Ofcom
making communications work
**for everyone**

# CONNECTED NATIONS **2016**

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FULL DOCUMENT

# About this document

The United Kingdom depends on various infrastructures, and one of the most important is the nation's communications.

Fast, reliable communications enable businesses to generate prosperity and employment, and our countries to compete. They empower every citizen to take a full part in society and benefit from life's opportunities. Communications also save lives, bind families and friends together, and keep us entertained.

Part of Ofcom's role is to make sure that, as far as possible, we can make the calls we want to, where we need to and that we can use the internet at acceptable speeds.

This annual report tracks the communications providers' progress in growing the availability of good communications, and how the UK is working towards a robust and visionary next generation of services.

# Contents

Section 1

# Dashboard

The data for 2016 was collected during June. Data for 2015, where available, is provided for comparison[1], and all figures for data usage combine both download and upload volumes.

| Fixed broadband | 2016 | 2015 |
|---|---|---|
| **Broadband, all speeds** | | |
| Coverage, premises | ≈100% | ≈100% |
| Take-up, premises | 78% | 78% |
| Average download sync speed | 37Mbit/s | 29Mbit/s |
| Average upload sync speed | 4Mbit/s | 4Mbit/s |
| Total fixed data usage | 2,750PB | N/A |
| Average monthly data usage, per residential connection | 132GB | 97GB |
| **Broadband (download speed of 10Mbit/s and higher)** | | |
| Coverage, premises | 95% | 92% |
| Take-up, premises | 54% | 50% |
| Average download sync speed | 51Mbit/s | N/A |
| Average upload sync speed | 5Mbit/s | N/A |
| Total fixed data usage | 2,230PB | N/A |
| Average monthly data usage, per residential connection | 153GB | N/A |
| **Superfast broadband (download speed of 30Mbit/s and higher)** | | |
| Coverage, premises | 89% | 83% |
| Take-up, premises | 31% | 27% |
| Average download sync speed | 74Mbit/s | 65Mbit/s |
| Average upload sync speed | 8Mbit/s | 8Mbit/s |
| Total fixed data usage | 1,434PB | N/A |
| Average monthly data usage, per residential connection | 169GB | 112GB |
| **Ultrafast broadband (download speed of 300Mbit/s and higher)** | | |
| Coverage, premises | 2% | 2% |
| Take-up, premises | 0.09% | 0.003% |
| **Broadband (download speed up to 10Mbit/s)** | | |
| Coverage, premises | 5% | 8% |
| Take-up, premises | 24% | 26% |
| Average download sync speed | 6Mbit/s | N/A |
| Average upload sync speed | 1Mbit/s | N/A |
| Total fixed data usage | 521PB | N/A |
| Average monthly data usage, per residential connection | 81GB | N/A |

[1] This year our fixed networks analysis is based on a more detailed data set than was available in previous years. Therefore, it is not possible to provide year-on-year comparisons for all metrics.

| Mobile[2] | 2016 | 2015 |
|---|---|---|
| **4G services** | | |
| Premises (indoor) covered by all operators | 72% | 29% |
| Premises (indoor) not covered by any operator | 4% | 16% |
| Geographic area covered by all operators | 40% | 8% |
| Geographic area not covered by any operator | 28% | 52% |
| Coverage of A and B roads by all operators | 38% | 9% |
| A and B roads not covered by any operator | 20% | 47% |
| **Voice services (2G, 3G and 4G)** | | |
| Premises (indoor) covered by all operators | 89% | 85% |
| Premises (indoor) not covered by any operator | 1% | 2% |
| Geographic area covered by all operators | 66% | 58% |
| Geographic area not covered by any operator | 10% | 13% |
| Coverage of A and B roads by all operators | 61% | 52% |
| A and B roads not covered by any operator | 6% | 10% |
| **Data services (3G and 4G)** | | |
| Premises (indoor) covered by all operators | 80% | 77% |
| Premises (indoor) not covered by any operator | 2% | 3% |
| Geographic area covered by all operators | 52% | 38% |
| Geographic area not covered by any operator | 16% | 21% |
| Coverage of A and B roads by all operators | 45% | 37% |
| A and B roads not covered by any operator | 11% | 15% |
| **Mobile (data use)** | | |
| Total number of active mobile connections | 83.6m | 83.7m |
| Total mobile data usage | 105.5PB | 72.9PB |
| Average monthly data usage, per SIM | 1.3GB | 0.87GB |

[2] Coverage thresholds are: 2G indoor (-71dBm), 2G outdoor (-81dBm), 3G indoor (-90dBm), 3G outdoor (-100dBm), 4G indoor (-105dBm) and 4G outdoor (-115dBm).

Section 2

# Executive Summary

2.1 Over the course of 2016, the UK took another step forward in the coverage of its fixed and mobile communications. More people are, or can be, connected to the communications they need, and they are consuming more data as fixed and mobile services become increasingly woven into the fabric of their daily lives and work.

2.2 But it would be wrong to infer that the picture is universally a rosy one. For a significant number of consumers, and in many parts of the country, fixed broadband speeds are slow and mobile coverage is poor or indeed non-existent. Ofcom is therefore continuing to work with industry, the UK Government and the devolved administrations to explore ways to improve the availability and performance of these vital communications services.

2.3 A key part of this work is this annual Connected Nations Report; a 'state of the union' update on the coverage and performance of fixed broadband and mobile services that the UK's consumers and small businesses are receiving. We also cover important developments in broadcasting and internet services and track security incidents that affect communications networks and services.

2.4 Below we present the highlights of this year's findings, and expand on them further in the remainder of the report.

## Fixed broadband services

2.5 Three levels of fixed broadband service are offered in the UK, typically defined in terms of the download speed they offer. Standard broadband services have download speeds of between 10 and 30Mbit/s, whilst superfast broadband[3] services have download speeds greater than 30Mbit/s. The performance of both standard and superfast broadband services is limited by the use of copper-based technologies in the access network. We are now starting to see the emergence of new ultrafast broadband services, which make greater use of fibre connections, and which we currently define as delivering download speeds of at least 300Mbit/s[4].

2.6 The headline findings on the state of the UK's fixed broadband in 2016 are as follows:

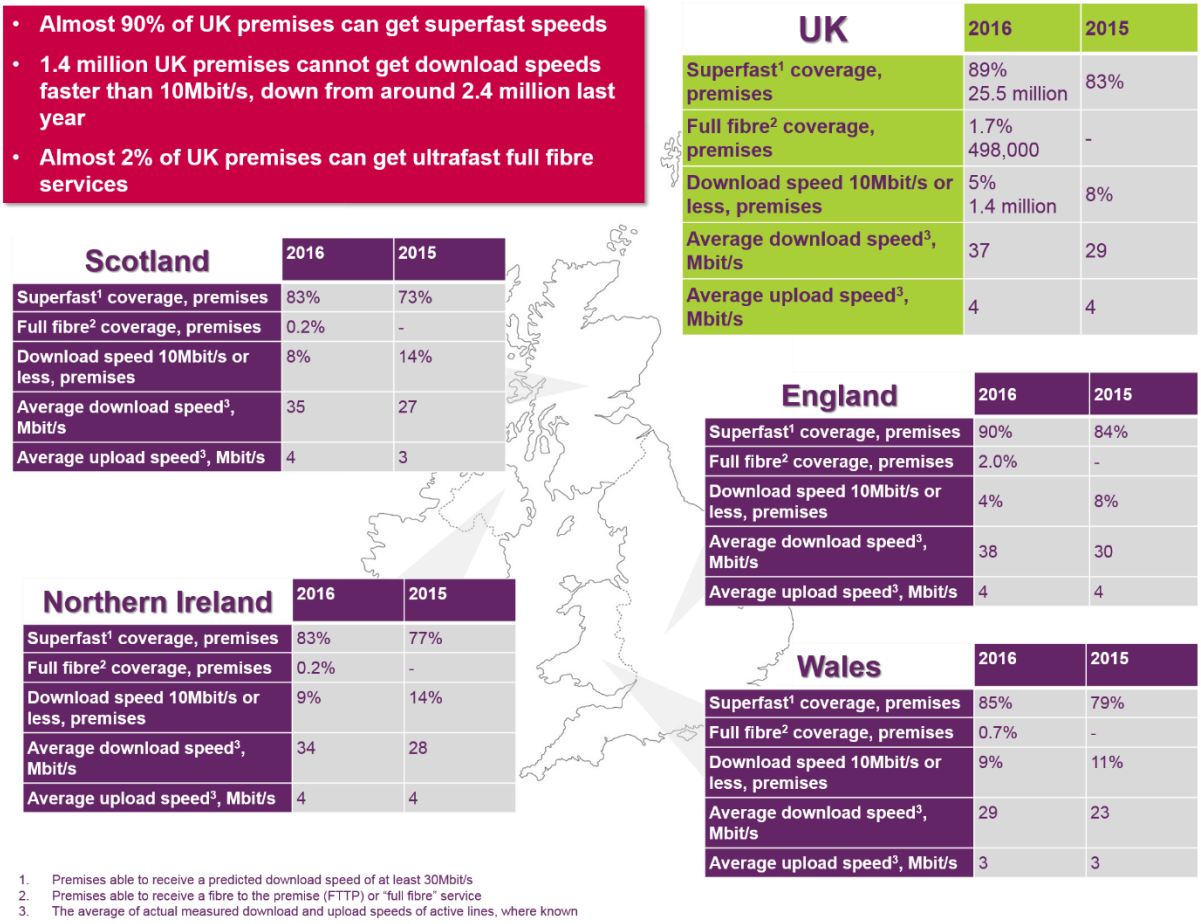
2.7 **The availability of superfast broadband has improved, but a significant number of homes and businesses are still at risk of digital exclusion.** In 2015 around 8% of UK premises (2.4 million) were unable to receive broadband speeds faster than 10Mbit/s. Although this figure has since fallen to 5% of UK premises, this still means 1.4 million premises are being poorly served and may fall within a broadband universal service obligation.

2.8 We recognise that upload, as well as download, speeds can affect the consumer experience, and increase the number of UK premises that are poorly served. If we also require a standard broadband service to deliver an upload speed of at least

[3] The UK Government defines superfast as having download speeds of 24Mbit/s or more.
[4] There is not a consensus on the definition of ultrafast services currently, with views ranging from 100Mbit/s to 1Gbit/s.

1Mbit/s, then the number of UK premises that are poorly served increases to 2.6 million.

**Figure 1: The state of fixed broadband in the UK**




*Source: Ofcom analysis of operator data*

2.9 **Superfast coverage has improved, though SMEs still see poorer availability than residential consumers.** 89% of UK homes and small and medium-sized businesses (25.5 million) are now able to receive superfast download speeds of 30Mbit/s or higher. This is up from 83% (24 million), last year. There is also an improving picture in rural areas, where more consumers are now better connected: superfast coverage is reaching 59% of homes and businesses (2.3 million), up from 44% in 2015. However, although superfast coverage has improved in Scotland, Wales and Northern Ireland, they still lag behind the UK as a whole.

2.10 SMEs still experience poorer superfast broadband coverage compared to consumers as a whole. This is because many are located in areas that are less well served. Only 80% of SMEs (1.9 million) have access to superfast services in the UK, compared to 89% of all premises; this leaves almost 480,000 SMEs without access to superfast broadband. Almost 192,000 SMEs cannot currently access speeds above 10Mbit/s.

2.11 The Government defines superfast as having a download speed of greater than 24Mbit/s, and plans to provide this to 95% of premises by the end of 2017. They have made progress, and our findings support their view that, by June 2016, 90% of UK premises were covered by these speeds or faster. This is up from 85% last year.

2.12 **Ultrafast Fibre to the Premises (FTTP) services**. Approximately 1.7% of UK premises (498,000) have access to "full fibre" FTTP services, which offer download speeds of between 250Mbit/s and 1Gbit/s. Around 450,000 of these premises are in England. A number of providers, of varying scale and reach, are committed to deploying full fibre services and we would expect to see coverage increase over the coming 12 months.

2.13 **Increased take-up of superfast services is driving greater consumption.** Around 31% of UK premises (9 million) now subscribe to superfast broadband services. Although this is up from 27% in 2015, it remains relatively low, given that superfast is an option for 89% of UK premises. The percentage of premises not taking up a fixed broadband service at all is 22%.

2.14 The average speed of superfast services has increased by 14% over the last year, to 74Mbit/s. This, coupled with increased take-up of superfast services, means that the average download speed across all active broadband services is now 37Mbit/s, a 28% increase compared to 2015.

2.15 As speeds and take-up of superfast broadband increased, households across the UK consumed an average of 132GB of data per month in 2016, up from 97GB in 2015. As in previous years, there is evidence that households with higher speed connections are consuming significantly more data, especially those with superfast speeds.

## Mobile services

2.16 Presenting a clear picture of mobile coverage across the UK is a challenge. Firstly, three different generations of technology are used in the UK's mobile networks, each with different characteristics and qualities. Secondly, consumers access mobile networks in many different ways and, as a result, there is an expectation that mobile phones will work both indoors and outdoors, in towns and in cities and while travelling on the roads and railways.

2.17 The headline findings on the state of the UK's mobile networks in 2016 are as follows:

2.18 **Indoor coverage has increased:** Effective indoor coverage[5] of voice services from all operators is around 89% of UK premises (26 million), up from 85% last year. The coverage of data services has also improved, rising from 77% of UK premises in 2015 to 80% (23 million) this year. We expect commercially-available technologies that build on the increasing availability of fixed broadband, such as Wi-Fi calling, to lead to further improvements in indoor coverage.

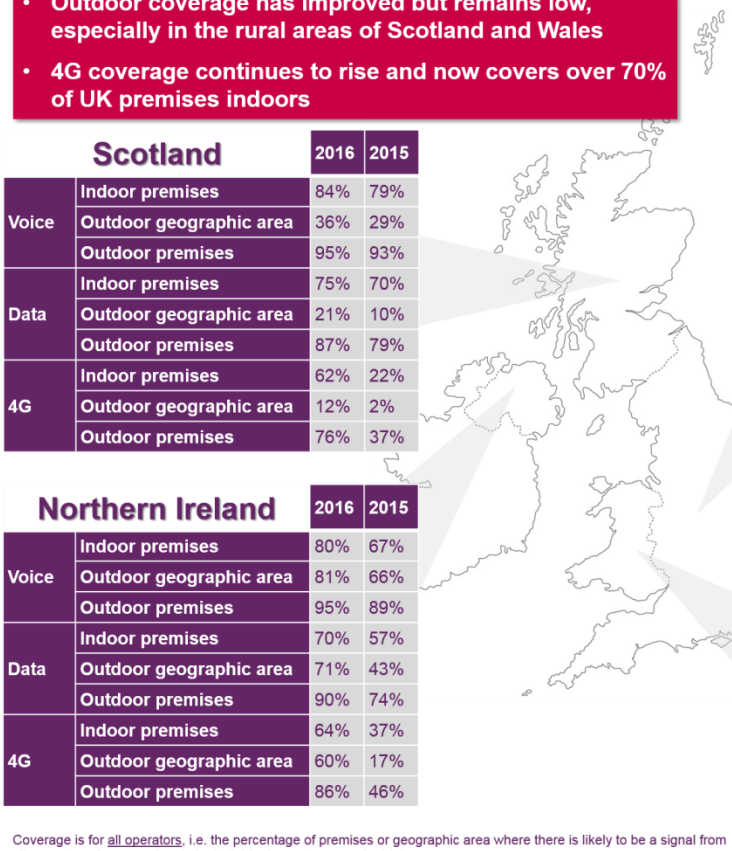
2.19 **There is still some way to go with geographic coverage:** Outdoor coverage of both voice and data services has increased. Consumers can now make and receive phone calls on all operators' networks in 66% of UK landmass, up from 58% last year; and the coverage of data services from all operators has increased from 38% to 52% this year. There is, however, an enduring concern that geographic coverage is still relatively low and that future commercial rollouts are unlikely to fully address the

[5] In this report we use definitions of coverage based on signal strength thresholds that we believe accurately reflect the typical consumer experience, e.g. there is a greater than 95% chance of being able to make a phone call using a modern smartphone. These definitions will be different from those used elsewhere, e.g. in current licence obligations.

situation. There is, therefore, a risk that consumers in rural parts of the UK and its constituent nations, and those travelling by car and train, will continue to experience difficulties in using their mobile phones.

### Figure 2: The state of mobile services in the UK

- Consumers can use their phones for voice calls inside almost 90% of UK premises and data services inside around 80% of UK premises
- Outdoor coverage has improved but remains low, especially in the rural areas of Scotland and Wales
- 4G coverage continues to rise and now covers over 70% of UK premises indoors



| Scotland | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 84% | 79% |
| | Outdoor geographic area | 36% | 29% |
| | Outdoor premises | 95% | 93% |
| Data | Indoor premises | 75% | 70% |
| | Outdoor geographic area | 21% | 10% |
| | Outdoor premises | 87% | 79% |
| 4G | Indoor premises | 62% | 22% |
| | Outdoor geographic area | 12% | 2% |
| | Outdoor premises | 76% | 37% |

| Northern Ireland | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 80% | 67% |
| | Outdoor geographic area | 81% | 66% |
| | Outdoor premises | 95% | 89% |
| Data | Indoor premises | 70% | 57% |
| | Outdoor geographic area | 71% | 43% |
| | Outdoor premises | 90% | 74% |
| 4G | Indoor premises | 64% | 37% |
| | Outdoor geographic area | 60% | 17% |
| | Outdoor premises | 86% | 46% |

| UK | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 89% | 85% |
| | Outdoor geographic area | 66% | 58% |
| | Outdoor premises | 97% | 96% |
| Data | Indoor premises | 80% | 77% |
| | Outdoor geographic area | 52% | 38% |
| | Outdoor premises | 93% | 88% |
| 4G | Indoor premises | 72% | 28% |
| | Outdoor geographic area | 40% | 8% |
| | Outdoor premises | 86% | 46% |

| England | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 91% | 87% |
| | Outdoor geographic area | 84% | 77% |
| | Outdoor premises | 98% | 97% |
| Data | Indoor premises | 82% | 81% |
| | Outdoor geographic area | 72% | 57% |
| | Outdoor premises | 95% | 91% |
| 4G | Indoor premises | 76% | 31% |
| | Outdoor geographic area | 60% | 11% |
| | Outdoor premises | 90% | 50% |

| Wales | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 73% | 65% |
| | Outdoor geographic area | 52% | 46% |
| | Outdoor premises | 90% | 88% |
| Data | Indoor premises | 57% | 47% |
| | Outdoor geographic area | 27% | 17% |
| | Outdoor premises | 76% | 67% |
| 4G | Indoor premises | 34% | 10% |
| | Outdoor geographic area | 13% | 2% |
| | Outdoor premises | 53% | 20% |

Coverage is for all operators, i.e. the percentage of premises or geographic area where there is likely to be a signal from all operators. Coverage levels for individual operators may be higher.

*Source: Ofcom analysis of operator data*

2.20 **Rapid strides in 4G coverage:** All four operators are in the middle of a major 4G rollout programme and the coverage of these higher-speed data services has increased significantly, with geographic coverage from all operators now reaching 40% of UK landmass, up from just 8% in 2015. The launch of 4G voice call services by EE and Three has started to have a beneficial effect on their voice network coverage, in particular by improving coverage indoors.

2.21 **…although 4G is mainly urban:** Most of the first phase of 4G deployments have been focused on urban areas. As a result, geographic 4G coverage in the UK's rural areas is only 37% of landmass, compared to 89% in towns and cities. Coverage inside premises, where many consumers use their phones, remains relatively low, even in urban areas; 72% of UK premises (21 million) receive a 4G signal from all operators indoors.

2.22 **4G is driving data usage:** With growing coverage and greater take-up, 4G is driving greater volumes of data downloads and uploads. The average volume of data consumed per subscriber is now 1.3GB per month, up from 0.9GB in 2015. A total of

106PB was sent over all mobile networks in June 2016, a 44% increase on the year before. Even so, this represents just 4% of the volume of data sent over fixed broadband networks.

2.23 We are committed to providing consumers with information on mobile coverage, via mobile apps and online tools, that is accessible, accurate and comparable. This equips consumers to make informed decisions on which operator best meets their needs. Equally, it gives operators an increased incentive to compete on coverage. Including coverage obligations in operators' licences is also an important lever, to make sure consumers receive an improved mobile experience.

2.24 However, the coverage improvements provided by these existing measures and commercial deployments are unlikely to fully address consumer needs. Without additional steps, the consumer experience in many rural areas, on roads and on the railways is likely to fall short of consumer expectations. We note, however, that achieving near universal coverage throughout the geographical area of the UK and across the road and rail networks, will require significant new investments in mobile infrastructure.

## Resilience

2.25 As consumers and businesses become ever-more dependent on communications services, Ofcom's duty to focus on network resilience becomes increasingly important. Although there has been no significant increase in network failures, in either number or impact, underlying changes in network technology have implications for consumers that need an appropriate regulatory and policy response.

2.26 In this year's report we have identified two resilience-related issues that could have a significant impact on consumers – the long-term provision of fixed voice services and the resilience of mobile communications.

2.27 An important technology change in the next few years will be so-called "PSTN switch off"[6]. This refers to the decommissioning of the legacy telephone network and migrating voice services to a service delivered over broadband and, as such, could have a significant impact on consumers. Our key principles are to ensure minimum disruption for consumers and businesses, that providers must communicate the migration process clearly to their customers and that no voice service users are worse off after the technology change, either financially or functionally. We will manage the risks through an active programme of engagement with CPs and other stakeholder groups.

2.28 Meanwhile, mobile is increasingly coming to the fore in meeting overall consumer and business communications needs. However, its infrastructure is more prone to failing during widespread power outages than typical fixed voice services. This is a concern, as mobile has become the primary life-line during emergencies, and it would need a significant investment to reduce its dependence on mains electricity. There will be a need for more focussed activity in this area involving Ofcom, Government and industry as part of the programme of securing and making key elements of critical national infrastructure more resilient.

[6] The Public Switched Telephone Network.

## Preparing this report

2.29 The information in this report is derived from a significant volume of raw data which is provided to us by a range of fixed and mobile network operators. The data is highly detailed and contains, among other things:

2.29.1 Predictions of the broadband speeds capable of being delivered to every home or small business in the country;

2.29.2 Actual measured download and upload speeds of every broadband line in the country;

2.29.3 Predicted signal strengths of the voice and data networks for every mobile operator and for each $100m^2$ grid of the UK's landmass; and

2.29.4 The amount of data downloaded and uploaded on all of the UK's fixed and mobile networks.

2.30 We also undertake technical studies, such as our continuing work to measure fixed and mobile broadband quality of experience, and collect information from operators on matters concerning security and resilience of networks and services.

Section 3

# Background to the report

3.1 Under the Communications Act 2003 ('the Act') Ofcom is required to submit a report to the Secretary of State every three years, describing the state of the electronic communications networks and services in the UK[7]. We published the first report in 2011 and the second report in 2014.

3.2 However, we recognised after publishing the first report that some aspects of the communications infrastructure were developing rapidly and/or were of particular interest to Government and industry stakeholders, and therefore committed to providing updates on an annual basis. These updates have mainly focused on the areas of greatest change, such as coverage and capacity of fixed and mobile networks. This year's Connected Nations Report updates the report[8] published in December 2015.

## Approach and context

3.3 For fixed broadband services this report considers services provided to residential consumers and to small and medium-sized enterprises (SMEs). We use data gathered from the largest operators in each sector, as well as information already held by Ofcom. Where possible we have re-used data already provided to Ofcom, in order to minimise the burden on stakeholders. We have also gathered data from a number of other smaller network and service providers for various aspects of this report, including some providers of fibre to the premises (FTTP) networks.

3.4 We present a detailed description of our data sources and methodologies in Annex 1.

## Improving the information available to consumers and other stakeholders

3.5 Alongside this report we are launching two tools to help consumers and other stakeholders find out more about fixed and mobile services in the UK:

3.5.1 **A new app for mobile phones and tablet PCs**, which enables consumers to find out about the fixed broadband and mobile services that are available at their address. In addition, the app will allow consumers to test the speed of their fixed and mobile connections and identify the issues most likely to be affecting their performance. A web-based tool will also be available for use on desktop and laptop computers.

3.5.2 **An online visualisation tool**, which presents some of the key highlights from this year's report in an intuitive and graphical way. The tool allows the user to drill down into the detail of some of the data, for example to find out more about mobile coverage in a specific area.

3.6 As in previous years, we will be making data available to download via our website. We recognise the value in making this data available to third parties for their own

[7] http://www.legislation.gov.uk/ukpga/2010/24/section/1
[8] http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/connected-nations-2015/

analysis and we continue to work as part of our broader open data initiative to explore ways in which to further improve this.

## The International Communications Market Report

3.7 Ofcom's International Communications Market Report (ICMR) 2016[9], published alongside this report, provides comparative international data on the communications sector. Its purpose is to benchmark the UK against 17 comparator countries in terms of the availability, take-up and use of communications services. A range of different data sources are used to inform the analysis presented in the ICMR, including consumer research commissioned by Ofcom, data already held by Ofcom and data sourced from either desk research or third party providers.

3.8 There are a number of metrics in the ICMR that are similar to those in this report (most notably those present in the *Telecoms and networks* chapter of the ICMR). However, data used in the ICMR differs from those used in this report on a number of counts, such as time period (data presented in the ICMR is generally end of 2015 unless otherwise stated, compared to June 2016 for the data in this report) and definitions behind metrics.

3.9 For example, 4G population coverage in the ICMR is defined as being from at least one operator, whereas this report typically expresses coverage from all operators. In instances where metrics differ between the ICMR and this report, the difference is explained. Further explanation behind differences is detailed in the document *Measuring the networks: the methodologies behind Ofcom's research reports*.[10]

## Outline of this report

3.10 The remainder of the report is structured as follows:

- Section 4: Fixed broadband networks and services
- Section 5: Mobile voice and data services
- Section 6: Internet Access Services
- Section 7: Security and resilience
- Section 8: The continuing evolution of television
- Annex 1: Methodology
- Annex 2: Glossary

3.11 We welcome comments from consumers and stakeholders on the report. Please contact us at connectednationsreport@ofcom.org.uk.

[9] https://www.ofcom.org.uk/research-and-data/cmr/cmr16/international
[10] https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016

Section 4

# Fixed broadband networks and services

4.1 The quality and reach of fixed broadband infrastructure in the UK has advanced considerably over the last few years, both in terms of technology and services offered. Superfast broadband is now available to almost 90% of homes and small businesses across the UK and continuing investment by industry and Government will ensure further increases in coverage over the next few years.

4.2 This section explores the coverage and performance of fixed broadband services in the UK and highlights how consumers are using their broadband connections to send and receive more data than ever before. We note, however, that many consumers still cannot access adequate broadband speeds and highlight ongoing Government and industry initiatives aimed at improving the quality of broadband services for all.

4.3 The most important messages are:

4.3.1 **Superfast broadband coverage in the UK has improved significantly over the last few years.** The coverage of superfast broadband has extended to over 25 million (or 89% of) UK premises, up from 83% in 2015. This creates the potential for better speeds and improved quality of service for both residential and SME consumers.

4.3.2 **There are still gaps in broadband coverage.** Progress has been made in reducing the number of premises that cannot get acceptable speeds. However, around 1.4 million, or 5% of, homes and small businesses in the UK are still unable to receive download speeds greater than 10Mbit/s. This represents the lowest number of premises that would fall within the UK Government's proposed broadband Universal Service Obligation (USO), depending in its specification;

4.3.3 **The growth in the number of premises taking up superfast broadband appears to be slowing.** Over 9 million, or 31% of, UK premises now subscribe to superfast services, up from 27% in 2015 and 21% in 2014. While this latest year-on-year increase is a reasonable improvement, these figures suggest that growth in superfast take-up might be reaching a plateau. Given the relatively high levels of superfast coverage, it is unclear why more consumers are not actively taking up faster services.

4.3.4 **Faster speeds mean that more data is being consumed.** The average download speed of all broadband products in the UK is now 37Mbit/s, up from 29Mbit/s in 2015. Average monthly data volumes per household have increased by 36% over the past year, from 97GB to 132GB. The total volume of data transferred over fixed broadband networks in June 2016 was 2,750PB[11].

[11] A petabyte, or PB, is equivalent to one million gigabytes.

**What is superfast broadband and how is it delivered to homes and small businesses?**

We define superfast broadband as supporting download speeds of at least 30Mbit/s. In order to deliver these speeds, service providers typically need to install fibre optic cabling, which supports higher speeds than the copper cables used in traditional networks.

The current generation of superfast broadband is typically delivered by replacing the copper cable between the local exchange and the street cabinet with optical fibre. The cable between the street cabinet and the consumer's home or business is still made of copper. The replacement of copper with fibre in the connection enables higher speeds for the consumer. It is also possible to use fibre optic from the exchange all the way to the consumer's premises. This offers speeds that are even higher than superfast, which we call ultrafast broadband.

Note that the UK Government uses a slightly different definition of superfast. They define superfast as supporting download speeds of at least 24Mbit/s.

Some common terms used to describe broadband services include:

*Fibre to the cabinet (FTTC)*: This describes a superfast broadband connection that uses optical fibre from the exchange to the street cabinet and a copper cable to connect the cabinet to the home or office, as described above. Providers such as BT, Sky and TalkTalk offer FTTC services.

*Cable*: This is a similar concept to FTTC, but the connection between the cabinet and the home or office is made of a particular type of copper cable that can support very high speeds. Virgin Media offers this kind of service, delivering superfast broadband and television services over its cable network.

