Infrastructure Report 2014

Ofcom's second full analysis of the UK's communications infrastructure

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About this document

Every three years, Ofcom is required by the Communications Act 2003 to prepare a report for the Secretary of State for Culture, Media and Sport on the status of electronic communications networks and services in the UK. We are then required to publish the report.[1]

The UK's communications infrastructure is a vital enabler, supporting a vast amount of economic and social activity, by both consumers and businesses. This report provides an overview of the state of that infrastructure: its coverage, capacity and reliability. We consider these at a national level and the variation across the UK.

The report looks at:

- the coverage, performance and capacity of networks and services;
- use of spectrum;
- infrastructure sharing; and
- security and resilience.

The main networks considered are the fixed broadband and telephony networks; mobile voice and data networks; Wi-Fi; and broadcast and radio networks. The report includes detailed analysis of operators' data, external research and an assessment of the main strategic and policy implications.

The first Infrastructure Report was published in November 2011. Since then we have issued annual updates, focusing on the areas of the most rapid change such as the coverage and capacity of fixed, mobile and broadcast networks.

This second full report will be of interest to those looking to understand the nature, performance and reach of the UK's communications infrastructure. It will be of direct relevance to policymakers and industry stakeholders and, we hope, will make interesting reading for anyone who wants to explore how our infrastructure is evolving.

Alongside this document, we are publishing data from the report in an interactive form on our website, at http://infrastructure.ofcom.org.uk. We are also publishing a number of research reports that we commissioned alongside this document. These are detailed in Annex 4.

[1] Sections 134A and 134B of the Communications Act 2003.

Contents

Section 1

Executive summary

Overview

1.1 Communications services are critical to the UK's economic success and social cohesion. They are used by the average UK adult for over half of their waking hours. The coverage, capacity and reliability of the digital infrastructure over which these services are provided are of fundamental importance to both consumers and businesses.

1.2 The majority of the investment to build and maintain communications networks is delivered by commercial providers, competing to deliver services to consumers and businesses. Ofcom is responsible for the regulatory framework that ensures effective competition. It is our role to help create the conditions that will foster efficient investment and innovation, leading to a wide range of high quality communications services throughout the UK.

1.3 However, the economics of networks means there are parts of the UK that will not be fully served by the market. There are also some services which may not be provided to all by the market. In these circumstances, Ofcom or the Government may intervene to further consumer and citizen interests.

1.4 Who takes action, and how, depends on the levers available. For example, Ofcom has moved to improve mobile coverage by attaching coverage obligations to mobile licences. The Government has intervened to improve the coverage of mobile networks and superfast broadband through public funding to subsidise wider roll-out.

1.5 The challenge when designing any intervention is to ensure that it is precisely targeted, so that it is an efficient means of achieving the policy goal, and at the same time minimises the risk of knock-on effects that could reduce competition or private sector investment. Such targeting requires an accurate and up to date understanding of the state of the UK's infrastructure.

1.6 This report is designed to provide this information. It follows the inaugural report in 2011 and a series of smaller annual updates. It considers how networks are adapting to increases in demand and highlights challenges for the future.

1.7 We have also created an online map and visualisation tool for much of the report's data. This allows users to assess the coverage and performance of the infrastructure in their area and compare it to others. The tool is available at http://infrastructure.ofcom.org.uk.

Fixed broadband services

Availability and take-up of broadband services

1.8 Fixed broadband technology is almost universally available and the average download speed for the entire UK is currently 23Mbit/s. However, broadband speeds available to consumers vary considerably and it is more useful to consider the availability of broadband services in several tiers:

- **Basic broadband – greater than 2Mbit/s.** The Government's Universal Service Commitment aims for universal availability of at least 2Mbit/s broadband. We estimate that only 3% of UK premises fall below this availability threshold. Although this percentage is small, the lack of even a basic broadband service poses considerable problems for those affected.

- **Standard broadband – greater than 10Mbit/s.** There is emerging evidence that a typical household requires a download speed of around 10Mbit/s. Below this level, demand is likely to be constrained. We estimate that 15% of UK households cannot currently receive 10Mbit/s.

- **Superfast broadband – greater than 30Mbit/s.** The deployment of superfast broadband, delivering download speeds of 30Mbit/s and above, started in 2009. Coverage and take-up have increased rapidly: superfast broadband is now available to 75% of premises in the UK, with take-up of 21%.

1.9 Superfast broadband is being delivered through a combination of commercial roll-out and a publicly-funded programme targeting those areas of the country which commercial providers are unlikely to reach. The Government's aim is to deliver superfast broadband to 95% of UK premises by 2017. This is an aggressive target and publicly-funded roll-out is currently reaching up to 40,000 new premises a week.

1.10 Finally, we note that 27% of households still do not take a fixed broadband connection of any kind. Some of these will be using mobile data services, such as 3G and 4G connections on their smartphones or tablets. However, around 18% of households have no home access to the internet, fixed or mobile.

Challenges for broadband roll-out

1.11 Although the overall availability of broadband services is improving, specific challenges remain for some consumers and businesses. And for those who are affected by poor performance, it is no consolation that the national average is improving.

1.12 We identify four specific sets of concerns: rural availability, city not-spots, the availability of superfast broadband to small and medium sized enterprises (SMEs) and the need for a roadmap from superfast to 'ultrafast' broadband.

1.13 **Rural roll-out.** Reaching the most rural premises in the UK is always a challenge, as it is more expensive to deploy networks in areas of low population density. The Government is looking at the range of technological options which might be used to provide superfast broadband to the 'final 5%'.

1.14 One specific challenge is that the Fibre to the Cabinet technology commonly used by BT to deliver Next Generation Access (NGA) does not always deliver superfast broadband speeds. This happens when the length of the connection from a customer to a cabinet is too long to support a speed of 30Mbit/s. It is a particular issue in Northern Ireland, where 17% of premises have access to an NGA service which does not deliver superfast speeds. In the UK as a whole the equivalent figure is 3%.

1.15 **City not-spots.** Availability concerns are not restricted to rural areas. For example, central London also has areas of poor superfast broadband coverage. Such urban not-spots are generally caused when there is no street cabinet to upgrade, because a customer has a direct connection to the local exchange.[2]

1.16 Work is underway considering how best to take fibre closer to the customer where there is no cabinet. Alternative commercial solutions are already available in a number of urban areas, including wireless solutions from a variety of competing providers.

1.17 **Availability of NGA technology for SMEs.** Small and medium sized enterprises (SMEs) make a substantial contribution to the UK economy. It is therefore particularly important that they have high quality connectivity. Their needs vary and some use widely available business-grade infrastructure and services such as traditional leased lines.

1.18 However, the improved performance of superfast broadband services compared to previous generations of broadband, coupled with its relatively low price compared to leased line services, means that SMEs will increasingly look to superfast broadband as a primary source of connectivity.

1.19 The current availability of superfast broadband based on BT and Virgin Media NGA technology is lower for SMEs than for residential premises.[3] At a national level, 56% of SMEs have access to NGA-based superfast broadband, compared to 75% for UK premises overall. Note however that some SMEs – especially larger ones – will have the option of other high speed connectivity services. We will be investigating the scale of the residual concern, and potential solutions, in the work we have recently announced on the availability and choice of communications services for SMEs.[4]

Figure 1 - FTTC and/or cable superfast broadband coverage for SMEs

	UK overall	Micro (excl. sole traders) *1-9 employees*	Small *10-49 employees*	Medium *50-249 employees*	Total SMEs *1-249 employees*
UK	75%	58%	51%	47%	56%
Urban	83%	70%	59%	53%	67%
Rural	22%	15%	17%	17%	16%

Source: Ofcom analysis of operator data

The development of ultrafast broadband

1.20 Looking further ahead, industry and policy-makers are now considering the phase of broadband evolution beyond superfast broadband. Since the technologies being used to deliver superfast broadband are capable of delivering speeds of around 100Mbit/s, the forward-looking debate tends to focus on developing a roadmap to speeds of a gigabit per second (1Gbit/s), commonly referred to as 'ultrafast broadband'.

[2] These direct connections are referred to as 'exchange-only lines or 'exchange outlet lines' (EOLs)
[3] Note that the definition we have adopted of SMEs excludes sole traders.
[4] In September this year we announced a range of work on SMEs. We are inviting views on current levels of availability, choice and quality of communications services for SMEs through a Call for Inputs: http://stakeholders.ofcom.org.uk/consultations/smes-cfi/.

1.21 This is a debate which is taking place internationally. A number of countries are considering how to move beyond current infrastructure to offer the highest possible broadband speeds in order to improve their international competitiveness. We are seeing some early deployments of ultrafast broadband in the UK and we need to consider how to build on this. A range of options are available, some evolutionary, others more revolutionary.

Evolutionary upgrade options

1.22 One route to ultrafast broadband is a further round of investment to upgrade the existing hybrid copper-fibre access networks. There are two main technology options for this:

- **'G.Fast'** is a new means of carrying broadband services over copper. It can deliver very high speeds over short lengths of copper. 800Mbit/s has been achieved in trials, but speeds above 1Gbit/s are practically feasible. A typical installation involves placing new equipment at distribution points close to the customer's premises, for example on street telephone poles. The distribution point is then connected by fibre to the core network.

- **Cable** networks also have an evolutionary path, through the adoption of DOCSIS3.1[5] and physical network rearrangement. This could also deliver peak headline speeds in excess of 1Gbit/s.

More revolutionary upgrade options

1.23 The evolutionary options described deliver benefits in their own right. They should also be seen as incremental steps in a longer term evolution which takes fibre to every home and every business. There are a variety of technology options for achieving this, generically referred to as **Fibre to the Premises (FTTP).**

1.24 The deployment of FTTP is not simple, with a range of technology uncertainties remaining. For traditional telecommunications networks, such as those operated by BT, there are two main technology options: passive optical networks (PON) and point-to-point fibre.

- PONs remove the need for active electronics in the access network reducing operational complexity and power consumption. However, they are fundamentally 'shared' amongst a number of end users, meaning maximum speeds may be limited.

- Point-to-point network architectures offer dedicated connections and potentially higher speeds as a result. However, they require active electronics in the access network and more fibre, increasing the overall cost.

1.25 Today we are seeing deployments of both types of network internationally. FTTP deployment in the UK has been limited so far. BT is offering 'fibre on demand' alongside its FTTC network, but has seen very limited take-up so far. We have seen smaller scale commercial FTTP developments in specific areas. For example, CityFibre is investing in all-fibre networks in various UK cities, with a trial deployment in progress in York. KCOM is rolling out its largely FTTP 'Lightstream' broadband in the Hull area, marketed with speeds up to 100Mbit/s.

[5] Data Over Cable Service Interface Specification is the technology used to deliver broadband over cable TV networks.

1.26 For cable networks such as that operated by Virgin Media, cable-specific fibre technologies such as Radio Frequencies over Glass (RFOG) and DOCSIS over Ethernet Passive Optical Networks (DPoE) can be used to deliver ultrafast broadband by exploiting the inherently greater bandwidth available in direct fibre connections to users.

1.27 In addition to providing potentially improved mobile performance, 5G technology may also open up new options for providing ultrafast broadband connectivity to homes and business, as an alternative to fibre-based access solutions.

Beyond broadband speed

1.28 As broadband speeds and superfast broadband availability increase over time, factors other than download speed may become more important in determining the consumer experience.

Upload speed

1.29 Firstly, it is important not to overlook upload speed, which can be crucially important for some services. High quality video calling, for example, requires both fast download and fast upload speeds. The average upload speed in the UK is currently 3Mbit/s, compared to the 23Mbit/s average download speed. For those premises with superfast broadband connections, the average upload speed is 8Mbit/s compared to the 56Mbit/s average download speed.

New evidence on drivers of broadband quality of experience

1.30 This report includes new analysis on the broadband quality of experience and its link to broadband speed. This suggests that for broadband speeds above 10Mbit/s, there are a variety of factors beyond speed which can have a greater on affect the consumer experience. These other factors include the performance of in-home equipment and wiring, backhaul capacity, and the means by which communications networks interconnect with content and service providers. Next year we will build on the work presented here, by quantifying these factors more accurately and considering how they can best be communicated to consumers.

Traffic management

1.31 The way that fixed and mobile providers use traffic management has a direct effect on network performance delivered to users. Operators use traffic management to minimise the effects of network congestion. Whilst the effect is often invisible to consumers, the issue has become high profile due to the ongoing ‘Net Neutrality’ debate.

1.32 Having reviewed the operators’ summaries of broadband and mobile traffic management practices, we believe they are now being more transparent with consumers over this issue. The most significant development is that all UK mobile operators have now discontinued packages which block access to VoIP services. On top of this, EE, Vodafone and Virgin Media have signed up to the Broadband Stakeholder Group (BSG) Open Internet Code of Practice. This means that all major consumer internet providers are committed to the self-regulatory approach, a key part of the Government’s policy on Net Neutrality. We will continue to monitor the market closely to ensure that transparency continues to improve.

Resilience and security

1.33 As the UK increases its dependence on communications infrastructure, the need for resilience and security grows. This report provides a detailed analysis of major network outages. We show, for example, that last year's severe flooding did not have a significant impact on the availability of communications services although it did prolong incident resolution times. We also report on the nature of cyber-attack incidents and our work with the Government to improve network security.

Fixed voice

1.34 Fixed ('landline') voice is near universally available across the UK. However use of traditional landlines for voice calls has been declining for several years and traditional voice networks are aging. Alongside this we see an increasing use of alternatives, including voice services delivered over broadband connections and mobile voice services.

1.35 Communications providers are therefore starting to consider the long term evolution of their traditional voice networks. This is likely to include greater use of voice delivered over broadband and may ultimately lead to the switching off of the traditional landline network (the 'PSTN' network).

1.36 This evolution has a number of implications for services built on PSTN functionality, including for example the level of service guaranteed for calls to the emergency services. We will be carrying out further work on this next year, to ensure that the long term evolution of voice networks is not disruptive for consumers and businesses.

Mobile network coverage and usage

1.37 Mobile services, both voice and data, are increasingly considered vital by consumers and businesses. Some 95% of households in the UK have mobile phones, and 16% are mobile-only: they have no voice landline. Mobile is important in business too: 79% of SMEs use mobile phones.

1.38 The consumer experience of mobile services depends very substantially on the quality of mobile coverage. There are however two practical issues which complicate measurement of mobile coverage:

- The maps of mobile coverage produced by operators are based on theoretical models, calibrated using measurements of actual performance that are broadly accurate overall but can never be absolutely accurate in predicting coverage at a specific location. We will continue to carry out work in this area.

- Consumers use mobile phones in many different situations – indoors, outdoors, on the move, in cars, as pedestrians along roads in built-up areas and in wide open spaces. No single measure of coverage can capture all these use cases. For this report, we have assessed mobile coverage against a range of different measures in order to gauge the overall consumer experience.

1.39 No theoretical model is perfect and there will always be some variance between predicted and actual coverage. We have carried out our own measurement programme for this report, as well as gathering data from operators.

Mobile voice coverage

1.40 The most commonly quoted measure of mobile coverage is the percentage of UK premises where a customer standing outdoors can make a call. Based on this measure, mobile voice coverage in the UK is generally good, with only 0.3% of premises having no coverage by any major network operator, sometimes referred to as 'complete not-spots'. The picture is somewhat less good for indoor coverage, with 2% of premises not covered by any operator. In-car coverage is similar, with 9% of A and B roads not covered by any operator.

1.41 Of greater concern are areas where at least one operator has a signal, but not all. These are referred to as 'partial not-spots'. From a consumer perspective, what matters most is whether their operator provides a service in their current location. We estimate that 3% of UK premises are in partial not-spots for outdoor coverage, rising to 16% for indoor coverage, and that 33% of A and B roads are in partial not-spots for in-car usage. The scale of partial not-spots in the UK means they are more likely to have a practical impact on the consumer experience than total not-spots (of which there are fewer). This is a priority for the Government and we are working closely with it and industry to improve coverage to address partial not-spots in particular.

MNO 2G coverage predictions[6] - UK level	Complete not-spots (no MNO has signal)	Partial not-spots (at least one MNO signal, but not all)	Served by all MNOs
Premises (outdoors)	0.3%	3%	97%
Premises (indoors)	2%	16%	83%
In car (A and B roads)	9%	33%	59%
Geographic (land area)	11%	21%	68%

1.42 2G networks are operated by EE, O2 and Vodafone. They provide similar total levels of coverage of the UK, but the network footprints do not perfectly overlap (leading to partial not-spots).

MNO 2G coverage predictions[7] - by operator	O2	Vodafone	EE
Premises (outdoors)	99%	99%	98%
Premises (indoors)	94%	92%	90%
Geographic coverage	78%	82%	78%
In car (A and B roads)	74%	78%	78%

[6] Coverage predicted using a threshold level of -86dBm for outdoor and in-car, -76dBm for indoor.
[7] Coverage predicted using a threshold level of -86dBm for outdoor and in-car, -76dBm for indoor.

Mobile broadband coverage

1.43 The availability of **mobile broadband services based on 3G** is lower than the availability of voice services. We estimate that 16% of UK premises are in either partial or complete not-spots based on outdoor coverage, rising to 29% for indoor coverage. 55% of A and B roads are in either partial or complete not-spots for in-car use.

1.44 **4G roll-out** has begun relatively recently, but the latest statistics show that good progress has been made, with some operators making significant increases in coverage over the period June to October 2014. We expect that 4G coverage will fairly quickly overtake 3G coverage and provide a substantial improvement in the availability of mobile broadband. This is partly because of the coverage obligation we have attached to one of the licences, and partly because some of the spectrum being used is intrinsically better at providing wide area coverage. O2's licence requires it to provide indoor 4G coverage to at least 98% of the population by the end of 2017, with at least 95% in Scotland, Wales and Northern Ireland. The other operators have indicated publicly that they will match these coverage levels.

1.45 4G services are currently available to 72% of premises, although only 35% are served by Vodafone, O2 and EE.

MNO coverage predictions[8] - UK aggregate		Complete not-spots	Partial not-spots	Fully served[9]
Premises (outdoors)	3G	1%	15%	84%
	4G	28%	37%	35%
Premises (indoors)	3G	3%	26%	71%
	4G	37%	34%	30%
In car (A and B roads)	3G	17%	54%	30%
	4G	71%	20%	9%
Geographic (land area)	3G	22%	52%	26%
	4G	77%	17%	5%

1.46 All four mobile network providers operate 3G and 4G networks. The most widely available 4G service is EE's, with 68% coverage of premises outdoors. There is more variation between the operators' 3G and 4G coverage than between their 2G coverage. For example, EE and Three have significantly greater 3G geographic coverage than O2 and Vodafone.

8 Coverage predicted using a 4G threshold level of -113dBm for outdoor, -103dBm for indoor and in-car.

9 By 'fully served' we mean coverage is provided by Vodafone, O2 and EE. This is because 4G coverage by Three has not been reported - see section 5 for details.

MNO coverage predictions[10] - by operator		O2	Vodafone	EE	Three
Premises (outdoors)	3G	91%	87%	98%	98%
	4G	43%	37%	68%	-
Premises (indoors)	3G	84%	76%	93%	93%
	4G	38%	32%	59%	-
In-car (A and B roads)	3G	44%	37%	78%	73%
	4G	14%	10%	26%	-
Geographic (land area)	3G	44%	33%	74%	68%
	4G	9%	7%	19%	-

Mobile data use

1.47 Mobile data use continues to grow, linked to the increasing take-up of smartphones and tablets. Data use grew 53% between 2013 and 2014, similar to the rate of growth in the previous year. Web browsing accounts for 42% of traffic, video streaming for 39%.

1.48 Although the percentage growth in mobile data is large, absolute levels of use are still much lower than for fixed broadband. Mobile users are now using an average of 0.5GB of data per month, compared to an average of 58GB over fixed broadband connections. This suggests that there is substantial scope for further growth in mobile broadband as consumers increase the range of services they access over mobile networks.

