published a call for inputs in December 2023 exploring what measures MNOs could take regarding additional power resilience for mobile access networks. In light of this, we are seeking comments about what power back-up MNOs can and should provide for their networks and services, to consider whether to address this in our guidance in the future, and/or working with industry and the Government to identify and pursue other ways to address this issue.

Other network and service resilience items

Resilience and the Telecommunications (Security) Act 2021

With the introduction of the Security Act the guidance we provide on Security and Resilience has been split into separate standalone documents.

This year we have worked on updating the Resilience guidance that we provide to communication providers and published a consultation in December 2023.

The proposed guidance describes a range of practices in the architecture, design, and operational models that underpin robust and resilient telecommunications networks and services, as well as more specific measures that we expect communications providers to consider. These are designed to help achieve our aim of ensuring an appropriate level of resilience for services across the UK.

Electronic Communications Resilience and Response Group (EC-RRG)

The EC-RRG is a cross government and telecoms industry forum whose aim is to ensure the telecoms sector remains resilient to threats and risks to services.

They have refreshed their workplan to deliver against their current priorities and generated progress in the consolidated key areas of work delivery, developed by the EC-RRG chair, deputy and members, in partnership with DSIT. Key parts of the workplan were informed by experience of areas of low resilience and potential weaknesses in the past. The storms of 2021/22 added focus not just in relation to adverse weather preparedness, but also to understanding the implications of loss of power, which is a key input to the industry.

A substantial cross sectoral piece of work is taking shape and has led to the first of a number of potential projects, involving power distribution network operators and mobile network operators in a couple of regions of the UK. This is piloting possible models of more effective local coordinated responses to extreme weather events. This piece of work is intended to understand and exploit potential synergies that can be generated through these organisations working closely through adverse situations.

5. Climate change and telecoms networks

Ofcom's statutory duties include that our regulatory functions are carried out in a way that secures the availability throughout of the UK of a wide range of electronic communications (telecoms) services, and the optimal use for wireless telegraphy of the radio spectrum.[174] So, while our duties do not currently include specific climate change objectives, we have an interest in the long-term sustainability of the telecoms sector. This includes its preparation for net zero and climate change impacts, as well as improving its sustainability practice to meet the expectations of investors.

In 2019, the UK Parliament amended the Climate Change Act 2008 by introducing a requirement of a 100% reduction of UK greenhouse gas (GHG) emissions by 2050, compared to the UK's GHG emission levels in 1990.[175] These actions mean, in practice, that all sectors of the UK economy will need to take actions to reduce their GHG emissions. Climate change and the UK's transition to a net zero future are particularly relevant to the telecoms sector in relation to:

a) Extreme weather events driven by climate change means it is necessary for providers to ensure their networks are sufficiently resilient against the risks posed by the elements.

b) Telecoms providers responding to Government legislation, and the expectations of many consumers and investors in the sector, need to reduce their GHG emissions.

c) Telecoms networks and services can have a partnership role in helping enable other industries and the UK Government to deliver against climate change commitments. For example, the use of fixed or wireless communication in place of travel, or connectivity to power smart devices which in turn enable more efficient business practices.

Given this context, we have been engaging with UK telecoms providers and other regulators to support and contribute to discussions on the challenges and opportunities the transition to net zero presents to the UK telecoms sector and users of networks and services.

Climate-related events affect telecoms networks and other sectors that rely on them

Recent extreme weather events such as Storm Arwen in late 2021[176] highlighted the need for providers to prepare their networks to reduce the risk of potentially disruptive impacts. The growing importance of broadband and mobile services, combined with predictions that climate events will be more frequent and of greater severity, suggest this is becoming a key issue for the sector.

More frequent and intense extreme weather events are likely

According to the Met Office, the effects of climate change on local weather could result in warmer and wetter winters, hotter and drier summers, and more frequent and intense weather extremes.

[174] Those duties also include that Ofcom has regard to the desirability of encouraging investment and innovation, and the availability and use of high-speed data transfer services throughout the UK.
[175] The CCA 2008, section 1.
[176] Storm Arwen caused over one million consumers to lose power and left many unable to use their mobile and home phones.