*Fibre to the premises (FTTP)*: This describes a service that uses fibre from the exchange directly to the consumer's home or office. FTTP, or "full fibre" networks can deliver very high speeds and is offered to different extents by BT, KCOM in and around Kingston Upon Hull, and several smaller providers such as B4RN in rural Lancashire, Hyperoptic and Gigaclear.

*Wireless*: This describes a service that uses a wireless connection between the consumer's home or office and the provider's network. This kind of service is often based on similar technologies to those used in mobile networks, and can deliver superfast speeds. These services are offered by providers such as Relish and Quickline.

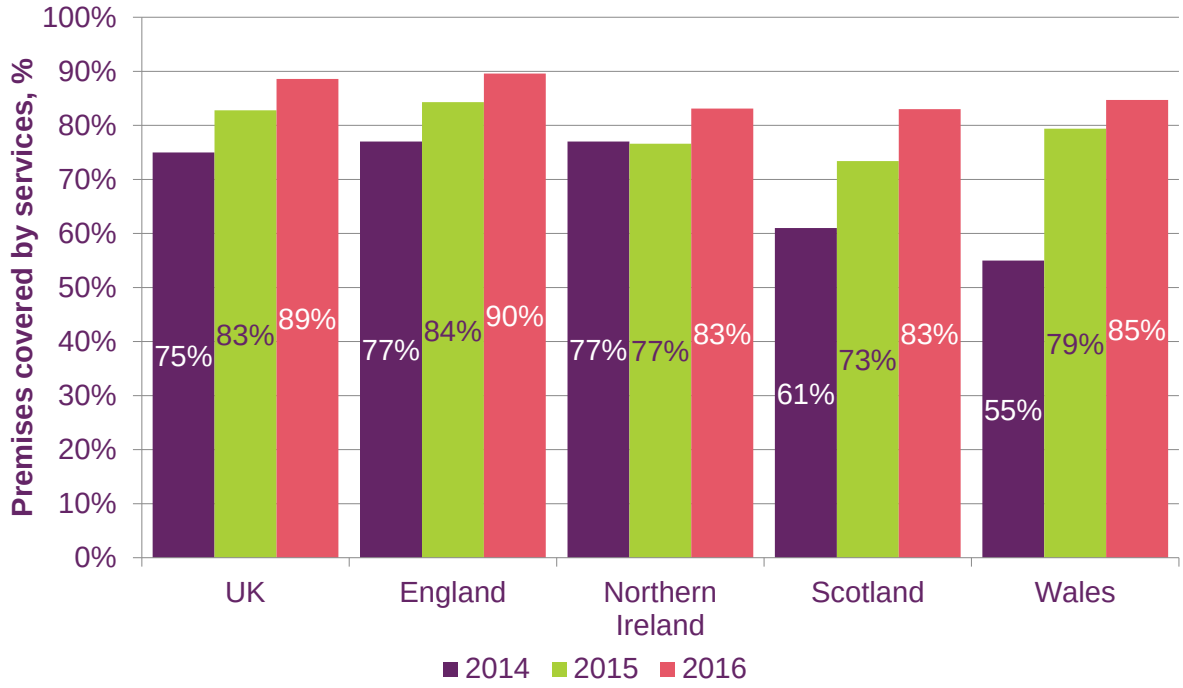
## Coverage of superfast broadband has increased to almost 90% of UK premises

4.4 Around 25.5 million, or 89%, of premises across the UK can now access networks offering at least 30Mbit/s. The average download speed[12] of these superfast connections is now 74Mbit/s, a 14% increase on last year's speeds. The average

[12] This is the average of actual measured speeds of active superfast or ultrafast lines, where known. The sync speed of a connection is the maximum speed achievable between a consumer's premises and their internet service provider's (ISP's) network.

upload speed for superfast services in the UK is unchanged from last year, at 8Mbit/s.

**Figure 3: The number of properties that can access broadband services with superfast speeds or higher continues to increase**



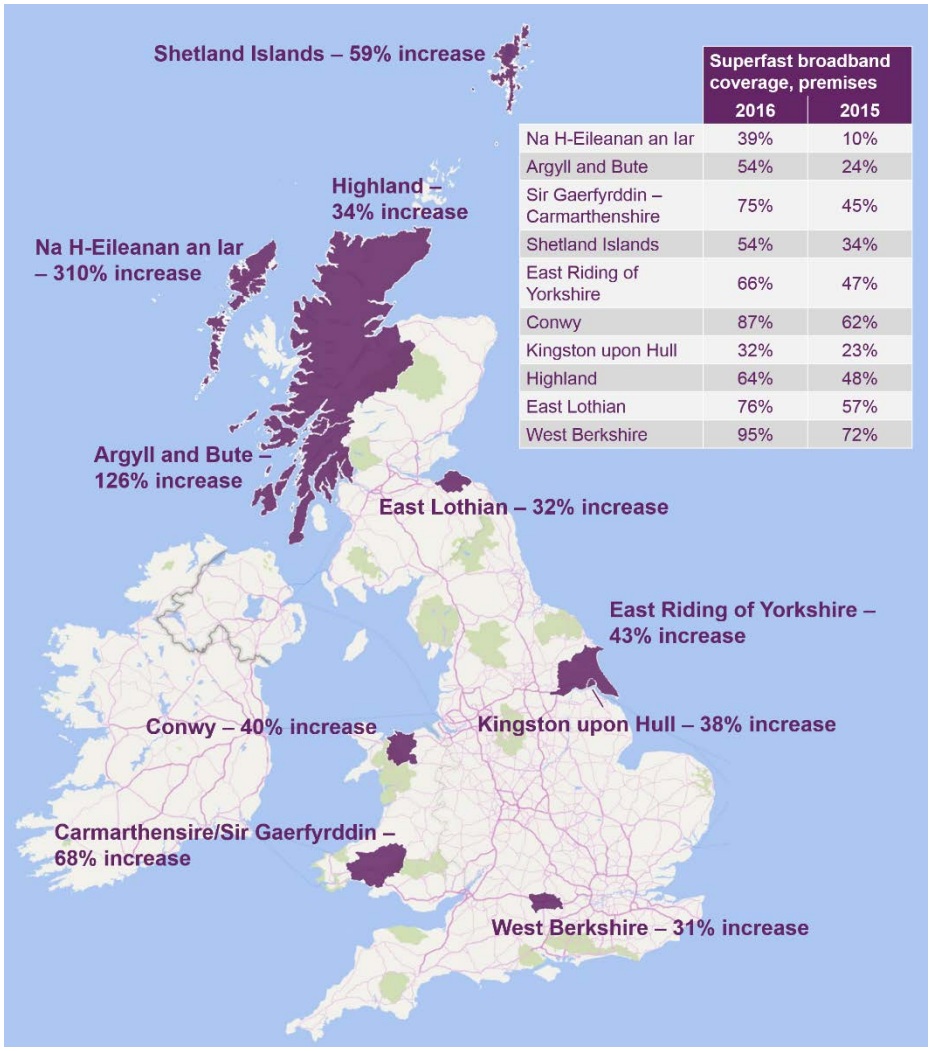

*Source: Ofcom analysis of operator data*

4.5 As Figure 3 shows, coverage of services offering superfast speeds of 30Mbit/s or higher has increased across all of the UK's nations. The greatest increase was in Scotland, with a year-on-year rise of almost 14%, compared to an average of around 7% for the other nations. However, superfast coverage in Scotland and Northern Ireland still remains lower than in other nations.

4.6 Targeted investment by industry and Government has led to some areas of the UK experiencing significant increases in superfast broadband coverage over the past year, as shown in Figure 4. In many cases, these areas previously had very low levels of coverage and, even with recent increases, the availability of superfast broadband remains low compared with the UK as a whole. Nonetheless, these improvements will be welcomed by consumers in these areas, many of whom will be experiencing significant improvements in the quality and speed of their broadband services.

4.7 Although the coverage of broadband services remains better in urban areas, there has been significant increase in the availability of superfast in rural areas. As Figure 5 shows, around 60% of UK rural premises can now access speeds of over 30Mbit/s, up from 44% in 2015.

## Figure 4: Areas of the UK have seen a significant increase in the availability of superfast broadband




| | Superfast broadband coverage, premises | |
|---|---|---|
| | 2016 | 2015 |
| Na H-Eileanan an Iar | 39% | 10% |
| Argyll and Bute | 54% | 24% |
| Sir Gaerfyrddin – Carmarthenshire | 75% | 45% |
| Shetland Islands | 54% | 34% |
| East Riding of Yorkshire | 66% | 47% |
| Conwy | 87% | 62% |
| Kingston upon Hull | 32% | 23% |
| Highland | 64% | 48% |
| East Lothian | 76% | 57% |
| West Berkshire | 95% | 72% |

*Source: Ofcom analysis of operator data*

## Figure 5: Superfast broadband coverage in rural areas has increased by around 35%

| | Availability of superfast broadband in rural areas, premises | | |
|---|---|---|---|
| | 2016 | 2015 | Approximate year-on-year increase |
| **UK** | 59% | 44% | 35% |
| **England** | 62% | 45% | 38% |
| **Northern Ireland** | 52% | 40% | 29% |
| **Scotland** | 46% | 31% | 46% |
| **Wales** | 57% | 54% | 5% |

*Source: Ofcom analysis of operator data*

## The coverage of ultrafast services is largely unchanged

4.8 Alongside the continuing roll-out of superfast services, a new range of broadband services are now increasingly available that offer download speeds of several hundred Mbit/s or higher. These services are enabled via upgrades to the capacity of existing networks or by new technologies such as FTTP (see the box above).

4.9 As we noted last year, there is not a consensus on a definition for these ultrafast services, with views on the minimum download speed ranging from 100Mbit/s to 1Gbit/s. Figure 6 shows the coverage of broadband services for this range of speeds[13].

**Figure 6: Coverage of faster broadband services with download speeds of 100Mbit/s or higher**

| | Coverage of premises, % | | |
|---|---|---|---|
| | Download speed of at least 100Mbit/s | Download speed of at least 300Mbit/s | Download speed of at least 1Gbit/s |
| **UK** | 46% | 1.7% | 0.8% |
| **England** | 49% | 1.9% | 1.0% |
| **Northern Ireland** | 27% | 0.2% | 0% |
| **Scotland** | 36% | 0.2% | 0.2% |
| **Wales** | 22% | 0.7% | 0.2% |

*Source: Ofcom analysis of operator data*

4.10 The coverage of these services is broadly unchanged from 2015. Around 13 million, or 46% of, UK premises have access to broadband services with download speeds of 100Mbit/s or more; and download speeds of 300Mbit/s and above are available to around 2% of UK premises (480,000).

4.11 Since supplying us with their network coverage data in June, Virgin Media has started to offer services with download speeds of 300Mbit/s. The availability of these services is not reflected in this year's data but we would expect to see a significant increase in the number of premises that can receive download speeds of 300Mbit/s or more in subsequent reports. We would also expect to see these figures increase as a result of Virgin Media's ongoing Project Lightning activity, which is seeking to extend their network coverage to around 17 million premises by 2020.

4.12 As with last year, for this report we have defined ultrafast services as those delivering a download speed of 300Mbit/s or more. We will continue to monitor the coverage of these faster services and may, if appropriate, refine our definition as the market evolves.

[13] Last year we reported that the coverage of services with download speeds of at least 300Mbit/s in Scotland and Wales was 2% and 5% respectively. This year we are reporting lower levels of coverage; however, this is likely a result of this year's more accurate data set, which is based on address-level granularity, rather than any real reduction in coverage.

## Almost half a million homes and small businesses have access to "full fibre" broadband

4.13 In addition to the ongoing deployment of fibre to the cabinet (FTTC) services to support superfast speeds, some operators are also in the process of rolling out fibre to the premises (FTTP) or "full fibre" networks. These are networks where the entire connection, from the operator's core network to the customer's premise, is based on fibre optic links.

4.14 One important benefit of full fibre networks is that they are able to support very high speeds, ranging from several hundred Mbit/s to 1Gbit/s or more. In addition, full fibre networks can be more reliable and experience fewer faults than services based fully or partially on the traditional telephone networks, as they are less susceptible to damage from water ingress. The increased capacity of full fibre networks also can mean that the speeds actually experienced by consumers will be more stable and less likely to degrade at peak times.

4.15 Coverage of full fibre services is low, reflecting what is currently an immature market. Around 1.7% of homes and small businesses (500,000) have access to full fibre services across the UK and, as Figure 7 shows, most (over 90%) of these premises are in England.

**Figure 7: Percentage of premises that receive full fibre services**

| | Premises covered, number (%) |
|---|---|
| **UK** | 500,000 (1.7%) |
| **England** | 480,000 (2.0%) |
| **Northern Ireland** | 1,600 (0.2%) |
| **Scotland** | 6,000 (0.2%) |
| **Wales** | 11,000 (0.7%) |

*Source: Ofcom analysis of operator data*

4.16 A range of providers, both large and small, are beginning to offer full fibre services:

4.16.1 Openreach is a national provider of full fibre services, with the largest coverage footprint in the UK. In addition to its commercial roll-out, Openreach has been deploying full fibre services to some parts of the country as part of its agreement with the UK Government to improve broadband speeds as part of the BDUK Superfast Broadband Programme[14];

4.16.2 Virgin Media is also starting to offer full fibre services across the country. The company intends to add around four million premises to its coverage

[14] The UK Government's Broadband Delivery UK (BDUK) Superfast Broadband Programme is seeking to deliver download speeds of 24Mbit/s or more to 95% of the UK by the end of 2017.

footprint by 2020 as part of its Project Lightning expansion plans, around half of which will be full fibre connections[15];

4.16.3 KCOM, who are responsible for operating the network in and around the city of Kingston upon Hull; and

4.16.4 A number of smaller providers, such as Gigaclear, Hyperoptic and B4RN that often target areas that would otherwise remain unserved by other, larger operators.

4.17 While levels of superfast coverage are relatively high, the UK has a low level of full fibre coverage compared to other countries, as we describe in our International Communications Market Report[16]. For example, Germany, France and Portugal have full fibre coverage levels of 7%, 16% and 75% respectively. Further afield, 95% of premises in Singapore, and 97% in Japan, have access to full fibre broadband.

4.18 The next two sections look in more detail at deployments of full fibre networks in Kingston upon Hull and by smaller providers throughout the country.

## Kingston upon Hull has a relatively high availability of full fibre services

4.19 The English city of Kingston upon Hull is the only city in the UK that is not served by BT. Telecommunications services are instead provided by KCOM, which is the incumbent operator in the city and the neighbouring areas in East Yorkshire.

4.20 KCOM has followed a different approach to upgrading its broadband network, compared to BT in other parts of the country. KCOM is pursuing a strategy of upgrading its network to offer mainly full fibre services, rather than the fibre to the cabinet (FTTC) services that underpin most of BT's superfast services[17].

4.21 KCOM's focus on the deployment of full fibre networks means that around 35% of homes and small businesses in the Hull area[18] can now benefit from download speeds of at least 250Mbit/s, more predictable performance at peak times and a more reliable service. The network is also more future-proofed than fully or partially copper-based networks, meaning that the speeds delivered to consumers can continue to grow.

4.22 KCOM have more recently announced[19] that they are accelerating their FTTP plans with the aim of passing 150,000 properties by the end of 2017. This would represent a significant increase in FTTP availability in the area where they are the incumbent.

4.23 However, the shorter tem price of this revolutionary approach, as opposed to the evolutionary approach of upgrading to FTTC services, is that it runs the risk of creating a two-tier online community. Where these full fibre services are not available, the relative lack of FTTC deployment in the Hull area means that consumers in the city rely on slower, all copper-based services. As a result, based on

[15] Virgin Media Q3 2016 results, http://www.virginmedia.com/corporate/media-centre/press-releases/virgin-media-q3-2016-results.html
[16] https://www.ofcom.org.uk/research-and-data/cmr/cmr16/international
[17] KCOM has deployed some FTTC and will continue to do so but FTTP will provide the main NGA connectivity solution.
[18] The “Hull area” refers to the area where KCOM operates as the incumbent and consists of the Kingston upon Hull City Council area and some parts of the East Riding of Yorkshire Council area.
[19] http://www.kcomplc.com/business-insight/news-and-media/kcom-announces-major-milestone-in-ultrafast-broadband-rollout/

the June 2016 data used in this report, around 24% of premises in the Hull area are unable to get more than 10Mbit/s.

### Smaller providers are playing an important role in delivering high speed broadband services throughout the country

4.24 As we reported in previous years, a number of smaller providers are continuing to invest in the infrastructure required to deliver high speed broadband services. These providers sometimes target areas with little or no superfast coverage and, without their deployments, consumers in these areas would continue to experience poor broadband performance.

4.25 Recognising the important role that these smaller providers play in improving the coverage of broadband services, we collected data from a sample of five providers operating throughout the UK. The combined coverage of these providers is around 570,000 premises, or 2% of all premises in the UK. As a result of this coverage, around 185,000 premises that previously were unable to get superfast speeds or higher are now connected.

**Figure 8: Number of premises that are served by superfast services, or faster, from smaller providers**

| | Number of premises served |
|---|---|
| England | 563,000 |
| Scotland | 4,540 |
| Wales | 2,430 |

*Source: Ofcom analysis of operator data*

4.26 As Figure 8 shows, the majority of the premises served by smaller providers are in England. The majority of these premises are in London, where coverage is provided by a mix of full fibre and fixed wireless services. Outside of larger cities there are also targeted deployments of full fibre services in rural areas, such as the counties of Lancashire, Cumbria and North Yorkshire. In these cases, smaller providers are playing a vital role in delivering superfast, or even ultrafast, services to consumers who had previously lacked acceptable broadband.

4.27 In Scotland and Wales, coverage is focused in the cities of Glasgow and Cardiff respectively. We do not currently hold data on the coverage of smaller providers in Northern Ireland. We aim to include coverage from a greater number of smaller providers in next year's report.

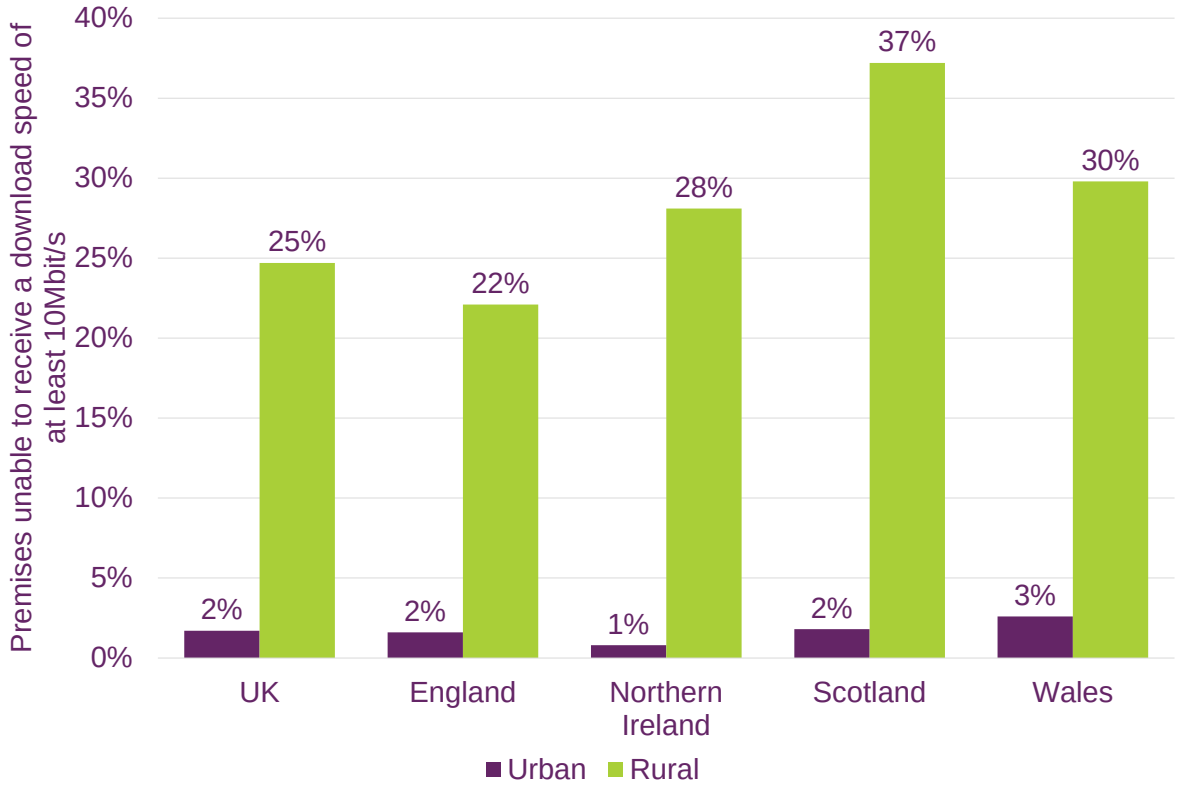
## Many consumers remain unable to access broadband with acceptable speeds

4.28 Despite the increase in coverage of superfast services, many homes and small businesses still are unable to receive broadband speeds that are adequate to reliably perform a range of common online activities. Almost a quarter of a million UK premises, around 1% of the total, cannot get a download speed of more than 2Mbit/s and over 600,000 premises cannot get 5Mbit/s.

4.29 As Figure 9 shows, the problem is particularly bad in rural areas. One of the main reasons for poor broadband speeds in rural areas is the length of the connection to the property. Rural properties are often further from the exchange or street cabinet than in urban areas and, for copper-based telephony networks, the longer the connection, the slower the speeds are likely to be due to attenuation of the broadband signal.

4.30 Around 1.4 million, or 5%, of UK premises are unable to receive a download speed greater than 10Mbit/s. We continue to regard this as the minimum download speed required to fulfil the basic needs of the average UK household. As Figure 9 shows, a much higher proportion of premises unable to access a connection speed of at least 10Mbit/s are in rural areas, and across the UK 25% of rural premises (approximately 960,000 premises) are unable to receive download speeds greater than 10Mbit/s. Government programmes, such as those administered by Broadband Delivery UK (BDUK), are helping to address the problem of poor broadband coverage, in particular in rural areas. We expect to see improvements in the coverage of faster services over the coming 12 months.

**Figure 9: Many premises are unable to receive a download speed greater than 10Mbit/s, especially in rural areas**




*Source: Ofcom analysis of operators' data*

**Why are broadband speeds lower in rural areas?**

The distance between the premises and the exchange has an impact on the quality of service received, and in particular the speed of a consumer's connection. Consumers who live in less densely populated parts of the UK are more likely to live further from the exchange, and therefore achieve lower broadband speeds.

The resistance of copper wire increases with the length of the wire, so speeds decay as the distance between the premises and the exchange increases. Speeds typically start to decrease between 1 and 2km from the exchange and are reduced considerably at distances more than 3.5km.

FTTC-based broadband uses optical fibre to the cabinet and therefore the length of copper wire is reduced. It can currently support superfast speeds up to 80Mbit/s. However, as some copper wire remains between the cabinet and the premises, there can be some decay in speeds for customers located a long way from a cabinet. Customers further than 300m from a cabinet can expect their speeds to be less than half the maximum possible.

However, most consumers who live too far from the cabinet to receive superfast broadband may still benefit from the upgrade at the cabinet, as the reduction in the length of the copper access line will improve their broadband speeds.

4.31 There are some consumers that are connected to FTTC networks but do not currently receive superfast speeds. Many of these premises are found in rural areas, where the distance between properties and street cabinets can be higher than those in urban areas. Despite the cabinet being upgraded to fibre, the long copper lines between the cabinet and the premise results in reduced speeds.

4.32 We estimate that around 3%, or 780,000, premises in the UK are connected to FTTC networks but cannot receive superfast speeds. The situation is broadly similar in England, Scotland and Wales, where around 3% of premises are affected in this way. However, Northern Ireland has a much higher proportion of such lines; around 7% of premises in the nation as a whole and 16% of rural premises are connected to FTTC networks but do not receive superfast speeds. This is because Northern Ireland has a relatively large number of dispersed rural properties, needing longer lines to connect them to street cabinets.

## Broadband coverage remains relatively poor for many small businesses

4.33 The UK's 5.5 million small and medium enterprises (SMEs)[20] constitute 99.3% of all UK private businesses, account for 60% of private sector employment and 47% of business revenue[21]. Providing all SMEs with access to superfast broadband services is vital for improving efficiencies of business and providing equal opportunities to participate and utilise the benefits of a digital economy.

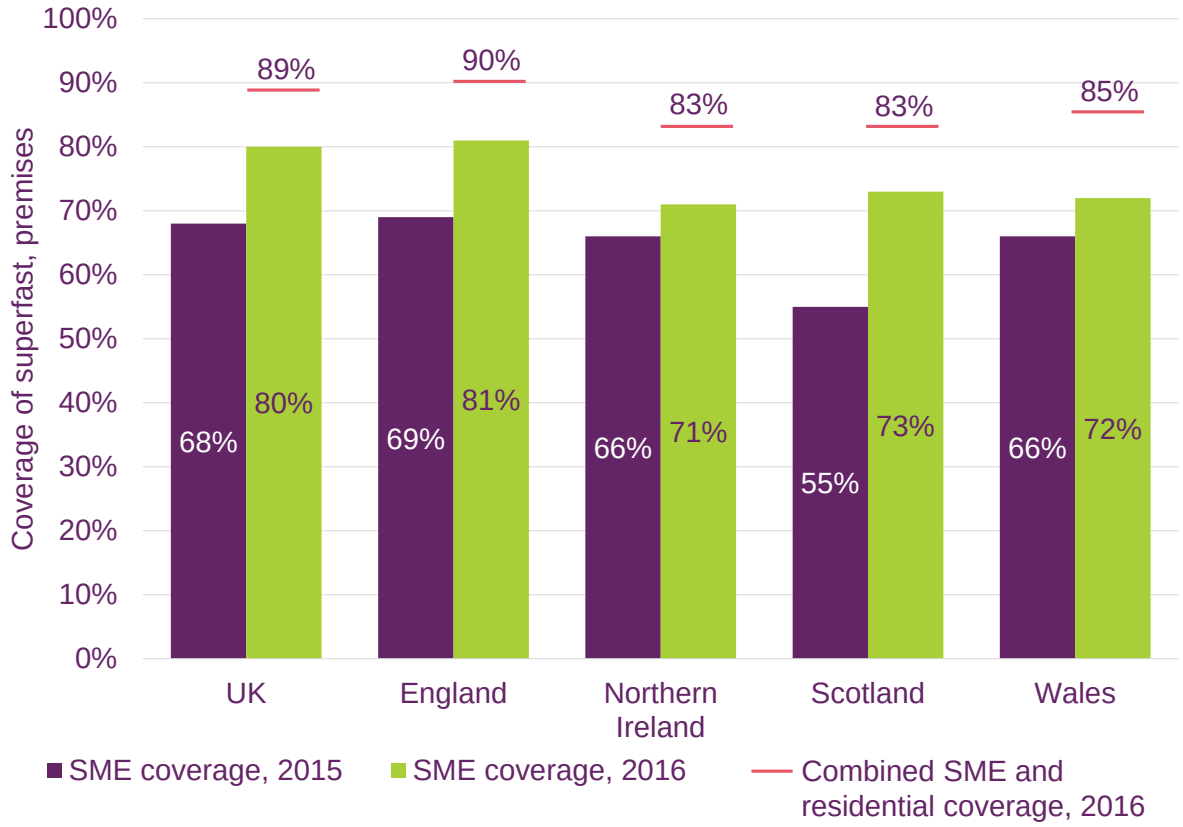
4.34 We have analysed the availability of superfast broadband delivered to 2.4 million SMEs with at least one employee (i.e. not including sole traders)[22]. We have compared coverage of SMEs against the average, split by geography, shown in Figure 10.

[20] Defined as businesses with fewer than 250 employees. In this report we use the terms “SME” and “small business” interchangeably.

[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/559219/bpe_2016_statistical_release.pdf

[22] This year we have used a more detailed dataset that identifies more active SMEs (around 2.4 million) than the dataset we used last year (that identified around 1.3 million). As a result, accurate year-on-year comparisons cannot be made and should be considered an indication of broad changes in coverage.

**Figure 10: Superfast coverage for SMEs has increased but still lags the population as a whole**




*Source: Ofcom analysis of operators' data*

4.35 Superfast coverage for SMEs has increased to around 81% of premises (1.9 million), up from 68% in equivalent analysis last year. Across the UK, SMEs still experience lower coverage of superfast services than the population as a whole. For example, only 82% of SMEs in England have access to superfast services, compared to 90% of all premises in the country. We note, however, that some SMEs may have access to alternative sources of connectivity, such as within *incubator centres*, i.e. shared facilities intended to help SMEs become established.

4.36 SMEs in Northern Ireland, Scotland and Wales experience relatively low levels of superfast coverage, compared to the UK as a whole. This reflects the lower availability of superfast broadband in these areas overall. More generally, many SMEs are based in rural areas or in business parks, areas that to date have not been targeted for network upgrades.

4.37 Overall, around 8% of SMEs (190,000) in the UK are unable to access broadband services with download speeds of 10Mbit/s or higher, compared to around 5% of all premises. Most of these SMEs are in rural areas, where over 130,000 SMEs receive less than 10Mbit/s.

4.38 Operators are continuing to upgrade, or to deploy entirely new, networks and we expect the availability of superfast broadband to further increase for SMEs, and for all consumers more generally. Looking ahead to the coming year, we estimate that additional, planned network deployments will reduce the number of UK SMEs that are unable to receive superfast services from around 20% today to 10% (around 240,000 businesses) by the end of 2017.