The future development of mobile networks and services

1.49 Like fixed networks, mobile networks are continuing to develop and improve, supported by both competition and public policy. For example, Ofcom is seeking to improve both indoor and outdoor coverage by making more low frequency spectrum (sub-1 GHz) available. Low frequency spectrum is targeted because it has good propagation characteristics. The last significant release of low frequency spectrum was the 800 MHz band, sold in the 4G auction following digital television switchover. We recognise that demand for mobile broadband continues to grow, meaning more spectrum is needed for both coverage and capacity reasons. Hence we are looking at further spectrum releases: for example, we will make the 700 MHz band, currently used for DTT, available for mobile broadband use from 2022.[11]

1.50 MNOs are currently working to improve mobile broadband download speeds by deploying “LTE Advanced” 4G technology. This can significantly improve on the original 4G, meaning peak download speeds of 150 Mbit/s and beyond. Looking further forward, industry is also starting to develop new “5G” technologies. These are in early stages of development but will ultimately improve the capabilities of networks and offer a more seamless and responsive user experience.

[11] See http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf

1.51 We also expect to see significant progress in the coming years on the deployment of "Internet of Things" (IoT) applications and services. This means applications and devices communicating with each other without human involvement. Existing examples include home management sensors, smart meters, vehicle traffic management and wearable technologies such as fitness bands. While connectivity demands for bandwidth will generally be low, reliability, privacy, ubiquity and other performance needs may not be met by existing access technologies and networks. It is possible that the IoT will ultimately require dedicated networks. We are in the process of consulting on the issue.[12]

Broadcast infrastructure

1.52 There have been developments in the capacity of both traditional and the new broadcast infrastructure this year.

- **Traditional linear** broadcasting. Two additional multiplexes have been made available on the digital terrestrial TV platform. As a result we have several new high definition (HD) channels (BBC News, BBC Four and CBeebies, 4Seven, Channel 4+1, Al Jazeera and Community) as well as others in standard definition.

1.53 Despite the growth in online services, linear broadcasting remains the preferred way for most viewers to watch TV. There is a continuing shift towards higher definition formats, including '4K' as well as HD TV formats. These demand more capacity, though advances in digital video compression (such as the recently completed HEVC standard) will at least partially offset this.

- **New forms of** broadcasting. The growth in IPTV is providing additional capacity for the delivery of on-demand and linear (i.e. scheduled) broadcast-quality streamed TV. For example, more than one in ten UK households now subscribe to Netflix. The growth in broadband data consumption, primarily driven by video, underlines the need for continued investment in new network capacity even as new compression techniques are introduced.

1.54 For radio listeners, DAB services are available to more than nine in ten households. The BBC is set to expand its national DAB coverage to around 97% of UK households by March 2017.

Summary of key policy implications

1.55 The findings of this report raise a number of challenges which policy-makers will need to consider. The key ones are set out in the table below.

Ensuring inclusion through universal availability	The current **Universal Service Commitment for broadband** was set by the Government in 2009. It is that every household should have access to a broadband speed of at least 2Mbit/s. The publicly funded deployment of superfast broadband roll-out might mean that speeds of above 30Mbit/s are eventually available universally, or near universally. If not, the evidence in this report suggests that more detailed work may be required on whether the basic commitment should be increased.

12 http://stakeholders.ofcom.org.uk/consultations/iot/

	Extending mobile coverage beyond current levels may require continued public policy intervention. The Government is currently investing £150m in new infrastructure to bring **mobile coverage** to unserved households. It is also considering other policy measures to increase coverage and address partial not-spots, with options including national roaming, passive infrastructure sharing and a multi-operator MVNO. This is a matter of high priority for the Government and Ofcom is working closely with it and industry to improve coverage and to address partial not-spots in particular.
Deployment of new technologies to the mass market	To address the challenges of **superfast broadband roll-out**, various technological solutions already exist or are in development. At the same time, mobile operators are deploying 4G services, with one required to meet a coverage required of 98% of premises indoors. Others are planning to match this requirement. This will ultimately improve both voice and mobile broadband coverage. However, further deployment may require continued public intervention (for example, to get superfast broadband to the 'final 5%' and to improve SME coverage) or regulatory policy amendments (for example, changes to the Electronic Communication Code and planning rules).
Understanding options and defining an ambition for future infrastructure investment	Looking further ahead, there are numerous technological developments in progress that should help operators and the Government to extend, maintain and **significantly improve fixed and mobile broadband speeds** over time. These options should be considered thoroughly and quickly in order to understand the likely timescales of demand and supply, as well as the delivery models which will best deliver value for money. Many of these upgrades can be led by the market, building incrementally on investments already made in response to demand.

It is important for policy to consider all drivers of quality of experience

1.56 When considering these challenges across all three stages of infrastructure policy, it is increasingly important to consider a range of factors beyond just speeds. Our analysis of **broadband quality of experience** suggests that broadband performance is influenced by a much wider set of issues than simply the speed of the access network. We will continue to support the development of new measurement approaches that better reflect the broadband consumer experience and the range of issues that affect it.

1.57 To address the **consumer experience of mobile voice use**, Ofcom is carrying out further research to quantify the extent to which network capacity is affecting consumers. We will also consider whether more work is required to understand the **quality of experience of the mobile internet**, to complement our similar exercise on mobile voice calling.[13]

[13] http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/consumer-experiences-mobile-phone-calls/report.pdf

Availability of infrastructure for both consumer and business users should be considered when setting policy

1.58 Further work is needed to understand the drivers and barriers of **connectivity for SMEs**. We will develop the specific analysis in this report to estimate the number of SMEs without superfast broadband coverage and with no other relatively low cost and high bandwidth options. Ofcom will consider the broader issues further as part of a SME publication alongside the Business Connectivity Market Review in spring 2015.[14]

[14] See http://stakeholders.ofcom.org.uk/consultations/bcmr-passives/ and http://stakeholders.ofcom.org.uk/consultations/smes-cfi/.

Fast Facts

Figures relate to June 2014.

Fixed broadband	
Coverage of any broadband	Near universal
Take-up of broadband	73% of premises
Coverage of superfast broadband	75% of premises
Take-up of superfast broadband	21% of premises
Average broadband speed	23Mbit/s
Average monthly data throughput	58GB per residential connection

Mobile	
Mobile (2G)	
Premises (outdoor) covered by all operators	97% of premises
Premises (outdoor) not covered by any operator	<1% of premises
Geographic area covered by all operators	68% of land area
Geographic area not covered by any operator	11% of land area
Coverage of A and B roads by all operators	84% of roads
A and B roads not served by any operator	3% of roads
Mobile (3G)	
Premises (outdoor) covered by all operators	84% of premises
Premises (outdoor) not covered by any operator	1% of premises
Geographic area covered by all operators	26% of land area
Geographic area not covered by any operator	22% of land area
Coverage of A and B roads by all operators	45% of roads
A and B roads not served by any operator	9% of roads
Mobile (4G)	
Premises (outdoor) covered by Vodafone, O2 and EE	35% of premises
Premises (outdoor) not covered by any operator	28% of premises
Geographic area covered by Vodafone, O2 and EE	5% of land area
Geographic area not covered by any operator	77% of land area
Coverage of A and B roads by Vodafone, O2 and EE	12% of roads
A and B roads not served by any operator	63% of roads
Mobile (data use)	
Total number of active mobile connections	83.2 million
Total mobile data throughput	44,300,000GB
Average monthly data throughput	0.53GB per SIM

Broadcast	
Digital terrestrial television	
Households served by three multiplexes (public service broadcasting channels)	99%
Households served by six multiplexes (additional digital terrestrial television channels)	90%
Households served by seven multiplexes (all digital terrestrial television channels, including interim multiplex)	76%
Digital radio	
Households served by BBC national multiplex	95% of households
Households served by the national commercial multiplex	90% of households

Wi-Fi	
Number of public Wi-Fi hotspots	41,798
Total data uploaded/downloaded	2,260,000GB in June 2014
Average data throughput	54GB per hotspot in June 2014

Section 2

Introduction and background to the report

2.1 This is Ofcom's second full Infrastructure Report, following our first report which was published in 2011.

2.2 Under Section 134A of 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.

2.3 The Act sets out specific areas on which Ofcom must report. These are:

- the coverage of networks and services, by geography and population;
- the degree of infrastructure sharing and wholesale access on the networks;
- the capacity of the networks and their availability; and
- plans for resilience in relation to both networks and services.

2.4 We are also required to report on the use of spectrum for wireless telegraphy in the UK and to compare the standard of UK networks and services with those in other countries.

2.5 The report considers services provided to residential consumers and to businesses. We don't present statistics for large businesses, since the leased line infrastructure upon which they typically rely is widely available and services tend to be bespoke. We do present analysis for Small and Medium sized Enterprises (SMEs).

2.6 Since the first Infrastructure Report, we have published update reports in 2012 and 2013. These focused on the areas seeing the most rapid change, including the coverage of fixed, mobile and broadcast networks and the capacity of fixed and mobile broadband networks.

2.7 This new report provides the first update for other topics, such as passive infrastructure sharing, wholesale network access, the use of spectrum and the capacity of fixed and mobile voice networks.

2.8 We have excluded some information from the published version of the report, where we believe there would be grounds to refuse to disclose it in response to a request under the Freedom of Information Act 2000. Where we have redacted information from the report, we indicate it with this symbol: [✂].

Approach and context

2.9 This report uses new data gathered from the largest operators in each sector, as well as information already held by Ofcom. Where possible we have reused data already provided to Ofcom, in order to minimise the burden on stakeholders.

2.10 We have also used other reliable data sources, such as direct consumer research findings. Data sources and analysis methodologies are summarised in Annex 1. Where new information has been collected, it dates from June 2014.

2.11 In the main, we have gathered data from the communications providers who make up a significant proportion of the residential consumer and small business market. This relates to fixed networks, mobile networks, public Wi-Fi and the main broadcast technologies: digital terrestrial television (DTT) and digital radio (DAB).

2.12 For fixed networks, we present data from five networks making up over 80% of the market. For mobile networks and digital terrestrial broadcast networks, we gathered data from all the network operators.

Figure 2 – Providers, networks and services within scope of the Infrastructure Report

Name of provider	Types of networks or service
Arqiva	Public Wi-Fi, national DTT and national DAB
BBC	National DTT and national DAB
BT	Fixed networks: voice and broadband, public Wi-Fi
D3 and 4	National DTT
EE	Mobile networks: voice and broadband, public Wi-Fi
KCOM	Fixed networks: voice and broadband, public Wi-Fi (Hull only)
O_2 Telefonica	Mobile networks: voice and broadband, public Wi-Fi
SDN	National DTT
Sky	Fixed networks: voice and broadband, public Wi-Fi
TalkTalk	Fixed networks: voice and broadband
Three	Mobile networks: voice and broadband
Virgin Media	Fixed networks: voice and broadband, public Wi-Fi
Vodafone	Mobile networks: voice and broadband

2.13 We also gathered data from a number of other smaller network and service providers for different aspects of the report.

Publication of data

2.14 Much of the data underlying this year's report is available for download at: http://infrastructure.ofcom.org.uk

2.15 We have also created an online map and visualisation tool. This allows users to assess the coverage and performance of the infrastructure in their area and compare it to other areas.

2.16 The tool is available at http://infrastructure.ofcom.org.uk.

Outline of this report

2.17 The remainder of the report is structured as follows:

- **Section 3:** fixed broadband networks
- **Section 4:** SME connectivity
- **Section 5:** mobile networks and Wi-Fi
- **Section 6:** broadcast networks
- **Section 7:** security and resilience
- **Section 8:** convergence and seamless connectivity
- **Section 9:** internet networks

2.18 We don't cover international comparisons in any detail because they are the subject of a separate piece of work: Ofcom's *International Communications Market Report*. The latest edition is available at http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/icmr/ICMR_2013_final.pdf and the 2014 report will be published shortly.

Section 3

Fixed broadband networks

Overview

3.1 In the space of just a few years, the availability of fixed broadband technology has transformed the way we use the internet. From playing a niche role in the early 2000s, broadband is now regarded as one of life's essentials by the vast majority of consumers and small businesses. At home, there are more ways than ever to access it; from laptops and desktops to smartphones and tablets over in-home Wi-Fi.

- **Increasing take-up of superfast broadband has driven an increase in average speeds** (3.67 to 3.69). Household take-up of fixed broadband now stands at 73%, up from 72% last year. Take-up of superfast broadband is 22%. The increasing availability and take-up of superfast broadband has driven up the average broadband speed, which is now 23Mbit/s, up from 18Mbit/s last year. Speeds vary considerably from household to household, driven partly by availability and partly by the number of households that have decided to upgrade to superfast broadband.

- **The quality of broadband services varies significantly across the UK** (3.70 to 3.73). Although fixed broadband is now available to almost all UK premises, the technology and speeds available vary considerably. 97% of premises are able to access a basic broadband service, with download speeds of more than 2Mbit/s; 85% can access a standard service, with speeds of 10Mbit/s or more; and 75% can access superfast speeds of 30Mbit/s or more, due to the roll-out of fibre, and cable upgrades.

- **Superfast broadband coverage is significantly lower in rural areas, and there are also gaps in superfast coverage within cities** (3.24 to 3.36)**.** Only 22% of rural premises across the UK can access superfast broadband. However there are also gaps in some urban centres; this is due in part to technical challenges that require a different approach to superfast upgrades. The effect of these availability issues may have a disproportionate impact on SME customers and this is further analysed in section 4. Some gaps are being filled by providers other than the traditional networks, such as community broadband groups formed to provide coverage in a specific area. The aim of the Government's ongoing broadband roll-out intervention programme is to push broadband with speeds over 24Mbit/s[15] to 95% of premises by 2017. It is also testing options to extend faster broadband coverage to 'the final 5%'.

- **Roadmaps are in place for future development, including 'ultrafast' broadband networks** (3.42 to 3.65)**.** There are several active technological developments which may extend coverage of superfast broadband, or maintain capacity when take-up increases, or increase the maximum speeds available, potentially far beyond current superfast levels. These fixed and wireless technologies provide an evolutionary path

[15] The definition of 'superfast' for the purposes of Ofcom's analysis in this report is 30Mbit/s, which is in line with the European Commission's definition and targets.

towards meeting future demand for ‘ultrafast’ broadband. More revolutionary options are also possible.

- **It may be time to review public policy around universal service** (3.65 to 3.66). The current universal service commitment, set by the Government in 2009, specified that every household should have broadband access of at least 2Mbit/s.[16] It may now be time to review that policy, as consumer expectations of broadband rise along with the availability and take-up of faster broadband. There is evidence that broadband of at least 10Mbit/s is required to support typical consumers’ use. Below that speed, overall broadband performance is generally impaired. Indeed, use may be constrained for broadband below this threshold, because some applications will not work properly, if at all.

- **Upload speeds are also an important consideration** (3.85 to 3.86)**.** This is especially the case for services such as high quality video calling. The average upload speed in the UK is currently 3Mbit/s.

- **Access speed is not the only determinant of broadband performance** (3.101 to 3.115). The quality of the broadband experience is not solely dependent on the access speed as supplied; factors such as in-home wiring and peering arrangements between internet service providers can also be important. Indeed for connections with a download speed greater than 10Mbit/s, access speed appears to become less significant than these other factors. We are therefore developing new measurement approaches to take account of all the factors that can affect broadband performance.

- **Data use is increasing steadily** (3.87 to 3.95)**.** The UK is now using far more data, as users migrate to faster connections and access data-hungry applications such video streaming. All operators have seen an increase in the amount of data downloaded, with some variation between them. On average, there has been a 93% increase in the amount of data downloaded over the last year.

Coverage of broadband services

3.2 This section considers fixed broadband networks that serve households and small commercial premises.[17] Voice services provided over fixed networks (i.e. landlines) are covered in section 8.

3.3 BT Openreach and Virgin Media are the two main operators in the UK, with Kingston Communications (KCOM) operating a network in Hull and surrounding areas. Openreach and KCOM together cover virtually the whole of the UK. Virgin Media has a separate cable network covering 44% of UK premises. Broadband is therefore available to almost all UK premises.

[16] The Universal Service Commitment was introduced in the Digital Britain report. See p.53 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228844/7650.pdf

[17] This is because large commercial premises are served by bespoke and private networks which are outside the scope of this report. The capacity and coverage of the majority of these networks are negotiated on a commercial basis to serve a particular customer need, and issues related to these networks are considered elsewhere, in particular in Ofcom’s *Business Connectivity Market Review*. This approach is consistent with the first *Infrastructure Report* (2011) and subsequent update reports.

3.4 For residential and small commercial buildings, there are four main types of fixed network technology:

- **Asymmetric digital subscriber lines (ADSL) and ADSL2+.** The most common way broadband is delivered in the UK is over copper telephone lines. These provide download speeds of up to 24Mbit/s, depending on the distance to the exchange and the capability of the equipment.

- **Hybrid fibre-coaxial (HFC) cable using DOCSIS standards.** Broadband is also provided over networks originally deployed for cable television. A fibre-optic cable links the telephone exchange to the street cabinet. Coaxial cable connects the cabinet to the home. These networks deliver download speeds of up to 152Mbit/s, depending on the amount of cable capacity allocated to broadband (rather than TV) and the number of consumers using the shared link at the same time.

- **Fibre to the cabinet (FTTC).** This is where fibre is laid between the exchange and the cabinet, where very high bit rate digital subscriber line (VDSL) systems are deployed. The maximum download speed at the moment is 76Mbit/s. However, this depends on the distance to the cabinet, since the cabinet-to-home connection still relies on the copper network.[18]

- **Fibre to the premises (FTTP).** These networks rely entirely on fibre to connect the home or premises to the exchange, delivering very high speeds of up to 1Gbit/s.

3.5 Cable, FTTC and FTTP are collectively known as 'next generation access' (NGA) networks. The roll-out of NGA technologies has increased the availability of superfast broadband (SFBB), which is defined as having download speeds of at least 30Mbit/s.[19] Most, but not all, NGA lines provide superfast broadband.

Coverage of broadband faster than 2Mbit/s has reached 97%, and coverage of broadband faster than 10Mbit/s has reached 85%

3.6 We estimate that 97% of UK premises can now receive a broadband connection of 2Mbit/s or more - the target speed set in the Government's universal service commitment (USC). We also estimate that around 85% of premises can access 10Mbit/s or more. We discuss later in this section how 10Mbit/s is increasingly appearing to be the 'base standard' that a typical household needs.

Superfast broadband coverage has reached 75%

3.7 Superfast broadband is now available to 75% of UK premises, enabling these households to subscribe to services of at least 30Mbit/s. This coverage is also increasing, primarily due to the ongoing roll-out of BT Openreach's FTTC network. Coverage of the underlying NGA networks by the main network operators has now reached 78% of the UK in total.

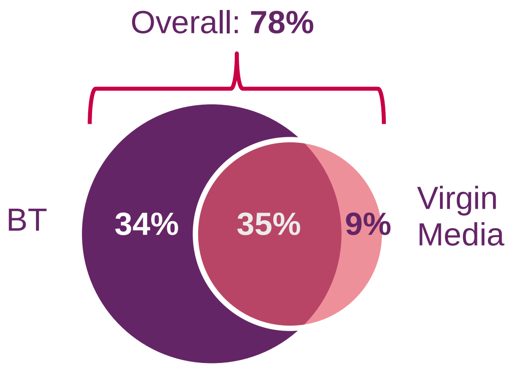
[18] Future enhancements to the underlying VDSL technology may increase this to over 100Mbit/s in the near future.

[19] Ofcom and the European Union define 'superfast' broadband services as those delivering download speeds of 30Mbit/s or more. DCMS defines superfast broadband as more than 24Mbit/s (which is the maximum speed of ADSL technology).

3.8 Figure 3 shows the degree of overlap between the NGA coverage of the Openreach and Virgin Media networks, with 35% of premises covered by both. 9% of premises can only access NGA services from Virgin Media, and 34% are only served by BT Openreach. Some smaller providers have also deployed NGA in specific areas, as described at 3.16.