Intense weather extremes, including heatwaves, heavy downpours, and strong windstorms, present challenges to the resilience of networks and the day-to-day operations of providers. For example, heatwaves can compromise the cooling systems of server rooms that house communications network systems, windstorms can cause damage to masts, and heavy downpours may cause flooding, damaging infrastructure and making it difficult for providers to access sites and carry out repairs.[177]

Case study: Severe flooding in Yorkshire

In 2015, parts of the UK saw record levels of rainfall, leading to the flooding of an exchange in York and a data centre in Leeds.[178] The flooding in York left some 50,000 consumers without telephone services for 36 hours. The impacts of the consequent service outages were felt across a larger part of Northern England than was expected. This emphasises the need to review network deployments on an end-to-end basis, to identify critical bottle necks.[179]

A vital component of the nation's critical national infrastructure

The Government has identified telecommunications as one of the top ten sectors deemed to be part of the 'Critical National Infrastructure' (CNI) of the UK. Vulnerability to the risk of network outages may increase as society's dependence on digital services continues to grow.

Consequently, the development of mitigation strategies to adapt to climate change have become a key consideration for providers. Examples of the actions taken include the carrying out of risk assessments to assess the vulnerability of network infrastructure to extreme weather,[180] the development of incident response plans to minimise the amount of time services are out for,[181] and investments in cooling system upgrades and flood prevention equipment.[182] These actions require effort and investment from providers, as well as collaboration with other interdependent industries. For instance, the energy sector is reliant on telecoms networks for the control and monitoring of its infrastructure and provides a key input to the running of telecoms networks.[183]

Ofcom has recently published a consultation on proposed revisions to our guidelines on how communications providers can demonstrate they meet the resilience obligations under the Communications Act 2003. We are also working with Ofgem and the UK Government to address the cross sectoral issues, and the Electronic Communications Resilience and Response Group has a related ongoing work programme with the Energy Networks Association. This work is informed by the likely impacts of climate change. Further details can be found in section 4 on network security and resilience.

Case study: UK heatwaves caused cloud data centre outages

As outlined in our cloud services market study, telecoms providers, like most businesses across the economy, are making increased use of cloud services such as compute, storage, and networking. During the summer of 2018, the UK experienced several heatwaves, setting new temperature

[177] BT, Tackling climate change and environmental challenges.
[178] Environment Agency, Estimating the economic costs of the 2015 to 2016 winter floods, January 2018.
[179] City of York Council, York Flood Inquiry.
[180] Cellnex, 2022 Environment and Climate Change Report.
[181] Telefonica, Climate Action Plan, July 2023.
[182] BT, Tackling climate change and environmental challenges.
[183] IET, Interdependencies and resilience in digital transformation, August 2021.

records. In London, this abnormal weather led to two cloud data centres experiencing cooling-related failures that resulted in service outages.

Providers are addressing their GHG emissions

Globally, the Information and Communication Technology (ICT) sector, of which the telecommunications industry is a subset, has been estimated to account for 2.1-3.9% of global annual GHG emissions.[184] The business activities of providers result in the direct and indirect production of GHG emissions. Organisations typically use the Greenhouse Gas Protocol's 'Scopes' accounting method to estimate and group the GHG emissions that they are directly and indirectly responsible for. Within this method, emissions are grouped into one of three categories, based on their source (see Table 5.1).

Table 5.1: Summary of Greenhouse Gas Protocol's Scopes with telecoms specific examples

Scope	Definition	Telecoms specific example
Scope 1 (Direct)	GHG emissions produced from sources owned/controlled by the reporting company	• Emissions produced from the operation of a fossil fueled vehicle fleet
Scope 2 (Indirect)	GHG emissions that are produced as the result of the reporting company purchasing electricity, steam, and heating/cooling	• Electricity used to power offices, retail stores, and network infrastructure such as mobile base stations
Scope 3 (Indirect)	Indirect GHG emissions generated across the end-to-end value chain of the reporting company	• Emissions from the electrical power used to power the WiFi router provided with a broadband package • Emissions produced during the manufacturing of telecommunications network equipment

The main UK telecoms providers have made net zero commitments ahead of the UK-wide 2050 deadline

Providers are taking steps to reduce their emissions across the three scopes identified above. Some actions taken include electrification of vehicle fleets[185] and purchasing electricity from low carbon providers (e.g., those who source a significant proportion of energy from renewable means).[186]

Some major UK providers and infrastructure owners are publicly committing to, and making progress against, net zero targets set on or before the UK wide deadline of 2050. Table 5.2 is a high-level list of publicly stated net zero target dates set by the some of the largest providers in the UK. We have

[184] This estimate considers the global carbon footprint of the ICT sector across all three scopes. For more information please see: C. Freitag, M. Berners-Lee, K. Widdicks, B. Knowles, G. Blair and A. Friday, The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations, September 2021.
[185] Vodafone, Vodafone's European network 100% powered by electricity from renewable sources, June 2021.
[186] Openreach, Sustainability: Our commitments.

also included some examples of specific public commitments made by providers to reach these targets. It should be noted that the GHG emission methodologies used by companies can vary considerably, and this table is not intended to be used as a basis for comparisons between providers.