Superfast coverage in business parks is lower than in the rest of the country

4.39 We estimate that around 15%, or 340,000, of the 2.4 million SMEs that we have analysed are located within areas, typically business parks that include no residential premises. As the deployment of superfast broadband services has, to date, been driven by demand from residential customers, many of these areas currently have little or no coverage of these services.

4.40 Across the UK a whole, around 67% of SMEs in business parks (230,000) have access to superfast broadband. This compares to 80% of SMEs throughout the country and 89% of the wider population. Coverage in the individual nations' business parks is broadly similar to the UK average, apart from in Northern Ireland, where 83% of SMEs in business parts have access to superfast services.

4.41 Given the lower availability of superfast services in business parks, the actual speeds delivered to SMEs in these areas is lower than in the country as a whole. We estimate that the average speed of broadband connections in business parks is 24Mbit/s, compared to 38Mbit/s for SMEs as a whole.

## Improving the coverage of broadband services for all

4.42 While the coverage and speed of broadband services across the UK have continued to increase, many consumers and small businesses are still unable to get online with acceptable speeds and quality of service. A quarter (25%, or 960,000) of premises in the UK's rural areas cannot get download speeds greater than 10Mbit/s. Even in the UK's towns and cities, where coverage is typically high, there are still some consumers that cannot get fast speeds; almost 1.7 million urban premises cannot receive superfast services and over 410,000 cannot receive download speeds greater than 10Mbit/s.

4.43 We expect the situation to improve over the coming years as operators, both large and small, continue to invest in their networks to both improve the reach and speed of broadband services. There are also a number of ongoing public policy initiatives that are intended to improve superfast broadband availability in areas that may otherwise not be covered by commercial deployments.

4.44 The largest of these programmes is the UK Government's intervention under the Broadband Delivery UK (BDUK) initiative, which aims to deliver download speeds of 24Mbit/s or more to 95% of the UK by the end of 2017. Based on our analysis, we estimate that, as of June 2016, 90% of UK premises (almost 26 million) are covered by broadband services at this speed.

4.45 Even with these current commercial deployments and public policy initiatives, there will still be some UK premises that will lack access to superfast services at the end of 2017. Below we examine a proposal from the UK Government for a broadband Universal Service Obligation (USO), intended to extend the availability of a broadband service to all homes and businesses. We also summarise some recent or emerging technology developments that could improve broadband speeds for all consumers.

## Between 1.4 and 3.5 million premises may fall within the broadband Universal Service Obligation

4.46 Ofcom has been asked[23] by the Department for Culture, Media and Sport to provide technical analysis and recommendations to support the design of the broadband Universal Service Obligation (USO).

4.47 The Government has said that its ambition is for a download speed of 10Mbit/s to be available to all on reasonable request. We have published a detailed report[24] on the USO which examines how the provision of USO could work in practice. It also considers how the specification of the USO could affect both the number of premises that are eligible and the costs that could result in meeting the specification if the Government makes a decision to implement it.

4.48 Currently around 5% of premises cannot receive a download speed of 10Mbit/s, a figure which has come down significantly over time - it was 15% in 2014. While small in percentage terms, it should be remembered that 5% represents around 1.4m premises that are currently unable to receive a download speed of 10Mbit/s. Furthermore, as we showed in Figure 9 on page 19, a far greater proportion of rural premises are unable to receive a speed of 10Mbit/s than urban premises, and Wales, Scotland and Northern Ireland have a greater proportion of premises unable to do so.

4.49 However, the number of premises could rise if, for example, the threshold also took upload speeds and other factors into account. One option would be to extend the specification above to include properties that *can* get a download speed of greater than 10Mbit/s, but have an upload speed of less than 1Mbit/s, as well as other technical measurements that can affect a consumer's broadband experience. In this scenario, we estimate that around 2.6 million premises may fall within the USO's technical specification. If Government were to choose a superfast option (30Mbit/s), we estimate that around 3.5 million premises could be in scope.

## Technology continues to evolve to meet the demand for higher speeds

4.50 The physical characteristics of full fibre networks mean that they are best placed to deliver reliable, ultrafast speeds both now and for the foreseeable future. Other technologies are emerging, however, that could play a complementary role in delivering broadband where full fibre networks are not available. They include:

4.50.1 **G.fast**: Openreach is partnering with Huawei and Nokia to support its planned rollout of this technology to over 10 million homes and businesses across the UK by 2020. The technology has been trialled in two areas of the UK, and a trial extension to more areas has been announced for early 2017[25]. G.fast has the potential to deliver download speeds up to 330Mbit/s over Openreach's existing copper-based network.

4.50.2 **Long range VDSL**: This emerging technology, also currently being trialled, has the potential to deliver superfast speeds over longer distances than can be achieved using current fibre to the cabinet (FTTC) technologies. In theory, download speeds of up to 40Mbit/s and upload speeds of up to

[23] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/53676/dcms_letter.pdf
[24] https://www.ofcom.org.uk/consultations-and-statements/category-1/broadband-uso-cfi
[25] https://www.openreach.co.uk/orpg/home/updates/briefings/ultrafastfibreaccessbriefings/ultrafastfibreaccessbriefingarticles/nga200216.do

10Mbit/s could be delivered using this technology to premises that currently receive much lower speeds due to the distance to their serving VDSL cabinet.

4.50.3 **Next generation cable**: Virgin Media is in the process of upgrading its network and is beginning to offer services with download speeds of 300Mbit/s. Later versions of the technology used could support, in theory, download speeds of up to 10Gbit/s and upload speeds of up to 1Gbit/s[26].

4.51 The above technologies are all related to the evolution of fixed broadband networks. However, wireless networks can also play an important role in delivering broadband services. In London and Swindon, for example, Relish provides a fixed wireless broadband service based on 4G technology that is capable of delivering superfast speeds. The Swindon project is part of a BDUK programme to evaluate "fixed wireless" solutions for superfast and the programme also includes equivalent projects involving Airwave and Quickline elsewhere in the country.

4.52 Satellite broadband is another wireless approach that is currently being used to deliver broadband to some parts of the country that are hard to reach with the above terrestrial technologies. Current satellite broadband services use geostationary satellites (which, like those used for satellite TV, stay at a fixed point in the sky) and can offer near universal coverage. A number of companies operate satellites that are used to provide broadband services to users in the UK including Avanti Communications, Eutelsat and SES. These offer download speeds of up to 20Mbit/s, depending on the satellite and package selected. Services are usually offered to consumers via a service provider rather than directly by the satellite operator.

4.53 The next generation of satellite broadband services are expected to provide superfast speeds and better overall performance than existing geostationary satellite broadband services. These services are likely to be available from 2020.

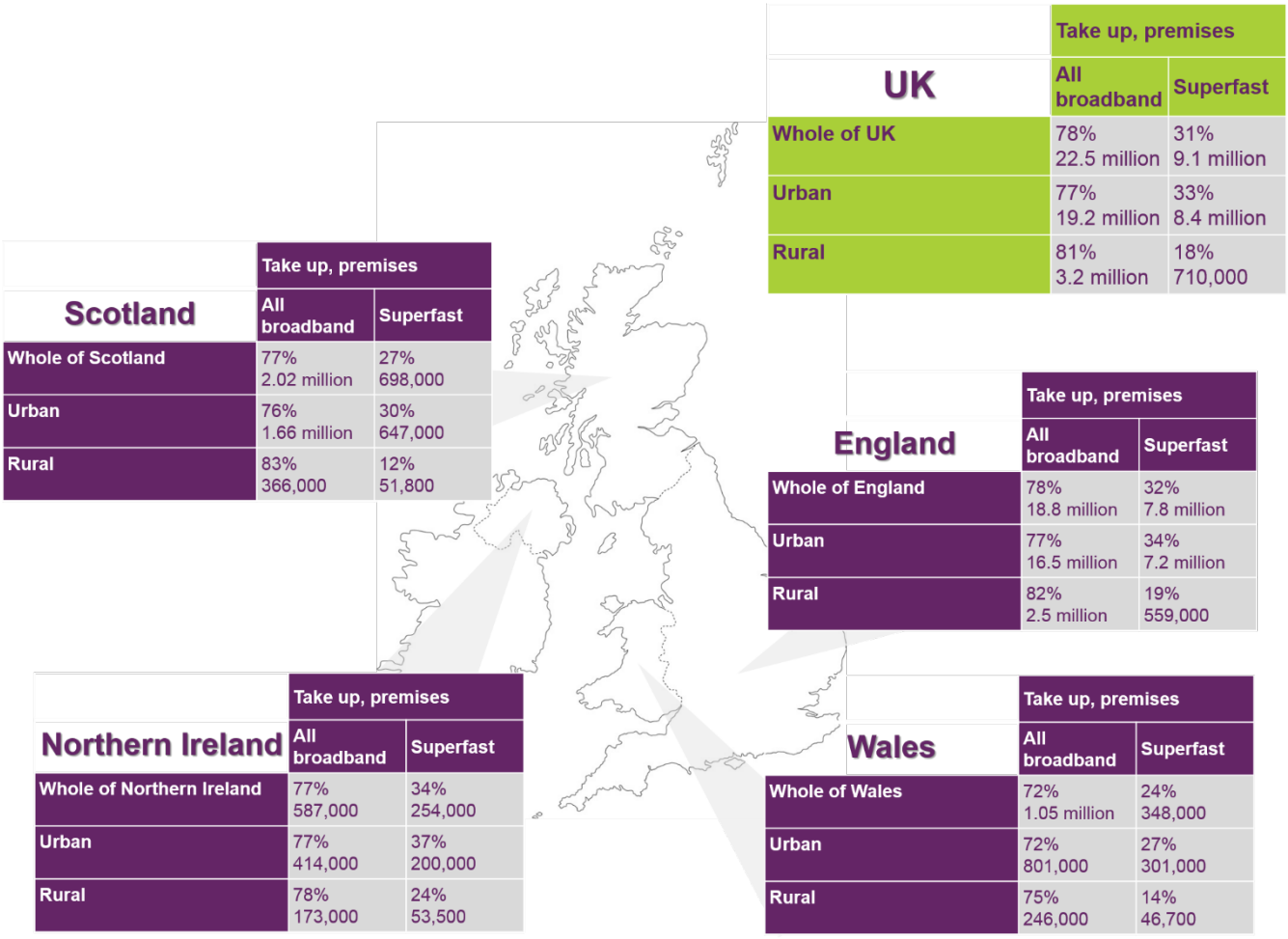
## Increased coverage and take up of superfast services means that consumers are using more data

4.54 In the UK, 31% of premises (9.1 million) now have an active superfast broadband connection. This is an increase from 27% in 2015. Nine out of 10 of these properties are in urban areas, which reflects the higher levels of superfast coverage in towns and cities.

4.55 Around 22% of UK premises (6.5 million) have not taken up any fixed broadband product at all, down slightly from 24% in 2015. Take up of broadband is lowest in Wales where almost 28% of the population have not subscribed to broadband services.

[26] See the commentary on DOCSIS3.1 and other cable futures in http://www.libertyglobal.com/pdf/public-policy/Liberty-Global-Policy-Series-Connectivity-for-the-Gigabit-Society.pdf

**Figure 11: Take-up of broadband services across the UK**



| UK | Take up, premises | |
|---|---|---|
| | All broadband | Superfast |
| Whole of UK | 78%<br>22.5 million | 31%<br>9.1 million |
| Urban | 77%<br>19.2 million | 33%<br>8.4 million |
| Rural | 81%<br>3.2 million | 18%<br>710,000 |

| Scotland | Take up, premises | |
|---|---|---|
| | All broadband | Superfast |
| Whole of Scotland | 77%<br>2.02 million | 27%<br>698,000 |
| Urban | 76%<br>1.66 million | 30%<br>647,000 |
| Rural | 83%<br>366,000 | 12%<br>51,800 |

| England | Take up, premises | |
|---|---|---|
| | All broadband | Superfast |
| Whole of England | 78%<br>18.8 million | 32%<br>7.8 million |
| Urban | 77%<br>16.5 million | 34%<br>7.2 million |
| Rural | 82%<br>2.5 million | 19%<br>559,000 |

| Northern Ireland | Take up, premises | |
|---|---|---|
| | All broadband | Superfast |
| Whole of Northern Ireland | 77%<br>587,000 | 34%<br>254,000 |
| Urban | 77%<br>414,000 | 37%<br>200,000 |
| Rural | 78%<br>173,000 | 24%<br>53,500 |

| Wales | Take up, premises | |
|---|---|---|
| | All broadband | Superfast |
| Whole of Wales | 72%<br>1.05 million | 24%<br>348,000 |
| Urban | 72%<br>801,000 | 27%<br>301,000 |
| Rural | 75%<br>246,000 | 14%<br>46,700 |

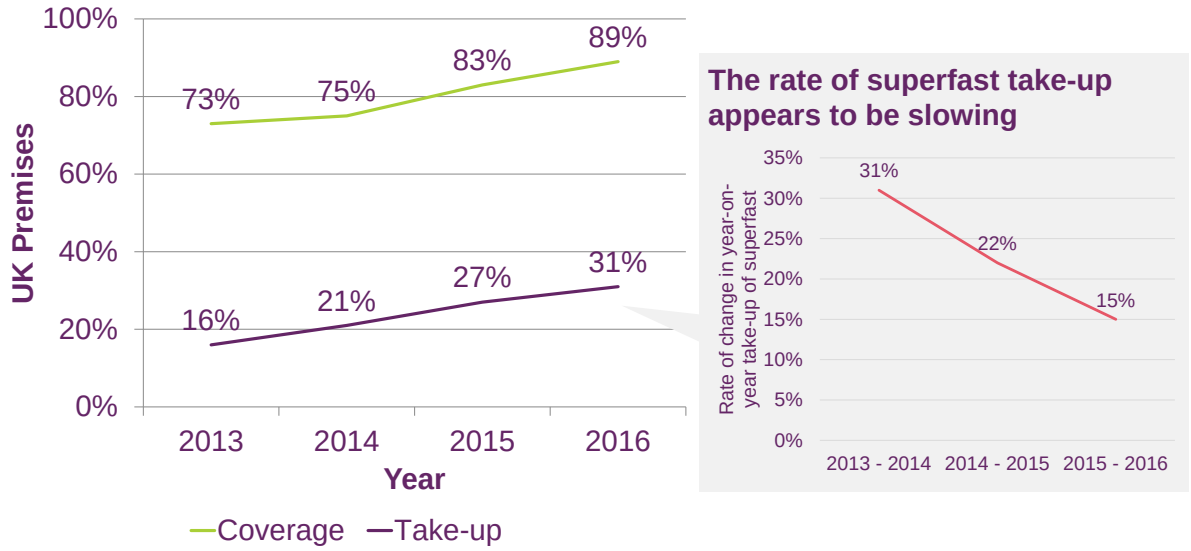
*Source: Ofcom analysis of operators' data*

## Take up of superfast broadband remains lower than availability

4.56 While take up of superfast broadband services has continued to increase, it remains relatively low; 89% of UK premises are able to receive superfast services, but only 31% have active superfast broadband connections.

4.57 Figure 12 shows how coverage and take up of superfast broadband has increased over the past three years. The rate that new subscribers are migrating from basic broadband services and adopting superfast services appears to be slowing, dropping from 31% in the year to 2014, to 15% over the past year.

**Figure 12: Take up of superfast broadband has tracked the increase in coverage, but remains significantly lower**




*Source: Ofcom analysis of operators' data*

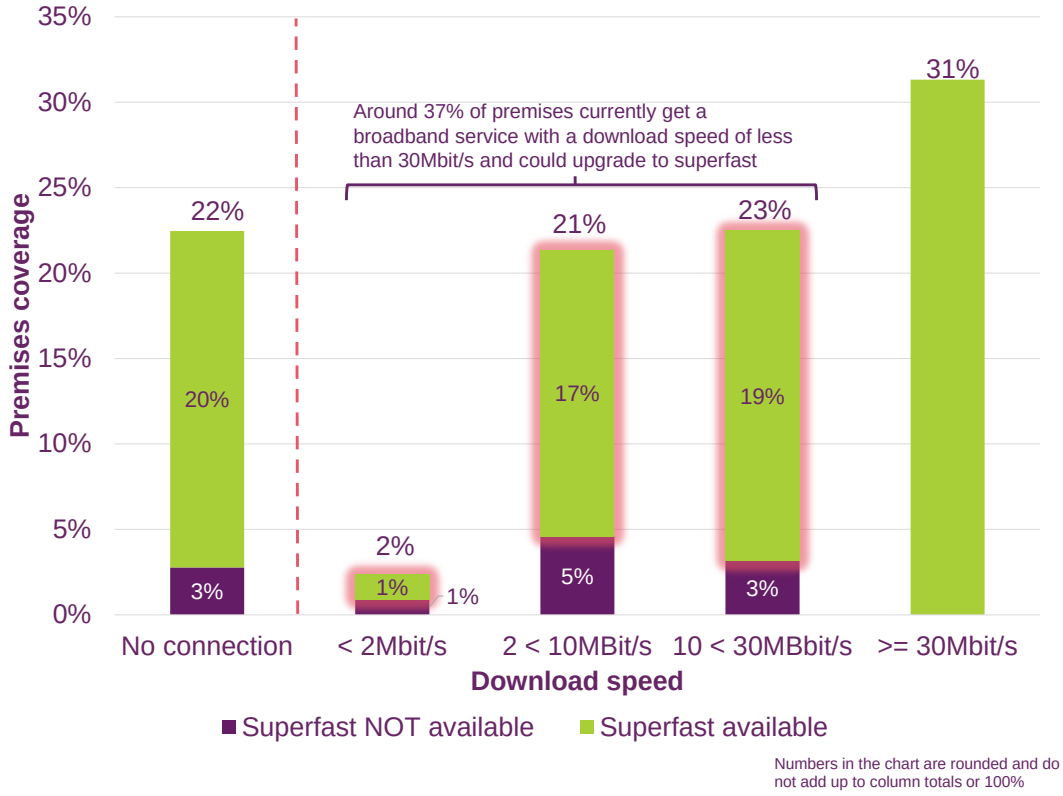
4.58 Some consumers may be unable to take up superfast broadband because these services are not yet available at their property. On the other hand, some consumers with slow broadband could upgrade to superfast, but have not yet done so.

4.59 Figure 13 shows the take up of broadband services grouped by download speed and indicates the extent to which superfast services are available to consumers with those broadband speeds. It shows that around 37% of premises currently get a broadband service with a download speed of less than 30Mbit/s and could upgrade to superfast.

4.60 It is not clear from this data why some consumers are choosing not to take superfast services where they are available and further market research is needed. In order for superfast broadband take up to continue growing at the same rate as it has in the past, providers may need to consider new approaches for attracting customers, including articulating its benefits more clearly and lowering prices further.

4.61 Just less than 0.1% of UK premises (27,000) have taken up a service offering download speeds of 300Mbit/s or more. This relatively low level of take up is understandable, given current low levels of coverage. However, take up has increased significantly since 2015, when we reported that just 0.003% of UK premises had subscribed to these services.

**Figure 13: Over three quarters of premises with standard broadband could get superfast broadband**




*Source: Ofcom analysis of operators' data*

## The average download speed of active connections has increased, but upload speeds have remained static

4.62 The growth in take up of superfast broadband has led to an increase in average speeds across the UK. The average download speed of all active connections in the UK is now 37Mbit/s, an increase of 28% from 29Mbit/s in 2015. Speeds are lower in rural areas, where there is a lower availability of superfast services. The average download speed in the UK's rural areas is just 21Mbit/s, although this still represents an increase on the speed last year, which was 13Mbit/s.

4.63 Download speeds have also risen for those consumers that subscribe to superfast services. The average download speed of superfast services in the UK is now 74Mbit/s, up from 65Mbit/s in 2015. We do not yet have sufficient data to estimate the average speeds of ultrafast or full fibre services, but will explore ways to calculate this in future reports.

4.64 While download speeds have increased, upload speeds have remained static. This may restrict the quality of experience for some popular online services that require good upload, as well as download, speeds, such as social media sites and cloud backup services. The average upload speed of all broadband services has increased

by just 7% to 4Mbit/s over the past year, while the average upload speed of superfast services has remained the same at 8Mbit/s.[27]

4.65 The average download speed of 37Mbit/s reflects both the speeds available to consumers and their choice of package; if consumers were to choose faster packages, the average speed would rise. We estimate that the average download speed would rise to around 132Mbit/s if all consumers subscribed to the fastest available broadband service at their property.

## Faster broadband speeds lead to more data being consumed

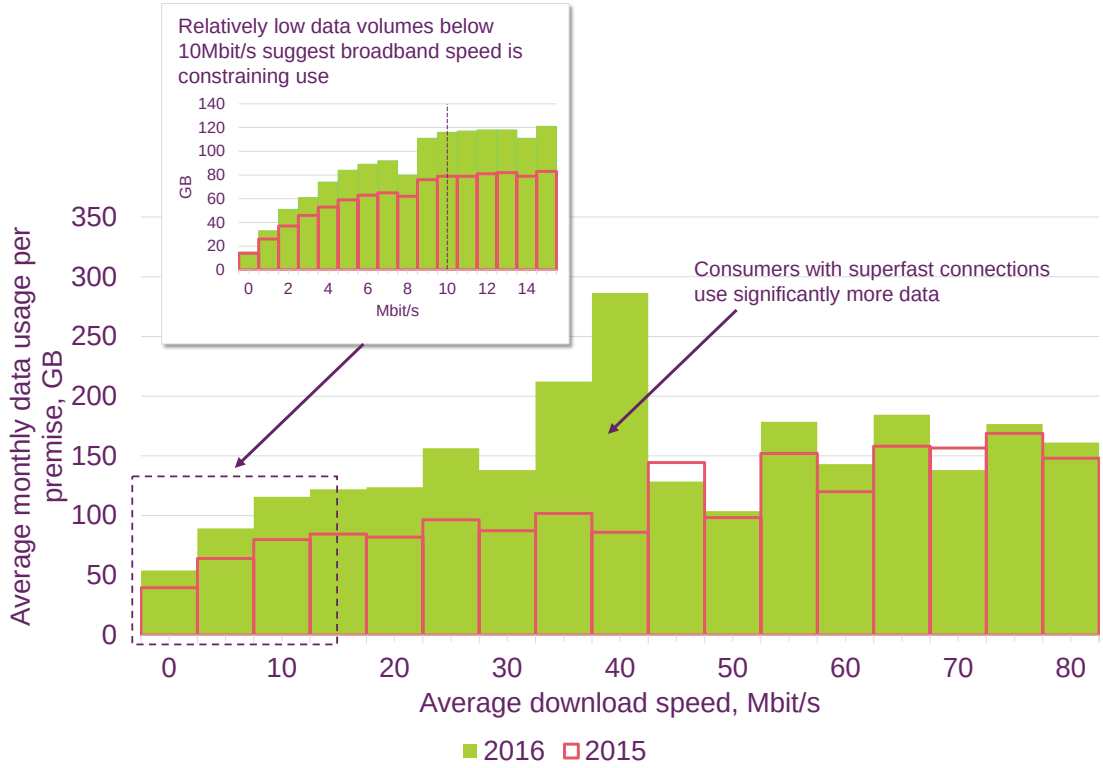
4.66 Consumers who take up superfast broadband will find that the faster download and upload speeds will enable them to use a much wider range of multimedia applications than they could with slower connections. They include:

4.66.1 Online video services, such as You Tube, iPlayer and Netflix. These services offer video for download or streaming in standard, high and, increasingly, ultra-high definition formats;

4.66.2 Video calling services, such as Skype or Apple's FaceTime; and

4.66.3 Cloud-based services for back-up of data or sharing content with friends or colleagues.

**Figure 14: Users with faster broadband connections tend to use more data**




*Source: Ofcom analysis of operator data*

[27] This asymmetry of download and upload is a feature of both DSL and DOCSIS technology implementations currently. The degree of asymmetry can be reduced but this is normally at the expense of reducing download speeds. Future technologies may suffer less from this problem.

4.67 On average UK households consumed 132GB of data per month over the past year, up from 97GB in 2015. Figure 14 shows that, on average, more data per household is being consumed for all broadband speeds. As in previous years, there is evidence that households with higher speed connections are consuming significantly more data, especially those with superfast speeds.

4.68 Users with broadband speeds of around 40Mbit/s appear to be consuming very high volumes of data. We believe that this is evidence of an increase in the consumption of online video. Services such as the BBC's iPlayer, Sky's Now TV and Netflix are increasingly popular and are integrated into smart TVs and set-top boxes. Consumers are often unaware that content they access via these services is delivered over their broadband connection as they are intended to deliver a seamless viewing experience.

4.69 In addition, many video services are also available on smartphones and tablets. This means that content could be streamed to multiple devices within a home simultaneously, adding to the overall volume of data consumed.

4.70 We might also expect the impact of video on demand services to be reflected in higher average data volumes for broadband connections faster than 40Mbit/s. This is not apparent from Figure 14. In the case of Virgin Media's customers, many of whom are on a package with a download speed of 50Mbit/s or higher, this could be explained by some on demand video services being delivered over the cable TV connection, rather than the broadband connection.

4.71 Figure 14 also shows that the average usage per household drops notably for connections with speed less than 10Mbit/s. This may be evidence that users would use more data if their connections were faster.

## Measuring the broadband speeds consumers actually receive

4.72 One of the most commonly used ways to describe the performance of broadband connections is speed and, in particular, download speed. However, there are a number of ways to express broadband speed, as shown in Figure 15:

4.72.1 **Headline speed** is the speed at which a particular broadband service is the maximum speed available by at least 10% of the customer base. It is normally preceded by the words "up to".

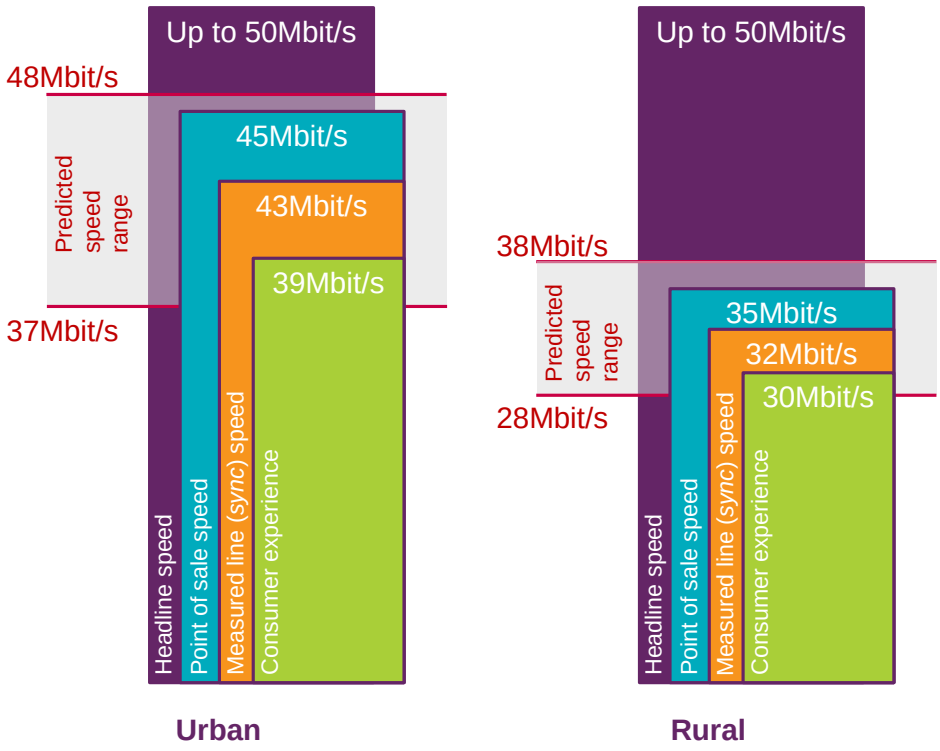
4.72.2 **Point of sale speed** is the estimated speed that a customer is quoted before they purchase the broadband service for the first time. Signatories of the Broadband speeds Code of Practice undertake to give this estimated speed, normally in the form of a range, although it can also sometimes be a point estimate. Specifically, this constitutes an estimate of the max speed a customer will be able to experience on his or her individual line. The speed is based on a technical assessment of factors such as the length of the line to the customer's property, which could affect the performance of the line. As a result, the point of sale speed is often lower than the headline speed

4.72.3 **Measured line, or sync, speed** is the maximum rate at which the line connecting the customer's property to the street cabinet or exchange can operate. In many cases, ISPs are able to measure this speed and this data is provided to us as part of preparing this report. Sync speeds can be lower than the point of sale speeds as a result of local technical factors, such as

interference on the line, which are difficult to predict when calculating the point of sale speed; and

4.72.4 **Consumer experience speed** is the measured speed that the consumer actually experiences during the course of using the broadband service. This is measured through a panel based methodology using SamKnows "Whiteboxes" that are connected to panellists' routers. This does not include any Wi-Fi measurements, and indicates the speeds that may be experienced if a consumer was to connect their device to the router with an Ethernet cable. The consumer experience speed is likely to be lower than the sync speed because it is an end-to-end measure of performance, i.e. it also takes into account the speed of the ISPs backhaul and core network.

**Figure 15: Illustration of different ways to express broadband speed**




Speeds are illustrative only and are not based on actual measurements

*Source: Ofcom*

4.73 Consumers may receive slower speeds than they expect, because of the factors described above. In addition, the difference between headline and consumer experience speeds may be greater in rural areas than in urban areas because factors such as longer line lengths.