Figure 3 - Overlapping NGA coverage from network operators

	NGA Coverage
BT	68%
Virgin Media	44%
KCOM	0.1%



Source: Ofcom analysis of operator data

3.9 Figure 3 shows the NGA and superfast broadband coverage services available in the different nations, from networks provided by Openreach, KCOM and Virgin Media. Northern Ireland still has the highest availability of NGA networks, having been first to begin significant roll-out in 2011 following early public-sector intervention. Scotland and Wales continue to have the lowest coverage, although they have seen the largest increases since last year.

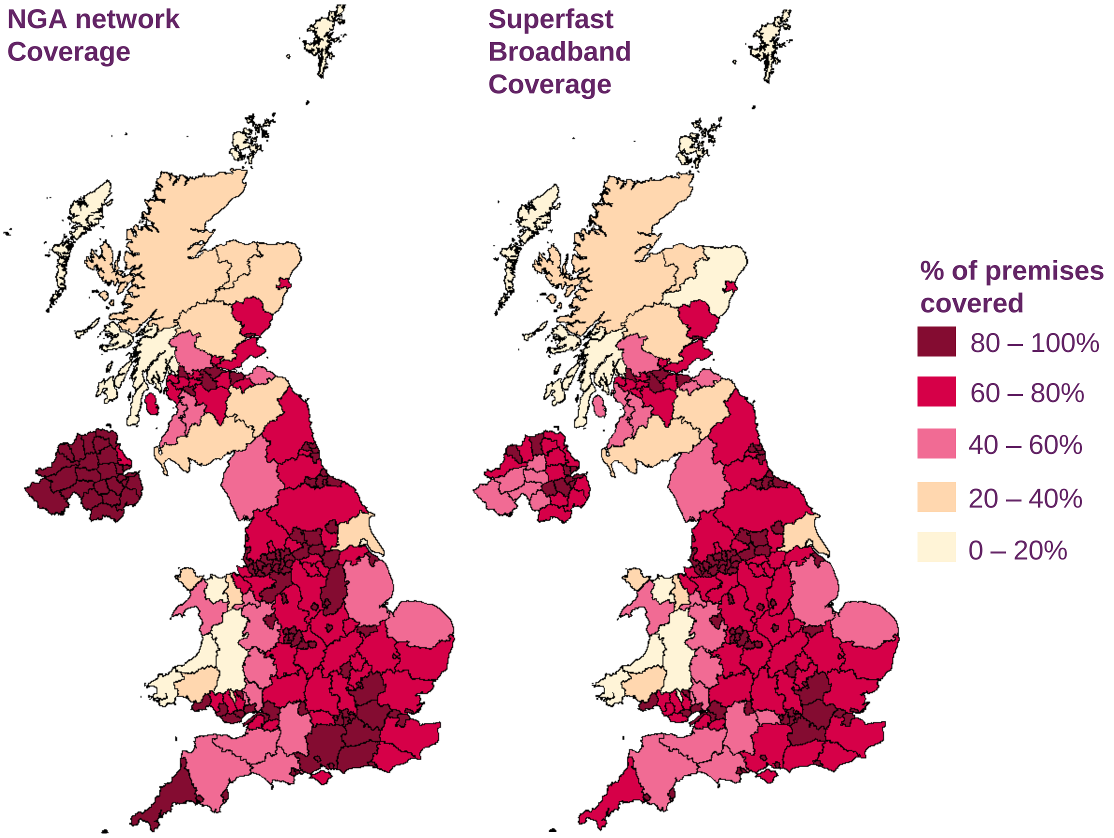
Figure 4 - Availability of NGA and SFBB services, by nation

	2014 SFBB	2014 NGA	2013 NGA
UK	**75%**	**78%**	**73%**
England	77%	80%	76%
Scotland	61%	63%	52%
Wales	55%	58%	48%
NI	77%	94%	96%

Source: Ofcom analysis of operator data

3.10 Figure 4 shows that NGA technology does not deliver superfast speeds for all premises. This is primarily due to geography: Northern Ireland has a relatively large number of dispersed rural premises. Lines running between cabinets and premises are often long enough to impair performance, sometimes significantly. We discuss the issue of long lines on p.16. On average there is a 3% gap between NGA and superfast coverage. The difference is greatest in Northern Ireland.

Figure 5 - Availability of NGA and SFBB by local authority



Note on methodology. We have refined the methodology for data collection and analysis, meaning that the NGA coverage we report here is not directly comparable with previous reports. There are two significant differences in our approach this year:

a) Under our previous methodology, where we identified the presence of an NGA network in a postcode, we modelled that postcode as being fully covered. This year, we have collected more detailed information about the percentage of premises in each postcode with NGA access. This allows us to provide a more accurate estimate of NGA coverage across the UK. We estimate that last year's coverage figure would have been approximately 2% lower under our refined methodology.

b) We make a clear distinction between NGA coverage and coverage of superfast broadband services. This is because some premises have been upgraded to FTTC (and are therefore within the NGA coverage footprint) but cannot receive superfast speeds. This is typically due to the distance between the cabinet and the premises. This is discussed further at below.

The Government expects 95% of the UK to have access to broadband speeds over 24Mbit/s by 2017

3.11 The Government has set a target that 95% of the UK should have access to speeds of over 24Mbit/s by 2017. The increase in superfast coverage has so far been largely driven by commercial roll-out, exceeding the original estimate that it would cover two thirds of premises. Commercial roll-out is continuing to some degree. At the same time, public funding has extended coverage to areas where commercial roll-out will not reach. We set out below a summary of the Government's programme of work, administered by Broadband Delivery UK (BDUK) on behalf of the Department for Culture, Media and Sport (DCMS).

Figure 6 – BDUK programme

	BDUK funding (£m)	Approach/target	Status
Phase 1 ***Rural Broadband Programme***	530	90% coverage by early 2016	November 2014: 1.5 million premises passed. All contracts awarded.
Phase 2 ***Superfast Extension Programme***	250	95% coverage by 2017	First contract awarded in South Yorkshire.
Phase 3 ***Competitive Fund***	10	Fund for pilot projects to identify possible solutions to the 'final 5%'	Pilots under way.
Superconnected Cities	150	Vouchers of up to £3000 to help businesses with cost of installing high-speed broadband in 22 cities until March 2015	September 2014: around 3000 businesses have received grants.

3.12 In addition, £150m has also been allocated to improve the quality and coverage of mobile phone and basic data network services. Further detail is provided in section 5.

3.13 Phases 1 and 2 of the scheme are based on a model in which the state pays the provider the difference between the commercial investment and the actual cost. BDUK funding is supplemented by local authorities and, in some cases, European funding.

3.14 The roll-out part-funded by the BDUK programme is underway. Up to June 2014 – the month in which we collected data for this report – almost 900,000 premises had a superfast broadband service made available as a result of BDUK-supported projects. This represents around 9% of superfast broadband premises in the UK, and around 3% of all UK broadband lines.[20] Since then, roll-out has accelerated. In November 2014 DCMS announced that more than 1.5 million premises could access superfast broadband as a result of BDUK-supported projects, and that it was reaching 40,000 homes and businesses a week.[21]

3.15 The devolved administrations in Northern Ireland, Scotland and Wales are responsible for national projects that use funding both from BDUK and other sources:

[20] Ofcom analysis based on BDUK statistical release: (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/341628/Broadband_Performance_Indicator_-_June_2014.pdf)
[21] https://www.gov.uk/government/news/superfast-broadband-rollout-now-one-of-the-fastest-in-the-world

- In Northern Ireland, the Department of Enterprise, Trade and Investment (DETI) led the Next Generation Broadband project, which invested more than £52m in FTTC across the country. It was completed in 2011. DETI is now implementing the Broadband Improvement Project (BIP) to further extend basic and high-speed broadband services to around 45,000 premises across Northern Ireland (see 3.40).

- In Wales, the Superfast Cymru project is a partnership between the Welsh Government and BT. It aims to achieve 96% coverage of fast fibre broadband in Wales by 2016. The majority of premises will be able to access broadband speeds in excess of 30Mbit/s, in some areas more than 100Mbit/s. The total investment in fibre broadband in Wales, including the Superfast Cymru programme and BT's commercial roll-out, is around £425m. More than 275,000 premises can now access superfast broadband as a result.[22]

- In Scotland, the Digital Scotland superfast broadband initiative comprises two projects: one for the Highlands and Islands area and the other for the rest of Scotland. Its aim is for 95% of premises in Scotland (750,000 homes and businesses) to be covered by fibre broadband infrastructure by the end of 2017. Its funding partners include the Scottish Government, Highlands and Islands Enterprise, the UK Government through BDUK, local authorities, the European Development Fund and BT. The Digital Scotland roll-out has now reached more than 150,000 homes and businesses across the country, including 30,000 in the Highlands and Islands.[23] By October 2014, ten of the programme's 20 sub-sea fibre optic cables had been laid, connecting island communities.

Smaller providers are also offering NGA services

3.16 Openreach, Virgin Media and KCOM are not the only providers of NGA infrastructure in the UK. A number of other networks providers are also rolling out their own networks to provide broadband or superfast broadband services with smaller network footprints, usually where Openreach and Virgin Media's NGA networks are not present.

3.17 Figure 7 below gives examples of these types of deployment.

Figure 7 - Deployment of NGA networks by smaller providers

Type of deployment	Examples (not exhaustive)
Commercial NGA networks	Cityfibre: wholesale provider of fibre infrastructure including joint venture announced with Sky and TalkTalk to roll out FTTP in York. See case study below. Hyperoptic: FTTB (fibre to the building) to blocks of flats in cities including London, Cardiff, Reading, Bristol, Manchester, Liverpool and Leeds. Gigaclear: FTTP to rural villages.

22 http://www.superfast-cymru.com/news/2014/november/superfast-cymru-reaches-275000-milestone

23 http://news.scotland.gov.uk/News/Fibre-broadband-reaches-150-000-homes-and-businesses-1215.aspx

Commercial satellite networks	Satellite broadband: commercial satellite service providing up to 20Mbit/s broadband.
Commercial wireless networks	Call Flow: Call Flow offers radio links delivering bandwidth from 2Mbit/s to 100Mbit/s+, in addition to ADSL and fibre options.
Community NGA networks	Cybermoor and fibre broadband in Alston Moor, Cumbria. B4RN: FTTP in the rural north west Shetland Telecom: wireless broadband around Lerwick.

Network technologies used by non-major NGA providers

3.18 Fixed access technologies such as FTTP are generally used where premises are sufficiently close together, such as new-build apartments or a cluster of houses in a small community. They provide networks that are capable of delivering reliable superfast broadband speeds of up to 1Gbit/s depending on the network technology used.

3.19 Wireless or satellite solutions can also be used to provide connectivity to premises which are further apart. Customers on these networks will share the available bandwidth. This means that they are less likely to achieve superfast speeds.

3.20 As these wireless networks do not require a fixed connection at the premises, it is harder to form a definitive understanding of the coverage of these networks. Satellite broadband provides coverage to almost all of the UK as it can serve any premises within the satellite footprint. In reality, satellite broadband would have capacity constraints if demand became extremely high. The latency of the connection to the satellite means a fast response time isn't possible, and for many this means satellite broadband is most suitable where there are no other networks available.

Coverage and take-up of services

3.21 Recognising the important role played by non-major network providers, Ofcom commissioned Prism Business Consulting to review the market for non-major NGA broadband.[24] Prism estimated that non-major networks, in aggregate, provide coverage to around 1% of UK households.[25] The report indicated that 70% of these schemes are in rural areas (mainly rural remote), while 30% are in urban areas.

3.22 Prism reported that community schemes tended to have relatively high levels of take-up. This is not surprising, for several reasons. Some schemes offer incentives to community groups to support roll-out. For example, Broadband for the Rural North (B4RN) offers shares to volunteers who help to build the network.[26] This also raises awareness of the network among the local community. Prism reported that community-led schemes are usually motivated by existing poor connectivity; the

[24] Prism Business Consulting report on UK NGA provision by non-major providers
[25] Excluding satellite, as satellite is available to almost all of the country, but will not be the first choice for everyone due to capacity and quality constraints.
[26] http://b4rn.org.uk/how-you-can-help

users therefore have an even greater incentive to take up these schemes' services. Some non-major commercial providers also reported high take-up. These are mainly providers supplying fibre broadband to new-build developments, where no other fixed-line providers are available.

Case study: CityFibre

CityFibre plans to become the largest independent provider of fibre-optic infrastructure to mid-sized cities and major towns. It owns and operates urban fibre-optic networks, using a shared passive infrastructure model. As a wholesale operator, CityFibre does not provide services in its downstream market.

So far, the company has launched four 'Gigabit City' projects: in York, Peterborough, Coventry and Aberdeen. CityFibre is actively engaged with many cities that seek better digital infrastructure, and aims to cover around 25 Gigabit Cities; a footprint that it says would address around 15% of the UK urban population.

York

Based on its initial commitment to connect 105 local authority sites to its passive infrastructure, CityFibre invested in 95 km of new network construction. Since the completion of the initial build, CityFibre reports that it has more than doubled the number of sites connected to the network, covering public sector, businesses, CCTV and wireless applications. The York network now stands at around 120 km, with further expansion planned.

CityFibre is using this fibre infrastructure to deploy widespread FTTH that will extend the fibre network to the residential market. This is being undertaken by a joint venture between CityFibre, Sky and TalkTalk. The first phase of construction is currently under way, and CityFibre reports that it will connect tens of thousands of homes and businesses. The first customers benefiting from 1Gbit/s ultrafast broadband are expected to be connected in summer 2015.

Other 'Gigabit Cities'

CityFibre is also deploying Gigabit City projects in Peterborough, Coventry and Aberdeen. It will expand its private-investment 'anchor tenant' methods to include demand aggregation from business ISPs (in Aberdeen) or via network acquisition (in Coventry). In all its Gigabit City projects, CityFibre engages with the business community through its 'Gig-Up' campaigns. It reports that in six months, 'Gig-Up Peterborough' attracted around 25% of local businesses, which registered their intent to connect to CityFibre's infrastructure, thereby helping to accelerate network roll-out.

There are challenges to overcome in order to move towards near-universal coverage of superfast broadband

3.23 A range of infrastructure providers will play in part in extending superfast broadband to reach near-universal coverage. In general, the most effective and efficient way to provide superfast broadband on the BT Openreach network is to upgrade existing cabinets to fibre. This is feasible for most of the 95% of UK premises that are covered under the existing BDUK programme.

3.24 However, there are still challenges facing the government, Ofcom and industry if near-universal coverage is to be achieved. The three main challenges, and the potential solutions, either existing or under development, are described below.

1. Extending infrastructure capable of delivering superfast speeds to the most rural areas

3.25 This challenge relates to premises that are not covered in current roll-out plans – referred to as the 'final 5%' beyond the 95% Government target. They are mostly in very rural areas, and there is probably a limit to what can be achieved by conventional large-scale network infrastructure such as fibre networks. In these rural areas, premises are further apart and the costs of roll-out are shared between fewer users. Therefore, more efficient and cost-effective solutions are needed.

3.26 In June 2014, the Government announced eight pilot trials to test alternative approaches, backed by a £10m fund.[27] These are discussed at 3.42. The pilots will test a variety of technologies, which fall into two main categories:

- **Satellite**. The latest solutions (using Ka-band VSAT) appear to offer superfast speeds of over 30Mbit/s downstream. However, overall capacity and latency constraints mean that this may only be suitable to serve a subset of the 'final 5%'.

- **Fixed wireless access**. Fixed wireless has the advantages of low cost-of-entry and flexibility. Options range from conventional Wi-Fi and WIMAX[28], based on sub-licensed spectrum (e.g. UK Broadband), to LTE and white space approaches**.**

3.27 The Welsh Government is seeking bids to extend access to premises not covered by either the private sector commercial roll-out or the Superfast Cymru project. Procurement for this infill project is under way. In parallel, the Access Broadband Cymru scheme provides grants of up to £900 to the occupants of premises unable to receive broadband services of 2Mbit/s and above. The money can be used to fund up to 90% of the cost of installing alternative technology; for example, wireless and satellite, on the condition that it will deliver speeds of at least 24Mbit/s.

3.28 Some rural areas will receive fibre coverage from non-BDUK projects such as the community broadband schemes described above.

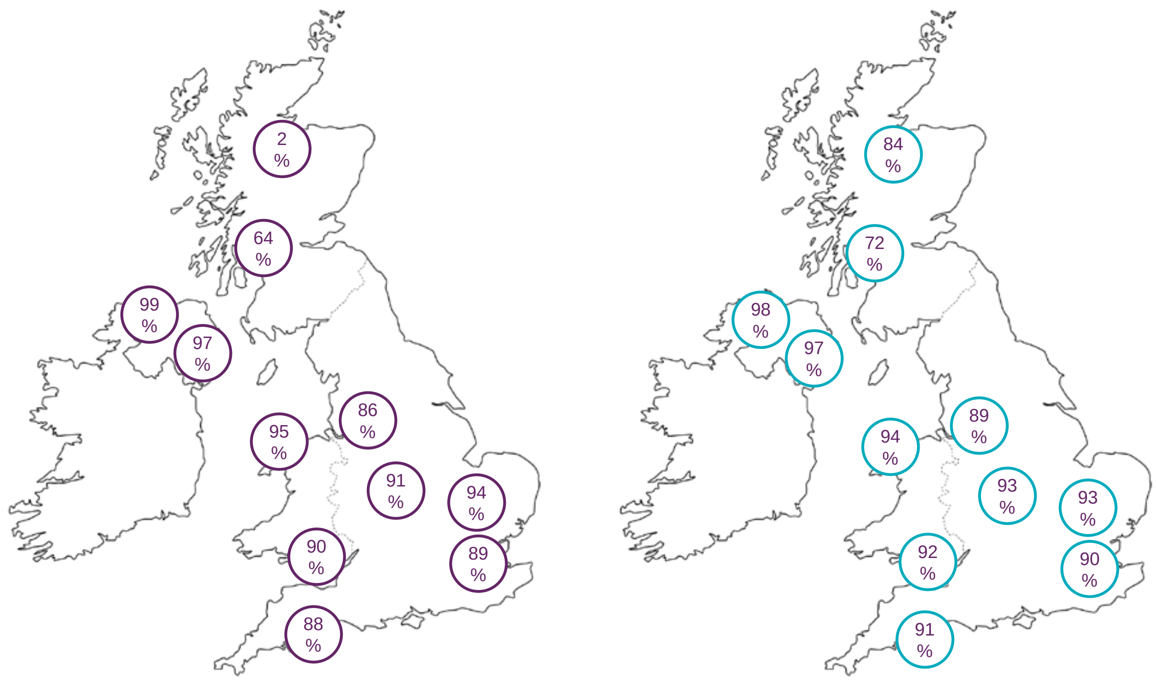
2. Closing gaps in coverage in urban centres

3.29 Coverage of high-speed broadband is generally high in urban areas. However, there are some parts of cities that are not yet covered. We published a report on the availability of communications services in UK cities ('the Cities Report') in June 2014. It showed that there were significant gaps and variations in the availability of superfast broadband services in a selection of 11 UK cities in 2013.[29] Figure 8 shows the 2014 coverage of NGA in these cities.