Table 5.2: Net zero target dates of some UK providers[187]

Provider	Net zero target year across value chain (Scopes 1, 2 and 3)	Science-based targets[188]	Examples of public commitments / actions
BT[189]	2041	• 87% reduction of scope 1 and 2 GHG emissions intensity ($CO_{2\text{-}e}$ per gross value added) by March 2031 (from a 2016/17 baseline year) • 42% reduction of upstream scope 3 (supply chain) emissions by end of March 2031	• Enable customers to avoid 935k tonnes of emissions • Electrification of majority of vehicle fleet by 2030
Cellnex	2050	• 70% reduction of scope 1 and 2 GHG emissions and fuel and energy related scope 3 emissions by 2030 (from a 2020 baseline year) • 21% reduction of purchased goods and services and capital goods GHG emissions (scope 3) by 2025	• 100% of electricity sourced from renewable sources by 2025 • Stop usage of fossil fuel backup generators by 2035

[187] Target dates and commitments are taken from public announcements produced by providers as of December 2023.
[188] Science-based targets have been taken from the Science-Based Targets Initiative's dashboard. Reductions are relative to a baseline year selected by the provider.
[189] BT's Science-based targets have been taken from their Annual Report 2023.

Provider	Net zero target year across value chain (Scopes 1, 2 and 3)	Science-based targets[188]	Examples of public commitments / actions
Openreach[190]	2041	• 87% reduction of scope 1 and 2 GHG emissions intensity ($CO_{2\text{-}e}$ per gross value added) by March 2031 (from a 2016/17 baseline year) • 42% reduction of upstream scope 3 (supply chain) emissions by March 2031	• Electrification of majority of vehicle fleet by financial year 2031
Sky	2050	• 50% reduction of scope 1, 2 and 3 GHG emissions by 2030 (from a 2018 baseline year)	• Committed to electrification of entire vehicle fleet by 2030 (EV100) • Commitment to 100% renewable energy pledge (RE100)
TalkTalk	2050	• 93.5% reduction of scope 1 and 3 GHG emissions by 2030 (from a 2020 baseline year) • 42% reduction of scope 3 emissions by 2030	• Began the electrification of vehicle fleet in 2020 • Switched to a renewable energy provider in 2020
Three	No date set for Scope 3[191]	• 50% reduction of Scope 1 and 2 emissions by 2030 (from a 2020 baseline year) • 42% reduction of scope 3 emissions by 2030	• 97% of procured electricity will be from renewable means • Have implemented a sustainable travel programme, aiming to reduce business travel by 25%

[190] Openreach is covered by BT's Science Based Targets.

[191] In 2021, CK Hutchison Group Telecom Holdings set a 2040 net zero target date for its scope 1 and 2 emissions. Three UK's emissions are included within this target.

Provider	Net zero target year across value chain (Scopes 1, 2 and 3)	Science-based targets[188]	Examples of public commitments / actions
Virgin Media O2	2040	• 90% reduction of scope 1 and 2 GHG emissions by 90% by 2030 (from a 2020 baseline year) • 50% reduction of scope 3 emissions by 2030 • Net zero across their value chain by 2040	• By the end of 2025, all new products will be made from recycled plastic • Electrification of entire vehicle fleet by 2030
Vodafone	2040	• 90% reduction of scope 1 and 2 emissions by 2030 (from a 2020 baseline year) • 50% reduction of scope 3 emissions by 2030 • Net zero across their value chain by 2040	• Electrification of entire vehicle fleet by 2027 • Enable global customers to avoid 350m tonnes of emissions between 2020 and 2030

Source: Ofcom analysis of public announcements produced by providers as of December 2023