## Investigating broadband performance using physical measurement units

4.74 Each year we publish a report on the performance of residential fixed broadband services[28] as part of our work to monitor the UK communications industry. The objective of this research is to provide better information about the *actual performance* (i.e. the measure of consumer experience described above) of UK

[28] https://www.ofcom.org.uk/research-and-data/broadband-research/home-broadband-performance

residential fixed broadband connections to inform Ofcom's policy making and help consumers make better-informed purchasing decisions.

4.75 This section of the Connected Nations report uses data collected by our research partner, SamKnows Limited (SK), in September, from a panel of volunteers. The panel is selected to be representative in terms of a number of factors, including geographic location, broadband connection technology, internet service provider (ISP) and broadband package.

4.76 Volunteers are required to connect a hardware measurement unit (a “whitebox”) to their broadband router. These units run tests that measure various metrics that help determine the user experience of various online activities. The software is configured to identify other network activity and not to run tests when such activity was detected. This avoids compromising results by running tests at a time when bandwidth was being used by other internet-connected devices in the household (including those using a Wi-Fi connection).

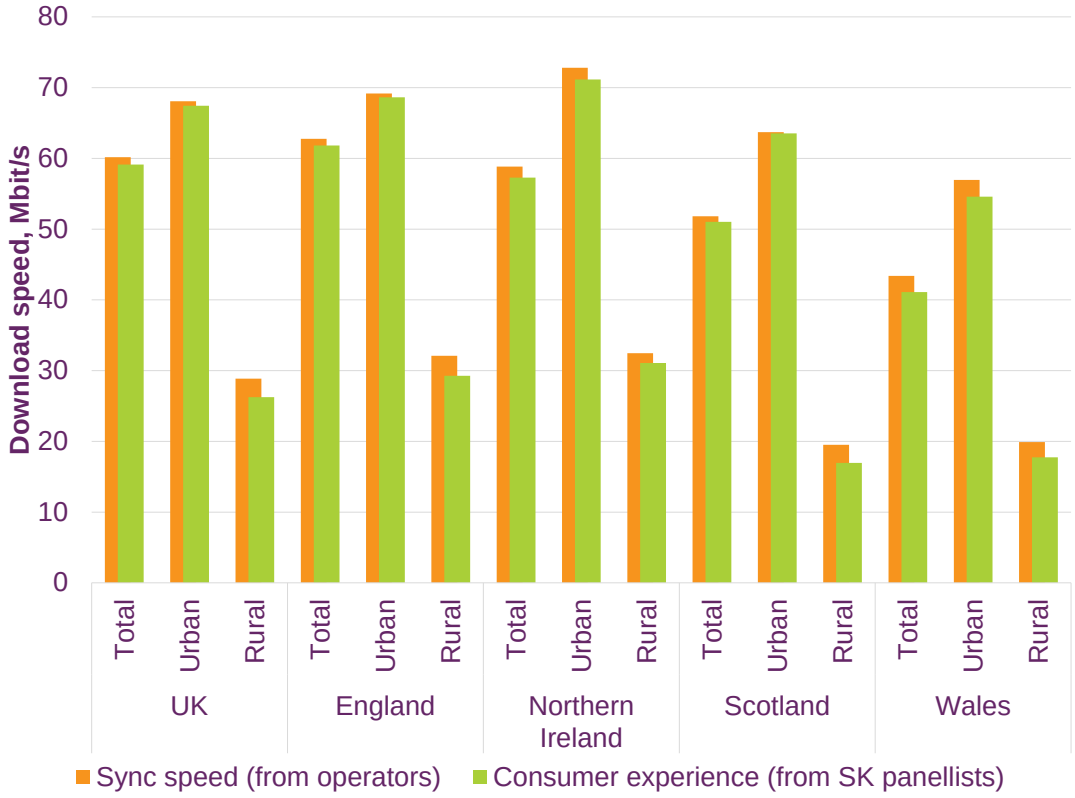
4.77 We carried out analysis to match the sync speed data collected from fixed network operators for the purposes of preparing this report, to the data collected from SK panellists across the month of September 2016. This matching process has allowed us to compare the two data sets across download and upload speed metrics.

4.78 We would not expect the results of the two data sets to match exactly, given the differing timescales of the data and that one data set contains sync speed data and the other consumer experience data. However, comparing the values will highlight the extent of any systemic difference between sync and consumer experience speeds, and whether this difference varies between urban and rural properties.

4.79 Figure 16 shows a comparison of the download speeds of each data set, split by nation and rurality. As we illustrated in Figure 15, when comparing consumer experience speeds to sync speeds there is some disparity between the two measures. Across all panellists, measured consumer experience speeds were around 2% lower than the sync speeds, rising to a 5% difference for those panellists in Wales.

4.80 This disparity is more pronounced in rural areas, which could suggest that speeds in these areas are lower than they could be under ideal conditions due to the amount of available backhaul, impeding optimal performance. For example, consumer experience speeds for panellists in the UK’s urban areas were just 1% lower than sync speeds; whereas, in rural areas, the difference was 9%. For panellists in the rural areas Wales and Scotland the difference was greater, 11% and 13% respectively.

**Figure 16: Comparison of sync and average consumer experience speeds, for only those premises with a SK measurement unit**




*Source: Ofcom analysis of operator data / SamKnows*

4.81 We are aiming to continue analysis between these joined data sets and will endeavour to include further analysis in the UK home broadband performance report planed for publication in H1 2017.

Section 5

# Mobile voice and data services

5.1 Mobile services are playing an increasingly important role in our daily lives. This means consumers increasingly expect their mobile devices to work reliably wherever they are, whether at home, at work, or on the move. In this section we provide an update on the levels of mobile voice and data coverage achieved in different parts of the UK as of June 2016, and the total amount of mobile data being consumed. We also discuss the minimum levels of mobile signal needed to make a good quality voice call and how these relate to the mobile operators' geographic coverage targets for voice call services.

5.2 The key highlights are:

5.2.1 **4G roll-out:** All four operators are in the middle of a major 4G rollout programme, which provides in some locations similar connection speeds to those of fixed networks. To date the rollout of 4G services has primarily focussed on providing higher speed services to users in cities and towns. As they are rolled out more widely, it is likely that 4G landmass coverage will continue to increase to at least match the coverage of earlier generation 2G and 3G services. Some operators have also enabled voice calling on their 4G networks, which together with voice over Wi-Fi, are helping to increase the number of places where consumers can make and receive voice calls.

5.2.2 **Mobile data growth:** In the past year, mobile data consumption per subscriber has grown at a rate of 49%. Although still growing, this is less than last year's growth rate of 64%. It is almost identical to the data growth rate on fixed networks. The volume of data carried over mobile networks remains a small proportion (around 4%) of data carried over all networks.

5.2.3 **More needs to be done to extend mobile coverage to all of the locations consumers want to use their mobile devices**. There are two main reasons why additional steps are likely to be needed to meet future consumer expectations on mobile coverage.

5.2.4 Firstly, the additional coverage improvements resulting from commercial investments by mobile operators in new network infrastructure will reach a plateau.

5.2.5 Secondly, the existing geographic voice call coverage targets in licences, requiring 90% landmass coverage by the end of 2017, are based on lower mobile signal levels than those we have found to be necessary from our field testing work to deliver a good consumer experience. This means that when these targets are met, good geographic landmass coverage is likely to be below 90%.

## Our assessment of coverage is representative of how consumers use their mobiles

5.3 In this report, we provide mobile coverage numbers based on the mobile signal levels we have found to be necessary to provide a good consumer mobile experience.

These relate to the areas shown in green on our interactive maps[28]. We also show on these maps areas in amber and red where a mobile signal is available but is likely to provide a less reliable consumer experience.

5.4 In previous years, we have reported on mobile coverage in terms of the number of premises where a signal can be received outdoors. We will continue to report on outdoor coverage in this way but, from this year, our focus will be on reporting on mobile coverage in a way that we believe better reflects how and where consumers use their mobile phones – both indoors and outdoors.

5.5 For **indoor coverage**, we will report on the percentage of premises where a good mobile signal is likely to be available indoors. This metric is useful to describe the coverage that a consumer will experience when using their phone at home, at work or in a shop. It is more challenging to deliver reliable mobile coverage indoors than outdoors, as walls, buildings and doors reduce the strength of, or even block, mobile signals as they pass through.

5.6 We will report on **outdoor coverage** in three ways:

5.6.1 **Geographic coverage**, which represents the percentage of landmass where good coverage is likely to be available. This metric is useful to describe the coverage that a consumer will experience when using their phone outside or on the move between outdoor locations;

5.6.2 **Coverage on the transport network**, which focuses this year on roads. This metric represents the percentage of distance covered by the road network where a good mobile signal is likely to be available inside the car. This metric is useful to describe the coverage that a consumer will experience when using their phone while travelling in a vehicle and not using a car kit with an external antenna. Next year we also aim to report on coverage on the rail network;

5.6.3 **Outdoor premises coverage**, which represents the percentage of premises where a good mobile signal is likely to be available outdoors. This metric is still commonly used by operators and we will continue to report on coverage in this way to aid comparisons.

5.7 The levels of mobile coverage in this report are based on data supplied by the operators which has been scaled to indicate where a good consumer experience is likely to be available. This scaling is based on our own field testing of the minimum mobile signal levels needed for a good consumer experience. These signal levels are generally higher than those used in existing mobile operator licence obligations and, as a result, levels of coverage shown in this report are generally lower than the target coverage levels set out in these obligations.

5.8 While our use of these metrics make it more difficult to compare our coverage figures with those from other sources, we believe that using these metrics is important for two reasons:

5.8.1 **They offer a more realistic view of current coverage levels.** Figures for coverage expressed in terms of outdoor premises tend to be higher than those for indoor or geographic coverage. Presenting information in terms of

[28] http://maps.ofcom.org.uk/check-coverage

outdoor premises can be potentially misleading for consumers, who may feel that their actual experience of coverage does not correspond to the relatively high coverage figures presented. Additionally, and as mentioned above, expressing coverage in terms of outdoor premises does not reflect the locations where the majority of consumers use their phones most; and

5.8.2 **They provide an important baseline against which future improvements in coverage can be measured.** Several current public policy initiatives are targeting improvements in coverage by requiring operators to achieve agreed levels of indoor and geographic coverage by certain dates. By reporting on mobile coverage in terms of geographic and indoor coverage, it is easier to identify the progress being made towards meeting these coverage targets. In addition, the use of Ofcom's scaling of the mobile coverage data provided by operators to show where good reliable coverage is available provides a useful benchmark for the actual improvements being delivered by these initiatives, and the improvements any new coverage improvement initiatives should be aiming to achieve.

5.9 In the remainder of this section, we summarise the levels of coverage from all operators for both mobile voice and data networks, i.e. we consider an area or property to be in coverage if a mobile signal can be received from all operators. In addition, we highlight the coverage of 4G networks, given operators' ongoing focus on deploying these networks.

5.10 In order to facilitate year on year comparison, we are using data collected in June 2016 to calculate coverage. We note that since this data was collected, further network deployment is likely to mean that coverage levels have continued to increase. Our coverage checking tools[29] use the most up-to-date mobile coverage data.

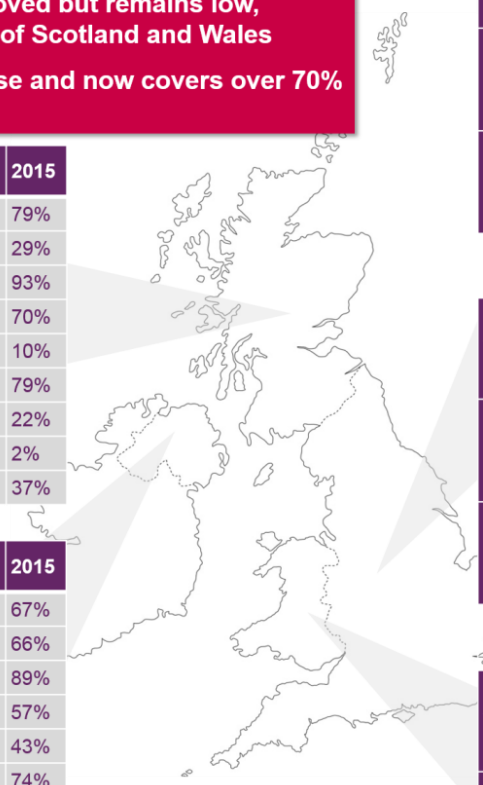
## Status of mobile coverage across the UK and in the nations

5.11 Figure 17 summarises the mobile coverage available in the UK and constituent nations from all operators, for voice, data and 4G networks.

[29] https://checker.ofcom.org.uk

## Figure 17: Summary of mobile coverage from all UK operators

- **Consumers can use their phones for voice calls inside almost 90% of UK premises and data services inside around 80% of UK premises**
- **Outdoor coverage has improved but remains low, especially in the rural areas of Scotland and Wales**
- **4G coverage continues to rise and now covers over 70% of UK premises indoors**



| Scotland | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 84% | 79% |
| | Outdoor geographic area | 36% | 29% |
| | Outdoor premises | 95% | 93% |
| Data | Indoor premises | 75% | 70% |
| | Outdoor geographic area | 21% | 10% |
| | Outdoor premises | 87% | 79% |
| 4G | Indoor premises | 62% | 22% |
| | Outdoor geographic area | 12% | 2% |
| | Outdoor premises | 76% | 37% |

| Northern Ireland | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 80% | 67% |
| | Outdoor geographic area | 81% | 66% |
| | Outdoor premises | 95% | 89% |
| Data | Indoor premises | 70% | 57% |
| | Outdoor geographic area | 71% | 43% |
| | Outdoor premises | 90% | 74% |
| 4G | Indoor premises | 64% | 37% |
| | Outdoor geographic area | 60% | 17% |
| | Outdoor premises | 86% | 46% |

| UK | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 89% | 85% |
| | Outdoor geographic area | 66% | 58% |
| | Outdoor premises | 97% | 96% |
| Data | Indoor premises | 80% | 77% |
| | Outdoor geographic area | 52% | 38% |
| | Outdoor premises | 93% | 88% |
| 4G | Indoor premises | 72% | 28% |
| | Outdoor geographic area | 40% | 8% |
| | Outdoor premises | 86% | 46% |

| England | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 91% | 87% |
| | Outdoor geographic area | 84% | 77% |
| | Outdoor premises | 98% | 97% |
| Data | Indoor premises | 82% | 81% |
| | Outdoor geographic area | 72% | 57% |
| | Outdoor premises | 95% | 91% |
| 4G | Indoor premises | 76% | 31% |
| | Outdoor geographic area | 60% | 11% |
| | Outdoor premises | 90% | 50% |

| Wales | | 2016 | 2015 |
|---|---|---|---|
| Voice | Indoor premises | 73% | 65% |
| | Outdoor geographic area | 52% | 46% |
| | Outdoor premises | 90% | 88% |
| Data | Indoor premises | 57% | 47% |
| | Outdoor geographic area | 27% | 17% |
| | Outdoor premises | 76% | 67% |
| 4G | Indoor premises | 34% | 10% |
| | Outdoor geographic area | 13% | 2% |
| | Outdoor premises | 53% | 20% |

Coverage is for all operators, i.e. the percentage of premises or geographic area where there is likely to be a signal from all operators. Coverage levels for individual operators may be higher.

*Source: Ofcom analysis of operator data*

**Mobile delivery technologies**

There are currently three generations of technology used to deliver mobile services to consumers in the UK.

**2G** was the first digital mobile technology, launched in the UK in 1992. It is used to deliver voice, text services and low-speed data services. 2G services are delivered by $O_2$, Vodafone and EE.

**3G** is a later generation of digital mobile technology, launched in 2003, and provides typical download speeds of over 5Mbit/s. 3G supports voice, text and data services, and services are operated by $O_2$, Vodafone, EE and Three.

**4G** is the latest generation of mobile technology, launched in 2012, and provides typical download speeds of over 10Mbit/s, with some services able to deliver significantly higher. These services are operated by $O_2$, Vodafone, EE and Three. There has been a significant roll-out of additional 4G services by all operators over

the past year. Three and EE have also upgraded their 4G networks to support voice services. Other operators may introduce similar services over the coming months.

When we report on mobile coverage, we often focus on the services offered by networks, rather than the technologies themselves. This is because the latest generation of mobile phones support all of these technologies and if, for example, a 3G network is unavailable, the phone will automatically switch to a 2G network to make the call. We therefore report on voice and data services.

The coverage of **voice services** is determined by the combined coverage of 2G and 3G networks, plus the 4G voice networks operated by EE and Three. The coverage of **data networks** is determined by the combined coverage of 3G and 4G networks.

5.12 The coverage of voice services has increased over the past 12 months, with 66% of the UK's geographic landmass having coverage from all operators, up from 58% in 2015. Indoors, voice services from all operators are now available within 89% of the UK's premises, up from 85% in 2015. The increase in voice coverage has been driven by both increases in 3G coverage and the deployment of 4G voice services.

5.13 The coverage of mobile data networks has also improved, but remains lower than voice coverage. 52% of the UK's geographic landmass has mobile data coverage from all operators, up from 38% in 2015. Around 82% of UK premises can receive a mobile data network signal from all operators indoors, up from 77% in 2015.

5.14 Geographic coverage of both voice and data networks is lower in Scotland and Wales than other parts of the UK. This is because a greater proportion of their landmass is rural, and mobile coverage is more difficult to provide in these areas than urban areas on a commercial basis due to their lower population density.

5.15 Operators are continuing to increase the coverage of their 4G networks. All operators now provide some 4G coverage to the UK's major cities and coverage is beginning to reach into smaller towns and some rural areas. Around 40% of the UK's landmass is now covered by a 4G signal from all operators, up from just 8% a year ago. In-building 4G coverage has also increased significantly; 72% of UK premises can now receive a 4G service from all operators indoors, compared to just 28% in 2015.

5.16 4G coverage has increased the most in Wales and Scotland, with both countries experiencing a six-fold increase in geographic coverage. However, overall coverage levels are still low, with only 12% and 13% of landmass in Scotland and Wales respectively covered by 4G networks from all operators.

5.17 The information on coverage levels in this chapter is based the mobile signal strength data provided to us by all mobile operators in June 2016. Operators are continuing to upgrade their networks and deploy new base stations. It is therefore possible that coverage levels may have increased since this data was collected. For example, we note that in November EE switched on 700 4G sites[30] which use spectrum at 800MHz. This spectrum is particularly well suited to providing coverage over wide areas and deep into buildings. These and other recent improvements will be reflected

[30] http://newsroom.ee.co.uk/ee-calls-on-industry-to-get-clear-on-coverage-as-it-covers-5000-square-kilometres-of-4g-not-spots-overnight/

in the next report. In addition, our online coverage checker[31] uses the most up-to-date information provided by operators.

5.18 We explore the coverage of mobile voice and data networks in more detail below.

**Some 4G networks have been upgraded to support voice calls**

Until recently, the 4G networks deployed in the UK only supported high speed data services; in order to make or receive a voice call, a mobile phone connected to a 4G network needed to automatically switch to a 2G or 3G network, switching back to the 4G network once the call is complete.

However, in the past year EE and Three have upgraded their 4G networks to support voice calls, using a technology known as 4G Voice or VoLTE. Combined with the ability, supported by all operators, to make voice calls over Wi-Fi, this development means that consumers should be able to make and receive phone calls in more places than before.

In calculating voice coverage, we include data from the 2G and 3G networks of all operators, plus the 4G networks of EE and Three. We understand that Vodafone and $O_2$ are undertaking trials of 4G Voice and could include their networks in the future.

## Coverage of mobile voice services

5.19 Operators mostly use their 2G and 3G networks to provide voice services. EE and Three have upgraded their 4G networks to also support voice services and an increasing number of handsets are compatible with this new technology. Figure 18 shows the coverage of mobile voice services for each operator in the UK.

**Figure 18: UK coverage for each operator's mobile voice services**

| | $O_2$ (2G, 3G) | Vodafone (2G, 3G) | EE (2G, 3G, 4G) | Three (3G, 4G) |
|---|---|---|---|---|
| **Indoor, premises** | 96% | 95% | 96% | 95% |
| **Outdoor geographic, landmass** | 78% | 82% | 80% | 76% |
| **Outdoor, premises** | 99% | 99% | 99% | 99% |

*Source: Ofcom analysis of operator data*

5.20 In the case of EE and Three, the activation of 4G voice services on their networks has helped improve voice coverage[32], but for slightly different reasons. EE's 4G network is the most mature amongst the operators in the UK and enabling 4G voice on this network offers their customers an additional means to make and receive calls. EE provides an indoor mobile voice service to 96% of UK premises, but this falls to 94% of premises if their 4G coverage is disregarded and only their 2G and 3G networks' coverage is included.

[31] https://checker.ofcom.org.uk

[32] We are currently undertaking further field testing work to more firmly establish the minimum 4G signal level needed to provide reliable 4G voice call coverage.

5.21 For Three, the benefit is mainly derived from their use of lower frequency spectrum at 800MHz for some parts of their 4G network. The characteristics of this frequency band make it good at covering wide areas and, in particular, penetrating deep into buildings. Three's use of their 4G network takes their geographic voice coverage to 76% of UK landmass, as opposed to 70% of landmass if they only used their 3G network. The difference is even more pronounced with indoor coverage, with 95% of UK premises covered if 4G is included, compared to just 86% of premises if only their 3G network is used to deliver voice.

5.22 We can expect some further improvement mobile voice call coverage with the further deployment of voice-enabled 4G networks by all operators, in particular those operating in the 800MHz spectrum band.

## Coverage of mobile data services

5.23 Operators mostly use their 3G and 4G networks to provide higher-speed mobile data services to their customers; 2G networks are only capable of supporting lower-speed data connections and we exclude them from this assessment of coverage. Figure 19 shows the coverage of mobile data services for each operator in the UK.

**Figure 19: UK coverage for each operators' mobile data services, based on combined 3G and 4G coverage**

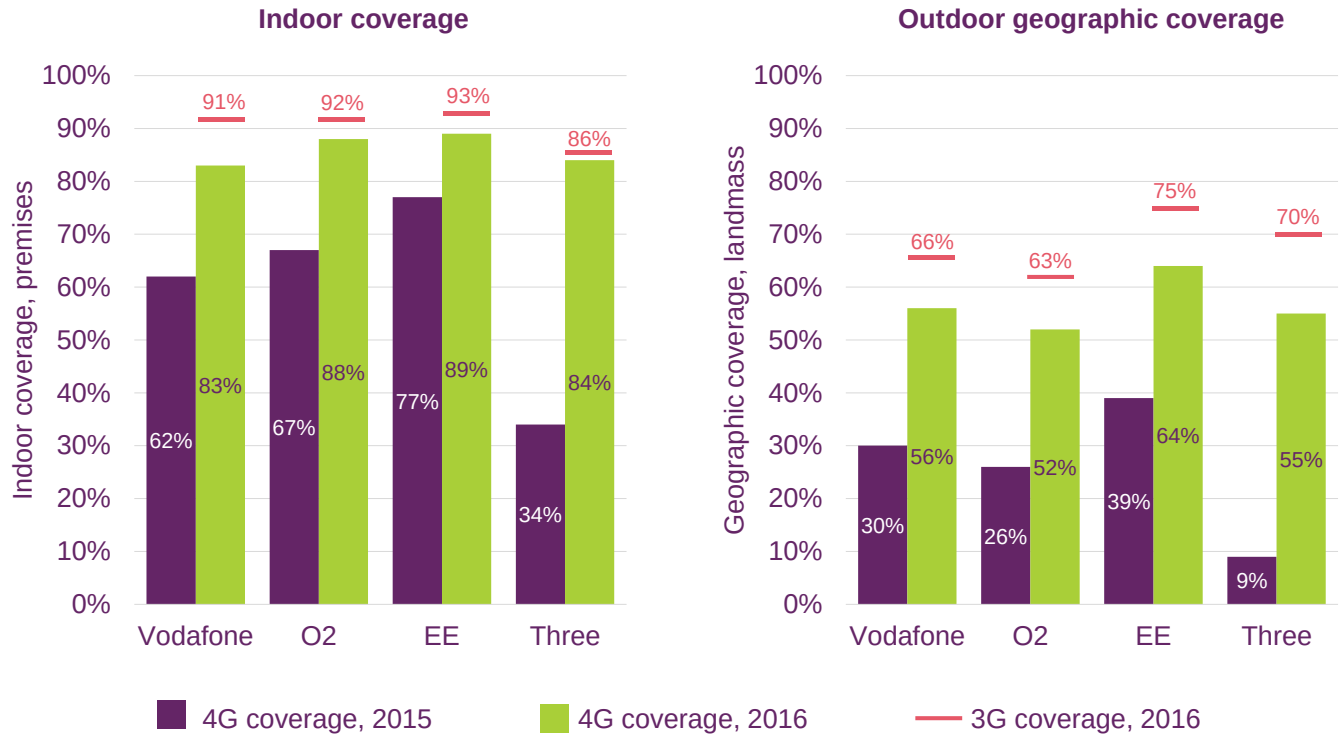
| | $O_2$ | Vodafone | EE | Three |
|---|---|---|---|---|
| **Indoor, premises** | 92% | 92% | 95% | 87% |
| **Outdoor geographic, landmass** | 63% | 66% | 76% | 70% |
| **Outdoor, premises** | 96% | 97% | 99% | 97% |

*Source: Ofcom analysis of operator data*

5.24 3G networks have been deployed in the UK since 2003 and their levels of coverage are relatively high, compared to more recently deployed 4G networks. The coverage of mobile data services is, therefore, largely determined by the level of 3G coverage. However, this will change as operators continue their 4G network deployment, especially where those networks make use of spectrum at 800MHz, which is better suited to covering large areas and reaching deep into buildings.

5.25 Coverage of 4G services has increased significantly over the past year as all operators continue to roll out these networks. Each operator now provides indoor coverage to over 80% of the UK's premises, offering levels of coverage similar to their more mature 3G networks. Geographic coverage is lower, with operators' 4G networks covering between a half and two thirds of the UK's landmass.

**Figure 20: Coverage of 4G networks has increased over the past year**




*Source: Ofcom analysis of operator data*

## Coverage of mobile services on the transportation network

5.26 Consumers spend a significant amount of time travelling on the roads or on trains and frequently experience poor coverage. This may be because these roads or railway lines pass through rural areas, tunnels or cuttings, where mobile signals are weak or totally blocked. In urban areas, the problem could be because too many people are trying to use the network at the same time.

5.27 Being able to communicate on the move is important to consumers. Yet providing reliable coverage across the transportation network can be challenging. This year, as in previous years, we report on the coverage of mobile networks across the UK's road network. We have also undertaken some research to understand levels of mobile coverage on key train routes.

### Mobile coverage on roads

5.28 Good mobile coverage is important for road users. For workers on the move it provides a vital means to stay in contact with colleagues and customers; it allows drivers or pedestrians to call for help in an emergency; and, increasingly, it will connect vehicles and roadside sensors as part of the emerging Internet of Things.

5.29 As Figure 21 shows, coverage on A and B roads reflects levels of geographic coverage and is relatively low. Just 62% of the UK's network of A and B roads is covered by a voice service from all operators. Data coverage is even lower, at just 45% of the A and B road network. Coverage is worst in Scotland and Wales, which reflects the relatively low levels of geographic coverage in these countries. Voice calls are only possible on around 40% of Scotland and Wales' network of A and B roads.

5.30 Coverage on motorways is better, as these major roads are often targeted by operators at an early stage of network deployment. 97% of the UK's motorway network is covered by voice services from all operators, with motorways in the nations similarly well covered for voice. Data coverage on motorways is lower, but still significantly better than A and B roads; 83% of the UK's motorway network is covered by a data service from all operators.

**Figure 21: Mobile coverage on many roads is poor**

| | A and B roads, % road network | | Motorways, % road network | |
|---|---|---|---|---|
| | Voice coverage | Data coverage | Voice coverage | Data coverage |
| UK | 62% | 45% | 97% | 83% |
| England | 72% | 55% | 97% | 85% |
| Northern Ireland | 59% | 43% | 92% | 74% |
| Scotland | 39% | 25% | 95% | 75% |
| Wales | 40% | 22% | 97% | 89% |

*Source: Ofcom analysis of operator data*
*Note: For in-car coverage, we assume that the mobile phone is used within the vehicle. Coverage would be better if a car kit with an external antenna were used.*

## Mobile coverage on trains

5.31 As explained in the box below, mobile coverage inside train carriages can be poor for a combination of reasons. The apparently obvious approach of simply deploying more base stations to cover all of the rail corridor may not an effective solution in all cases, and would certainly be high cost.

**Why is mobile coverage on trains often so poor?**

While the coverage of mobile networks continues to improve in many places, many of us still experience the frustration of dropped calls and poor speeds when trying to use our mobile phone on a train. Why is delivering reliable mobile coverage to train passengers so difficult?

One reason is the location of the tracks. Intercity railway tracks often pass through rural areas, where levels of coverage tend to be lower than in urban areas. However, consumers often experience dropped calls and slow data speeds even in dense urban areas, such as around railway stations. This is more likely caused by the mobile networks lacking the capacity to deal with high numbers of users simultaneously. In addition, many railway tracks are laid in deep cuttings and tunnels, which are difficult and costly to cover with standard network base stations.

The construction materials used in some newer trains also contribute to poor coverage. In particular, the train windows are sometimes coated in a metallic film or mesh. While this has the desired effect of helping to regulate the temperature within the train, the coating also weakens or blocks mobile signals from passing through.