[27] https://www.gov.uk/government/news/10m-broadfund-fund-winning-bids-announced
[28] WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 Gbit/s for fixed stations. WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL.
[29] http://stakeholders.ofcom.org.uk/market-data-research/market-data/cities-summary-14/

Figure 8 – NGA coverage in 11 UK cities

2013 **2014**

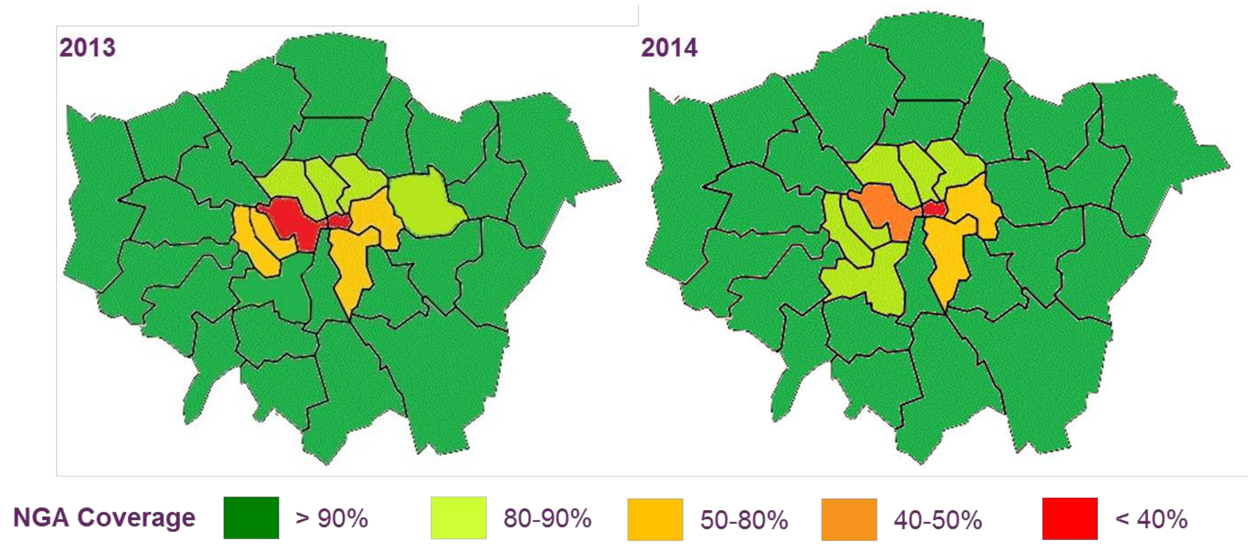


3.30 Figure 8 shows that NGA coverage has increased in most of the cities since 2013, with particular progress in Glasgow and Inverness. This shows the impact of the extension of the BT Openreach network in these cities. Inverness benefited from investment in broadband across the Scottish Highlands and Islands, led by the Highlands and Islands Enterprise (HIE).

3.31 However, some urban gaps remain. This may be due to a range of factors. Technical difficulties in deploying FTTC may be significant in some locations. Some inner city areas have a high number of 'exchange-only lines' (EOLs) where there is no cabinet between the premises and the exchange. Premises served by EOLs cannot be upgraded to FTTC because of the absence of cabinets to upgrade to fibre, and because VDSL equipment cannot be co-located with ADSL equipment. Openreach is therefore exploring two main options to upgrade these lines. First, inserting a cabinet between the premises and the exchange, and second, developing new technology deployment options such as fibre to the remote node (FTTRN) – see below.

3.32 Overall, 64% of EOLs are in urban areas. The availability of NGA in postcodes with EOLs is 48%; significantly lower than the average 85% in urban areas. Figure 9 shows that NGA coverage is particularly low in four inner-London boroughs: the City of London, Westminster, Tower Hamlets and Southwark. Low coverage relates to the high number of EOLs in these boroughs and limited cable roll-out. The problem is pronounced in the City of London, due to the lack of street cabinets. The City of London Corporation is therefore exploring options to extend coverage, including trials with BT and mobile broadband solutions.

Figure 9 – NGA coverage in Greater London



	2014 NGA coverage	% postcodes with at least one EOL
City of London	0.4%	91%
Westminster	47%	31%
Tower Hamlets	59%	31%
Southwark	74%	40%

3.33 Other cities are also affected by EOLs. For example, 23% of postcodes in Glasgow and 17% of postcodes in Inverness have EOLs. In line with the pattern we see in London, EOLs are often particularly concentrated in the areas affected, resulting in marked variations in superfast coverage within cities.

3.34 However, the absence of FTTC does not necessarily mean that consumers are unable to access superfast broadband. Some consumers who are served by EOLs from Openreach can already access superfast services from alternative providers with different technical solutions. These include cable, and services delivered using 4G or fixed-wireless broadband.

3.35 Virgin has announced that it is extending its cable network. This will deliver up to 152Mbit/s connections in east London (100,000 homes), Glasgow (5000 homes) and Teesside (5000 homes in Hartlepool, Darlington, Sunderland and Stockton-on-Tees).[30]

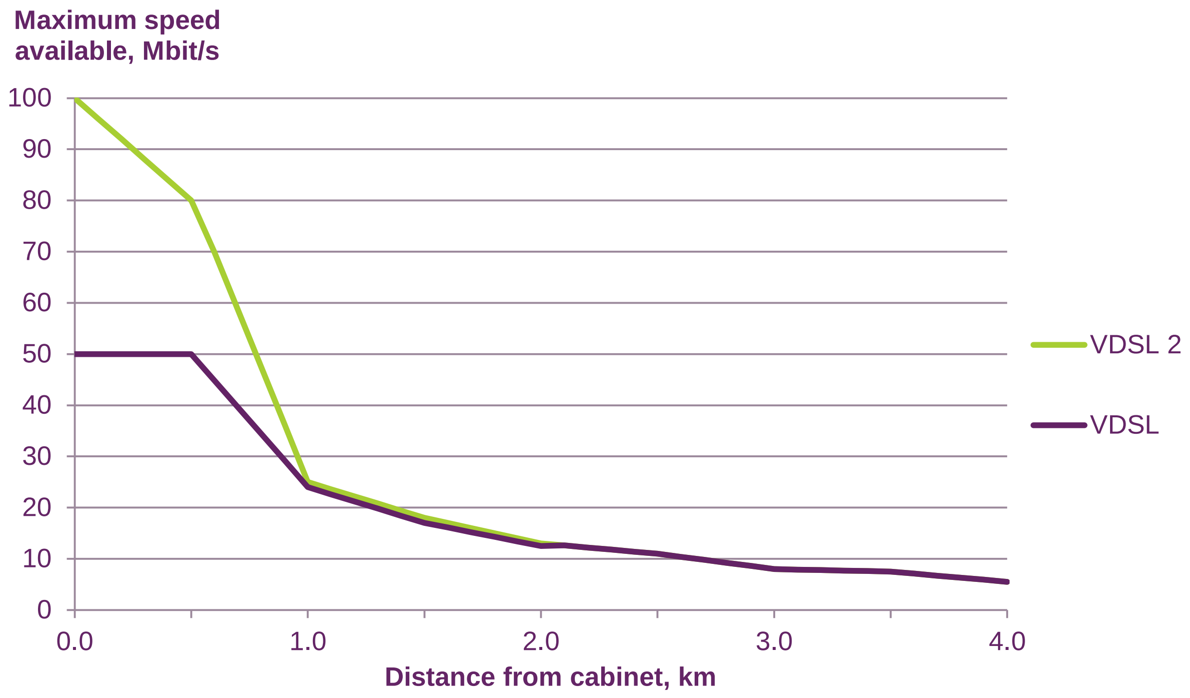
[30] http://about.virginmedia.com/press-release/9444/virgin-media-takes-superfast-broadband-to-east-london
http://about.virginmedia.com/press-release/9458/virgin-media-brings-superfast-broadband-to-5000-more-glasgow-homes
http://about.virginmedia.com/press-release/9455/thousands-more-teesside-homes-to-benefit-from-virgin-media-superfast-broadband

3. Ensuring premises at the end of long lines can achieve superfast speeds

3.36 This challenge relates to premises that cannot get download speeds of 30Mbit/s or above, even though they are served by cabinets that have been upgraded to fibre. VDSL speeds degrade over the copper lines between the cabinet and the premises. When lines are very long, speeds can drop below superfast levels. However, this does not happen over the hybrid fibre-coaxial cable used by Virgin Media.

3.37 The distance between a premises and the cabinet for FTTC connections has a large impact on the speeds available. For example, BT sets its download speed caps for its two Infinity products at 38Mbit/s and 76Mbit/s respectively. Up to 500m away from the cabinet, these speeds can be achieved, but when premises are between 500m and 1km from the cabinet, speeds decrease significantly. Beyond 1km, it is unlikely that superfast speeds will be achieved with an FTTC connection using the current BT VDSL implementation.

Figure 10 - Speeds available vs. distance from cabinet

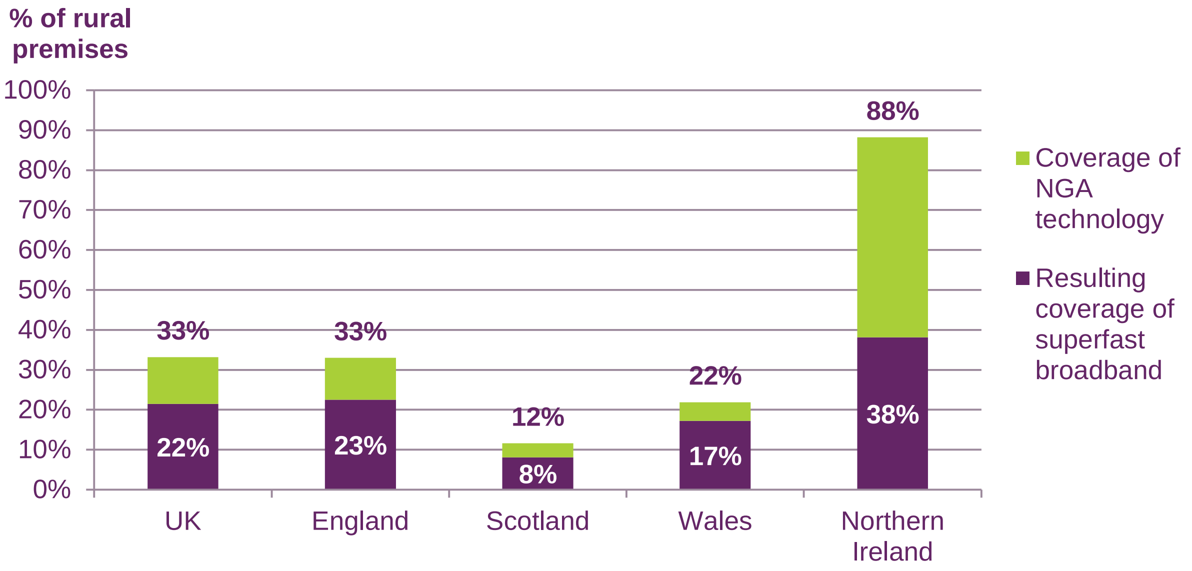


Source: IDATE

3.38 This is mainly a problem in rural rather than urban areas. Although 33% of premises in rural areas are covered by NGA, only 22% are covered by superfast broadband. This is because distances between premises and cabinets are often greater in these areas. By contrast, 85% of premises in urban areas are covered by NGA, and 83% are covered by superfast broadband.

3.39 The difference between NGA coverage and SFBB coverage is currently greatest in rural parts of Northern Ireland, as illustrated by Figure 11. Fifty per cent of Northern Ireland's 246,000 rural premises (123,000) have access to NGA technology but cannot receive superfast broadband from it. A further 225,000 rural premises across England, Scotland and Wales also suffer from this problem. The difference between NGA and SFBB coverage may increase for the other nations, as NGA extends into the most rural areas, where the problem of long lines is more common.

Figure 11 - Comparison of rural NGA and SFBB coverage, by nation



Source: Ofcom analysis of operator data

3.40 The Broadband Improvement Project (BIP) in Northern Ireland will install new cabinets in rural areas. This will reduce the length of copper lines to premises, enabling more premises to benefit from superfast speeds. The £23.7m project is being delivered by BT Ireland in eight phases, using a planning model taking account of local demographics, geography, planning requirements, existing infrastructure and the availability of suitable technologies.[31] The technology will be deployed on a value-for-money basis, to deliver best coverage to the maximum number of beneficiaries. BIP is scheduled to conclude by December 2015, by which point DETI estimates that 96% of premises in Northern Ireland will be able to access basic fixed-line broadband of at least 2Mbit/s, and 85% of premises will be served by at least 24Mbit/s.[32]

Road-maps for future broadband developments

3.41 We have outlined above that there are three main challenges in broadband roll-out: gaps in rural coverage; gaps in urban coverage; and providing superfast speeds to premises where normal FTTC roll-out is ineffective (typically because of long lines to premises). Looking further ahead, there may come a time when most consumers look for speeds greater than superfast. We have already seen commercial moves towards deploying fibre that is capable of delivering gigabit speeds to household premises. As the market develops, the government and industry will want to monitor technological options for moving to these ‘ultrafast’ broadband speeds.

[31] http://www.nidirect.gov.uk/index/information-and-services/leisure-home-and-community/technology-and-online-services/broadband-improvement-project.htm

[32] The first two phases of BIP are already complete and consumers are able to obtain details of the deployment through the Northern Ireland Government’s online service – NI Direct. The project is part-financed by the European Regional Development Fund under the European Sustainable Competitiveness Programme for Northern Ireland, and is also supported by the Department of Agriculture and Rural Development.

Technical developments to address gaps in rural and urban superfast broadband coverage

3.42 BDUK will pilot satellite and fixed-wireless solutions in the most rural areas. In June 2014, the Government announced eight pilot trials which will test alternative approaches to deploying superfast services to the most rural areas, supported by a £10m fund.[33] This will involve further development of the satellite and fixed-wireless solutions currently being trialled in the BDUK 'final 5%' pilots. Figure 12 summarises these pilots.

Figure 12 - BDUK pilots for the 'final 5%'

Approach	Operator	Pilot area	Solution
Wireless	AB Internet	Wales	Hybrid fixed line/wireless network to deliver speeds up to 50Mbit/s
Wireless	Airwave	North Yorkshire	Deployment of multiple wireless solutions: Wi-Fi at 2.4GHz, point-to-multipoint broadband fixed wireless at 2.4GHz or 5.8GHz, LTE small cells and TV white space
Wireless	Quickline	North Lincolnshire	Line of sight, near-line of sight and non-line of sight technologies, with a BDUK voucher scheme to encourage take-up
Satellite	Avanti	Northern Ireland and Scotland	Superfast satellite broadband using Ka-band satellite to deliver 30Mbit/s
Satellite	Satellite Internet	Devon and Somerset	Using Ka-band satellite as backhaul to local wireless networks
Fibre, Fixed Wireless, SLU	Call Flow	Hampshire	Range of access technologies
Financial Model	Cybermoor	Northumberland	Social investment for FTTP and wireless network roll-out
Operating Model	MLL	Kent	Creating a wholesale OSS/BSS platform to aggregate rural wireless networks.

3.43 Solutions such as these are already available for consumers to buy on the open market, but the cost can be prohibitive. It is possible that some form of public subsidy will be required, and joint public-private funding models are being considered. Timelines for roll-out are not yet known.

33 https://www.gov.uk/government/news/10m-broadfund-fund-winning-bids-announced

3.44 **Fibre to the remote node (FTTRN)**[34]**.** FTTRN is a deployment approach which brings the fibre network closer to the premises. The fibre line is deployed to a manhole or telegraph pole – i.e. a 'remote node' – nearer to the premises. This reduces the length of copper between the premises and the fibre network. It can provide superfast broadband to premises that are too far from existing cabinets, and to those connected directly to an exchange. FTTRN could use conventional VDSL technologies (which are currently used for FTTC deployments) or new 'G.Fast' technology (which we discuss further below). FTTRN deployments should help to extend the roll-out of superfast broadband services in both rural and urban areas.

3.45 BT is trialling FTTRN in a range of locations including North Yorkshire, and Shoreditch and Rotherhithe in London.[35] One of the challenges in rolling it out is providing sufficient power to this equipment. In BT's current trials, power is provided through separate cables. However, in the future spare copper pairs from the exchange could be used. 'Reverse powering' should also be possible, where the power is drawn from the premises it serves.

Technical improvements to maintain the capabilities of networks as take-up increases

3.46 Superfast broadband networks are built to deliver high speeds while assuming a certain level of take-up. As take-up increases, new technologies should help to maintain the capabilities of existing networks so that consumers do not experience degraded quality and speeds.

3.47 **Vectoring.** This is a technique used to reduce 'noise' on a line and thereby improve speeds. It will help to ensure that customers who currently have superfast broadband through FTTC maintain superfast speeds as take-up increases. Without vectoring, increasing cross-talk between adjacent copper lines could cause interference and, in some cases, reduce speeds by more than 50%. Openreach has been trialling vectoring technology in Braintree and Barnet since 2013.[36]

3.48 However, vectoring will not increase the speed of broadband for those premises that cannot currently access superfast speeds. Nor will it be suitable for all areas; this is because all copper lines from a cabinet need to be controlled and vectored by the same system to achieve the greatest improvement in speeds.

3.49 If only some of the lines are managed, the presence of the unmanaged lines (sometimes called 'alien' lines) can degrade performance. Therefore, vectoring may not be suitable where there is more than one provider at a cabinet - as happens when an alternative broadband operator is using sub-loop unbundling (SLU)[37] to control its customers' lines.

[34] In our 2012 *Infrastructure Report update*, we described FTTRN as Fibre to the distribution point (FTTdp) technology.

[35] http://www.ispreview.co.uk/index.php/2014/08/first-bt-fibre-remote-node-fttrn-broadband-trial-set-q4-2014.html

[36] http://www.btplc.com/news/articles/showarticle.cfm?ArticleID=712032ae-e0b8-4627-a6d2-b7a8a05c62c9

[37] Sub-loop unbundling (SLU) allows CPs to rent the copper access connection between end-users and an intermediate point in BT's access network, usually the street cabinet.

3.50 In its *Fixed Access Market Review*[38] (FAMR) Ofcom said that BT and the SLU operators should co-operate where either, or both, providers wished to roll out vectoring at a shared cabinet. This should be done so that vectoring by one or both parties can be implemented in the best possible way. However, as we note in our FAMR, there has been limited adoption of SLU in the UK to date.

3.51 **Cable technologies.** There are various developments which may increase Virgin Media's cable broadband speeds. Cable networks use a hybrid fibre-coaxial link, which means that line length is not an issue, unlike in the Openreach network. However, the architecture of cable networks means that a number of premises share the same access connection. A customer could find the available bandwidth limited by the data usage of others on the same access network.

3.52 Virgin Media has good control of the downstream and upstream speeds available to an end-user, which is mostly limited by the bandwidth it reserves for data services. Alongside broadband services, the connection is also used to carry cable television services.

3.53 However, as demand grows for download speeds and data, the cable network infrastructure will need upgrades to maintain sufficient capacity. Recognising this, Ofcom commissioned a report on likely developments [39]:

- **Node splitting**. This reduces the number of premises connected to a node, in order to increase the proportion of shared bandwidth to each home.

- **Improved spectrum use.** This involves bonding multiple frequency channels to increase the bandwidth available for downstream capacity, increasing the range of spectrum allocated for broadband and reallocating spectrum currently reserved for other uses.

- **Other technology developments**. Virgin Media currently uses DOCSIS 3.0, but a new standard, DOCSIS 3.1, was agreed in October 2013. This introduces better modulation technologies that could boost efficiency by up to 40%.

3.54 We expect these improvements to take place gradually, both in terms of upgrading the equipment in the network as well as redesigning the network architecture. DOCSIS 3.1 is backwards-compatible with DOCSIS 3.0, so these upgrades can take place wherever additional capacity is required in the network.

Technologies to achieve higher speeds

3.55 At some point, users may start to demand broadband speeds that NGA technologies typically can't deliver. There are a number of technical possibilities:

3.56 **Cable upgrades**. Within the cable network, it may be possible to extend the use of fibre technology closer to premises, and further increase the bandwidth available to end-users. New transmission techniques such as radio frequency over glass (RFoG) could then be used to exploit the increased bandwidth available. This would transform the speeds available to consumers, moving them well into the ultrafast range.