The migration away from legacy networks could facilitate energy savings

The MNOs have highlighted that emission reductions can be realised through the planned switch-off of 2G and 3G networks. Legacy networks can consume a disproportionate amount of power relative to their usage. For example, EE has said its 3G network is responsible for 35% of its mobile network power consumption, whilst only carrying 0.6% of its total traffic.[192] MNOs could realise energy savings (reducing their scope 2 emissions) when their legacy networks are switched off and existing users and services are transferred onto newer, more energy efficient wireless communication technologies, such as 4G and 5G.[193]

Meanwhile, the transition from copper to full-fibre networks could allow fixed operators to reduce their emissions through more efficient use of energy. Full-fibre networks are more energy efficient, largely achieved through rationalising infrastructure and consuming less energy than copper

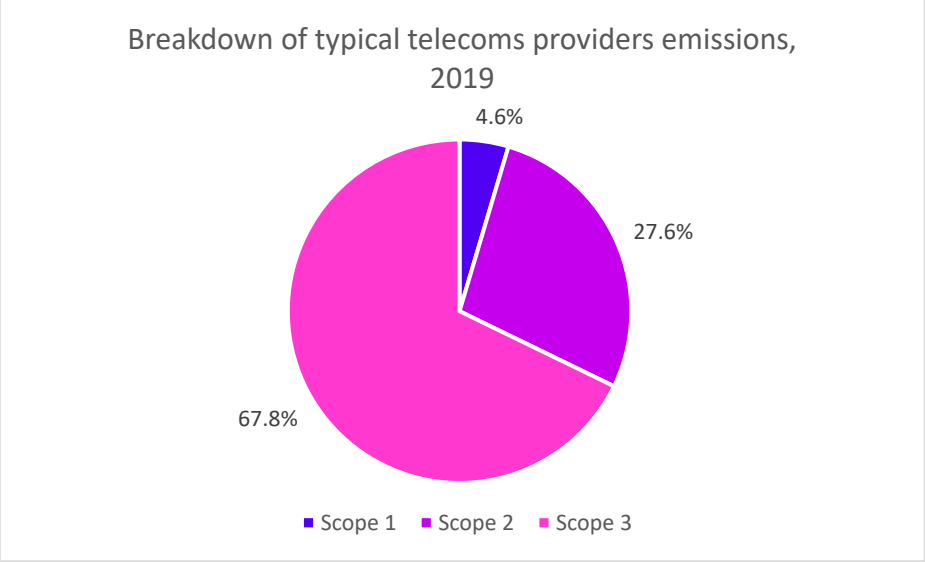
[192] LightReading, UK telcos prepare to turn off 3G to boost energy efficiency, July 2023.
[193] Vodafone estimate their 5G network uses 7% of the energy required to send a terabyte of data across their 3G networks.

networks to transmit the same amount of data.[194] TalkTalk has estimated that transitioning to a full-fibre network could yield up to an 80% improvement in network energy efficiency.[195]

UK telecommunications companies are working together to address Scope 3 emissions

For most telecoms providers, around two-thirds of their GHG emissions are produced outside of their own operations (Scope 3), as shown in Figure 5.1. These emissions arise within their supply chain (such as during the manufacturing of network equipment) and from the usage activities of their customers (such as from the energy required to use equipment like WiFi routers).

Figure 5.1: Breakdown of a typical telecoms provider's GHG emissions by Scope



Source: Oliver Wyman, The Next Level of Emission Reductions in Telecom Operators

Reducing Scope 3 emissions is perhaps the greatest net zero challenge for the telecoms sector because emissions arise at a point where providers have less control and direct visibility of GHG generating activities.

In May 2023, Ofcom and Accenture invited twelve communications providers and infrastructure owners to an industry roundtable meeting to facilitate discussions on this important topic. This event presented an opportunity for the industry to discuss and identify priority areas where and how it could collectively reduce supply chain emissions (Scope 3). During the event, participants discussed opportunities for further activity and coordination to reduce supply chain emissions.

The Digital Connectivity Forum's Climate and Sustainability working group (CSWG)[196] has coordinated subsequent work to develop proposals for SMEs. As a first output from this group, the CSWG recently published net zero guidance for SMEs within the telecoms sector. Recognising the important role that SMEs will play in achieving the UK's net zero goals, the publication provides

[194] 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.
[195] TalkTalk, Making the 'climate case' for full fibre, October 2023.
[196] The Digital Connectivity Forum is a UK Government's advisory group on the provision of digital connectivity.