5.32 Consequently, the train industry (Network Rail and the Train Operating Companies or TOCs) have been working on a number of different approaches to improving connectivity as the rail travelling public's expectations have risen. Some TOCs have deployed repeater technology, but these have tended only to improve matters for customers of a single mobile operator and do not solve the problem of deep cuttings and tunnels, or lack of coverage.

5.33 More generally, many TOCs, particularly those running the main long distance routes have installed Wi-Fi systems into their rolling stock, providing internet connectivity to the travelling public via on train gateways, provided by specialist service providers, that use either satellite or, now more commonly, mobile coverage. These solutions also do not provide contiguous coverage because of the tunnel and cutting problem and lack of mobile coverage and capacity in some areas. Additionally, these services have typically been provided on a "pay as you go" basis and have not supported voice connectivity. The latter point is becoming less of an issue with increasing adoption of Wi-Fi calling functionality by the operators, and this functionality is likely to be widely available and commonly used by most consumers within a few years.

5.34 Government has taken a keen interest in these developments and recently announced that the Department for Transport is proposing a new set of conditions on TOC franchises that will deliver free Wi-Fi services to travellers on all of the main routes, both long distance and commuter, over the next few years. The aim is to provide uninterrupted coverage along the entire route with sufficient capacity to meet the basic internet access and voice connectivity needs of the normal passenger loads, based on actual route data. The requirement specified per passenger will increase over time to meet increases in expectation and usage.

5.35 The approach taken is technology agnostic as far as "backhaul" solutions providing connectivity to the on train gateways are concerned. Additional operator capacity targeted at the rail corridor is one approach already being deployed on the Chilterns line through an agreement between Arriva and EE. Other radio spectrum, aside from that licensed to mobile network operators, could potentially be used and Ofcom would welcome further dialogue with the TOCs and their service partners on these issues.

5.36 In order to meet the goal of service contiguity, access to facilities close to or on the rail corridor will also be necessary for any backhaul solution deployed. The planned reforms to the Electronic Communications Code contained in the Digital Economy Bill will facilitate this but it is envisaged that Network Rail, as the rail corridor landowner, will also play a key role in providing a range of active and passive services to the service providers, particularly with regard to deploying solutions in tunnels.

5.37 Ofcom is already planning additional service monitoring activity to assess the effectiveness of these measures and will remain in active dialogue with Government, the rail industry and service providers to ensure their success.

## Challenges remain in delivering mobile coverage in rural areas and to consumers on the move

5.38 Mobile operators face a number of challenges in delivering high levels of geographic coverage. Many of these result from the challenges associated with installing mobile network equipment in very rural areas, and include:

5.38.1 **Terrain**, e.g. steep mountains make it harder to reliably deliver mobile signal coverage deep into valleys;

5.38.2 **Policy**, e.g. planning restrictions on where mobile base stations can be built, especially in areas of natural beauty; or

5.38.3 **Practical factors**, such as difficulties in securing and maintaining a reliable power supply for the base station.

5.39 As a result of these, and a commercial focus by mobile operators on first deploying networks where population density is highest, levels of mobile coverage in rural areas are significantly lower than in urban areas. Figure 4 below shows the voice service coverage from all operators in rural areas.

**Figure 22: Coverage of voice services from all operators in rural areas**

| | Indoor | Outdoor | |
|---|---|---|---|
| Rural areas in | Premises | Geographic | Premises |
| UK | 50% | 64% | 84% |
| England | 53% | 83% | 88% |
| Northern Ireland | 52% | 80% | 86% |
| Scotland | 41% | 35% | 71% |
| Wales | 32% | 50% | 66% |

*Source: Ofcom analysis of operator data*

5.40 The figures in Figure 21 highlight two important themes of rural coverage:

5.40.1 Firstly, indoor coverage of voice services across the all of the UK's rural areas is poor, with only 50% of premises in these areas served by all operators; and

5.40.2 Coverage is particularly poor in Scotland and Wales, both in terms of indoor and geographic coverage.

5.41 We have published alongside this document an update to our Economic Geography report[33], which is a more detailed analysis of the factors that affect the provision of mobile coverage. The decision to offer mobile coverage in a particular area is essentially a commercial judgement by the operators. Profitability will depend on the likely demand for mobile services and the costs of providing these services. Based on actual coverage data provided by operators, we can observe that there are generally more areas in London that have full 3G and 4G coverage than the UK average while the opposite is true for areas within Scotland and Wales.

5.42 This may create the perception that certain parts of the UK are 'under-served' in terms of the level of 3G or 4G coverage that they receive. However, a region may have below-average coverage in part because it is less densely populated or has more challenging terrain than other regions.

[33] https://www.ofcom.org.uk/research-and-data/multi-sector/economic-geography-2016

5.43 We have used regression techniques to examine how much of the regional variation in 3G and 4G coverage can be explained by differences in the demand and cost factors. Applying this technique, we find that once factors such as population density, population composition, topography and whether the locality is urban or rural are taken into account, the probability of good 3G coverage is relatively similar between different parts of the UK. This indicates that much of the variation that we see in coverage can be explained by these factors. However, there would appear to be other factors that are specific to the East of England, Scotland and Wales that negatively affect coverage. Further work will be needed to understand the reasons for this.

5.44 In the case of 4G, there remains a considerable amount of unexplained regional variation particularly in the West Midlands, East of England, the South West, Wales and Scotland. However, 4G roll-out is ongoing and this only represents a snapshot of a dynamic environment. Over time, as 4G networks mature, we would expect that the amount of unexplained regional variation may become smaller, as it has for 3G.

## Mobile coverage obligations

5.45 Licence obligations to meet particular coverage levels are also playing a role in helping extend mobile coverage. In December 2014 the UK Government signed a binding agreement with the four network operators to improve mobile coverage. This agreement, since reflected in a licence obligation, guarantees coverage of a mobile voice service from each operator 90% of the UK's land mass by 2017.

5.46 This agreement uses a different definition of coverage to the one we use in this report. In particular, it is based on a lower mobile signal level requirement. This lower signal level relates to a lower likelihood of reliably being able to make a call when there are localised signal blockages by trees, buildings and other obstructions. Hence when this agreement is met it will correspond to a geographic mobile coverage level of between 80 and 85% based on the definitions used in this report, depending on the frequency bands used by each operator to provide voice services[34]. We intend to report in more detail on the progress being made by mobile operators in meeting their geographic mobile coverage licence obligations in Q1 2017, using more up to date coverage data from the operators[35].

5.47 As with voice services, licence obligations are also playing a role in improving the coverage of data services. $O_2$ has a coverage obligation in its Wireless Telegraphy Act licence, requiring it to provide indoor coverage to 98% of UK premises by the end of 2017. Other operators have indicated their intention to match this level of coverage over the same timescale.

## The increase in 4G coverage is helping to drive consumers' demand for mobile data

5.48 Data consumption on mobile has increased to 106PB per month with the data per active connection per month now over 1GB (Figure 23); this is a ten times increase

[34] Unless the operators exceed their licence commitments.

[35] We estimate that as of June 2016, based on the lower minimum mobile signal level requirements used in their agreements, the level of geographic mobile voice call coverage achieved by the different operators for the purposes of their agreements are: $O_2$ – 89%, Vodafone – 93%, EE – 85%, Three – 78%.

over five years. The increase in 4G coverage, as shown in Figure 20 on page 40, has been instrumental in facilitating data consumption growth across the UK.

**Figure 23: Mobile data use continues to increase**

| Traffic Type | June 2016 | June 2015 | June 2014 | June 2013 | June 2012 | March 2011 |
|---|---|---|---|---|---|---|
| Active Connection (millions) | 83.6 | 83.7 | 83.2* | 82.7 | 82.2 | 81.1 |
| Total data uploaded/downloaded (GB, millions) | 105.5 | 72.9 | 44.3 | 28.9 | 19.7 | 9.0 |
| Data per active connection (GB) | 1.26 | 0.87 | 0.53 | 0.35 | 0.24 | 0.11 |

*Source: Ofcom analysis of Mobile Network Operator data and Connected Nations Report 2015*[36]
*Note:* * figure from March 2014

5.49 Data traffic distribution is roughly in line with population distribution across the UK, as can be seen in Figure 24. England has the highest 4G coverage in the UK and, with just under 93PB, it accounts for 88% of the total data traffic generated in a month. The 2016 data traffic in England has outstripped the total data traffic in the UK for 2015.

5.50 Wales has the lowest 4G coverage in the UK and accounts for 3% of data traffic generated in a month, ahead of Northern Ireland, as a result of higher population. With regards to Northern Ireland, it has the second best 4G coverage in the UK, but only accounts for 2% of the total data traffic generated in a month.

**Figure 24: Share of data traffic and population between UK nations**

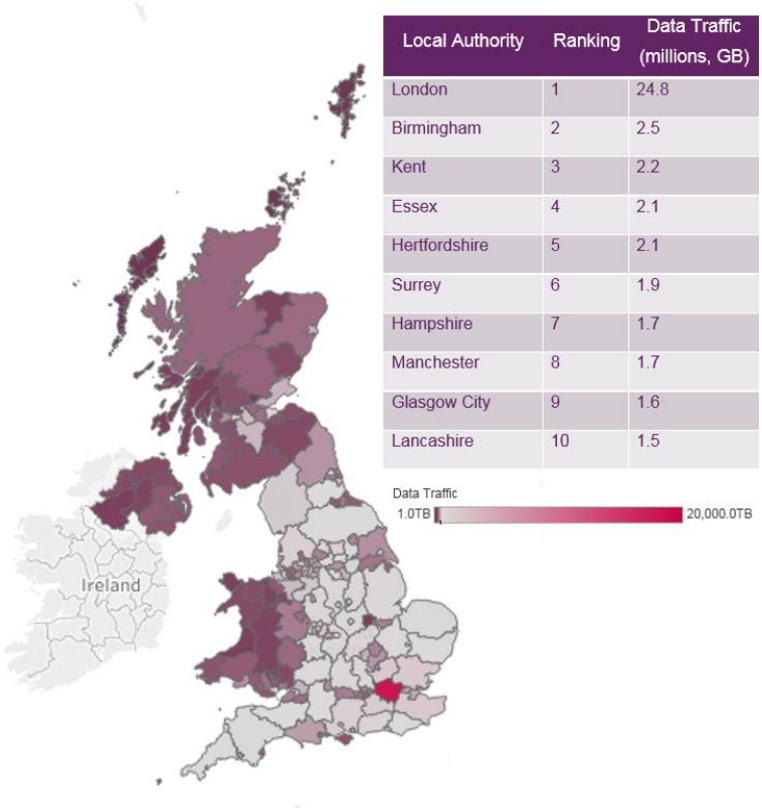
| Nation | Data Traffic (GB, millions) (%) | | Population (millions) (%)[37] |
|---|---|---|---|
| | 2015 | 2016 | Mid-2015 |
| England | 64.0 (88%) | 92.7 (88%) | 54.8 (84%) |
| Northern Ireland | 0.8 (1%) | 1.8 (2%) | 1.9 (3%) |
| Scotland | 5.4 (7%) | 7.6 (7%) | 5.4 (8%) |
| Wales | 2.7 (4%) | 3.4 (3%) | 3.1 (5%) |
| UK | 72.9 | 105.5 | 65.1 |

[36] https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2015
[37] ONS estimates of UK population: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2015

*Source: Ofcom analysis of Mobile Network Operator data.*

5.51 Figure 25 shows the distribution of data traffic by local authority. Data consumption in London is 24.8PB per month, which accounts for almost a quarter (23.5%) of the total UK data consumption. The second highest local authority by data traffic consumption is Birmingham with a tenth of London's data traffic consumption. The least data traffic is consumed in the local authority of the Isles of Scilly.

**Figure 25: Data traffic heat map at each local authority[38] and top 10 local authorities by data traffic**




| Local Authority | Ranking | Data Traffic (millions, GB) |
|---|---|---|
| London | 1 | 24.8 |
| Birmingham | 2 | 2.5 |
| Kent | 3 | 2.2 |
| Essex | 4 | 2.1 |
| Hertfordshire | 5 | 2.1 |
| Surrey | 6 | 1.9 |
| Hampshire | 7 | 1.7 |
| Manchester | 8 | 1.7 |
| Glasgow City | 9 | 1.6 |
| Lancashire | 10 | 1.5 |

*Source: Ofcom analysis of Mobile Network Operator data*

5.52 A greater proportion of data is being delivered over 4G networks. Given the faster download speeds of the technology, and its ability to handle high demand applications such as streaming HD video. In 2016, 60.2% of the total data traffic was delivered over 4G networks (63.5PB), in comparison to 39.3% on 3G network (41.5PB). This means that 50% more traffic is carried on 4G than on 3G.

[38] An interactive version of this map is available: https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016/interactive

**Figure 26: UK data traffic by technology type for each nation**

| | Data Traffic (GB, millions) (%) | | | |
|---|---|---|---|---|
| | 2G | 3G | 4G | Total |
| England | 0.4 (76%) | 35.7 (86%) | 56.4 (89%) | 92.7 (88%) |
| Northern Ireland | 0.02 (3%) | 0.67 (2%) | 1.1 (2%) | 1.8 (2%) |
| Scotland | 0.07 (13%) | 3.4 (8%) | 4.24 (7%) | 7.6 (7%) |
| Wales | 0.04 (8%) | 1.71 (4%) | 1.72 (3%) | 3.4 (3%) |
| UK | 0.53 (0.5%) | 41.5 (39%) | 63.5 (60%) | 105.5 |

*Source: Ofcom analysis of Mobile Network Operator data*

5.53 The table in Figure 26 highlights the marked difference between 3G and 4G data traffic across nations except Wales, where the data traffic for 3G and 4G are particularly close. Wales has relatively low 4G coverage, compared to the UK as a whole and as shown in Figure 17; as a result, the data traffic delivered over 4G networks is relatively low.

## Where and when consumer uses data plays an important role in the experience

5.54 Coverage is perhaps the most important factor in determining the consumer's quality of experience. Despite data traffic and coverage continuing to increase (as shown in Figure 17 and Figure 23), the quality of experience of a single consumer is affected by a range of factors, including whether they are indoors or outdoors, close to or far from a base station and whether they are moving. The service consumers receive will also be influenced by factors outside of their control, such as how many others are trying to use the network at the same time.

5.55 In Figure 27, we analyse data traffic in the busy hour. Each base station has a different busy hour; this is the hour in which the greatest data traffic is downloaded. Consumer quality of experience may be affected in the busy hour, and they may experience slower download speeds as more people are using the network.

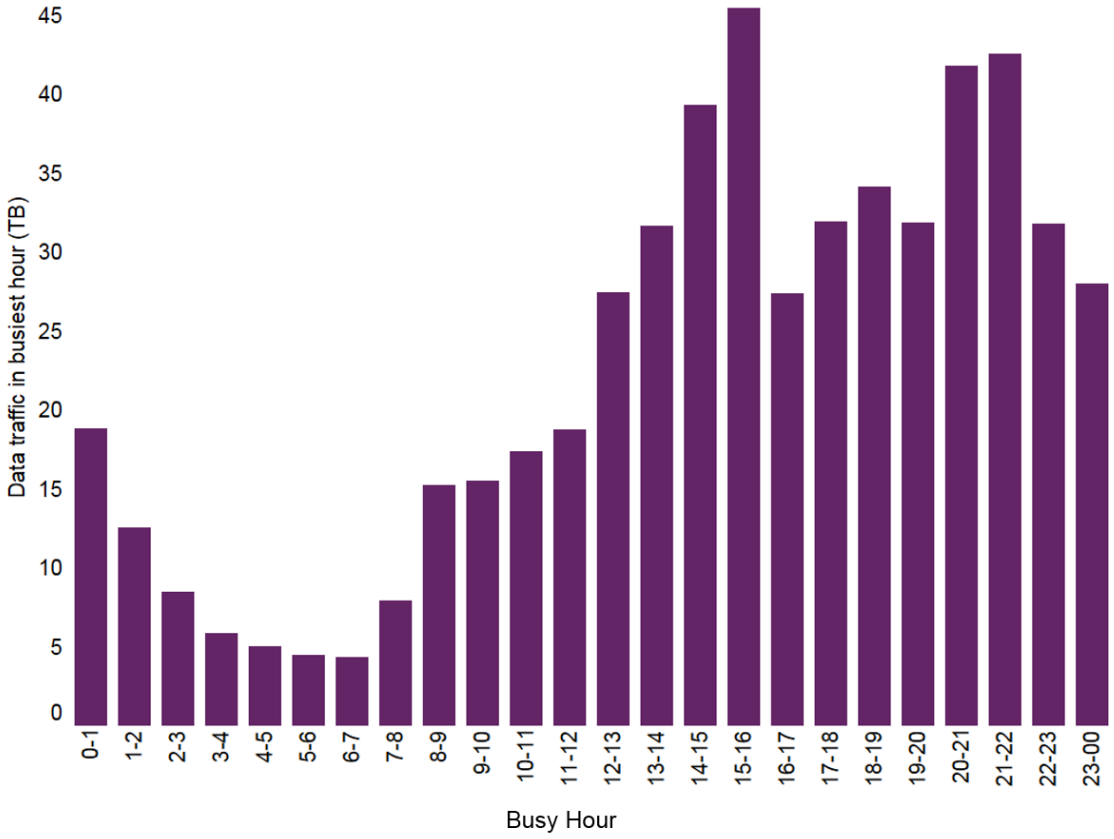
5.56 Our analysis of the data traffic carried in busy hours shows that 15:00 – 16:00, across the month, is the hour in which the most data is downloaded and uploaded across the UK, nevertheless the use of data never switches off. The 15:00 – 16:00 slot coincides with the end of the school day, and analysis of Digital Day data[39] shows a peak for smartphone reach for 11-15 year olds at 3-5pm.

5.57 Consumers at different hours and locations may have a lower quality of experience. Base stations can have their busiest hour across any of the 24 hours of a day. For

[39] http://www.digitaldayresearch.co.uk/

example, busy hour for some sites surround the $O_2$ arena in London is between midnight and 01:00 as events finish around that time.

**Figure 27: Average busiest hours for data traffic in the UK**




*Source: Ofcom analysis of Mobile Network Operator data*

Section 6

# Internet Access Services

## Overview

6.1 The fixed and mobile services discussed in the preceding two sections of this report are used predominantly for the delivery of internet access services. In this section we touch on some of the issues relating to how these services link consumers to the online services and content they wish to access and, in particular, on the increasing role of regulators and policy makers in ensuring that these services operate in an equitable and open way.

6.2 These services now constitute the majority of traffic delivered over access networks and consumers have become increasingly reliant on them for both economic and social activity. As a result, consumers are becoming increasingly concerned about the quality of their internet connection, in addition to the performance of the more traditional services such as voice telephony. Policy makers have recognised this and taken steps to ensure that all sources of content continue to be generally available to all end users and that particular services or classes of service are not unduly favoured unless justifiably necessary.

6.3 In this section we report on how Internet Service Providers (ISPs) are supporting the delivery of internet services over their networks, including how they manage the flow of data over their networks and how they interconnect with other ISPs, content delivery networks and the wider internet. We also touch on how the new regulatory regime for internet access services aimed at ensuring "net neutrality" is being delivered.

6.4 The highlights are:

6.4.1 **A major package of new regulatory obligations coupled with complementary enforcement powers for regulators is in the process of implementation**. This will result in greater transparency in how ISPs manage traffic, market their services and contract with customers.

6.4.2 **ISPs have already been improving the information they provide to consumers about the use of traffic management on their networks as part of a voluntary Code of Practice administered by the Broadband Stakeholder Group (BSG)[40]**. Current traffic management practices in widespread use have minimal or no impact on most users on fixed networks but, given the fixed capacity and variable demand in specific parts of mobile networks, may have an appreciable effect on mobile users during peak periods in busy areas.

6.4.3 **The amount of internet data being delivered to consumers by major video content providers continues to increase**. The use of content delivery networks (CDNs[41]) also continues to increase: internet content is increasingly being served from caching servers embedded in the ISPs' access networks and provided by the content providers.

[40] See http://www.broadbanduk.org/policies/the-open-internet/open-internet-code-of-practice-2016/
[41] Akamai, Google, Amazon, Netflix and the BBC.

6.4.4 Larger-scale ISPs are progressively **introducing support for the latest IPv6 internet addressing system**;

6.4.5 The **lack of security of Internet of Things (IoT)** and other low cost internet connected devices is leading to their being targeted by malware and their use to launch distributed denial of service (DDoS) attacks, increasing concerns over security of personal data.

## EU Regulation on Net Neutrality

6.5 In April of this year, the EU Telecoms Single Market (TSM) Regulation on net neutrality rules came into force in the UK. The regulation introduces new rights for consumers and places certain obligations on ISPs. These rules were introduced to address concerns that ISPs might manage traffic on their networks in ways that would limit competition and innovation, which in turn could lead to consumer harm.

6.6 The rules impose requirements on ISPs in terms of how they can manage traffic on their networks and place transparency obligations on informing consumers how they do so. The rules also place an obligation on regulators to closely monitor and ensure compliance with the rules.

6.7 The relevant provisions in the EU regulation are:

6.7.1 **Article 3** sets out end-user rights to "access and distribute information and content, use and provide applications and services, and use terminal equipment of their choice" when accessing the internet. It imposes specific obligations on ISPs intended to secure this outcome. The obligations cover traffic management practices and commercial aspects relating to internet access services such as the provision of "zero-rated"[42] content.

6.7.2 **Article 4** imposes a range of specific transparency obligations on ISPs in relation to the speed and quality of their services. It also introduces requirements about the handling of complaints and the circumstances under which consumers have rights of redress when an internet access service is unsatisfactory.

6.7.3 **Article 5** requires regulators to monitor and ensure compliance and to report annually to the European Commission on compliance and on the general quality of internet access services. It also reinforces regulators' powers to impose quality of service obligations on ISPs.

6.7.4 **Article 6** requires member states to introduce an effective penalties regime for non-compliance.

## The duties on regulators

6.8 In order to provide clarity and guidance to the regulators on their obligations, BEREC, the Body of European Regulators for Electronic Communications, published guidelines in August of this year to National Regulatory Authorities (NRAs) on the implementation of net neutrality. NRAs have a range of new tasks under the Regulation, which fall into two groups.

[42] An online content service is “zero-rated” on an internet access service when use of that content service does not count against the data cap applying to the internet access service.

6.9 Firstly, monitoring and reporting on compliance with the Regulation and the quality of internet access in the country. NRAs must "closely monitor" the quality of internet access, and ISPs' compliance with the obligations in the Regulation, specifically:

6.9.1 The transparency obligations for ISPs to provide additional information in contracts about the broadband speeds - the minimum, maximum, normally-available and advertised speeds for fixed services; the estimated maximum and advertised speeds for mobile services; to handle consumer complaints about these issues, and provide remedies/redress when necessary.

6.9.2 To ensure that ISPs do not limit end-users' ability to: access and distribute information and content; use and provide applications and services; and use terminal equipment of their choice, irrespective of the end-user's or provider's location or the location, origin or destination of the information, content, application or service, via their internet access service.

6.10 Secondly, enforcement of ISP compliance with the Regulation:

6.10.1 NRAs must enforce the Regulation, investigating complaints or potential breaches identified in the course of monitoring compliance. They may require ISPs to change their practices and impose sanctions in the event of serious breaches.

6.10.2 NRAs must also report annually to the Commission on these issues, with the first report due in June 2017.

6.11 Ofcom will continue to maintain a close dialogue with industry to ensure that the appropriate balance is struck between restricting ISP practices, in order to protect innovation in online services, and allowing ISPs to evolve their networks and the range of internet and non-internet services they offer – whilst avoiding harming incentives to invest and ensuring the Internet remains an open and innovative environment.

## Implementation actions

6.12 Ofcom currently has an on-going programme of work that is in line with the requirements of the EU Regulation. This programme includes reviewing the voluntary Broadband Speeds Code, and establishing a process to discharge our obligations with regard to the measurement and reporting on the quality of Internet Access Services (IAS).

6.13 Article 4 requires ISPs to ensure that any contract which includes IAS specifies the following:

6.13.1 How traffic management measures could impact on the quality of IAS, the privacy of end-users and the protection of their personal data;

6.13.2 Any impact of fair usage policies, data caps and specialised/managed services on IAS;

6.13.3 Important broadband speeds for both fixed and mobile networks; and

6.13.4 The circumstances under which consumers should be able to exercise their rights of redress, and the remedies available to them, when an internet access service (IAS) is unsatisfactory.

6.14 ISPs also need to have transparent and efficient procedures for handling complaints about such matters.

6.15 Ofcom is currently checking the compliance of the UK's main ISPs' residential consumer contracts in relation to the impact of traffic management on the quality of the IAS and on privacy and the protection of personal data.

6.16 We already have an active monitoring and enforcement programme covering providers' obligations under General Condition 14.4 in relation to complaints handling, including for IAS. We will continue to actively monitor communications providers' (CPs) compliance with these obligations, considering formal enforcement action if breaches are identified.

6.17 We will be revising the Broadband Speeds Codes of Practice for businesses and residential consumers. We aim to strengthen the Codes and ensure that speed information given at point of sale and after sale is in line with the specification of the TSM regulation and consistent across CPs. This will ensure more realistic estimated speed measures are given to consumers, as well as an easier route to redress. The Codes will provide guidance to CPs on the interpretation of the TSM regulation in the UK. We are currently engaged in discussions and workshops with CPs and aim to consult on the revised Codes and guidance in summer 2017.

6.18 In this context, it is worth noting that the Advertising Standards Authority (ASA) recently published research into consumers' understanding of broadband speed claims made in adverts[43]. The study was commissioned following growing concerns that consumers were misled by adverts for broadband services citing headline speeds that customers did not actually receive.

6.19 The research found that speed is an important factor for a significant proportion of consumers who are making decisions between providers. However, levels of knowledge and understanding of broadband speeds vary, and are low overall with many not knowing what speed they need to carry out daily online tasks

6.20 Most understand that the higher the number in the advertisement, the higher the speed of the service, but many are unclear on what this means for them and what speed they would likely achieve. Despite that uncertainty, most consumers believe they are likely to receive a speed at or close to the headline speed claim when, for many, that is not likely to be the case

6.21 As a result, the ASA is reviewing its guidance to advertisers on broadband speed claims. A report will be published in spring 2017. Ofcom will work with the ASA to ensure consistency of approach.

## Traffic management practices

6.22 Traffic management is a necessary aspect of ISPs' network management practices. Better controlling the flow of traffic across an ISP's network by using traffic management (TM) can benefit consumers by improving the performance of their broadband connections at peak times. However, there are concerns that through their use of it, ISPs might manage traffic on their networks in ways which can cause consumer harm or limit online innovation. These potentially harmful practices may

[43] See https://www.asa.org.uk/News-resources/Media-Centre/2016/ASA-calls-for-a-change-in-the-advertising-of-broadband-speed-claims.aspx#.WDxjtX2uggE

include ISPs restricting or 'slowing down' subscribers' access to specific online content, in order to further their own commercial interests, or attempting to charge CPs to access their subscribers. Practices such as these can stifle innovation, be considered anti-competitive and could restrict freedom of expression.

6.23 In light of this, Ofcom has required ISPs to be fully transparent in what they do in this regard, to ensure that consumers can make informed decisions. Before the coming into force of the European Union Telecoms Single Market (TSM) Regulation, ISPs in the UK were already subject to a regulatory obligation[44] to be transparent with consumers about their TM practices. There is an industry-wide code of practice explaining how they should comply with this obligation (the Traffic Management Transparency Code of Practice[45]) which requires that each ISP publish a table summarising its TM policy for each package on offer. These tables have been available on signatories' websites since July 2011.

6.24 In late 2013, Ofcom conducted research on consumer awareness and use of the TM information provided by ISPs. It found that, while the information provided by ISPs was largely accurate and understandable, consumer awareness of TM generally was low. Following this, during 2014 we worked with ISPs to help them improve the impact of the information they provide, with a focus on improving consumer awareness and usability.

6.25 This work, pursued via the BSG Open Internet Forum has resulted in voluntary agreement by the ISPs that they adopt a common approach to defining the traffic management techniques they deploy. The ISPs now provide introductory information explaining their policies and the impact of these policies on their services, and have updated their websites to include glossaries of technical terms.

6.26 We review these key facts indicators and report on them each year as part of this report. Our conclusion is that, broadly, transparency about TM practices has improved, and in general TM policies are less restrictive than they were a few years ago.

6.27 For many fixed networks, TM policies are rarely if ever invoked, although CPs do publish what they would do if networks are congested to ensure adequate performance for time critical applications. Virgin Media continues to apply TM to very heavy data users as part of its demand management policy during busy periods

6.28 Mobile networks also now generally claim not to use TM unless congestion becomes an issue, but this can happen both as a result of normal "time of day" variations in overall loading and as a result of more random increases in users and consequent traffic in particular geographic areas and the cell sites that serve them. They also use data caps and speed limits as another means of managing demand, which may have a much more fundamental impact on the customer experience

6.29 Ofcom continues to explore how best to assess and measure the mobile broadband consumer experience. The "Smartphone Cities, Measuring 4G mobile broadband and voice performance" report[46] that is being published concurrently with this report looks

[44] General Condition 9.2e

[45] http://www.broadbanduk.org/wp-content/uploads/2013/08/Voluntary-industry-code-of-practice-on-traffic-management-transparency-on-broadband-services-updated-version-May-2013.pdf

[46] https://www.ofcom.org.uk/research-and-data/broadband-research/smartphone-cities/december-2016

at how each of the MNO networks performs in a number of major urban areas. In addition to average speed measurement and key web service delivery performance, it has established that generally users in all of the cities can expect to receive more than 2Mbit/s for 90% or more of the time. Whilst this seems likely to deliver a good quality of experience for users, it does emphasise that congestion and, hence, TM can have a significant impact during peak periods or other congestion episodes.