[38] http://stakeholders.ofcom.org.uk/binaries/telecoms/ga/fixed-access-market-reviews-2014/statement-june-2014/volume1.pdf

[39] Analysys Mason report, "*Future capability of cable networks for superfast broadband*". Available at: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/cable-sfbb.pdf

3.57 **G.Fast.** G.Fast is a broadband transmission standard that further increases the access speeds possible on copper lines. It increases the range of frequencies used to support broadband services, and download speeds of 800Mbit/s can be achieved. However, G.Fast has the limitation of only functioning over short lengths of copper line. It is typically deployed alongside FTTRN, which often reduces copper line lengths to within the usable range. BT has recently announced plans to test G.Fast.[40]

3.58 **Fibre to the premises (FTTP).** FTTP deploys fibre from the local exchange directly to the home. Fibre can support much higher bandwidths than copper-based technologies, and it is not limited by distance[41], so the speeds offered by this technology are appreciably higher.

3.59 The deployment of FTTP is not simple, with a range of technology uncertainties remaining. In relation to traditional telecommunications networks, such as those operated in the UK by BT and Kingston Communications, there are two main technology options: passive optical networks (PON) and point-to-point fibre:

- PONs remove the need for active electronics in the access network, thereby reducing operational complexity and power consumption. However, they are fundamentally 'shared' among a number of end-users, so maximum speeds may be limited.

- Point-to-point network architectures offer dedicated connections and potentially higher speeds as a result. However, they require active electronics in the access network and more fibre, increasing the overall cost.

3.60 These technologies are being developed and standardised, which could lead to further bandwidth increases. For example, using separate wavelengths (colours) of light over an existing PON to address a small number of, or even individual, end-users could offer very high bandwidths.[42] This type of innovation, although potentially some years away, could open up the possibility of more differentiated competition over a fibre-optic network.

3.61 Although BT's initial ambition for FTTP was that it would constitute up to 25% of NGA deployments[43], this has not occurred in practice. This is likely to be due to the lower costs and faster installation associated with FTTC deployments. Openreach deployments of FTTP can provide download speeds of up to 330Mbit/s and upload speeds of up to 30Mbit/s, based on using a PON technology known as G.PON[44]. In November 2014, BT reported that FTTP was available to 160,000 homes and businesses.[45] By contrast, 90% of KCOM's network uses FTTP, also based on G.PON technology offering download speeds of 100Mbit/s and upload speeds of 15Mbit/s.[46] Cityfibre and other smaller providers are also deploying FTTP to deliver

[40] http://www.btplc.com/News/Articles/ShowArticle.cfm?ArticleID=1F647C20-6F61-4E0F-A545-E23443E128AB
[41] Distance limitations in fibre optic technology normally arise for distances far in excess of those found in the access networks in the UK
[42] Referred to as wave division multiplexing passive optical network - WDM-PON
[43] http://www.bcs.org/upload/pdf/sfisher-090311.pdf
[44] Gigabit Passive Optical Network. It has a downstream capability of 2.5Gbit/s which is shared between all connected end-users.
[45] http://www.ispreview.co.uk/index.php/2014/11/bts-330mbps-ultrafast-fttp-broadband-reaches-250000-uk-premises.html
[46] http://www.kc.co.uk/products/broadband/
http://www.kc.co.uk/news/articles/kc-launches-uks-fastest-fibre-broadband-service/

very high speeds of around one Gigabit, based on either G.PON or the more ‘fibre rich’ Point to Point approach.

3.62 **5G** In addition to providing potentially improved mobile performance, 5G technology may also open up new wireless access network solutions for providing ultrafast broadband connectivity to homes and business as an alternative to FTTRN or fibre to the premises solutions. The aims of the initial research now underway include the capability of completely supplanting any final fixed connection to user devices for even ultrafast requirements, with very high densities of small cells and much higher spectral efficiency.

Backhaul technologies

3.63 Advances in access technologies generally lead to increases in headline connection speeds between the end-user and the local exchange (or cable head-end). However, in order to exploit fully the higher bandwidths available, other parts of the network may need to be upgraded. One of the most important parts is the backhaul section, which links the local exchange to an ISP’s core network.

3.64 The advances in optical fibre transmission now allow transmission speeds over a single fibre to exceed thousands of Gbit/s: Tbit/s (Terabits per second).[47] These advances should allow the backhaul and core networks to keep pace with the bandwidth demands anticipated, due to the increased consumption of video content over the internet.

Universal service commitment in broadband

There may be a case to review the current universal service commitment, set by the Government in 2009

3.65 The current universal service commitment is that every household should have access to broadband speeds of at least 2Mbit/s. This was set in 2009 and may now be insufficient. The current superfast broadband roll-out may result in speeds of above 30Mbit/s becoming available universally, or near-universally. If this does not happen, evidence in this report suggests that we may need a more detailed study on whether the basic USC should be increased. This includes evidence that:

- simultaneous, multi-person use of common applications will often require a speed well above 2Mbit/s – see Figure 30;
- consumers with a lower broadband connection speed, particularly those with below 2Mbit/s, generally have a lower quality of experience than users with higher speeds – see Figure 32; and
- there is suppressed demand at speeds below 10Mbit/s – see Figure 28.

3.66 There is international precedent of reviewing universal service arrangements over time. In the US, for example, the Federal Communications Committee has proposed changing the broadband performance standard from 4Mbit/s to 10Mbit/s for operators receiving Universal Service funding.

[47] http://phys.org/news/2014-01-fastest-real-world-fiber-14tbs.html

Broadband take-up and speeds

Take-up has increased

3.67 Take-up of fixed broadband has increased in the UK as a whole. In 2014, 73% of residential premises have a fixed broadband connection, compared to 72% in 2013. Scotland and Wales, in particular, have seen significant increases in broadband take-up.

Figure 13 - Take-up of fixed broadband, % of residential premises

	2014	2013
UK	**73%**	**72%**
England	73%	73%
Scotland	73%	67%
Wales	69%	63%
Northern Ireland	70%	71%

Source: Ofcom, Communications Market Report 2013 and 2014

3.68 There has been a more substantial increase in the number of premises taking superfast broadband, with penetration of 21% of UK premises (2013: 16%). Increases in take-up have been seen across the country, with Wales accounting for the greatest rise.

Figure 14 - Take-up of superfast broadband, % of premises

	2014	2013
UK	**21%**	**16%**
England	22%	16%
Scotland	16%	13%
Wales	13%	9%
Northern Ireland	22%	19%

Source: Ofcom analysis of operator data

Average broadband speeds have increased

3.69 Average download speeds have increased by 36% across the UK over the past year, driven by the increased take-up of superfast broadband. In England and Scotland average speeds increased from below 20Mbit/s, to 23.9Mbit/s and 21.1Mbit/s respectively. Average speeds in Wales continue to improve, reaching 18.0Mbit/s this year. In Northern Ireland, despite a smaller increase in superfast broadband take-up this year, average speeds still increased by over 4Mbit/s.

Figure 15 - Average broadband speeds (modem sync speeds), Mbit/s

	2014	2013	2012
UK	**23.4**	**17.6**	**12.7**
England	23.9	18.0	12.9
Scotland	21.1	15.8	12.1
Wales	18.0	13.2	9.9
Northern Ireland	24.8	20.4	14.4

Source: Ofcom analysis of operator data

Measuring broadband connection speeds

Ofcom currently uses two approaches for measuring broadband connection speeds. Both are useful in different contexts:

1) Sync speed of consumers' broadband modems. This is the maximum connection speed achievable between the consumer's ISP's access network and the premises. The sync speed measurements provide the best overall picture of access network performance.

2) Line speed of the connection. This is the usable broadband connection speed provided by an ISP at different times of the day. Line speed measurements are made using a method developed by SamKnows. Here, dedicated measurement equipment is provided to a relatively small, but representative, sample of UK households. Test data are sent between this equipment and a dedicated server connected to the ISP's core network. The speed at which the test data can be sent is used to measure the household's broadband connection speed. The measured speeds typically vary throughout the day depending on the level of congestion in the ISP's network. Line speed measurements are typically a few Mbit/s lower than sync speed measurements.

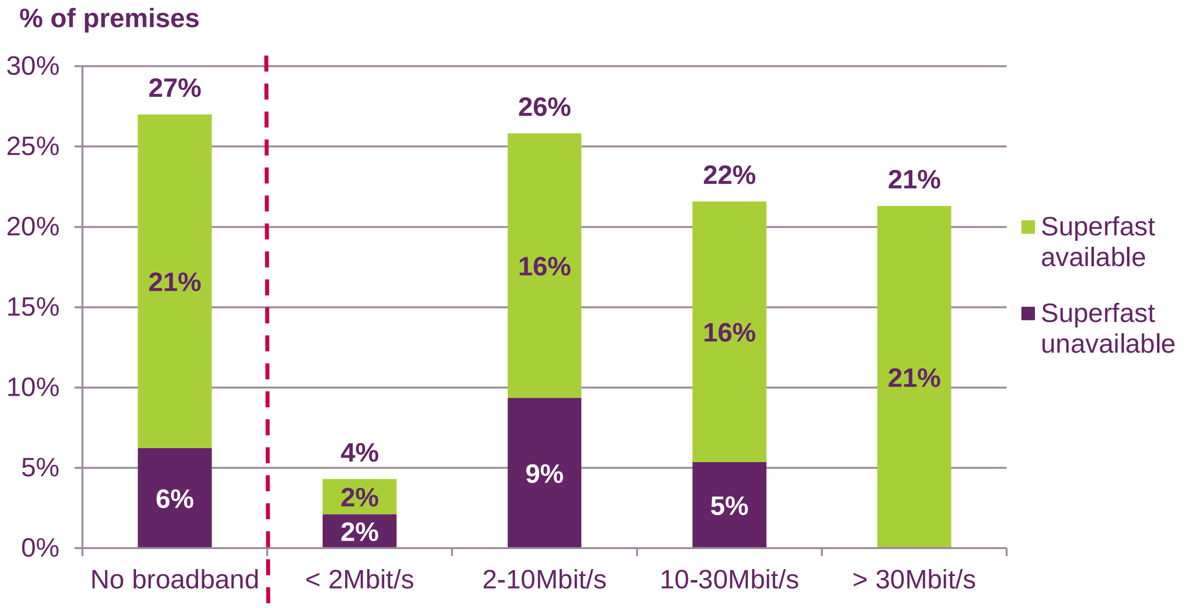
The measurements provide the best current measure of end-to-end performance from a consumer perspective. Actual Experience's report on broadband performance evaluation provides more information on how we are now developing new ways of measuring broadband quality.[48]

Increasing average broadband speeds mask significant variations

3.70 Figure 16 shows take-up of broadband by groups of speeds. It shows that there is considerable variation in the speeds received by consumers.

[48] Full report available at: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/performance-eval.pdf

Figure 16 - Take-up, by broadband speed[49]



Source: Ofcom analysis of operator data

3.71 A significant minority of broadband connections are achieving speeds of less than 10Mbit/s, with 4% of households in the UK on connections of less than 2Mbit/s. We discuss these thresholds on page 42 below.

3.72 This speed distribution is driven partly by coverage and partly by take-up. About two thirds of those premises with speeds of less than 10Mbit/s could choose to upgrade to superfast broadband; there is coverage in their areas. However, 27% of UK premises do not yet have superfast broadband coverage.

[49] 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 is therefore not available to the end-user. We do not apply a margin to 10Mbit/s or 30Mbit/s because these thresholds are derived differently.
We use 10Mbit/s because our data suggest that an average sync speed of 10Mbit/s is where data use begins to appear not to be constrained by speed. We use 30Mbit/s because this is Ofcom's and the European Commission's threshold for superfast broadband.

The number of connections receiving less than 2Mbit/s continues to fall

Figure 17 – Broadband connections below 2Mbit/s

	Percentage of premises receiving less than 2Mbit/s	
	June 2014	June 2013
UK	4%	6%
England	4%	5%
Scotland	4%	5%
Wales	6%	7%
NI	7%	9%

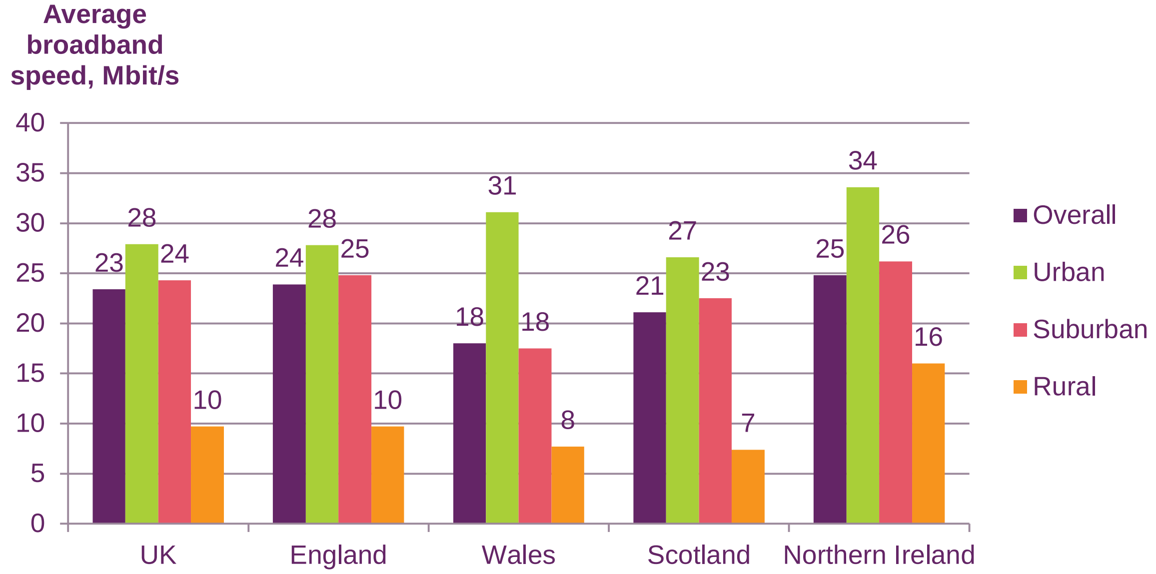
Source: Ofcom analysis of operator data

3.73 Figure 17 shows that the proportion of connections receiving less than 2Mbit/s is gradually falling. As discussed above, around half of those currently on less than 2Mbit/s could choose to upgrade to superfast broadband.

On average, rural areas have lower speeds

3.74 Rural areas typically have lower broadband speeds, and this is true across the UK, as Figure 18 below shows. Broadband connections in rural areas of Northern Ireland are fastest, at 16Mbit/s on average. This is more than twice the average speed in rural Wales and rural Scotland. This is due to higher NGA coverage and take-up, discussed at 3.39 above.

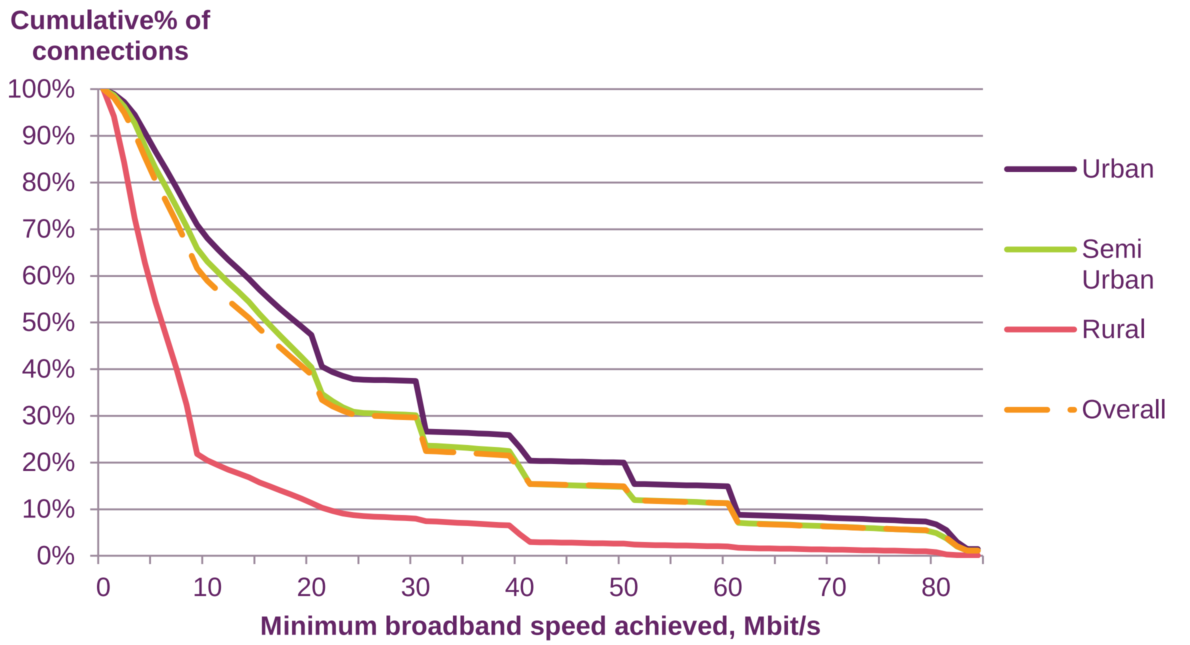
Figure 18 - Average broadband speeds, by nation and settlement type



Source: Ofcom analysis of operator data

3.75 This difference between urban and rural broadband speeds can also be seen in the figure below, which shows the distribution of broadband speeds for each category of population density.

Figure 19 - Distribution of broadband speeds, by population density



Source: Ofcom analysis of operator data

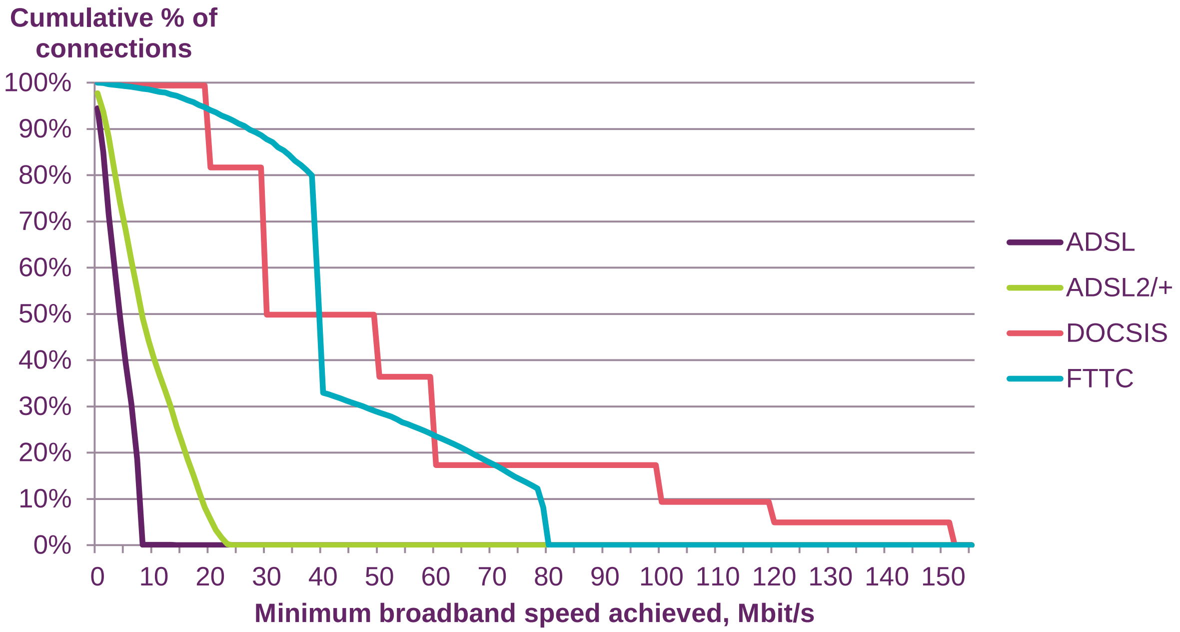
3.76 Only 20% of rural connections are faster than 10Mbit/s on average. This compares with 70% of urban connections, 65% of semi-urban connections and 60% of the UK as a whole.