SMEs with advice on how to calculate their GHG emissions, set emission reduction targets and reduce emissions.

In addition to their net zero guidance for SMEs, the DCF's CSWG have also endorsed the Joint Alliance for Corporate Social Responsibility (JAC)[197] 10-point principles. The CSWG says these principles, set out in JAC's Climate Change Report 2023, provide suppliers of the UK telecommunications industry with guidance on how to decarbonise, as well as act as the beginning of a dialogue between industry and suppliers towards sector wide decarbonisation.

Telecoms can also help enable other industries and government to achieve net zero targets

In addition to reducing its own emissions, the telecoms industry also has a significant role in the UK's net zero transition through the 'enablement effect'. It can work in partnership with other sectors to facilitate the use of technology to deliver net zero solutions and encourage some of the social changes required to enable significant emission reductions.[198]

There are many examples of this enablement effect across the UK economy. These include agriculture, where farmers are using sensors to tailor their fertilizer usage;[199] utilities, where smart meters provide real time measurements and reduce the travel needed for meter inspections;[200] and the logistics sector, where real time route optimisation is helping operators to identify the most efficient delivery routes.[201] All of these approaches are partially enabled by fixed, wireless and satellite connectivity, allowing data to be uploaded, stored, analysed and applied, regardless of where it has been captured.

Case study: The enabling potential of Fibre broadband – reducing Cornwall's emissions

A collaborative project – funded by the EU, Cornwall Council, UK Government and BT – was tasked with delivering fibre broadband to 95% of homes in Cornwall. The project report estimated the improved infrastructure, supporting remote working, access to digitalised goods and cloud services, helped to reduce the area's emissions by up to 0.5 $MtCO_2$ between 2011-2020 – equivalent to the emissions produced by powering around 18,000 homes.

The ICT sector, including technologies such as drones, sensors, and smart meters which require reliable connectivity, can potentially work with other sectors to support the transition to decarbonisation. Some studies have estimated that ICT solutions could help enable as much as a 10:1 reduction in GHG emissions.[202] This means that for every kilogram of emissions produced through the use of an ICT service there is the potential to remove up to 10 kg of emissions from the activities of another sector.

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[197] The Joint Alliance for Corporate Social Responsibility (JAC) is an association of telecom operators aiming to verify, assess and develop the Corporate Social Responsibility implementation across the manufacturing centres of important multinational suppliers of the ICT industry,

[198] For a discussion of the enablement effect, please see: GSMA, The Enablement Effect or IPCC, Innovation, Technology Development and Transfer.

[199] JRC, The contribution of precision agriculture technologies to farm productivity and the mitigation of greenhouse gas emissions in the EU, February 2019.

[200] Ofgem, British Gas's request for changes to its meter inspection license obligations, April 2012.

[201] Crown Commercial Service, Decarbonising freight transport: how the logistics industry can use software to reduce carbon emissions, October 2022.

[202] For example, please see: Global e-Sustainability Initiative, #SMARTer2030, May 2015; BT, The role of ICT in reducing carbon emissions in the EU, May 2016; GSMA, The Enablement Effect.

Case study: Automated water meter reading using bin lorries

In separate trials ran by South Staffs Water and United Utilities, bin lorries were used to take fortnightly water meter readings, using wireless technology, as they passed homes on rubbish collection days. Meter readings help water companies to identify leaks in customer homes, helping to reduce water loss.

Several sectors – including manufacturing, agriculture, logistics and energy – have highlighted the role technology will play in supporting their transition to net zero. They have identified technologies such as sensors, Artificial Intelligence, and autonomous machines helping to drive efficiency gains and reduce material usage, waste and energy demands. These digital technologies will have a wide range of connectivity requirements – with varying data rates, latency and coverage demands – where a 'one size fits all' solution will often not be adequate.

Meanwhile, the UK Government is considering, as part of the Wireless Infrastructure Strategy, commissioning an independent assessment to better understand the role of wireless connectivity in supporting the UK's net zero transition.

Climate change is likely to remain important context for the telecoms sector

Climate change and the transition to net zero present both challenges and opportunities for the telecoms sector. Through the 'enablement effect' providers can help support decarbonisation across the economy, alongside further reducing the sector's own emissions. At the same time, the widespread adoption of digital technologies increases the importance of network resilience, including from weather-related outages, which can be exacerbated by climate change. We expect this area will remain important context for the telecoms sector in the coming years.