6.30 As mobile networks, and the customers who use them, complete the transition to a fully 4G environment, voice services will be delivered using 4G voice or VoLTE technology, as discussed in Section 5. Since voice will now be transported as any other data service session, ensuring prioritisation during busy periods or localised congestion will become more important, particularly for calls to the emergency services. Ofcom will continue to monitor TM application in this context to ensure voice service quality is maintained.

## Internet interconnection trends

6.31 As part of our information requests to communications providers, we asked them how they connect their customers to the rest of the internet. In previous years we have used this information to review and report on the nature of the connection arrangements used by ISPs to deliver internet content.

6.32 Interconnection can be defined as a business relationship where there is an exchange of customer traffic, between administratively separate Internet networks. As referred to in last year's report, there are many different ways in which ISPs can exchange their customer's traffic with each other. These include transit, public and private peering and the deployment of CDNs.

### Peering

6.33 With peering, both parties tend to meet at a carrier neutral location known as an internet exchange point or IXP. At this exchange they are able to connect either directly or via the exchange's equipment. The latter is often known as public peering, the former as private peering, this term also being used to describe interconnection at one or other of the parties own premises.

6.34 In the case of public peering each ISP pays its own costs for connecting into the exchange's switch. In the case of private peering there are many commercial alternatives available to them, which in many cases may depend on the ratio of traffic exchanged between the two parties.

6.35 In the situation where the ISPs exchange traffic within a given ratio they cover their own interconnection costs, as the relationship is mutually beneficial and is considered a "balanced" peering.

6.36 With larger content providers, the ratio between the traffic sent by each of the peers is now typically relatively high and very different from the 1:1 ideal of "balanced" peering, as a content provider such as Netflix sends a significantly larger volume to the ISP's customers than *vice versa*.

6.37 Generally, in the scenario where the amount of traffic exchanged between the ISPs falls outside of the agreed ratio, the ISP responsible for sending excess traffic is likely to have to pay for the excess, as the relationship could be considered as being more beneficial for only one party. This change has led to a "settled" peering model, where billing is based on the out-of-ratio traffic.

6.38 However, in time this trend may reverse, with the increase in cloud computing and other consumer oriented and services that involve bigger uploads, the traffic flowing upstream to some content providers may tend more toward a balanced ratio. This is likely to result in further adjustments to commercial arrangements with both parties sharing the costs more evenly.

## Transit

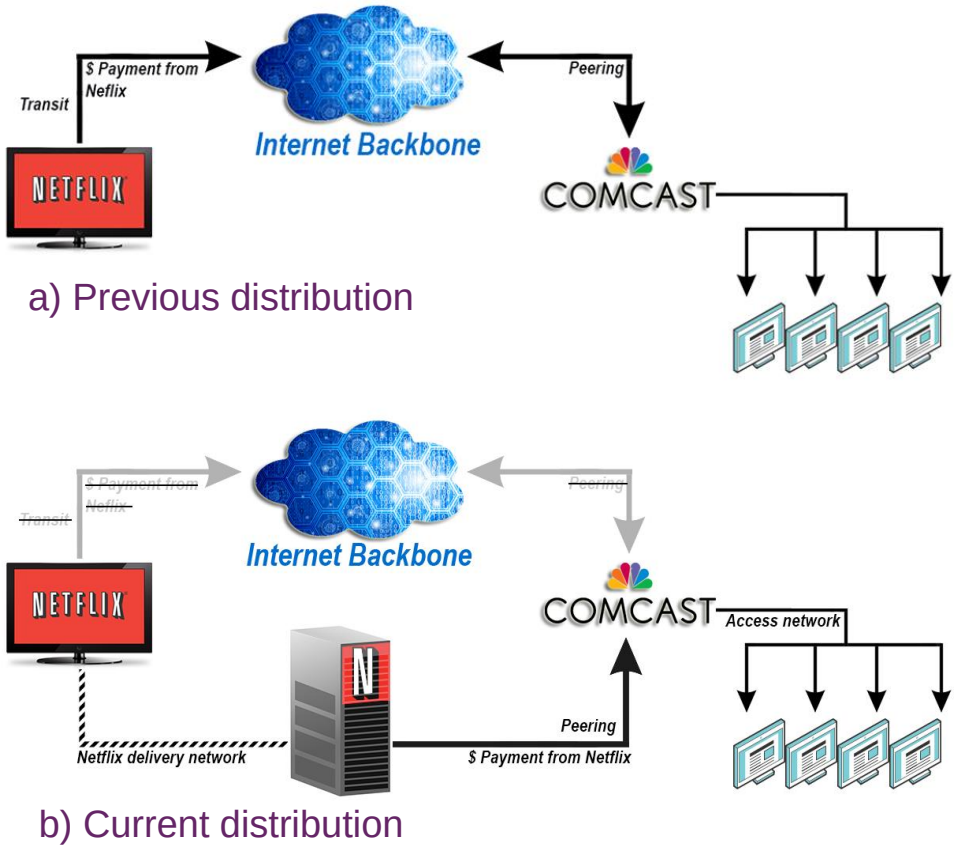
6.39 Transit is when a party pays for access to either all possible destinations in the Internet, or only within a geographic region i.e., destinations with the UK only. The commercial details may include the volume of traffic exchanged or where the customer commits to maintaining a minimum volume.

## Content Delivery Networks and caching

6.40 Over the last year, and as we have reported in previous years, both the number of transit and peering connections have been decreasing whilst the deployment of Content Delivery Networks and associated caching has been noticeably increasing.

6.41 Some of the largest content providers now operate their own delivery networks, which must interconnect with ISPs in order to deliver content to consumers. They can do this either by paying a transit network, which itself connects to the ISP, or by interconnecting directly as shown in Figure 28. Direct interconnection is cheaper (for the content provider) for the delivery of large volumes of data

**Figure 28: Changing approaches to interconnection**




*Source: Ofcom*

6.42 Particularly in the US, these 'direct' interconnection agreements between ISPs and content delivery networks have led to allegations that ISPs are attempting to become *gatekeepers*, extracting a charge from content providers to allow them to access the ISPs' subscribers. The allegations are particularly prominent in those countries (like the US) where there is limited competition among ISPs, and hence the negotiating position of content providers is seen to be weaker.

6.43 In fact, these arrangements are arguably no different from traditional network operator interconnection negotiations and arrangements that have always existed. We have no reason to believe that UK ISPs are abusing their position to extract payment from content providers.

6.44 In particular, we note that Netflix's CDN arrangements, and those of other leading content providers, are now being further extended into the access provider's own network using 'caching servers'. Caching servers are CDN servers which can be placed within the ISP's network or on a third-party network, storing the most popular content. This removes the need for the ISP to connect to the original source of the content every time a customer requests it.

6.45 There are many reasons why this approach may be preferred. The local delivery of content can result in better delivery times to the consumer, which may translate to a better quality of experience, and so is often a preferred option for content providers. This approach further reduces transit or backhaul connectivity costs, and can also improve the customer experience by reducing the likelihood of data congestion in these parts of the network. The commercials in this model are likely to include location services and port-based pricing.

6.46 This evolution is explored further in an academic paper called "Open Connect Everywhere: A Glimpse at the Internet Ecosystem through the Lens of the Netflix CDN[47]" published this year by a team at Queen Mary University of London. This notes, in particular, how Netflix as a content provider has moved to operating its own CDN whilst generally relying on third party cloud storage and, increasingly, caching servers it embeds in ISP networks. The variability of its network interconnection scenarios reflects the very differing network topologies and traffic flows in different markets.

6.47 Many CDN providers are now measuring and reporting on the performance of their content through each ISPs network. The publishing of this data on their websites may also influence how ISPs choose to interconnect with them.

## Overall trends

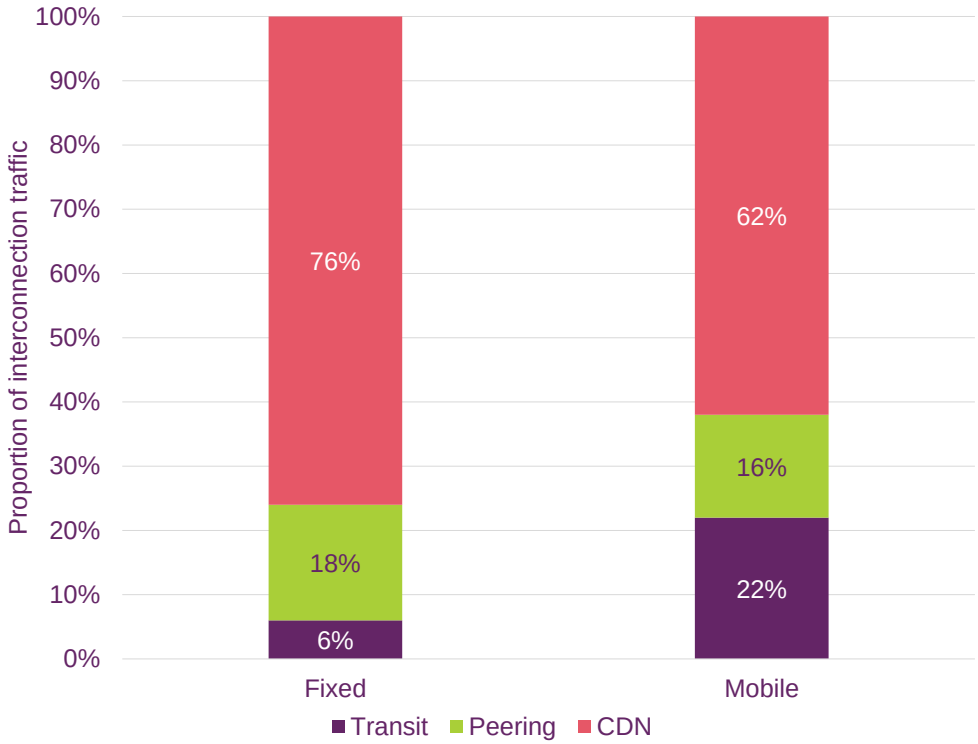
6.48 Last year we noted an increasing use of content delivery networks (CDNs) and direct connections between the access providers and the providers of content and services, and a reducing use of transit and public peering arrangements to deliver internet content.

6.49 This trend has continued - volumes of traffic across the interconnection points between the main ISPs and the internet core, other ISPs and the main providers of content have increased by around 45% since last year.

[47] See http://www.theregister.co.uk/2016/06/22/boffins_map_netflixs_open_connect_cdn/ and http://eecs.qmul.ac.uk/~boettget/mapping-netflix-coseners16.pdf

6.50 As Figure 29 shows, CDN connectivity is an even bigger proportion of the overall traffic than before, although there are notable differences between content providers. Generally, mobile networks have a lower proportion of CDN delivered traffic, probably reflecting the lower consumption of streamed video through devices connected directly to the mobile networks (as opposed to Wi-Fi).

**Figure 29: Breakdown of fixed and mobile interconnection traffic**




*Source: Ofcom analysis of operators' data*

## Further progress on migrating to IPv6

6.51 The availability of IPv6 to consumers is progressing. IPv4 address ranges are nearing exhaustion and new service deployment is inevitably going to increase the demand for unique, publicly accessible addresses that only the IPv6 regime can deliver. This will, in particular, facilitate the deployment of the Internet of Things (IoT).

6.52 According to the Akamai IPv6 Adoption[48] table, the UK is currently in 10th place in a list of countries who have adopted IPv6. However, compared to last year, most of the major ISPs have now launched IPv6 services to those customers who want it, building on the IPv6 support they already had in their core networks.

6.53 For example, Sky has progressively enabled "dual-stack[49]" IPv6 for approximately 90% of its customers by upgrading the firmware in existing routers. A small percentage of the remainder will need replacement routers as the existing units will

[48] https://www.akamai.com/uk/en/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp

[49] Dual-stack means that those with IPv6 addresses will be able to access both IPv4 and IPv6 sites. This is important as much of the Internet is still on IPv4 only.

not support IPv6. BT is adopting a similar path with their integrated Home Hub routers being mainly IPv6 compatible with a firmware upgrade that is shortly being rolled out.

## The Internet of Things - is security an afterthought?

6.54 Recently there have been a number of security breaches where Internet of Things (IoT) devices have been hijacked and used to create distributed denial of service (DDOS) attacks. One particular attack rendered Akamai helpless when they were unable to mitigate the effects of the attack on a target they were providing hosting and network security services for, and the website had to be shut down[50]. In the wake of these attacks, the security, or lack thereof, associated with IoT devices is gaining public interest.

6.55 As the adoption of IoT technologies continues to increase, the threat of security breaches is likely to rise, particularly as some IoT device manufacturers are not currently implementing particularly effective security measures into their products and, in many cases, do not have entirely convincing approaches to firmware upgrades and patching in the light of emerging threats.

6.56 In some cases, the most fundamental problems with these devices can be partly attributed to the default passwords not being changed, thereby allowing hackers to remotely gain access and install malware on them. These infected devices are then used directly or indirectly to launch DDoS attacks.

6.57 The lack of security with these devices may also have an impact on the consumer's privacy, with hackers being able to gain access to personal information. Depending on the IoT device they have, it may reveal personal data related to their health, or their habits of when they leave and arrive home, leaving them vulnerable to higher insurance costs or targeted burglary.

6.58 Many creators of IoT devices, who are not security minded, may be unaware of how vulnerable their products are to cyber-attacks. The GSMA[51] has produced security guidelines on how developers of IoT devices can incorporate security safe guards into their products.

6.59 As the deployment of IoT continues, Ofcom will work to ensure that industry addresses the need to protect the consumer from data exfiltration and other exploits. This could involve educating consumers on how best to protect their devices and personal information.

6.60 The past year has seen a 34% increase in the number of IoT devices individually connected to mobile networks (with a dedicated SIM card) in the UK, as shown in Figure 30 below. The amount of IoT traffic carried over the mobile networks is steadily increasing. However, as the volume of traffic generated by IoT devices is very small, this remains only a small proportion of traffic overall. Figure 30 does not include those IoT devices that are not connected to mobile networks, such as those connected via short range links (e.g. Bluetooth) or wide area low power networks (such as Sigfox).

[50] http://www.networkworld.com/article/3123672/security/largest-ddos-attack-ever-delivered-by-botnet-of-hijacked-iot-devices.html
[51] http://www.gsma.com/connectedliving/future-iot-networks/

**Figure 30: Number of connections and proportion of total data traffic for IoT devices connected to mobile networks**

| | 2016 | 2015 |
|---|---|---|
| M2M (IoT) connections | 6,999,287 | 5,212,304 |
| Change | 34.3% | 28.2% |
| | | |
| Average proportion of M2M data to total traffic | 0.23% | 0.16% |
| Change | 44% | 78% |

*Source: Ofcom analysis of operator data*

Section 7

# Security and resilience

## Overview

7.1 As consumers and businesses become even more dependent on communications services, our duties with regard to network resilience become increasingly important. Overall, whilst network failure incidents are not significantly increasing in volume or impact, underlying changes in network technology have implications for consumers that need an appropriate regulatory and policy response. This section summarises the major security and resilience issues that were reported to Ofcom over the past year and the key issues that need addressing in the near future.

7.2 Key themes are:

7.2.1 The majority of security incidents reported relate to **voice services**, often affecting consumer access to the 999 emergency services;

7.2.2 The majority of incidents are caused by the **failure of hardware components, the loss of power supply or by software bugs**;

7.2.3 Incidents with an impact above one million customer-hours are uncommon, and are often the result of a **unique and unexpected threat to security**;

7.2.4 The next few years will see a fundamental change in how voice telephony services are delivered, **as obsolete PSTN[52] legacy systems are replaced by new VoIP[53] solutions**. This process will bring benefits to users but it is important that it is managed in a way that minimises disruption to consumers. We outline a number of key principles that should be followed to ensure minimum disruption for consumers and businesses: that providers must communicate the migration process clearly to their customers and that no voice service users are worse off after the technology change, either financially or functionally.

7.2.5 Mobile networks are increasingly important both as the main general communications channel for many users and the first choice for calls to emergency services. In this context, **the current level of resilience of mobile networks, particularly to mains power outages, is an increasing concern**. There will be a need for more focussed activity in this area involving Ofcom, Government and industry as part of the programme of securing and making key elements of critical national infrastructure more resilient.

[52] Public Switched Telephony Network
[53] Voice over Internet Protocol

**Our role in security and resilience**

Ofcom and providers of communications networks and services are subject to certain requirements[54]. These include requiring operators to appropriately manage security risks, to minimise impacts on consumers and to report any breaches of security or network failures to Ofcom.

We first published guidance on the full range of security requirements in May 2011 and updated that guidance in August 2014. We are in the process of updating the guidelines[55]. The guidance sets out our expectations for a risk-based approach to the management of security. It highlights appropriate sources of industry best practice and details our incident reporting requirements.

Aside from these specific requirements, digital terrestrial television (DTT) operators have an obligation[56] to meet high standards of reliability and to provide us with an annual report on transmission performance.

## Reported fixed and mobile incidents

7.3 The majority of security incidents reported relate to voice services, often affecting consumer access to the 999 emergency services

7.4 In the past year, 581 security incidents were reported to us by fixed and mobile providers. The vast majority of reports were from fixed providers regarding disruption to telephony services (including 999 access) for fewer than 10,000 customers and for less than one day. Incidents with a wider impact, which affect tens of thousands of customers, are less common. Reporting data also show that incidents are more likely to occur in, or near, large population centres.

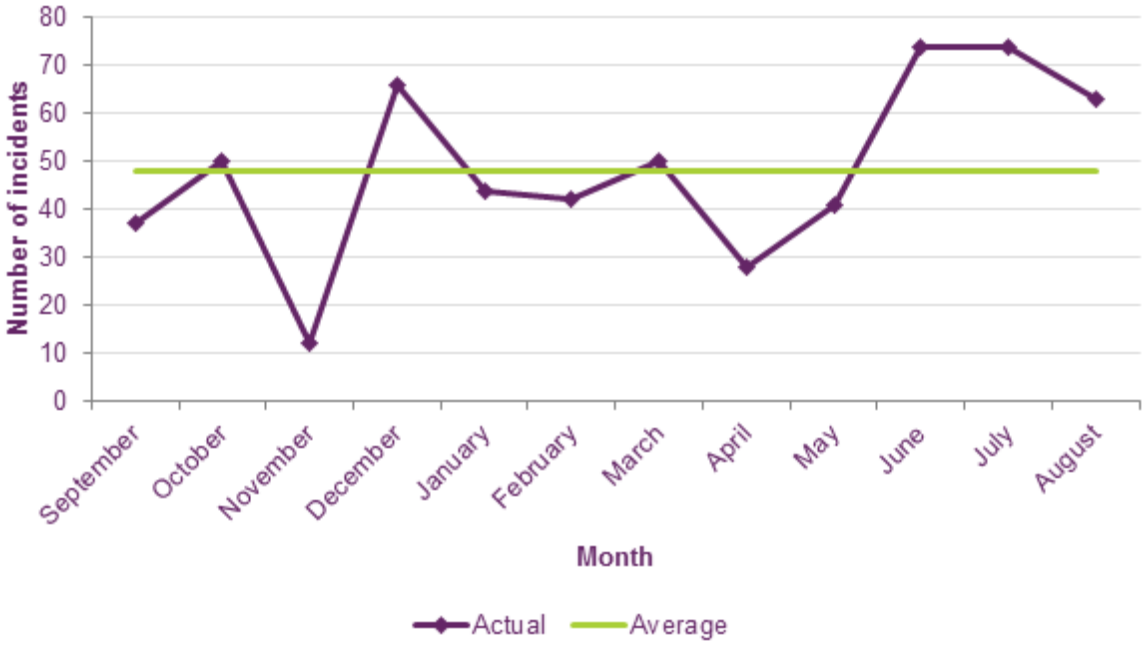
7.5 Figure 31 summarises the number of incidents reported each month between September 2015 and August 2016. The monthly variation could be the result of seasonal factors such as weather or school holidays. We continue to monitor for trends over time.

[54] In accordance with Article 13a of the Framework Directive, sections 105A-D of the Communications Act 2003 place requirements on providers and Ofcom regarding the security and resilience of communications networks and services.

[55] http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/security-resilience/ofcom-guidance.pdf

[56] http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/techguidance/tv_tech_platform_code.pdf

**Figure 31: The number of incidents reported between September 2015 and August 2016**



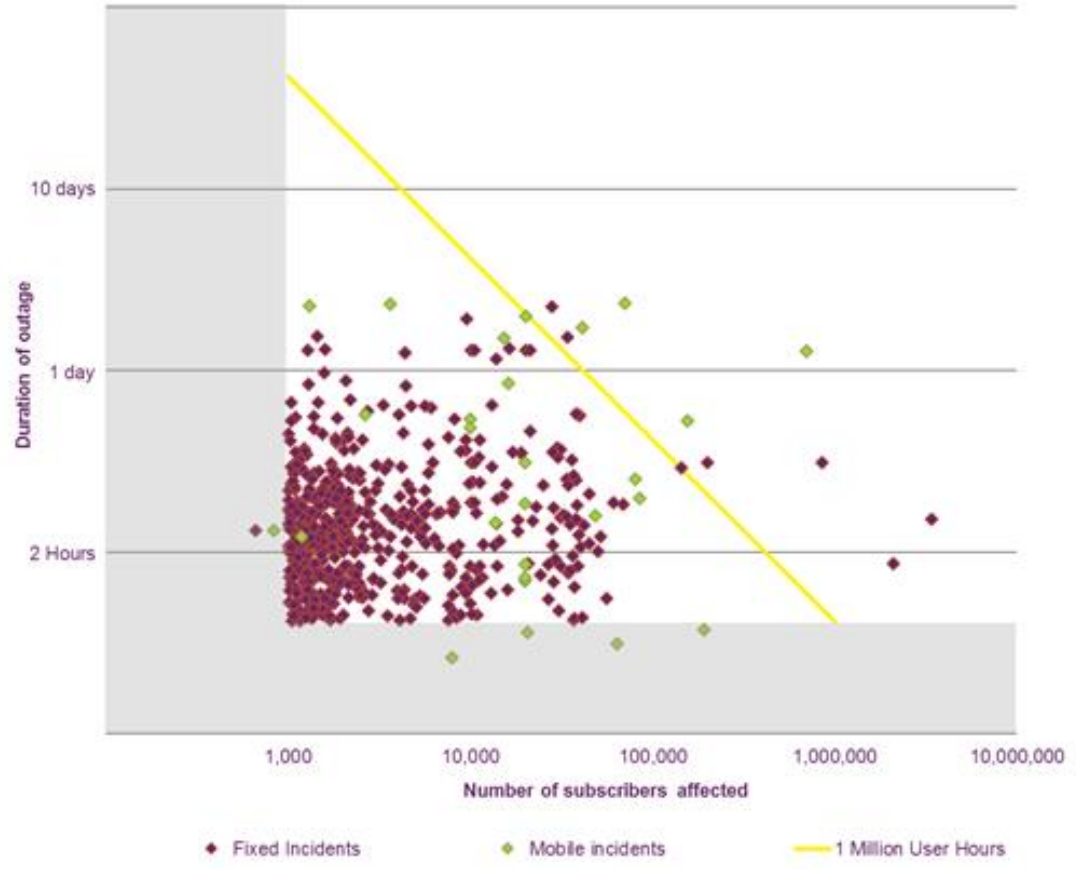

*Source: Ofcom analysis of operator data*

## Scope of Ofcom reporting guidance/ framework

7.6 Ofcom's guidance provides quantitative criteria, or thresholds, against which a provider can gauge the impact of an incident and determine if it should be reported. The most critical is the 'emergency services access' threshold which applies to incidents that affect voice access to the emergency services for 1000 customers, for one hour. There will be incidents that occur but which are not reported to us, since they do not have 'significant impact' as defined in relevant guidance.

7.7 We measure the impact of an incident in 'customer-hours'. This is the product of an incident's duration and the number of consumers affected. While customer-hours is not the only metric by which incidents may be measured, it provides a useful basis for comparison. Figure 32 shows the customer-hours impact of the 581 incidents reported to Ofcom.

**Figure 32: The impact of incidents reported to Ofcom, between September 2015 and September 2016**



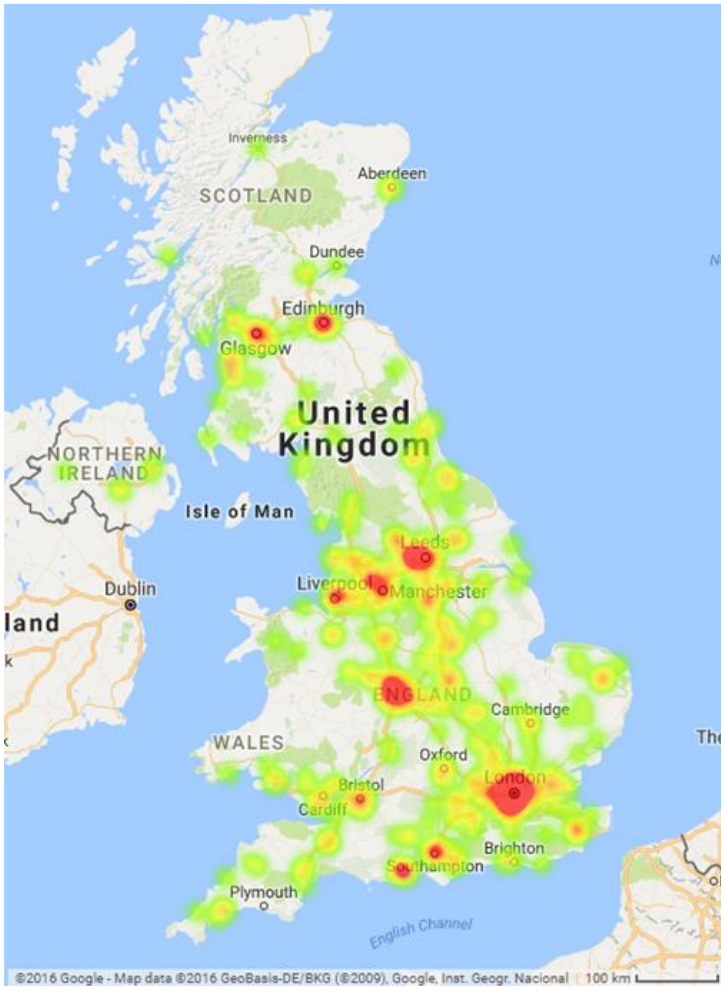

*Source: Ofcom analysis of operator data*

7.8 The majority of incidents have a relatively low customer-hours impact and are reported under the 'emergency services access' threshold.

7.9 Of the 581 reported incidents, 548 affected fixed networks and 33 affected mobile. The difference between these figures is explained by the emergency roaming agreement in place between mobile operators. This means that mobile operators have significant resilience in place for emergency service availability and therefore do not report often under the 'emergency services access' threshold.

7.10 Our revised guidance, published in August 2014, places a particular emphasis on receiving more incident reports from the mobile sector, given the growing importance of mobile services to consumers.

**Figure 33: Heat map showing the distribution of incidents throughout the UK**




*Source: Ofcom analysis of operator data*

7.11 Figure 33 shows how the 581 incidents are geographically distributed across the UK, and reveals that there is a correlation between incident frequency and population density. Where population densities are higher, a higher concentration of network equipment, or assets, is required to provide services.

7.12 It is logical to expect that where there are more assets, there is a greater likelihood of incidents. However, our minimum incident threshold of 1,000 end-users affected may result in some rural incidents not being reported.

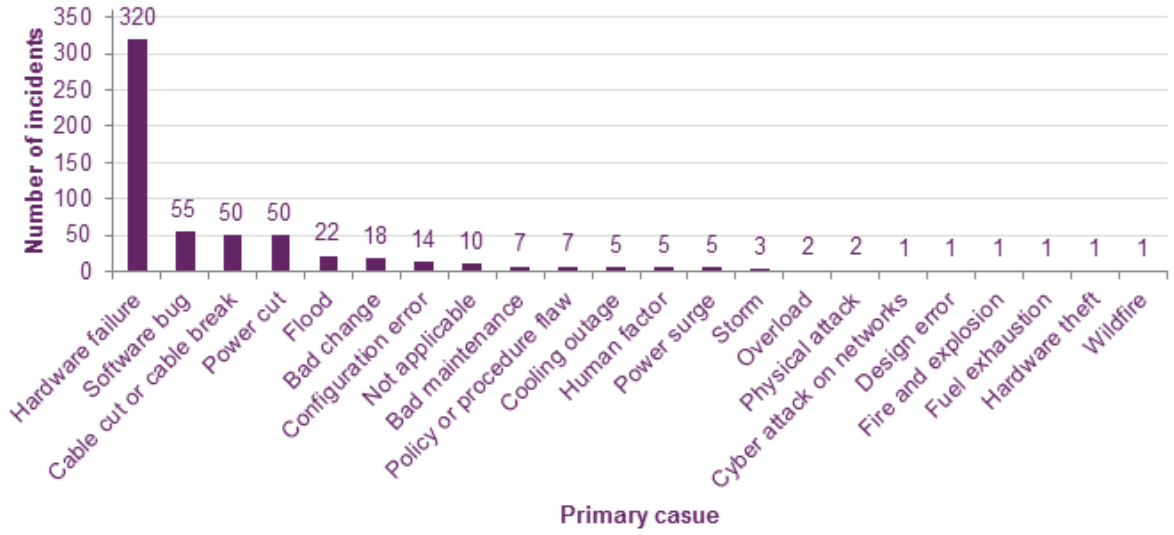
## The majority of incidents are caused by the failure of hardware components, the loss of power supply or by software bugs

7.13 Establishing the root causes of incidents is central to understanding risks to the security and resilience of networks and services. System failure is overwhelmingly the root cause of significant network incidents; over 89% of reported incidents fall into this category. This includes hardware and software failures, and the failure of systems, processes and procedures.