3.77 Rural speeds are more likely to be slower, on average, than urban connections on average because:

- there is less superfast broadband in rural areas. We expect this to change as BDUK's rural broadband programme progresses; and
- rural premises are more likely than urban connections to be further away from cabinets, with long copper lines, leading to slower performance.

Broadband speeds are restricted by the limits of the technology used

Figure 20 - Distribution of speeds, by connection technology



Source: Ofcom analysis of operator data

3.78 The chart above shows the distribution of all connections by technology in June 2014.

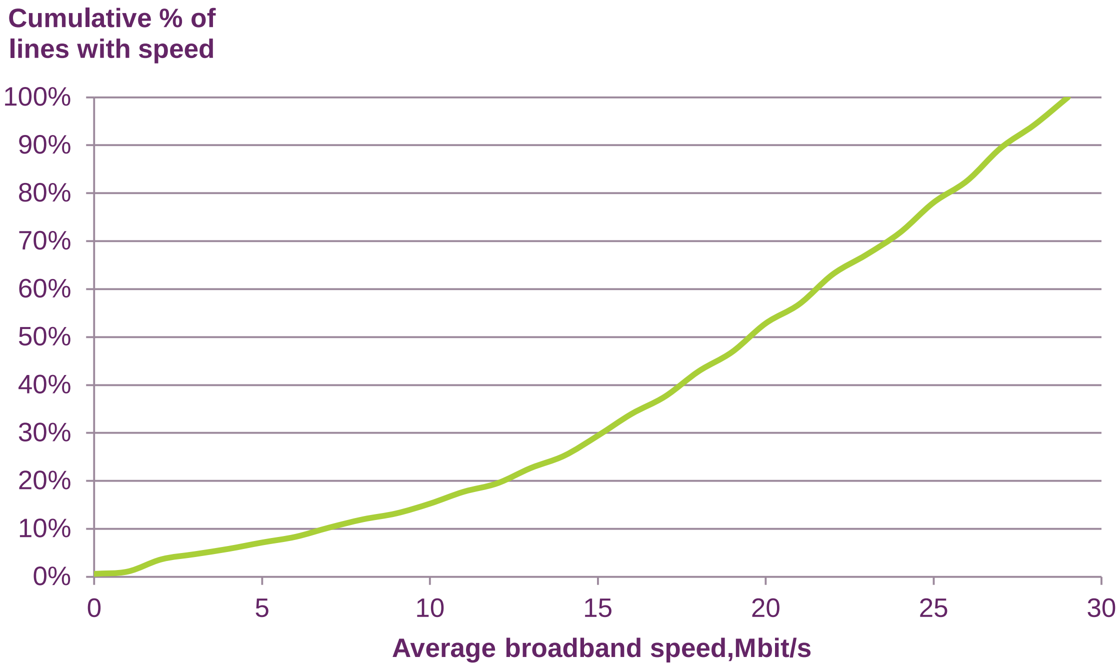
3.79 Average broadband speeds are restricted by the limits of the technology used. Figure 20 above shows that ADSL 2 connections can achieve up to 24Mbit/s, while ADSL connections reach a maximum of 8Mbit/s.

3.80 Cable provides connections with no variability in the delivered modem sync speeds. The large differences in the distribution of speeds are due to the different cable packages in use by customers, including legacy packages. Over 80% of cable connections are superfast, with 18% delivering over 80Mbit/s, and some customers have download speeds of up to 152Mbit/s.[50]

3.81 12% of FTTC connections are not superfast. Figure 21 shows the speed distribution for the FTTC lines that do not deliver superfast speeds. Around 4% of these lines do not provide 2Mbit/s speeds and 15% of these lines deliver speeds under 10Mbit/s.

[50] Not shown on the chart so as to ease readability of 0-80Mbit/s data.

Figure 21 – Speed distribution for BT's FTTC lines that do not deliver superfast speeds



Source: Ofcom analysis of operator data

3.82 BT's FTTC service has two possible headline speeds depending on choice of package: 38Mbit/s (using VDSL technology) and 76Mbit/s (using VDSL 2 technology). Approximately 39% of connections don't achieve these headline speeds in reality. Figure 22 below shows the distribution of FTTC connections. Those with speeds of less than 38Mbit/s (20% of connections) and those with speeds of between 40 and 76Mbit/s (19% of connections) will have been affected by some level of speed degradation. The remaining 61% of connections are more likely to be achieving their advertised headline speed.[51]

Figure 22 - Distribution of speeds for FTTC connections

Average modem sync speed, Mbit/s	Percentage of FTTC connections
< 38	20%
38 – 40	47%
40 – 76	19%
76 – 80	14%

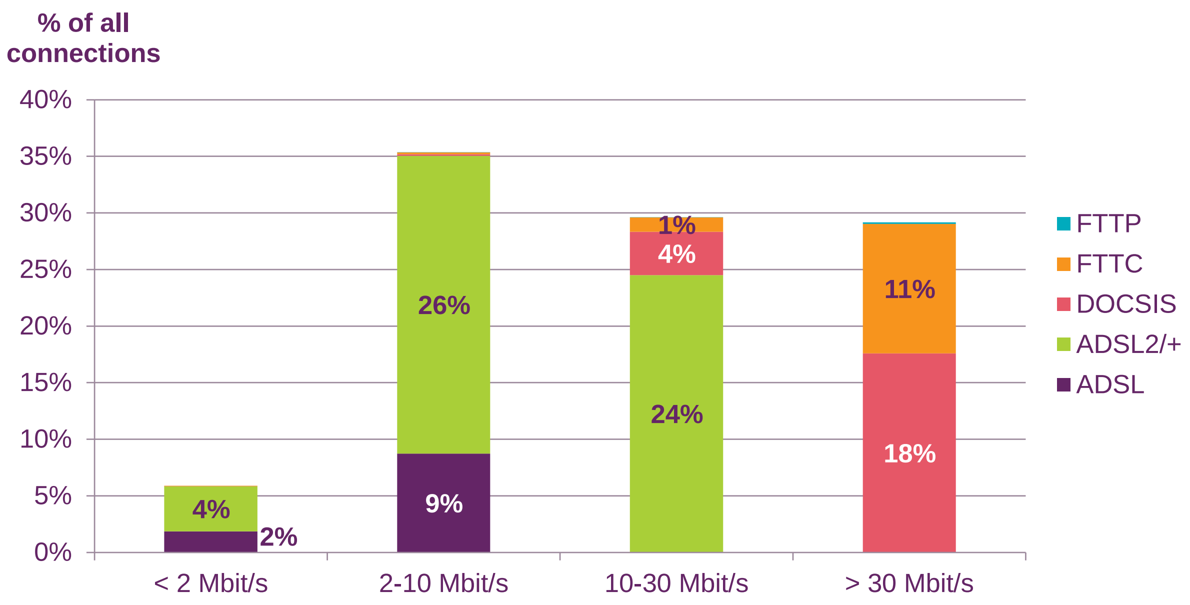
Source: Ofcom analysis of operator data

[51] The 47% of connections with speeds between 38 and 40Mbit/s may include some connections with speed degradation on a service with a headline speed of 76Mbit/s.

Despite growth in superfast, most UK broadband connections are still 'current-generation'

3.83 The figure below shows that the majority (59%) of connections in the UK are ADSL2 or ADSL2+, despite NGA coverage of 78% nationally. Seven per cent of UK broadband connections are still operating on the most basic ADSL technology; 22% are on Virgin Media DOCSIS, 12% on FTTC and 0.1% on FTTP.

Figure 23 - Technology used for broadband connections

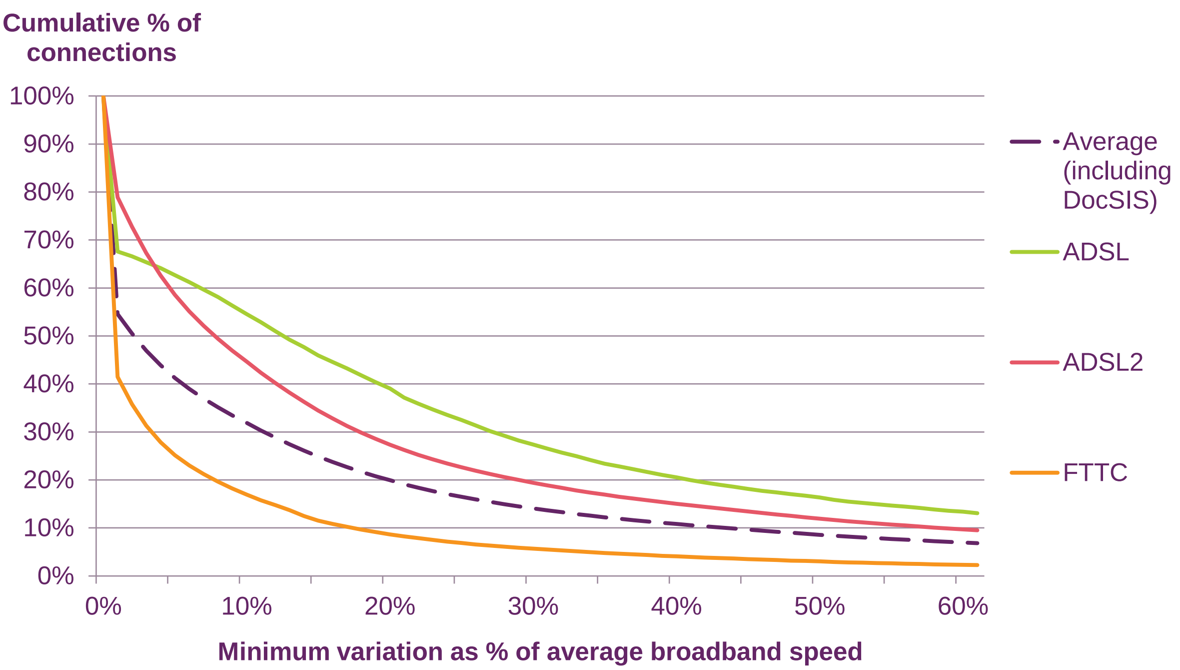


Source: Ofcom analysis of operator data

NGA technologies deliver greater line speed stability

3.84 Figure 24 shows that those who have migrated onto newer technologies experience a higher level of line stability. This is because the fibre infrastructure supports more consistent delivery of speeds than the copper used for first-generation connections.

Figure 24 - Variation in line speeds (range from a line's minimum to maximum speed as a % of the line's average)



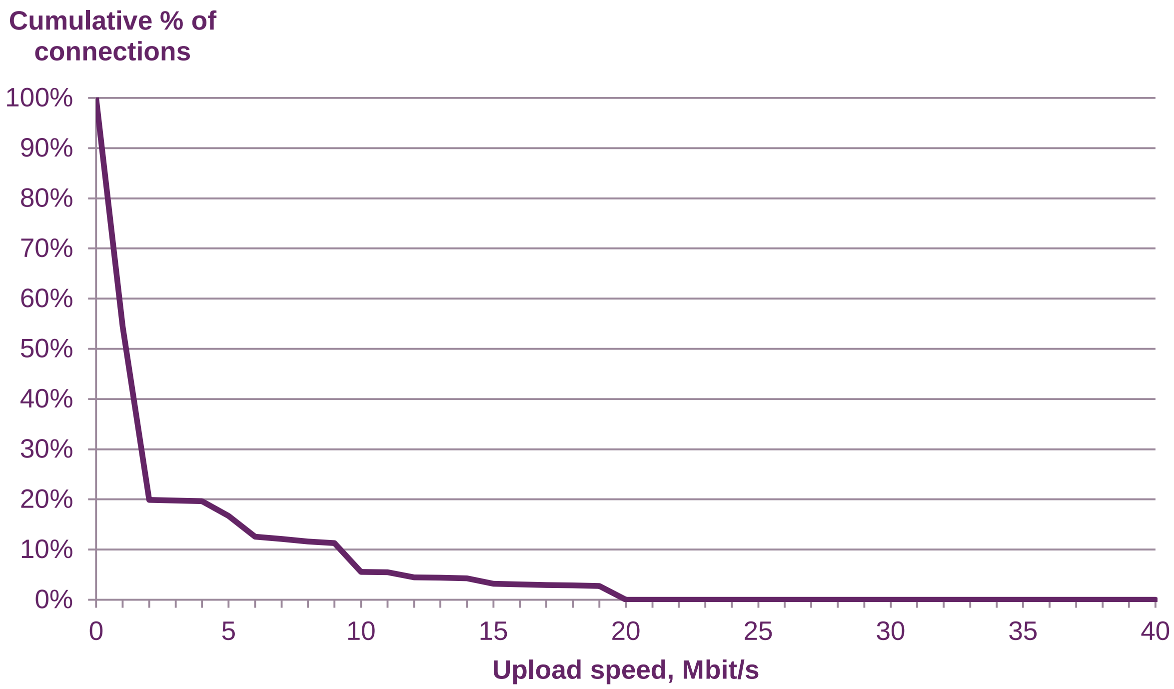
Source: Ofcom analysis of operator data

Upload speeds

3.85 Upload speed can be crucially important for some services. High-quality video calling, for example, requires equally fast download and upload speeds. The average upload speed in the UK is currently 3Mbit/s, compared to the 23Mbit/s average download speed. For those premises with superfast broadband connections, the average upload speed is 8Mbit/s compared to the 56Mbit/s average download speed.

3.86 Figure 25 below shows that the distribution of upload speeds is skewed towards the lower end, with 80% of connections having an upload speed of less than 2Mbit/s.

Figure 25 - Distribution of upload speeds



Source: Ofcom analysis of operator data

Data use

The amount of data used by consumers is growing rapidly

3.87 Overall data use has increased significantly. This is consistent with users migrating to faster connections, and because data-heavy services such as video streaming are becoming more popular.

Figure 26 - Data use and average speeds (all operators)

	2014	2013
Average download speeds, Mbit/s	23	18
Average data usage, GB	58	30

[✂]

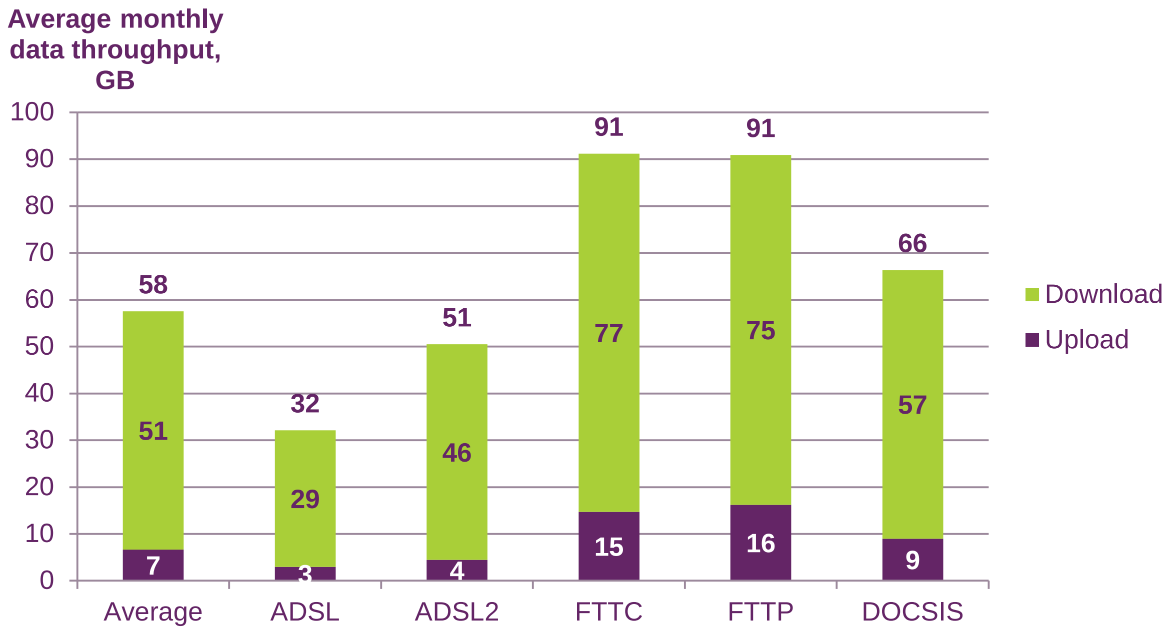
Source: Ofcom analysis of operator data

3.88 UK households and small businesses are, on average, downloading 51GB per month and uploading 7GB per month. This is a 93% increase on last year, with all operators seeing an increase in the amount of data downloaded. This corresponds with generally increased broadband speeds.

3.89 [✂]

3.90 The increases in data use may be due to the use of bundled TV content provided by these operators. For example, Virgin Media and Sky both offer bundled TV, broadband and phone services. Both offer video-on-demand services, but use different connections to deliver content. BT and TalkTalk also offer bundled broadband and IPTV.

Figure 27 - Monthly data downloaded and uploaded, by technology: UK averages



Source: Ofcom analysis of operator data

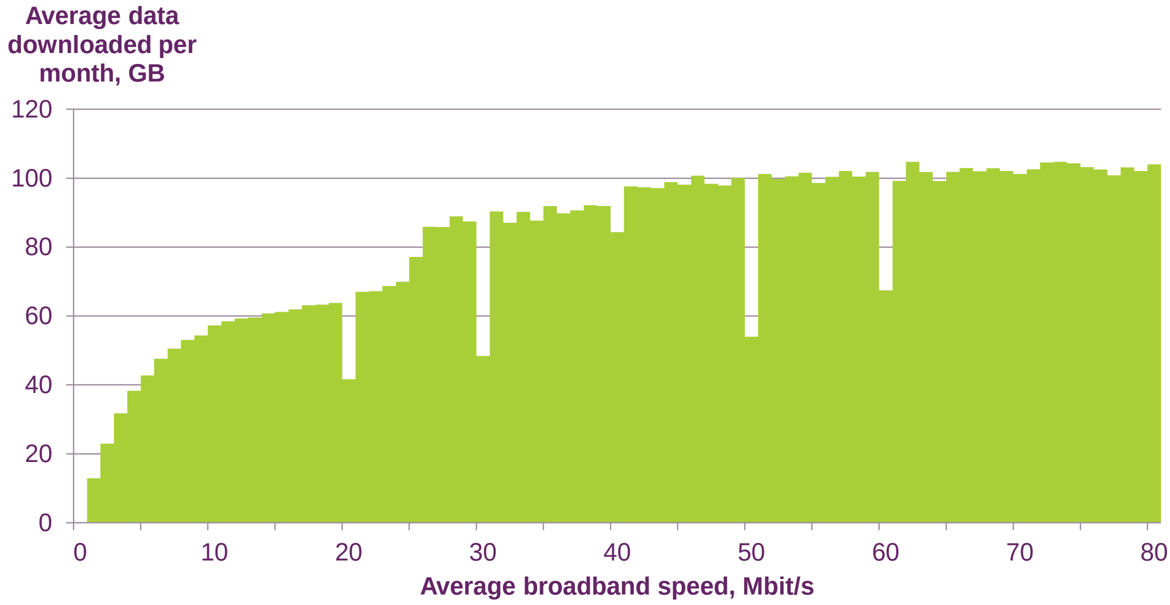
3.91 Data use varies according to broadband technology. As expected, data use is relatively low for first-generation ADSL connections and for the most commonly-used technology, ADSL2.

3.92 FTTC and FTTP connections, however, appear to lead to a doubling in downloading and uploading activity over ADSL technologies, with average downloads of 74.7 to 76.5GB, and average uploads of between 14.7 and 16.2GB per connection per month. To some extent, this may be a function of self-selection: those households who were heavy data users on previous technologies would be more likely to upgrade to NGA.

3.93 Cable users, however, have not downloaded as much as those using FTTC and FTTP. This is despite their having a higher average speed than FTTC connections overall.

3.94 When observing the relationship between speeds and data use for all technology, the drop in data use by cable users becomes more apparent, as shown in Figure 28 below.

Figure 28 - Average monthly data downloaded, by average download speed



Source: Ofcom analysis of operator data

3.95 There are a few points to note from the figure above:

i) There is a rapid increase in data use as speeds increase between 0 and 10Mbit/s.

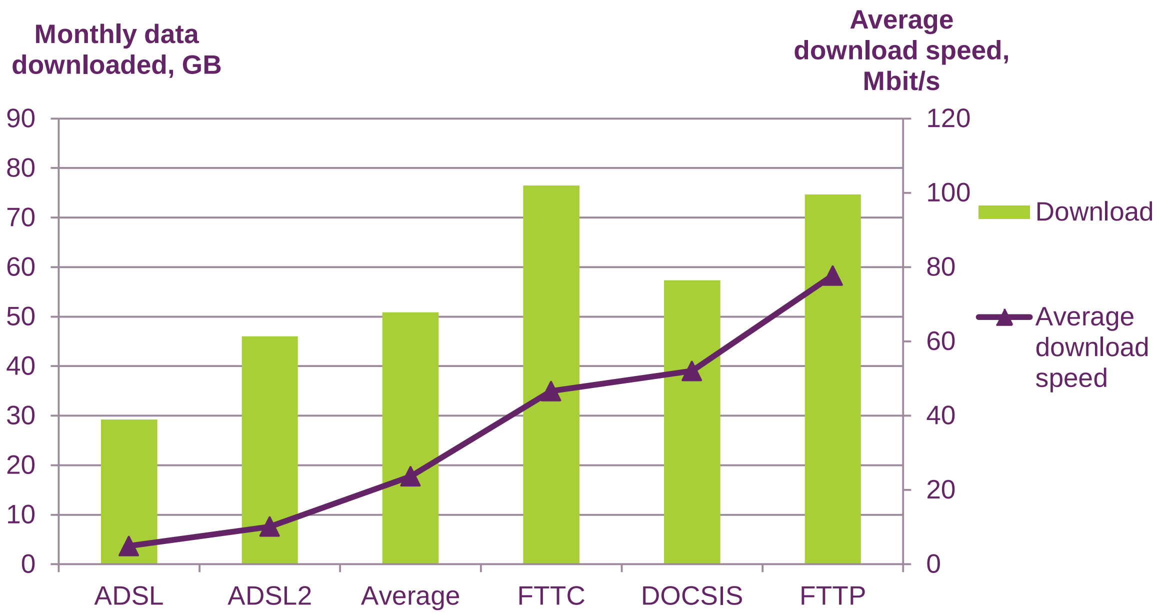
ii) The majority of superfast broadband users appear to be using on average around 100GB per month.

iii) Virgin Media users can be identified at the drops in average data use at its various points of package entry, i.e. at 20, 30, 50 and 60Mbit/s.[52] This suggests a lower-than-average data use through its primary broadband connections, in line with the overall technology averages shown in Figure 27.[53]

[52] 20, 30, 60 and 120Mbit/s are Virgin Media's legacy packages, with 50, 100 and 152Mbit/s currently being offered to new customers. The overall sample size for 100 and 152Mbit/s connections were too low to calculate average data use per connection.

[53] This could be for reasons unique to Virgin Media's network, for instance users with Virgin Media's DOCSIS 3.0 connection may not download much video content, preferring to use separate DVB-C VoD capacity, unlike users of other technologies, or that, as a result of bundling with more expensive TV packages, Virgin Media users might be getting higher broadband speeds than they would have otherwise chosen.

Figure 29 - Data downloaded and average modem sync speeds, by network technology

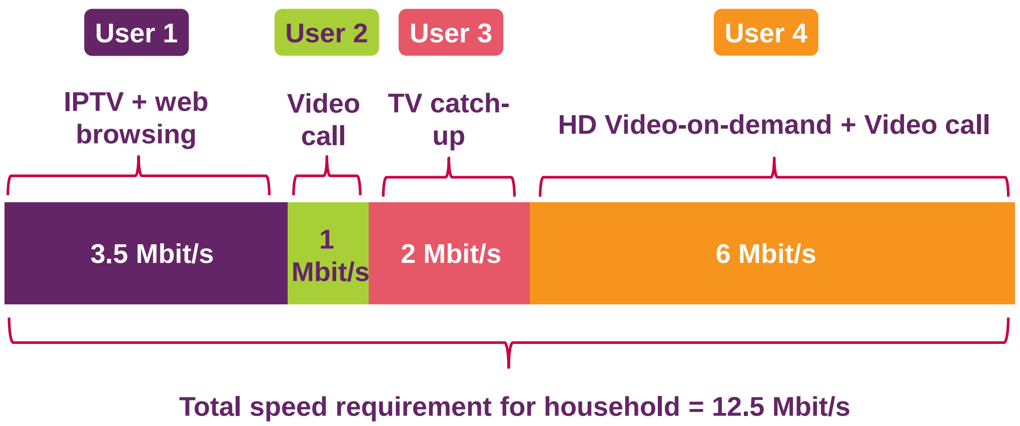


Source: Ofcom analysis of operator data

Changing broadband performance demands

3.96 Demands on broadband services have been changing, driven largely by availability and by the way we use new online services. If we take a hypothetical four -person household, this is how its typical data use might look at peak time:

Figure 30 - Hypothetical example of data use in a four-person household



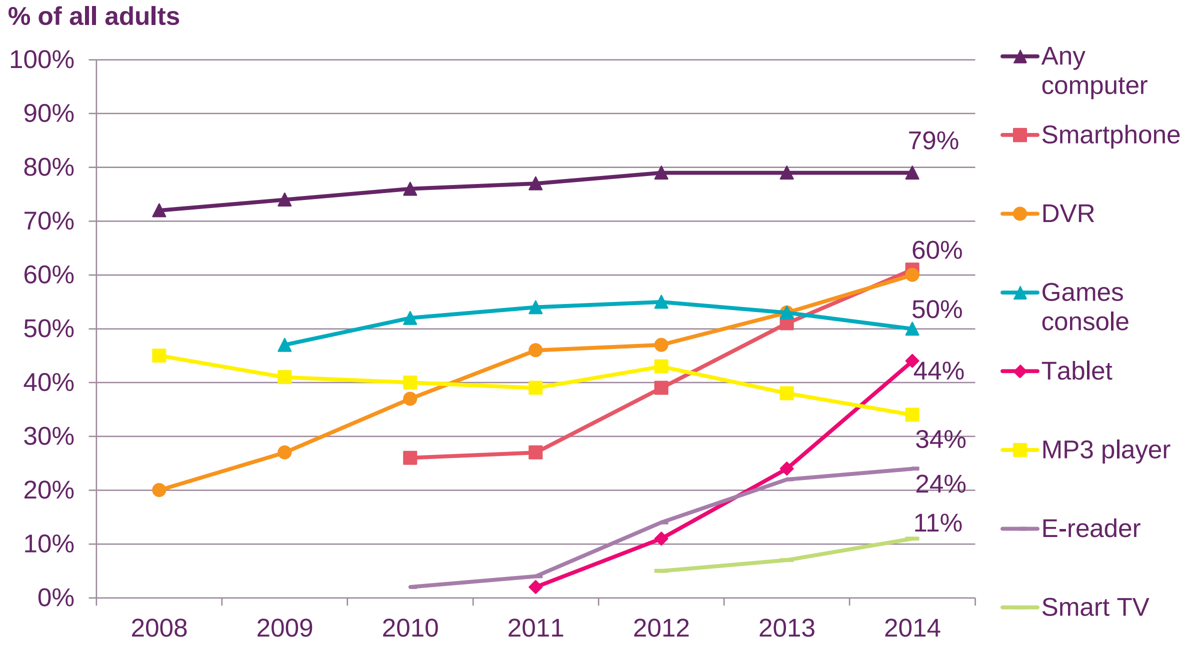
Source: Ofcom estimates

3.97 The increasing technical quality of content (high definition and ultra-high definition) will increase bandwidth requirements over time. But this effect may be offset by improved compression standards, so less bandwidth will be required to transmit the same amount of data.

3.98 The figure above highlights how a household's bandwidth requirements are increased both by the number of users and by their multi-tasking behaviour. We discussed the popularity of media multi-tasking in Ofcom's 2014 *Communications Market Report*. Ninety-nine per cent of adults undertake some form of media multi-tasking during any given week, made possible by the increase in media devices in the home.

3.99 In December 2013 Ofcom part-funded a report for the Broadband Stakeholder Group (BSG) on estimated future demand for bandwidth. It isn't possible to accurately predict future demand and the factors playing into it are diverse. Therefore the research developed a scenario-based approach which considered how the different drivers could play out for different kinds of households. Some scenarios suggested that four adult households could require 20-30Mbit/s in 2023, with 4K video streaming, HD content downloads and continued web browsing, among other activities. The median household scenario had an estimated demand of 19Mbit/s in 2023.[54]

Figure 31 - Take-up of media devices



Source: Ofcom, Communications Market Report 2014

3.100 Today, 44% of adults own a tablet (in 2011 this device was found in only 2% of households). Smartphone ownership has risen from 27% in 2011 to 60% in 2014. Smart TVs are also growing in popularity, although any significant growth is likely to be linked to the TV replacement cycle. Overall, these devices are expected to drive further demand for broadband bandwidth in the home. We discuss the implications of this further below.

[54] http://www.broadbanduk.org/2013/11/05/bsg-publishes-new-model-for-analysing-domestic-demand-for-bandwidth/

Broadband quality of experience

Line speeds provide only a partial picture of broadband quality of experience

3.101 Connection speeds are an important factor in the consumer's broadband experience, and especially when accessing data-heavy services such as video. To date, measurements of the speed of *last mile* broadband access network connections have been used to provide an indication of broadband performance.

3.102 However, in practice the speed of the access network is only one of a number of factors that can be equally important to the overall experience. For example, the upstream inter-connection arrangements between ISPs and online services, and the performance of in-home networking solutions such as Wi-Fi can have a significant impact.

3.103 Factors such as these, in the wider parts of the end-to-end broadband chain, are becoming more significant with the wider roll-out of higher-speed NGA technologies. This is because they are making the last mile access network connections a less significant constraint, putting greater emphasis on other potential bottlenecks in the delivery chain.

3.104 With this in mind, we describe below the results of our recent research into a new measurement approach. This looks beyond the access network and evaluates the effect of the full end-to-end connection chain.

All parts of the broadband connection can affect consumers' experience of using the internet

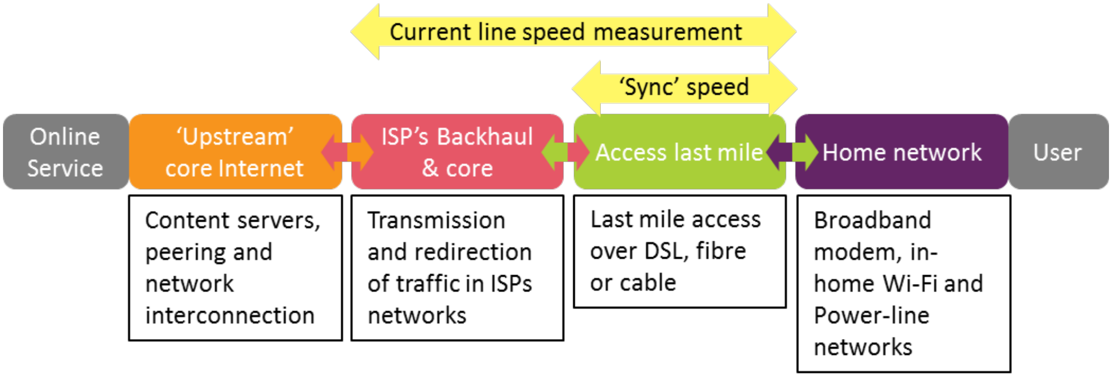
3.105 The broadband connection chain between a consumer and an online service provider can be separated into four main parts:

- **The in-home network.** This includes home routers as well as Ethernet, power-line and Wi-Fi connections to broadband equipment in the home.

- **The broadband access network.** This is the last-mile connection between the ISP and the consumer's premises. It can be provided using cable, DSL, wireless or fibre technology.

- **The ISP's backhaul and core network.** This includes the IP-based networks operated by the ISP, which connect the consumer broadband access network to the wider internet and/or content hosts.

- '**Upstream' core internet.** This includes the networks that are not directly owned by an ISP and constitute the wider internet, including the servers of online websites and services (e.g. video services).



3.106 All four parts of the connection chain can have an effect on the consumer experience. Broadband sync and line speed measurements (described above) only provide a partial view of this, because they do not measure the performance of either the upstream core internet or the home network parts of the connection chain.

End-to-end connection performance has different effects on different types of service

3.107 Different types of online services have different levels of sensitivity to the performance of the end-to-end connection chain. For example, high capacity live video streaming services are generally less tolerant of poor end-to-end connection performance than are lower capacity, non-real-time services such as email.

A new end-to-end, quality of experience measurement approach

3.108 Over the past year, Ofcom has commissioned independent research, by Actual Experience, into a new broadband measurement approach.[55] This new approach is capable of:

- evaluating the performance of the complete end-to-end connection chain between an online service provider and the consumer; and

- identifying the parts of the chain that have the greatest effect on the consumer experience, for different types of online services.

3.109 The approach uses software installed on a home computer that sends and receives small amounts of data through the network, between the home and online content providers. By analysing the delays and losses that these information flows experience over time, the software is able to estimate the user's likely online experience.

3.110 The research conducted to date has been primarily a proof-of-concept exercise. The initial results, illustrated in the chart below, suggest that consumers with a lower broadband connection speed generally have a lower quality of experience than those with higher connection speeds. At connection speeds above the range of 5-10Mbit/s, the relationship breaks down and broadband connection speed is no longer an important determinant of performance.

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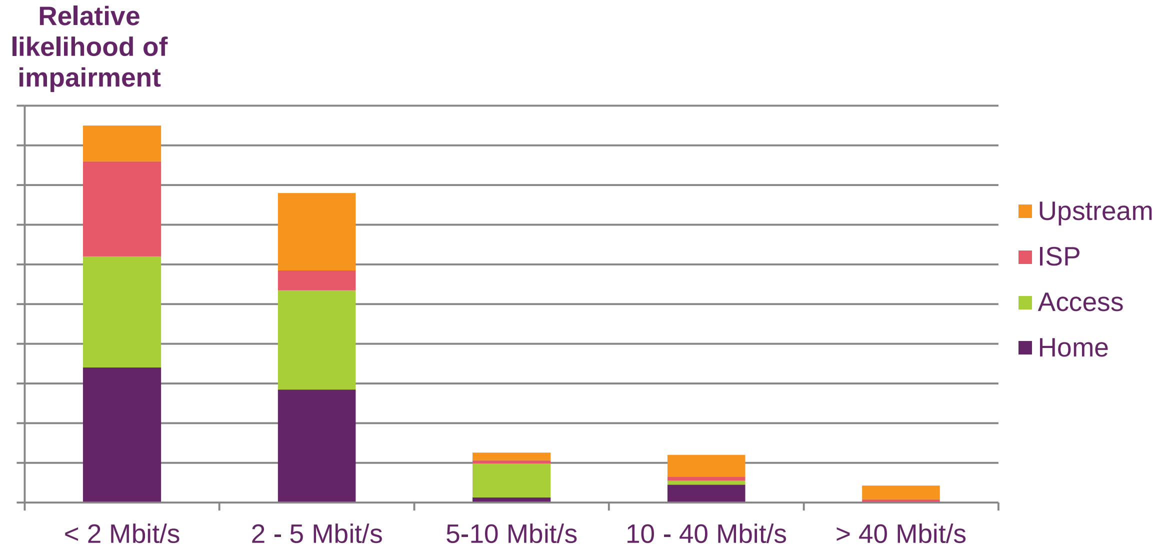
[55] More details can be found in the full report available at: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/performance-eval.pdf

3.111 The graph also shows that other parts of the connection chain, as well as the access network, are contributing to the reduction in performance at lower broadband connection speeds. For example, the increased contribution of the in-home network might result from poor Wi-Fi modem performance and/or an incorrectly configured home router.

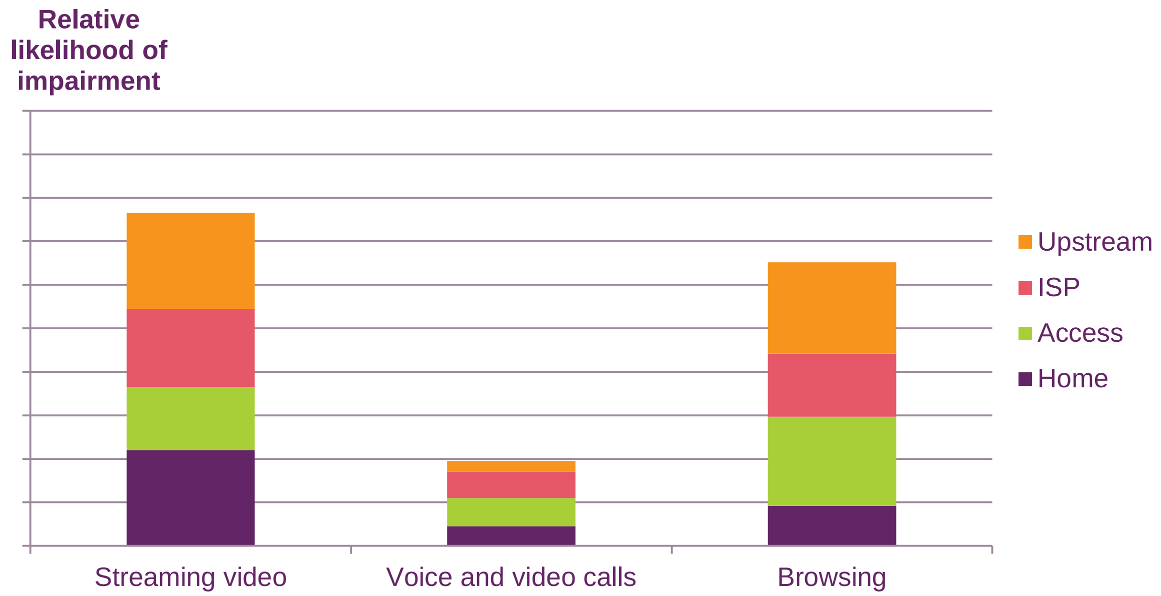
Figure 32 - The effect of different parts of the broadband connection chain on the consumer experience, at different broadband connection speeds



Source: Actual Experience plc

3.112 The new measurement approach was also used to investigate how different applications perform over the same broadband network. The results of these evaluations are shown in the figure below.

Figure 33 - The effect of different parts of the broadband connection chain on the consumer experience when using different online services



Source: Actual Experience plc

3.113 This chart shows that the experience of using broadband for low-capacity voice calls is generally better than for web browsing and accessing video streaming services.

3.114 Although the results of this new measurement approach are only indicative at this stage, they illustrate its potential to provide useful input for consumers and ISPs:

- consumers can access better information about the experience they are likely to have when accessing different online services; and
- ISPs can gain better insight, helping them to identify how and where performance degradations are arising in the broadband delivery chain.

We plan to carry out further research to develop our approach to evaluating the performance of the end-to-end broadband connection chain

3.115 In particular, we intend to conduct further tests to assess the correlation between the reported consumer experience of different broadband connections, and those predicted by end-to-end measurement approaches. This work will help us develop our approach to evaluating fixed broadband performance in the future.

Network sharing and wholesale services

3.116 Ofcom is required, under the legislation which underpins this report, to report on the extent to which providers allow other communications providers to use their networks. This can broadly be done in two ways: by network sharing and through wholesale services.

There has been little sharing of passive infrastructure between network operators.

3.117 Since 2011, BT has been obliged through Ofcom regulation to offer passive infrastructure access (PIA) to operators across the UK, excluding the Hull area, for the deployment of access networks. In our most recent *Fixed Access Market Review*, published in June 2014, we decided to maintain this obligation on BT.