7.14 The remaining categories are human error, natural phenomena (which includes severe weather) and malicious actions, which were responsible for 5%, 5% and <1% of the reported incidents, respectively.

7.15 Figure 34 shows that incidents were reported against a wide range of primary causes[57] 'Hardware failure' is the most common primary cause, followed by 'software bug', 'power cut' and 'cable break'. Together these causes account for over 80% of the incidents that are reported to us.

**Figure 34: Primary cause of incidents reported to Ofcom, September 2015 to August 2016**




*Source: Ofcom analysis of operator data*

## Incidents with an impact above one million customer-hours are uncommon, and are often the result of a unique and unexpected threat to security

7.16 The European Union Agency for Network and Information Security (ENISA) is a centre of network and security expertise for the EU. ENISA provides guidance[58] on the reporting of security incidents. This includes the requirement for national regulatory authorities, such as Ofcom, to report annually on incidents with a significant impact; this is defined as those incidents with an impact above one million customer hours.

7.17 In the reporting period of September 2015 to August 2016 there were 10 incidents which met this threshold: three affected mobile networks and seven affected fixed networks. System failure is still the main root cause, at 70%.

[57] We categorise the root and primary cause of reported incidents according to the taxonomy provided in the ENISA Article 13a Technical Guideline on Threats and Assets, https://resilience.enisa.europa.eu/article-13/guideline_on_threats_and_assets

[58] ENISA Technical Guidance on Incident Reporting. https://resilience.enisa.europa.eu/article-13/guideline-for-incidentreporting/Article_13a_ENISA_Technical_Guideline_On_Incident_Reporting_v2_1.pdf

# Evolution of voice services

## The way that voice services are being delivered is changing

7.18 Internet-based providers such as Skype and WhatsApp are already offering consumers low-cost calls, usually coupled with additional features such as messaging or photo and video sharing. Many businesses are exploiting the reduced costs and enhanced capabilities of voice-over-IP (VoIP) technology. In response, traditional communications providers are looking to improve the services that they offer.

7.19 At the same time, the Public Switched Telephone Networks (PSTN) that have traditionally delivered voice services are coming to the end of their economic life. Globally, it is becoming increasingly difficult to maintain them, as the availability of spare parts and the engineering knowledge to effect repairs reduces.

7.20 Different communications providers are at different stages of managing this process:

7.20.1 BT is planning to fully migrate customers off its PSTN network by 2025 and is currently trialling the first IP-based voice services that will replace those offered by the PSTN. It is expecting to start piloting a range of new services in late 2017 leading to a full commercial launch thereafter.

7.20.2 Virgin Media is deploying fibre to the home under Project Lightning between now and 2019 and we can expect it to move to the adoption of IP voice services to replace its current PSTN based offering.

7.20.3 KCOM expects around three quarters of its network will have ultrafast capability by the end of 2017 under its Project Lightstream. Consequently, we would expect introduction and increasing adoption of IP voice services over roughly the same timetable.

7.20.4 TalkTalk and Sky both already operate an IP-based voice network, albeit still using analogue transmission over the LLU copper connections it buys from Openreach. With the increasing adoption of superfast services, both may choose to migrate customers to “broadband voice”, using the experience gained in the full fibre trial they are undertaking in York with CityFibre.

7.21 The UK is not alone in this process. Internationally, operators are also considering strategies for this “PSTN switch off”. An Ofcom-commissioned study for the 2014 Infrastructure Report noted that Verizon and AT&T in the US are looking to migrate customers, as are various European countries (e.g., Germany). More recently, the Body of European Regulators for Electronic Communications (BEREC) has published a report of case studies on migration to voice over IP across Europe[59].

## Migration to new services will bring consumer benefits

7.22 Moving voice services to broadband, away from traditional delivery, means that new voice services will have different characteristics. New services can support new features and new functionality.

[59] http://berec.europa.eu/eng/document_register/subject_matter/berec/reports/6486-berec-report-case-studies-on-migration-from-potsisdn-to-ip-on-the-subscriber-access-line-in-europe

7.23 The evolution of voice services lowers barriers to entry to the provision of primary fixed voice and messaging services, and the cost of providing the service will fall to very low levels. We may see more companies enter, with better prices and more innovation; for example, intelligent call-blocking to combat nuisance calls, redirection and measures to improve digital inclusion. Using voice over broadband for fixed voice-only consumers may also help achieve 'universal broadband' by default. If connections to all homes are broadband-enabled even if only to allow an IP-based voice service, it should be possible to quickly (and potentially remotely) enable data services on demand to any household.

### In many cases, the consumer experience will be largely unaffected

7.24 It is important that migration itself does not cause disruption. Migration will work best where people migrate voluntarily, and where operators' migration strategies rely on developing new services which make it attractive to move. The BEREC report on migration across Europe found there tended to be fewer issues with the migration process where it was customer-driven.

7.25 For many, migration to voice over IP will be voluntary. Consumer and business use of voice services is already changing, as more people use mobile voice services instead of fixed, and as a number of users, especially businesses, are already choosing to move to voice over IP. In new-build housing developments, where providers are already deploying full fibre broadband services, residents are already using VoIP, as there is not a copper wire over which to deliver a voice service.

7.26 For those who have and use a fixed telephone line within the home, PSTN migration should result in little noticeable change, both in terms of the consumer experience, and of the steps required to make the change. For consumers who already use a broadband connection for data services, it should be a relatively simple matter of moving their existing telephones from the PSTN to their broadband connection, via an adapter or suitable broadband router. Below, we consider those consumers who do not already have a broadband connection.

### However, there are challenges to managing migration for some consumers

7.27 Whilst switch off should have few implications for the majority of consumers, for others there may be important challenges which require careful consideration.

7.28 There are 3.2m voice-only consumers in the UK. For these customers, broadband technology will need to be installed in the home in order for fixed telephony services to continue. While this technology may be capable of supporting telephony and broadband, it may have only the telephony elements of the service activated, depending on customer requirements and demands. Alternatively, customers who want voice-only services may be offered a telephony-only router.

7.29 Where required, voice services can be delivered to consumers in a manner that looks just like traditional telephony, and consumers may not even be aware that the underlying connection is now broadband. We estimate that it will be particularly important for around a half of voice-only customers to continue to benefit from a service that is delivered in a manner that they recognise as fixed telephony.

### For businesses, outstanding compatibility issues need to be resolved

7.30 There are a number of non-voice legacy applications which run over the PSTN which are typically used by business customers. These include the use of fax machines and

dial-up modems (for point of sale card readers for example) as well as point to point connections for industrial purposes such as process monitoring.

7.31 BT's previous work to move to broadband-based voice services during the 2005/6 21CN programme identified a number of the relevant issues which we are aware still exist today[60]. This programme revealed that there were a number of applications which depended on technical characteristics of legacy networks beyond basic delivery of voice, such as way that the PSTN handles signalling tones in the network. As the industry again looks to make this migration, it is clear the process will need to take into account the needs of these specialist service providers and end users.

7.32 Ofcom has addressed similar issues during other technology migrations. For example, we are overseeing an effective migration away from analogue leased lines used for critical applications such as the protection against overload conditions in the National Grid or to control water supplies. We have already publicly signalled that these are approaching end of life, and are actively monitoring migration to modern equivalent services.

## Resilience in emergency situations is a particular concern for Ofcom

7.33 One of the highest profile concerns about PSTN switch off is the ability of individuals to make 999 calls within the home during a power outage. Traditional telephones on fixed lines provided this capability, because they are powered from the local exchange. IP-based services require an alternative solution – typically some form of battery backup in the home and for any electronics in the access network, or a fall back solution such as the ability to send calls over a mobile network when power to the fixed network fails. Ofcom's initial conclusions from the Strategic Review of Digital Communications[61] stated that we will "assess what operators are doing on a case-by-case basis, provided the technical solution delivers a level of protection equivalent to that provided by traditional means".

7.34 In this context, it is important to note that two thirds of calls to emergency services are now made on a mobile phone. Of the remaining third, it is likely that the majority are made on cordless phones, which also do not currently work during a power outage. Nonetheless, there remains a significant minority of people for whom the capability for the landline to continue to work during a power cut could offer a lifeline in an emergency.

7.35 PSTN switch off also raises concerns about other services which may be required in an emergency. Certain social care devices, such as personal alarms, have traditionally run over the PSTN. The calls that these devices make can traverse a number of different networks between source and destination, and as some of these intermediate networks migrate to IP-based technologies, interoperability issues are beginning to manifest.

7.36 The scale of these problems may increase as widespread migration of networks from traditional to IP-based technologies increases. However, as network technologies are evolving, so too are the services and devices that run over them, in order to become more IP-compatible, and therefore able to offer additional functionality and features. The providers of such services have already engaged with Ofcom and with their CPs

[60] Many of these were identified in our NGN consultation: https://www.ofcom.org.uk/__data/assets/pdf_file/0016/43018/main.pdf
[61] https://www.ofcom.org.uk/__data/assets/pdf_file/0016/50416/dcr-statement.pdf, February 2016

regarding migration, to ensure that services can remain operational or are superseded in good time before PSTN switch-off occurs.

## Consumer protection principles Ofcom will apply during migration

7.37 We have set out above that it is important that migration itself does not cause disruption. It is important that Ofcom is satisfied that proposed migration processes will not result in bad outcomes for consumers and businesses. Fundamentally we are seeking to ensure that migration does not result in undue disruption to customers, and that they are no worse off, either financially or functionally, as a result of it.

7.38 As such, we will seek to uphold the following principles during any such migration:

7.38.1 Emergency services access should be provided by all voice services in accordance with the relevant General Conditions (GCs). Note that these GCs are currently being reviewed, and we expect to publish revised Conditions in Spring 2017.

7.38.2 Technical solutions for ensuring reliable operation of new voice services, for example during localised or widespread power outages, should provide levels of protections equivalent to that provided by traditional means. We will assess the suitability of such solutions on a case-by-case basis, taking into account the technical limitations and customer usage of both the traditional and new services.

7.38.3 New voice services will maintain existing protections for vulnerable consumers in a manner which is appropriate for the technology they employ and their usage.

7.38.4 Equivalents to the current social phone tariffs and rules on the sensitive handling of debt will be applied to future voice services where appropriate.

7.38.5 Before and during any planned withdrawal, providers of existing voice services will work with third party service providers which rely on them, in order to minimise end customer disruption. In particular, voice service providers should make all reasonable efforts to ensure their changes do not cause excessive disruption to services used by vulnerable customers, such as personal alarm systems.

7.38.6 Providers of traditional voice networks must give reasonable notice to their wholesale customers of any intention to withdraw relevant voice services, or to replace them with alternatives based on different network technology.

7.38.7 Customers who do not migrate on a voluntary basis should be no worse off than they were before migration.

7.38.8 Vulnerable consumers must receive any assistance they require for the migration process and continue to receive a service they recognise as a telephony service.

## Ofcom will need advance sight of operators' plans for migration

7.39 In order to ensure migrations proceeds in line with the principles set out above, there are a number of particular areas where Ofcom expects to have early sight of operators' planned approach.

7.40 Firstly, implications for the end user experience:

7.40.1 Prior notification to end users - how will users be notified and when?

7.40.2 The migration process - what form will this take, both for customers who move voluntarily, and those who do not?

7.40.3 Replacement services - what alternative options will be offered to consumers and businesses? In particular, for consumers, what replacement service will be offered to BT Basic customers?

7.40.4 Consumer access services - what is the migration process for access services, such as text relay?

7.40.5 Pricing - how will replacement services be priced? It is essential that voice-only customers do not face additional costs as a result of moving to VoIP.

7.41 Secondly, implications for emergency services:

7.41.1 Emergency access obligations - to what extent will the current requirements (free access, caller location, prioritisation) apply to new services, including over-the-top (OTT) services, i.e. services delivered over the internet?

7.41.2 Power resilience of replacement services - for how long will services continue to work during power outages, or by what other means would access to the emergency services be possible?

7.41.3 General resilience of replacement services - what level of resilience can be expected?

7.42 Thirdly, implications for downstream service providers:

7.42.1 Third party providers - how will these providers be consulted with ahead of migration? How will it be ensured that end customers are aware of the changes and their options in good time?

7.42.2 Alternative service providers - what will be the impact on competition?

## Ofcom will work with industry to prepare for PSTN switch off

7.43 We understand that preparation for PSTN switch off will necessarily involve complicated dialogue, involving a wide range of parties, both across the telecoms industry and beyond. As such, we recognise that there will be a need for co-ordination, which will likely require a new, specific forum to ensure that discussion can progress efficiently and effectively.

7.44 The responsibility to ensure that migration does not result in disruption to end users lies with industry. Ofcom has an important role to play in setting out our expectations for switch off, whilst it is industry's role to set out how this will be achieved. Ofcom will monitor industry's progress, and enforce specific obligations in due course, as the process takes place.

# Mobile network resilience

## Mobile services are increasingly used as the first choice and the last resort

7.45 As discussed above, the way that fixed voice services are delivered is changing and this raises particular concerns in relation to emergency services access, and more general communications during emergencies, particularly for vulnerable customers. Already though, fixed voice has made way to mobile voice as the primary mechanism used to contact the emergency services. We have also seen that in major emergencies native and "over the top" services on mobile networks are playing an essential role in allowing people to continue to communicate effectively and obtain information. This will soon include the communications systems used within the emergency services, as they move away from their current dedicated wireless network onto the public mobile network.

7.46 These trends shift the role of mobile services from desirable to essential. Major outages, such as those caused by the UK winter floods of 2015, have raised concerns about the resilience of mobile networks, and this issue is likely to become more prominent over time.

## This places requirements on both coverage and reliability

7.47 Understanding and improving mobile coverage is rightly an area which has received significant attention. However, coverage alone is not enough to discharge the role mobile services now play; services also need to be reliable in order to be available to perform their essential functions when required.

7.48 In common with fixed network operators, mobile operators take steps in the design and operation of their networks to ensure they are reliable. The mobile nature of the service provides additional levels of resilience, for example offering the possibility of a customer relocating to avoid a localised failure or perhaps taking advantage of overlapping coverage from adjacent cells in order to maintain service without doing anything at all. In the UK, calls to the emergency services can also be made from any other available network if the customer's own network is unavailable.

## Mobile networks are more vulnerable to widespread power outages than legacy fixed networks

7.49 The resilience to a loss of mains power is very different between fixed and mobile networks. The customer equipment used with fixed voice services requires an external source of power in order to operate. In the case of the cordless phone basestations used in most homes, this comes from the customer's own mains power, and so the ability to make a phone call will immediately be lost if the customer's home experiences a power cut. Traditional "wired" phones however, receive their power over the copper phone line that connects them to their network provider. Virgin Media supplies this power from its street cabinets and BT from its exchanges, the former typically having batteries capable of maintaining service for several hours, and the latter's back-up power typically sufficient for power cuts lasting several days or more.

7.50 Mobile handsets have their own power and will continue to operate until they next need charging. However, the extent to which the network itself will continue to operate during a power failure is variable. The central, or "core" network elements which can affect the services of a large proportion of an operator's customer base typically have similar protection to fixed networks, lasting several days. However,

individual base stations may have little or no ability to offer service during power cuts, but this varies by operator and by individual base station. Some base station locations impose practical limitations on aspects such as size, weight, noise generation and environmental impact which can limit the ability to install back-up power. In other cases, the operator may simply decide the cost of installing and maintaining additional back-up power is not justified.

7.51 The features such as mobility, emergency call roaming and overlapping base station coverage make it difficult to represent the relative levels of reliability between fixed and mobile services in a simple fashion. However, the evidence from recent winter storms suggests that when there is a widespread loss of mains power, mobile voice services typically suffer more than fixed voice. Although in practice many households will lose fixed voice service because their cordless phones rely on mains power, they do have the option of keeping a corded pone for such situations. In contrast, even if a mobile customer can keep their handset charged, there is little they can do if the network has failed due to power loss.

7.52 As the role of mobile services as the primary communications channel for many customers increases, a significant investment in the networks will be required if their vulnerability to loss of mains electricity is to be reduced.

7.53 As part of a project on cross sector resilience undertaken by the United Kingdom Regulators Network (UKRN)[62] and led by Ofcom, we identified this vulnerability in what is becoming an increasingly important element of the UK's "Critical National Infrastructure". Government has been working with industry to understand how this can be rectified, and the scope and scale of the network changes needed. It is vital that this work is progressed and brought to fruition.

[62] See http://www.ukrn.org.uk/wp-content/uploads/2016/07/2015AprCSR-Phase1Report.pdf

Section 8

# The continuing evolution of television

8.1 The means by which television services are distributed and consumed have continued to evolve over the last year. Increasingly, broadcast and broadband delivery technologies are being brought together by more sophisticated consumer receiver equipment to provide consumers with a hybrid viewing experience. There has also been a continuation of the move towards higher resolution, more *life-like* TV formats, with UHD (Ultra High Definition) content now available on some broadcast and broadband delivery platforms.

8.2 In this section we set out three key themes:

8.2.1 **The live consumption of TV channels remains popular with viewers:** Viewing of live TV (i.e. broadcast TV content watched at the time of transmission) represents over 80% of viewing and is being complemented by an expanding range and capability of catch-up modes (digital video recorder and online).

8.2.2 **There has been a significant increase in both the number and sophistication of hybrid broadcast/broadband TV platforms:** Hybrid TV platforms are continuing to develop, including the launch of Freeview Play on the DTT platform. These platforms are seamlessly merging broadcast and online content into one consumer experience, where the viewer becomes 'abstracted' from the actual means of delivery.

8.2.3 **The majority of consumers can receive HD and the first Ultra-High Definition (UHD) services are now available:** 59% of households now access HD services and approximately 30% of TV sales support HD and UHD[63]. UHD Blu-ray discs are available, and satellite and online distribution of UHD content has started. HD and UHD services require higher connection speeds, limiting their reach to households with higher speed broadband connections.

## Consumers are able to view TV from a growing range of sources

8.3 Consumers in the UK receive digital television from a number of providers:

8.3.1 **Satellite:** TV services over satellite are available through platforms such as Sky's pay-TV service, or at no cost through Sky's UK viewing card, and through Freesat, which is available for a one-off digital receiver cost.

8.3.2 **Cable:** Virgin Media makes TV available over its cable network and passes 44% of UK homes. It has set a target to increase the coverage of its cable network by 4 Million homes and, once implemented, this is expected to increase cable TV coverage to around 65% of UK premises.

[63] Many of these models also support the new High Dynamic Range (HDR) standard, which gives TV pictures greater contrast and more vibrant colours.

8.3.3 **Digital Terrestrial Television:** A wide range of free-to-air channels is available via an aerial, accessible through Freeview and through hybrid boxes (Freeview Play, Now TV and YouView).

8.3.4 **IPTV:** A number of different providers, including BT, Now TV, TalkTalk and Plusnet deliver linear broadband TV services. Synapse TV and Connect TV offer a range of IPTV channels linked from slots on the Freeview electronic programme guide (EPG). Channel related catch-up content is also delivered online (supplementing DVR use) and on-demand non-catch-up content is available from a wide variety of providers including Netflix, Amazon Prime, and YouTube.

8.4 The coverage of the different: national, commercial, regional and local DTT multiplexes is shown in Figure 35 and Figure 36 below.

**Figure 35: Coverage of DTT national, interim and local services**

| Multiplex | Standards | Bit rates (Mbit/s) | Coverage, premises |
|---|---|---|---|
| PSB1 (BBC A) | MPEG2 / DVB-T / 64QAM | 24 | 99% |
| PSB2 (D3&4) | MPEG2 / DVB-T / 64QAM | 24 | 99% |
| PSB3 (BBC B) | MPEG4 / DVB-T2 / 256QAM | 40 | 99% |
| COM4 (SDN) | MPEG2 / DVB-T / 64QAM | 27 | ~90% |
| COM5 (Arqiva A) | MPEG2 / DVB-T / 64QAM | 27 | ~90% |
| COM6 (Arqiva B) | MPEG2 / DVB-T / 64QAM | 27 | ~90% |
| COM7 | MPEG4 / DVB-T2 / 256QAM | 40 | ~76% |
| COM8 | MPEG4 / DVB-T2 / 256QAM | 40 | ~76% |
| LTVMux | MPEG2 / DVB-T / QPSK | 9 | ~54%* |

*Source:Ofcom*

** Local coverage from 21 currently on air stations, of 34 granted licences*

**Figure 36: Coverage of DTT regional services**

| Multiplex | Standards | Bit rates (Mbit/s) | Regional coverage |
|---|---|---|---|
| NIMux | MPEG2 / DVB-T2 / QPSK | 9.8 | ~71%† |
| GIMux (Manchester) | MPEG2 / DVB-T / 16QAM | 18.1 | ~55%‡ |

*Source:Ofcom*

† *Expressed as a percentage of households in Northern Ireland*

‡ *Expressed as a percentage of households in Greater Manchester*

**Figure 37: UK coverage of Digital satellite TV and Virgin Media cable broadband**

| Platform | Availability | Notes |
|---|---|---|
| Digital satellite TV | 98% | Relates only to the ability to achieve a necessary line of sight path to the satellite and does not include other factors that can affect coverage including: access in multi-dwelling units where it is not feasible to install a dedicated household satellite dish and there is no internal wired distribution system for satellite, and the need for planning permission in some locations. |
| Virgin Media cable broadband | 45% | Proportion of premises able to receive Virgin Media cable broadband services, June 2016 |

*Sources:Ofcom and operators*

## The ways in which consumers watch TV are evolving

8.5 Live TV remains by far the most popular way of viewing TV, but continues to decline slowly each year.

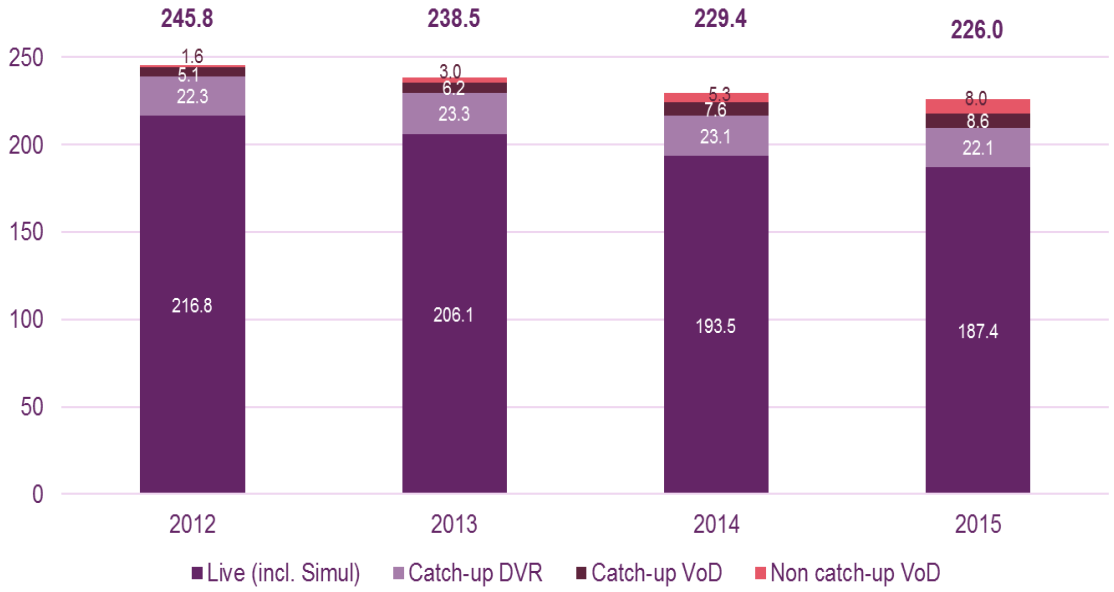
8.6 However, there has been an increase in the use of TV channel related catch-up services, through both digital video recorders (DVRs) and online sources such as the BBC iPlayer and All 4.

8.7 Non catch-up video on demand (VoD) viewing continues to increase, albeit from a low base.

8.8 Overall, there has been a continuing decline in the amount of time spent watching long-form video content. The Digital Day 2016 survey[64] shows that this decline is commensurate with a rise in the use of a variety of alternative media services including social media, games and short form video content.

[64] The Digital Day findings are in section 1.4 from pages 15-29 of CMR 2016. https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf

**Figure 38: Average daily viewing minutes across all devices for live TV, catch-up DVR, catch-up VoD and non-catch-up VoD.**



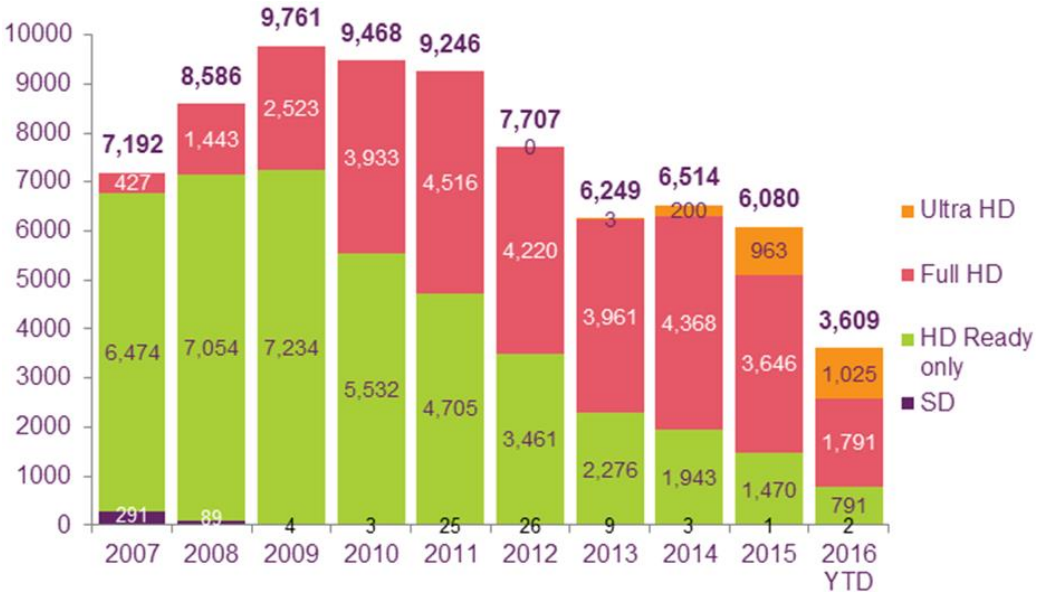

*Source: 3 Reasons estimates (including BARB data). Base: all devices, long-form professional audio-visual content. Live includes simulcast. Excludes physical consumption (e.g. DVDs) and short-form.content. DVR data is based on a 7 day playback period.*

## The majority of consumers are able to receive HD services, and the first UHD services are now available

8.9 Sales of HD compatible sets represent over 99% of new set sales (Figure 39Figure 39), and UHD compatible sets now represent 30% of new set sales. Sales of SD sets continue to decline and are now almost insignificant: a decision by Freeview that from 2017 only HD sets will be permitted to carry the Freeview brand logo is likely to mean that nearly all new DTT sets will be HD capable.

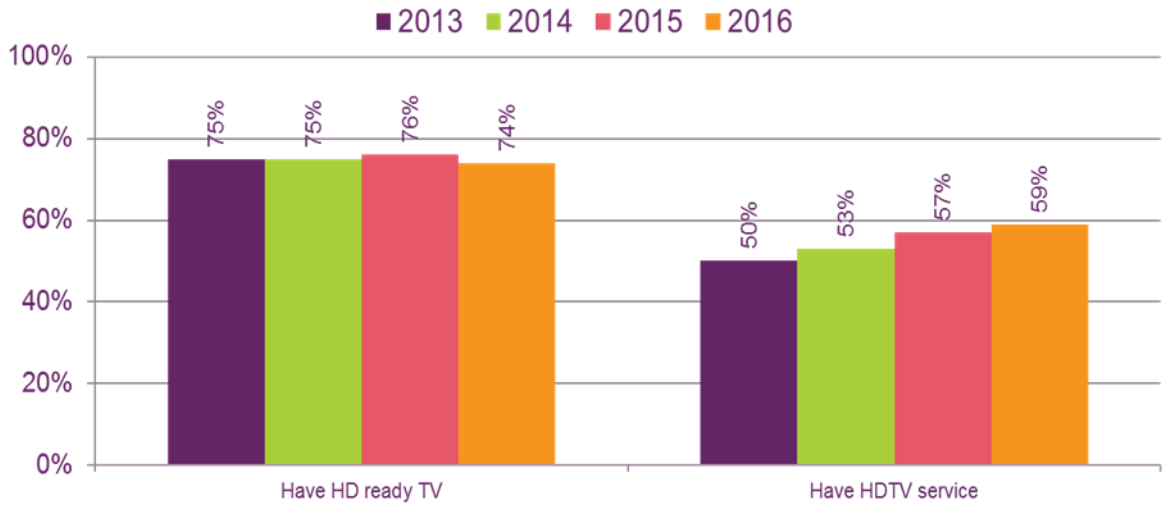
8.10 59% of all TV households are now accessing HD services (Figure 40). This figure is likely to grow further as more consumers replace existing SD sets with HD capable sets.

**Figure 39: Sales volume share of receivers, by technology (000's)**




*Source GfK: sales volumes of SD, HD Ready, Full HD and UHD receivers*

**Figure 40: Take-up of HDTV sets and HD services, smart TVs and DVRs.**



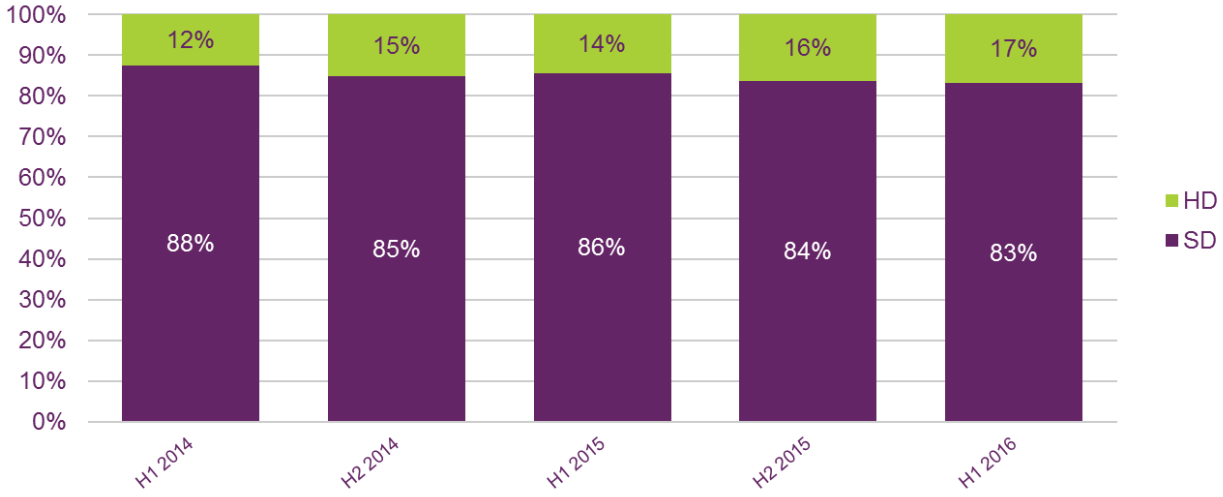

*Source: Ofcom Technology Tracker, data as at Q1 2013-2014, then H1 2015-2016.*
*Base: All adults aged 16+ with a TV in the household: 2013 (3661), 2014 (3635), 2015 (3616), 2016 (3606)*

8.11 Overall, viewing of the HD versions of the main five PSB channels continues to grow slowly (see Figure 41) and now accounts for 17% of viewing. There is a notable disparity between the amount of HD viewing of some PSB channels. For example, the HD viewing of BBC One is at 11% and BBC Two at 33%.

8.12 For a number of potential reasons the viewing of PSB channels in SD remains strong, including: the higher position of SD services in the electronic programme guide (EPG), relatively small differences between the perceived quality of SD and HD

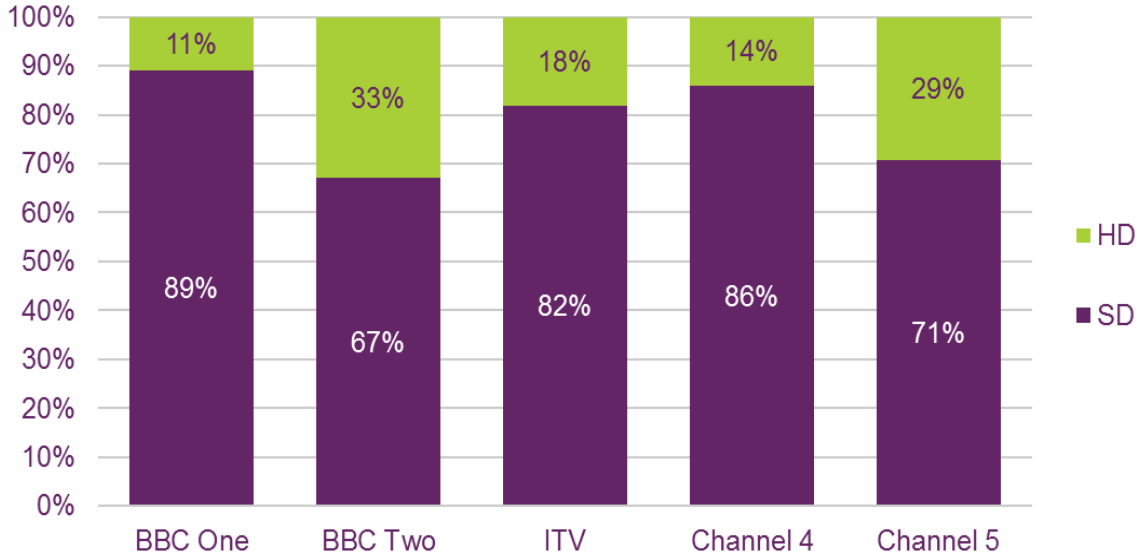
services, and a lack of regional opt-outs in some HD services. Figure 42 shows the average proportion of viewing of SD and HD for the main five PSBs individually.

**Figure 41: Average contribution of viewing of SD and HD for the main five PSBs combined, by half year January 2014 – September 2016**




*Source: BARB. Individuals 4+ with HD available in the home. Average proportion of viewing of the HD channels for BBC One, BBC Two, ITV, Channel 4 and Channel 5 combined.*

**Figure 42: Average contribution of viewing of SD and HD January – September 2016**




*Source: BARB. Individuals 4+ with HD available in the home. Not all available HD channel services are separately reported and so we have used the main five PSBs for our analysis (their combined share of total broadcast TV viewing in 2015 was 51%)*

8.13 The last year has seen a significant increase in the number of UHD (4K) capable devices and sales of UHD TVs have now reached 30% by volume of the market. UHD content is available on UHD Blu-ray disc; via Satellite from Sky (through Sky Q's silver's red-button - covering 124 games in the 2016/17 Premier League); and online through BT's Ultra HD YouView box and Amazon's Fire TV. The latest DTG (Digital Television Group) D-Book specification, released in November 2016, provides for online UHD content.

8.14 There have been, as yet, no announcements of UHD services on DTT.

## A number of trends are driving up IPTV viewing

8.15 As we set out in Section 4, the amount of data use on fixed networks has grown by 36% over the past year, driven in large part by video. A number of distinct trends suggests that video traffic will continue to grow over fixed networks:

8.15.1 **Increased take-up of broadband services:** The majority of households have a TV or set top box connected to the internet. Research conducted by media consultancy 3 Reasons at the end of 2015 shows that around 62% of UK TV homes had a TV connected to the internet via a set top box or a smart TV. This figure increases further if devices such as games consoles and dongles are included.

8.15.2 **Growth in hybrid TV services:** The growing range of hybrid broadcast/broadband services and devices is likely to further increase the consumption of broadband TV services. In addition, the improving ease of use of these services supported by better user interfaces and a more seamless integration of broadcast and online content are making it easier and more beneficial for viewers to access on-demand connected TV services.

8.15.3 **Growth in online catch-up TV viewing.** Catch-up TV is a significant and growing mode of viewing - fuelled by DVRs, connected boxes and smart TVs. And, as more catch-up viewing is carried out online, the demands for internet bandwidth and capacity are likely to grow further.

8.15.4 **Growth in other online TV services.** The use of non-catch-up video on demand services also continues to grow. For example, the proportion of adults watching short online video clips (e.g. YouTube and Vimeo) per week has risen from 20% in 2014 to 25% in 2016[65].

8.15.5 **The use of subscriber video on demand (SVOD) is also growing.** For example, more households are subscribing to discretionary video-on-demand services such as Netflix, Now TV and Amazon Prime[66]. However, subscription video-on-demand services are, on the whole, complementing rather than replacing conventional TV[67].

8.15.6 **Finally, there is a growing take up of linear IPTV services.** Linear internet TV (IPTV) services, such as BT TV and Now TV, are continuing to add customers, competing with existing pay-TV platforms such as Sky and Virgin Media, particularly at the low-cost end of the market.

8.16 As consumers move onto faster 4G and 5G mobile services it is expected that video viewing on mobile phones will continue to increase, but it is an open question as to

[65] See page 16 of the UK Communications Market Report 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf
[66] 27% of all UK households had a subscription service to at least one of Netflix, Amazon Prime or Now TV in Q3 2016 according to the BARB Establishment Survey.
[67] See pages 64-65 of the UK Communications Market Report 2016 *https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf*

whether the majority of this viewing in the future will be of live TV services or on-demand content.

## Implications of changing viewer behaviour for broadband infrastructure

8.17 As discussed in Section 4, the vast majority (99%) of broadband connections are, in principle, now capable of delivering IPTV in standard definition, since they have a speed of above 2Mbit/s.

8.18 Currently, a broadband connection speed of at least 2Mbit/s is needed to deliver an SD video stream, from 6 to 8Mbit/s for an HD stream, and from 20 to 25Mbit/s for a UHD stream. In practice higher headline broadband speeds than these may be needed to achieve a good consumer experience. This might be because other services might be being accessed at the same time over the broadband connection, or the headline connection speed is not available all of the time due to congestion in the internet delivery chain.

8.19 The new and more efficient HEVC (High Efficiency Video Coding) compression standard is helping to reduce the connection speeds needed to deliver video. This standard is being used to deliver the new UHD services available from Amazon Prime, BT, Netflix and YouTube. Despite the use of this more efficient compression standard, BT currently recommends that a connection speed of at least 44Mbit/s is needed to access its UHD sports services.

8.20 If HEVC is more widely utilised for IPTV, it could also reduce the connection speeds required to deliver SD and HD services.

## Implications of changing viewer behaviour for broadcast infrastructure

8.21 Viewers are starting to embrace higher resolution, more life-like TV services, and the use of internet connectivity to access a wider range of content at times that are more convenient to them. To meet these expectations, TV platforms need to continue to evolve; including:

8.21.1 Enhancing their hybrid DTT/broadband TV offer; and

8.21.2 Upgrading broadcast transmission and transmission standards.

8.22 Some of the improvements are already underway. For example, the Freeview Play service offers consumers easier-to-use IPTV services. Freeview has also announced that the Freeview label will be available only for HD (and UHD) products as of 2017, and the latest D-Book specification will support UHD IPTV services. Sky has similarly launched its Now TV platform which integrates DTT and IPTV services, and its Sky Q platform which integrates satellite and IPTV services, and which supports UHD.

8.23 An improved selection of HD channels on DTT made possible in part by two interim DTT multiplexes which have widened the range of HD services on the platform. HD services use more efficient compression and transmission technology (MPEG4 and DVB-T2) which provide more channel capacity and which can, therefore, effectively expand DTT capacity for other services in the future.

## Annex 1

# Methodology

A1.1 Sections 4 and 5 of this report use new data gathered from the largest operators in each sector, as well as information already held by Ofcom. For fixed networks, we used input from the four largest networks, KCOM for services in Hull and smaller network providers. In the case of mobile networks, we gathered data from all four main network operators.

**Figure 43: List of operators that provided data on network availability**

| Name of provider | Types of networks and services |
|---|---|
| Arqiva | Public Wi-Fi |
| B4RN | Fixed networks: broadband |
| BT Group | Fixed networks: voice and broadband, public Wi-Fi |
| EE | Mobile networks: voice and broadband, public Wi-Fi |
| Gigaclear | Fixed networks: broadband |
| Hyperoptic | Fixed networks: broadband |
| KCOM | Fixed networks: voice and broadband, public Wi-Fi (Hull only) |
| IFNL | Fixed networks: broadband |
| $O_2$ | Mobile networks: voice and broadband, public Wi-Fi |
| Sky | Fixed networks: voice and broadband, public Wi-Fi |
| TalkTalk | Fixed networks: voice and broadband |
| Three | Mobile networks: voice and broadband |
| UK Broadband | Fixed networks: broadband |
| Virgin Media | Fixed networks: voice and broadband, public Wi-Fi |
| Vodafone | Mobile networks: voice and broadband<br>Fixed networks: voice and broadband |

A1.2 Much of the data presented in this report is based on the analysis of the new data provided by the operators. In this annex we summarise our approach to this analysis.

# Fixed broadband networks

## Coverage

A1.3 Our data on coverage of fixed broadband services is collected from the three main network operators, BT, KCOM and Virgin Media, and five smaller providers. In 2016 operators were asked to provide data for each address where a service was provided.

A1.4 For the overall coverage of fixed broadband, reported in Section 4, we have identified the number of UK residential and small business premises. This will exclude PO boxes and large organisations. For 2016 we have used a premise base of 29 million.

A1.5 We use premises data from the OS Addressbase Premium dataset[68] (May 2016 version), OS Addressbase Islands dataset[68] (May 2016 version). This is combined with additional geographic classifications from the ONS National Statistics Postcode Lookup (NSPL)[69] (Feb 2016 version) and to Urban and Rural categories derived from the Locale classification (Feb 2016 version)[70].

A1.6 Where we report on the availability of superfast broadband for SMEs, we have used an address match process to link our premise base to a business classification. For 2016 our SME premises base, with between one and 249 employees is 2.4 million. Data is based on the Blue Sheep Business Universe[71].

A1.7 The availability of address-level data allows us to create a comprehensive data set describing the characteristics of all available services and all operators present at premises across the UK. Many operators provided a unique property reference number (UPRN), a common identifier available for use in the UK. Other operators provided address information that would need to be processed and linked to our premise base. Over 45 million records were received from across all operators and 99% of our premise base were matched using a UPRN or building address reference. For coverage this provides a base denominator of 28.8m premises.

A1.8 Each operator provides information on the technology available together with predictions of download and upload speeds. After the address matching process these characteristics are assigned to each premise that enables further detailed analysis to be undertaken. We are able to adjust thresholds for our analysis to investigate different patterns of provision. For coverage we have used the maximum predicted download speed available at a premise to determine the broadband category a premise is represented in.

A1.9 We use 10Mbit/s because our data suggest that an average sync speed of 10Mbit/s is where data use begins to appear to not be constrained by speed. We use 30Mbit/s because this is our threshold, and the European Commission's threshold for superfast broadband.

[68] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[69] http://www.ons.gov.uk/ons/guide-method/geography/products/postcode-directories/-nspp-/index.html
[70] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf
[71] http://www.allmapdata.com/products/digital-map-data/business-poi/blue-sheep-poi/

A1.10 In previous years Ofcom collected data from operators on the percentage of premises in each postcode unit that could receive a service above a specified threshold. This required Ofcom to estimate the degree of operator overlap in each postcode and would lead to an over or under-estimate of the number of premises covered by a service. The use of address-level data means that a more accurate and comprehensive analysis is now available, however, this will not be directly comparable to previous analysis.

## Take-up, speeds and data use

A1.11 We gathered data from the main fixed broadband internet service providers (BT, KCOM, Sky, TalkTalk, Virgin Media and Vodafone) on both their retail services and the services they provide to other ISPs as a wholesale service. Three smaller operators also provided data on the customers they serve.

A1.12 Our analysis of broadband speeds is based on the information provided by these ISPs regarding the sync speed of each active line. This gives a measure of the maximum possible connection speed achievable between the ISP's access network and the consumer premises. Line speed measurements are typically a few Mbit/s lower than sync speed measurement, and they typically vary throughout the day depending on the level of congestion in the ISP's network.

A1.13 This data was collected at the address-level and by line identifier and involves a more complex matching process. In addition to matching records via the UPRN or address to our premise base, we also need to match wholesale providers including BT, Sky, TalkTalk and Vodafone) to the BT Openreach infrastructure using either a line identifier (where these are common) or via address matching. Of the 24 million records representing take-up, 93% (22.5m) were matched using a UPRN or address matching process. Fewer than 1% (181,000) of records could not be matched to a premise, whilst the remaining 6% were matched by postcode approximation.

A1.14 A premise is considered in our take up analysis if any line associated with that premise has a measured speed greater than zero.

A1.15 We set certain speed thresholds in some of our analysis, of 2Mbit/s, 10Mbit/s and 30Mbit/s. We include any ADSL/ADSL2+/VDSL modem sync speed below 2.2Mbit/s in our assessment of sub-2Mbit/s broadband, as some data is used in protocol overheads and so is not available to the end-user. We do not apply a margin to 10Mbit/s or 30Mbit/s because these thresholds are derived differently.

A1.16 We use 10Mbit/s because our data suggest that an average sync speed of 10Mbit/s is where data use begins to appear to not be constrained by speed. We use 30Mbit/s because this is our threshold, and the European Commission's threshold for superfast broadband.

A1.17 Our analysis of data use is calculated from the amount of data downloaded and uploaded on each line as reported by operators. We also collected data on the total data use between the hours of 6pm and midnight, to assess data use at 'peak times'. Our analysis considers all lines where the amount of data downloaded was greater than zero.

A1.18 The analysis of overall traffic mix and encrypted traffic is calculated from the individual traffic mix provided by each ISP, weighted by the total data downloaded by customers of that network.

# Mobile

## Coverage

A1.19 Our data on the coverage of mobile networks were collected from the four mobile network operators, EE, $O_2$, Three and Vodafone as 100m x 100m pixels referenced against the OSGB[72] grid system, for their coverage in June 2016 for 2G ,3G and 4G networks. Premises coverage is calculated from a base of 1.6 million postal delivery points, taken from the OS Addressbase Premium dataset[73] (May 2016 version), OS Addressbase Islands dataset (May 2016 version)[73]. This totals to 29 million premises.

A1.20 In addition, geographic identifiers are added from the ONS NSPL (Feb 2016 version)[74] and urban and rural categories are added from the Locale classification (Feb 2016 version)[75]. Roads data is taken from Ordnance Survey Meridian and LPS OSNI datasets. We set the following signal strength thresholds when estimating coverage.

| | Metric | Outdoor | Indoor and in-car |
|---|---|---|---|
| **2G** | RxLev | -81dBm | -71dBm |
| **3G** | RSCP CPiCH | -100dBm | -90dBm |
| **4G** | RSRP | -115dBm | -105dBm |
| **Voice (2G, 3G+4G)** | RxLev, RSCP CPiCH & RSRP | -81 dBm, -100 dBm & -115 dBm | -71 dBm, -90 dBm & -105 dBm |
| **Data (3G+4G)** | RSCP CPiCH & RSRP | -100 dBm & -115 dBm | -90 dBm & -105 dBm |

*Source: Ofcom*

A1.21 We apply the above technology-specific thresholds to each of 100m x 100m pixels to determine whether a sufficiently strong signal is available to successfully make a phone call or send or receive data. These pixels are aggregated to provide an estimate of either the landmass or the number of premises that are covered by the corresponding mobile technology.

## Data use

A1.22 We also gathered data on the amount of data uploaded and downloaded on each mobile cell in these networks.

[72] Ordnance Survey of Great Britain (OSGB) Coordinate System
[73] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[74] http://www.ons.gov.uk/ons/guide-method/geography/products/postcode-directories/-nspp-/index.html
[75] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf

A1.23 The analysis of overall traffic mix and encrypted traffic is calculated from the individual traffic mix provided by the four network operators, weighted by the total amount of data downloaded by customers of that network.

## Femtocells and public Wi-Fi

### Femtocells

A1.24 The mobile network operators that have more than 1000 femtocells on their networks provided information on the postcodes where these femtocells are located.

### Public Wi-Fi

A1.25 Our data on public Wi-Fi was gathered from the main providers of this service (Arqiva, BT, KCOM, O2, Sky and Virgin Media). These public Wi-Fi providers reported on the total data downloaded and uploaded at each of their public Wi-Fi access points, and the postcodes of these access points.

A1.26 Where they were able to do so, operators also provided information on the proportion of data downloaded and uploaded on 2.4GHz and 5GHz Wi-Fi.

### Internet

A1.27 We collected data from fixed internet service providers and mobile network operators about the nature of their internet interconnection (peering, transit or CDN), the capacity of that connection, the total volume of data through that interconnection in June 2015 and the physical location of that interconnection.

A1.28 From this, we calculated the proportion of traffic by each type of interconnection for each CP and weighted this by the total data used by their customers, to estimate the overall mix of internet interconnection traffic.

## Urban and rural classifications

A1.29 In 2016 we have used the Locale[76] classification to identify premises as being in an urban or rural area. Locale is a third-party data source based on the analysis of 2011 census output areas (OAs). Each OA is assigned to one of seven Locale Groups using a combination of Government conurbation definitions, population density at the OA- and postcode sector-levels, urban sprawl boundaries, OS roadmaps and additional visual inspection. The Locale classification was previously used by Ofcom in 2014 and earlier reports.

A1.30 Each postcode is assigned to a postcode unit so that the Locale urban and rural classification can be matched to premises by their postcode. For mobile analysis, each postcode centroid is assigned to its nearest OSGB coordinate at a resolution of 100m. Then each pixel can be assigned an urban or rural flag based on matching this co-ordinate to the 100m x 100m pixels used for mobile analysis. Where multiple postcodes exist in a single 100m x 100m pixel, the category with the highest number of premises associated with it is used.

[76] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf

A1.31 In last year's report Ofcom used the rural/urban classifications developed by DEFRA, NISRA and The Scottish Registry Office to produce urban/rural splits. Figures in the Connected Nations 2015 report using urban or rural categories are not directly comparable to this report. However, we have also re-classified any 2015 figures used in this report to the Locale categories to allow direct comparisons.

## Annex 2

# Glossary

**2G** Second generation of mobile telephony systems. Uses digital transmission to support voice, low-speed data communications, and short messaging services.

**3G** Third generation of mobile systems. Provides high-speed data transmission and supports multi-media applications such as video, audio and internet access, alongside conventional voice services.

**4G** Fourth generation of mobile systems. It is designed to provide faster data download and upload speeds on mobile networks.

**Access network** An electronic communications network which connects end-users to a service provider; running from the end-user's premises to a local access node and supporting the provision of access-based services. It is sometimes referred to as the 'local loop' or the 'last mile'.

**ADSL** Asymmetric Digital Subscriber Line. A digital technology that allows the use of a standard telephone line to provide high-speed data communications. Allows higher speeds in one direction ('downstream' towards the customer) than the other.

**Backhaul** The part of the communications network which connects the local exchange to the ISP's core network

**BARB** Broadcasters' Audience Research Board compiles audience measurement and television ratings in the UK. It is jointly owned by the BBC, ITV, Channel 4, Channel 5, Sky and the Institute of Practitioners in Advertising.

**Base station** This is the active equipment installed at a mobile transmitter site. The equipment installed determines the types of access technology that are used at that site.

**BDUK** Broadband Delivery UK

**Blu-ray** A digital optical disc technology capable of storing HD (High Definition) and, with Ultra HD Blu-ray, UHD (Ultra High Definition) resolution television.

**Broadband** A data service or connection generally defined as being 'always on' and providing a bandwidth greater than narrowband connections.

**CDN** Content Delivery Network - Networks of servers based in many geographic locations designed to improve the speed and quality of content delivery by routing requests to the closest server.

**CGNAT** Carrier Grade Network Address Translation - a technique that makes it possible to use fewer public IPv4 addresses to support more subscribers.

**Core network** The central part of any network aggregating traffic from multiple backhaul and access networks.

**DCMS** Department for Culture, Media and Sport.

**DOCSIS** Data Over Cable Service Interface Specification. It is a standard for the high speed transmission of data over cable networks.

**DSL** Digital Subscriber Line. A family of technologies generally referred to as DSL, or xDSL, capable of transforming ordinary phone lines (also known as 'twisted copper pairs') into high-speed digital lines, capable of supporting advanced services such as fast internet access and video on demand. ADSL and VDSL (very high speed digital subscriber line) are variants of xDSL).

**DTT** Digital Terrestrial Television. The television technology that carries the Freeview service.

**DVB-T** Digital Video Broadcasting – Terrestrial. A combination of technologies used to carry standard definition television. DVB-T2 is nearly twice as efficient, and is key to the carriage of HD channels

**DVB-T2** Digital Video Broadcasting – Terrestrial 2. A new, more efficient combination of technologies used to carry standard definition television.

**DVR** Digital Video Recorder (also known as a PVR – Personal Video Recorder). A digital set-top box including a hard disc drive or other storage technology which allows the user (or the service provider) to schedule recordings and download content, and the user to pause and rewind live TV.

**ENISA** European Network and Information Security Agency - a European Union agency responsible for cyber security.

**Femtocell** A small base station, typically installed indoors to improve indoor mobile coverage. A residential femtocell uses the consumer's broadband connection to offload the mobile data onto the fixed network.

**FTTC** Fibre to the Cabinet. Access network consisting of optical fibre extending from the access node to the street cabinet. The street cabinet is usually located only a few hundred metres from the subscribers' premises. The remaining segment of the access network from the cabinet to the customer is usually a copper pair.

**FTTP** Fibre to the Premises. A form of fibre optic communication delivery in which the optical signal reaches the end user's home or office. Also known as full fibre broadband.

**HD** or **HDTV** High-definition television. A technology that provides viewers with better quality, high resolution pictures.

**HDR** High Dynamic Range television. The ability to display a far greater range of contrast, with deeper blacks and brighter highlights.

**HEVC** High Efficiency Video Coding. The latest generation of video compression, allowing television programmes to be represented by around half the data required by MPEG-4.

**IP** Internet Protocol. This is the packet data protocol used for routing and carrying data across the internet and similar networks.

**IPTV** Internet Protocol Television. The term used for television and/or video signals that are delivered to subscribers or viewers using internet protocol (IP), the technology that is also used to access the internet. Typically used in the context of streamed linear and on-demand content, but sometimes for downloaded video clips.

**IPv4** The fourth and most widely used version of the Internet Protocol. It defines IP addresses in a 32-bit format, which looks like 111.111.111.111

**IPv6** The successor to IPv4. It uses 128-bit addresses, increasing the number of possible addresses.

**ISP** Internet Service Provider. A company that provides access to the internet.

**LINX** London Internet Exchange. A not-for-profit membership organisation that provides peering services to Internet Service Providers.

**LTE** Long Term Evolution. This is 4G technology which is designed to provide faster upload and download speeds for data on mobile networks.

**M2M** Machine to Machine. Wired and wireless technologies that allow systems to communicate with each other.

**MNO** Mobile Network Operator, a provider who owns a cellular mobile network.

**Modem Sync Speed** The modem sync speed represents the highest possible speed at which data can be transferred across the line.

**MPEG** the Moving Picture Experts Group produces standards for digital video and digital audio compression, which are used to reduce the amount of data required to carry television pictures.

**Multiplex** Multiple signals or streams of information carried together in the form of a single, complex signal. The separate signals are then recovered at the receiving end.

**Not-spot** An area which is not covered by fixed or mobile networks.

**Peer to Peer (P2P)** A distributed application that uses end users' computers as nodes to deliver service applications.

**Peering** A mutual agreement between two network providers to exchange traffic, either in private or via a public peering exchange.

**PSTN** Public Switched Telephone Network. The network that manages circuit switched fixed line telephone systems.

**QAM** Quadrature Amplitude Modulation. A means of combining and recovering signals with different phases and amplitudes.

**RIPE NCC** Europe and the Middle East, Réseaux IP Européens Network Coordination Centre - The Regional Internet Registry with responsibility Europe, the Middle East and parts of Central Asia. It oversees the allocation and registration of IP addresses in these areas.

**RIR** Regional Internet Registry. Provide blocks of IP addresses to telecommunications companies and Internet Service Providers within an allocated region.

**SD** Standard Definition television.

**SIM** Subscriber Identity Module. A SIM is a small flat electronic chip that identifies a mobile customer and the mobile operator. A mobile phone must have a SIM before it can be used.

**Smartphone** A mobile phone that offers more advanced computing ability and connectivity than a contemporary basic 'feature' phone.

**Superfast broadband** Broadband services that deliver download speeds of at least 30 Mbit/s.

**Transit** This is a paid for connection used by Internet Service Providers (ISP) for bandwidth from a provider of core internet connectivity. It is used to provide connectivity to data hosted on services where the ISP does not have a direct peered connection.

**UHD** Ultra high-definition television, providing a resolution of 3840 x 2160 pixels (4K).

**Ultrafast broadband** Broadband services that deliver download speeds of greater than 300 Mbit/s.

**Usage cap** Monthly limit on the amount of data that users can download, imposed by fixed and mobile operators for some of their packages.

**VDSL** Very High Speed DSL. A high speed variant of DSL technology, which provides a high headline speed through reducing the length of the access line copper by connecting to fibre at the cabinet.

**VOD** Video-on-demand. A service or technology that enables TV viewers to watch programmes or films whenever they choose to, not restricted by a linear schedule (also see 'push' VOD and 'pull' VOD.

**VoIP** Voice over Internet Protocol. A technology that allows users to send calls using internet protocol, using either the public internet or private IP networks.

**VoLTE** Voice of LTE, also known as 4G voice. A service that allows voice calls to be made over 4G networks

**Wi-Fi** A short range wireless access technology that allows devices to connect to a network through using any of the 802.11 standards. These technologies allow an over-the-air connection between a wireless client and a base station or between two wireless clients.

**xDSL** The generic term for the Digital Subscriber Line (DSL) family of technologies used to provide broadband services over a copper telephone line.