3.118 The *Fixed Access Market Review* is focused on mass market fixed access (broadband) networks so the PIA remedy is designed to give other operators the opportunity to deploy their own fibre/copper-based access networks. Take-up of Openreach's PIA product has been low, in part due to BT having won all of the main BDUK programme contracts to date.

3.119 As part of our review of leased line markets (the *Business Connectivity Market Review*) we are considering whether passive remedies could play a role in promoting competition in broadband markets. We have recently published a consultation seeking input from stakeholders to inform our assessment.[56]

3.120 Network operators also provide passive access to their networks on a commercial basis, including access to their ducts, or more commonly in the form of dark fibre. As well as sharing the passive infrastructure, communications providers use other types of infrastructure to support their roll-out of new networks, including electricity poles to carry overhead fibre or copper networks.

[56] http://stakeholders.ofcom.org.uk/consultations/bcmr-passives/

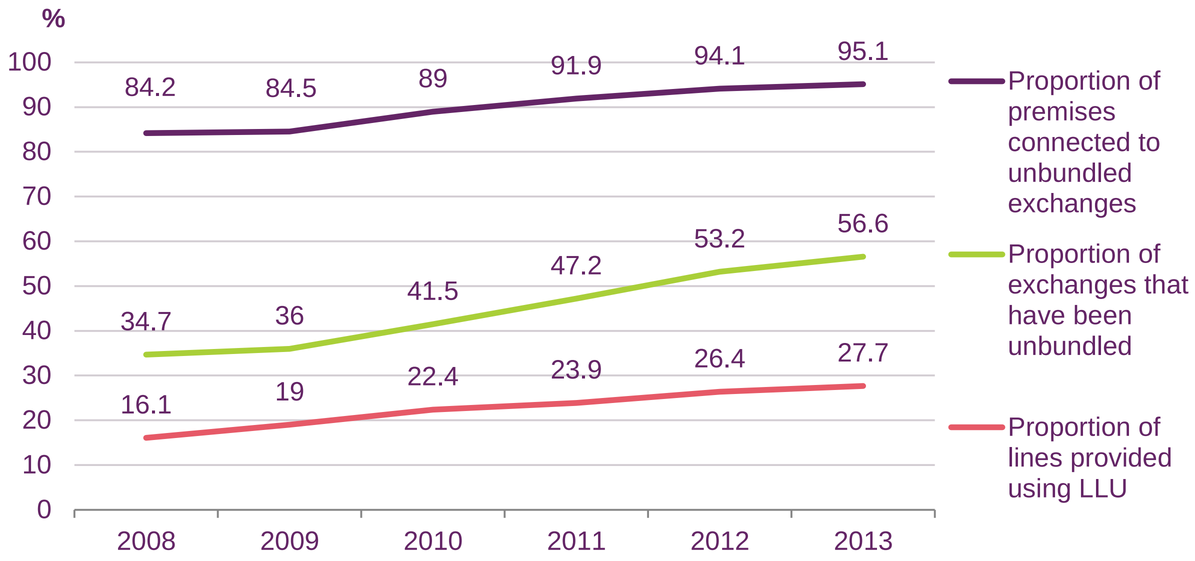
3.121 Network operators have reported very limited sharing of passive infrastructure for the roll-out of access networks. This is a similar situation to that which we reported on in 2011. However, operators this year reported greater sharing of passive infrastructure with companies in *other* sectors, such as energy providers. BT reported use of others' passive infrastructure in almost all its exchange areas. Similarly, KCOM uses electricity poles to support its network roll-out in rural areas.

3.122 The EU has identified this opportunity for cross sector infrastructure sharing as a potentially important boost to the prospects for more rapid and widespread deployment of superfast broadband networks. It has introduced a Directive[57] that will come into force in the UK by 2016 that should enable easier access to existing infrastructure, facilitate joint working and increase the likelihood of successful cross sector cooperation

3.123 Alongside access to its network infrastructure to support new network roll-out, there continues to be an obligation on BT Openreach to provide local loop unbundling (LLU). This allows an operator to take over the telephone line from the BT exchange to supply consumers and to install its own telephony and broadband equipment in the exchange.

3.124 Many operators, such as Sky and TalkTalk, provide services using the BT Openreach network. Virgin Media does not provide access to other operators. In Hull, KCOM has a very small number of resellers on its network.

Figure 34 - Proportion of unbundled BT local exchanges and connected premises



Source: Ofcom/BT

3.125 The number of premises connected to unbundled exchanges, and the number of lines which are using LLU, have both increased. However, the rate of increase is slowing, as the most recent exchanges to be unbundled tend to have fewer lines than the exchanges unbundled in the initial roll-out of LLU. Nevertheless, the majority of premises are now connected to unbundled exchanges.

57 http://ec.europa.eu/digital-agenda/en/news/factsheets-directive-201461ce-broadband-cost-reduction

3.126 Sub-loop unbundling (SLU), a variant of LLU, enables an operator to gain access to the end-user's copper access connection at an intermediate point between the exchange and the premises - usually at the street cabinet. There is currently little demand for SLU in its current form, as it is viable only in very specific conditions. The largest application of SLU was the FTTC roll-out in the South Yorkshire Digital Region, an enterprise which ultimately did not succeed and was discontinued in August 2014.

Wholesale services are available for providers without their own infrastructure

3.127 Companies can agree wholesale arrangements between one another on commercial terms. Operators that choose not to roll out their own network equipment can buy a wholesale service from another service provider. There are a range of wholesale services, giving operators a choice between different levels of management over the services they provide. In some cases operators have chosen to provide services over their own network in areas where it is cost-effective and buy wholesale services in other parts of the country.

3.128 Wholesale requirements can also be introduced through regulation. Where we identify a market problem through a market review, we often find it appropriate to introduce wholesale must-offer obligations. These require operators to offer services on a wholesale basis to other operators.

3.129 Openreach's generic Ethernet access (GEA) product is the primary way for operators to deliver a superfast broadband service using the BT Openreach network. This is an active service that gives operators a virtual connection to their customers, although they have less control than with passive infrastructure access over the services they can provide to an end-user. Beyond this, wholesale services are available from a range of providers, including BT Wholesale, TalkTalk, KCOM and Vodafone.

Section 4

SME connectivity

Overview

4.1 Businesses rely on telephone and internet services to sell goods and services, connect to customers, deal with suppliers and manage their workforce. Beyond this, many digital businesses rely on broadband services for the actual delivery of their products and services. Reliable and high quality broadband and mobile connections are becoming ever more important to commerce and to the wider economy.

4.2 Good connectivity is important for businesses of all sizes. In this report we focus on provision for businesses with 249 or fewer employees – referred to as Small and Medium Enterprises (SMEs). SMEs have a range of different connectivity requirements.

4.3 The infrastructure used to provide connectivity to large businesses is often dedicated high capacity 'leased lines'. Leased lines have near universal availability across the country because they are installed by arrangement with providers through commercial negotiation. The level of competition in leased lines is considered in detail in our *Business Connectivity Market Review.*[58] However large business needs can also vary. For example, large businesses may have local branches which depend on non-dedicated connections.

4.4 This chapter considers:

- **SME connectivity requirements.** Connectivity requirements vary depending on the size of SME and type of business. Research has shown that most SMEs say their needs are well catered for by the communications market. Some SMEs use dedicated business lines but others, particularly businesses with fewer employees, may use a mix of business and residential services, with some relying solely on residential services.[59] Mobile coverage is also important to SMEs, as it is for residential consumers.

- **Coverage of superfast broadband for SMEs.** We have analysed superfast broadband coverage for SMEs with at least one employee – i.e. excluding sole traders – and compared it with average coverage. Superfast broadband coverage has not reached all SMEs and our analysis suggests that SME coverage lags average coverage in urban areas in particular (67% vs. 83%). In rural areas overall coverage is lower, and the difference between superfast broadband coverage for SMEs and average coverage is smaller (16% vs. 22%).

[58] Every three years we carry out the Business Connectivity Market Review (BCMR) in which we assess competition in the supply of leased lines market, identify any providers with significant market power and impose appropriate regulation to address any competition concerns we have identified. The current BCMR is underway. We published a Call for Inputs on 1 April 2014 (http://stakeholders.ofcom.org.uk/consultations/business-connectivity-market-review /) and a further consultation on data analysis on 8 October 2014 (http://stakeholders.ofcom.org.uk/consultations/bcmr-data-analysis/

[59] Jigsaw research, 6 November 2014. *SME experience of communications services – a research report.* *http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/sme/sme_research_report.pdf*

- **Connectivity options.** Businesses often have multiple connectivity options, although some connection types may not be suitable. An NGA based superfast broadband connection using the same network being deployed for residential customers may be one option. Other options include traditional non-fibre broadband (ADSL), leased lines and, where available, fixed wireless or ultrafast solutions. There is a fairly active market of smaller scale providers of fixed wireless and ultrafast connectivity for businesses, especially in urban areas. Leased lines may be a good option when multiple businesses are based in the same premises if they can aggregate their demand or if the resilience or reliability of leased lines is required.

- **Improving superfast broadband coverage for SMEs.** The challenges around improving coverage for SMEs are broadly similar to the overall challenges of extending superfast broadband roll-out, discussed in section 3. Some SMEs may be able to take advantage of the Government's SuperConnected Cities voucher scheme, which can provide up to £3,000 to businesses to fund installation of a high speed broadband connection.[60]

- **Further work on SME connectivity.** In September this year we announced a range of work to ensure that the market is delivering for SMEs. As part of this work we will develop our initial analysis of the availability of broadband for SMEs to understand the extent to which areas without superfast broadband coverage may have other options available to them. We are inviting views on current levels of availability, choice and quality of communications services for SMEs through a Call for Inputs.[61] Responses will inform a report in spring 2015 on how the market for fixed and mobile connectivity is serving SMEs.

SME requirements

4.5 Connectivity requirements vary depending on the size of SME and type of business. Smaller businesses may be able to use ADSL or superfast broadband provided over NGA technologies. These connections are contended and offer asymmetric download and upload speeds. Larger SMEs are likely to require dedicated internet connections which offer guaranteed quality of service. Some will require uncontended bandwidth and symmetric upload and download speeds provided using leased lines or other bespoke options. It is therefore important to understand the connectivity requirements of SMEs and the degree to which they are currently satisfied.

4.6 Recent research conducted by Jigsaw for Ofcom found that most SMEs consider that communication services are fundamental to their business (83%) and that their needs are well catered for by the communications market (85%).

4.7 The Jigsaw research found that satisfaction with internet services was lower than for landline and mobile voice services. Speed and reliability were the most frequently given reasons for dissatisfaction. In particular, satisfaction with ADSL broadband – which is used by two thirds of SMEs – was significantly lower than with other services. SMEs that said their growth had been hampered by lack of suitable communications services (15%) reported higher than average dissatisfaction with ADSL. A minority of SMEs (11%) believed their business would benefit from

[60] Information on the SuperConnected Cities voucher scheme can be found here: https://www.connectionvouchers.co.uk/

[61] http://stakeholders.ofcom.org.uk/consultations/smes-cfi/

communication services not currently available. Faster/fibre broadband was the service most likely to be mentioned.[62]

4.8 The Federation of Small Businesses (FSB) published a report in July 2014 in which it claimed that 14% of small businesses consider a lack of reliable and/or fast broadband to be their main barrier to growth. It called on Government to adopt more ambitious targets for rolling out high speed broadband for businesses across the UK.[63] The Communication Consumer Panel research into micro businesses' experiences of communications services highlights the critical role that communications services play in the success of businesses with 0-9 employees. The report calls for greater support from the Government and industry to help maximise the opportunities presented by communications services, including supplying improved speeds and coverage for both fast broadband and mobile voice and data.[64]

4.9 Some SMEs, such as those that offer internet-based services, are likely to have higher resilience and/or bandwidth requirements. They would therefore be likely to require a service tailored to business needs, which provides better performance and has higher service levels than services which are typically taken by residential consumers. The majority of SMEs buy business broadband services rather than using residential products (77% for landlines, 74% for internet services and 50% of mobile phone services).[65]

4.10 There is evidence that superfast broadband has contributed to business benefits, suggesting that SMEs in areas not yet served by NGA could benefit from roll-out. In Cornwall, the site of a specific intervention to deliver superfast broadband[66], 79% of businesses surveyed reported that superfast broadband was saving time and/or money.[67] At the end of the interim phase of the Superfast North Yorkshire project 37% of businesses said that they had gained new customers since receiving the support.[68]

Case study - digital clusters

New "start-up" businesses working in similar fields often group together in tight geographical clusters. The benefits of industrial clustering include creating an environment that fosters collaboration and innovation and attracting talent and investment.[69] Digital businesses will have high connectivity requirements and in particular are likely to require more symmetric services to allow for large file uploads.

[62] Jigsaw research, 6 November 2014. *SME experience of communications services – a research report.* http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/sme/sme_research_report.pdf
[63] http://www.fsb.org.uk/policy/assets/FSB-The-Fourth-Utility.pdf
[64] http://www.communicationsconsumerpanel.org.uk/downloads/panel-micro-business-report-final.pdf
[65] Ibid.
[66] http://www.superfastcornwall.org/
[67] Serio Insight with Plymouth University, April 2014. *Superfast Cornwall Evaluation Update Report,* http://www.superfastcornwall.org/assets/file/Superfast%20Cornwall%20Evaluation%20Update%20Report%202014%20FINAL%20REVISED.pdf
[68] The Superfast North Yorkshire project is designed to improve availability and use of high speed broadband infrastructure by SMEs: http://www.superfastnorthyorkshire.com/home. Interim report: http://www.superfastnorthyorkshire.com/media/970722/Interim-Evaluation-of-NYnet-Final-Report.pdf
[69] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/206944/13-901-information-economy-strategy.pdf p18

The TechBritain project identified 32 tech/digital clusters in Britain in October 2014.[70] The top five by size were London, Manchester, Edinburgh, Cambridge and Newcastle upon Tyne. Some clusters are located in urban centres and others in purpose-built sites.

Tech City – the cluster of digital start-ups centred on Old Street roundabout in east London – has largely developed in buildings not previously used for office work. This has meant that there are sometimes fewer connectivity options for companies based there. Digital start-ups in Manchester's Northern Quarter have reported similar challenges.

When start-ups are located in the same building they can often benefit from grouping together to pool their demand. This can enable them to attract (and/or share) the cost of installing and leasing high bandwidth connections to their offices. The Perseverance Works provides an example of businesses successfully taking this approach. It houses 90 small businesses in a complex of buildings in Shoreditch, London at the heart of Tech City. Following technical advice to define connectivity requirements, they tendered collectively for a communications supplier. The contract was awarded to FibreOptions to install FTTP throughout the site. So far 30 businesses have signed up for services and used BDUK connection vouchers to fund the installation. The network provides a 100Mbit/s symmetric service with 10:1 contention ratio.[71]

In Cambridge the university has played a key role in the development of the cluster. Companies are based at campuses and parks in and around the city, for example the St John's Innovation Centre. Connectivity is planned into the development of campus-based clusters and companies' connectivity requirements are met as part of their tenancy agreements.

4.11 Mobile services are also important to SMEs, who often rely on doing business on the move. Research showed that 79% of SMEs used mobile phones for business. SMEs based in, or regularly working in, remote rural locations were less satisfied with the reliability of their signal and geographic coverage of their mobile service.[72] Similarly a recent Communications Consumer Panel report on microbusinesses highlighted that "those who were mainly on the road or working on site, were more reliant on the coverage of mobile networks".[73] Improving the coverage and quality of mobile services across the UK will benefit SMEs and residential consumers alike.

4.12 The current position, and initiatives underway to improve mobile network capabilities, are discussed in section 5. The remainder of this chapter focuses on fixed connectivity for SMEs, where we have a specific concern about the availability of superfast broadband.

Coverage of superfast broadband for SMEs

4.13 We have analysed the availability of superfast broadband delivered over BT, Virgin and KCOM's networks to SMEs of at least one employee (i.e. not including sole traders). We have compared coverage of SMEs against the average, split by geography and size of business.

[70] http://techbritain.com/. The TechBritain project seeks to identify clusters across the country through charting the location of tech companies and start-ups and grouping them according to their proximity to one another.

[71] http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/infrastructure-2014/next-gen/

[72] Jigsaw research, 6 November 2014. *SME experience of communications services – a research report.* http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/sme/sme_research_report.pdf

[73] http://www.communicationsconsumerpanel.org.uk/downloads/panel-micro-business-report-final.pdf

4.14 There is less data available about the location of sole traders. Therefore we have not been able to distinguish superfast broadband availability for sole traders from overall availability for residential and small commercial premises. We know that sole traders are a significant proportion of SMEs and will consider their connectivity options as part of our further work on SMEs.

Coverage by geography

4.15 Analysis of superfast broadband availability for SMEs (Figure 35) shows that it is available to 56% of SMEs across the UK, compared with 75% average coverage. Superfast broadband availability to SME business addresses is higher than the UK average in Northern Ireland (69%) and England (59%) and significantly lower in Scotland (40%) and Wales (37%). In all nations superfast broadband availability for SMEs lags average coverage.

4.16 Superfast broadband availability for SMEs is considerably lower than total coverage in urban areas (67% vs.83%). In rural areas, superfast broadband availability is lower for SMEs than total coverage but by a lesser degree (16% vs. 22%).

4.17 It should be noted that lower availability of superfast broadband to business addresses may be in part due to the availability of dedicated connectivity such as leased lines. Where SMEs are based in large buildings or are in business parks, dedicated fibre connections (which can potentially be shared across multiple businesses) may better meet the needs of SMEs than BT's FTTC network or Virgin Media's cable network. Ofcom's report on the availability, choice and quality of communications services for SMEs, scheduled for publication in spring 2015, will examine this further.

Figure 35 - Comparison of SFBB coverage for SMEs with total coverage

	Total SFBB coverage	SFBB coverage for SMEs with 1 or more employees
UK	**75%**	**56%**
England	77%	59%
Scotland	61%	40%
Wales	55%	37%
Northern Ireland	77%	69%
Urban	83%	67%
Rural	22%	16%

Source: Ofcom analysis of operator data

Coverage by SME size

4.18 The table below shows that superfast broadband coverage is higher for SMEs with 1-9 employees (58%) than small (51%) and medium (47%) businesses on a UK-wide basis. We will investigate this further but it may be due to the greater likelihood that smaller SMEs are based in residential areas, which have been the focus of superfast broadband roll-out. It may also reflect that larger businesses are more likely to have their needs met by the dedicated connectivity provided by leased lines. This pattern of decreasing superfast broadband availability as SME size increases is mirrored in England and Scotland but not in Wales and Northern Ireland.

4.19 In urban areas, larger SMEs have worse superfast broadband coverage, in line with the national trend for SME coverage. In rural areas coverage is slightly higher for small and medium businesses than businesses with 1-9 employees.

Figure 36 - SFBB coverage for SMEs by size of business

	SMEs with 1 or more employees ***1-249 employees***	Micro (excluding sole traders) *1-9 employees*	Small *10-49 employees*	Medium *50-249 employees*
UK	**56%**	**58%**	**51%**	**47%**
England	**59%**	61%	52%	48%
Scotland	**40%**	42%	38%	34%
Wales	**37%**	37%	38%	35%
Northern Ireland	**69%**	67%	74%	74%
Urban	**67%**	70%	59%	53%
Rural	**16%**	15%	17%	17%

Source: Ofcom analysis of operator data

Options for SMEs

4.20 Businesses often have multiple connectivity options available to them, although some connection types may not be suitable. An NGA-based superfast broadband connection may be one option, but a significant proportion of SMEs are unable to access superfast broadband due to gaps in coverage. These may be in cities, business parks and in rural areas.

4.21 SMEs (with or without NGA coverage) will typically have other options for connectivity including:

- Broadband up to 24Mbit/s (although typically much slower) using traditional broadband (ADSL lines) and available from a range of providers including products tailored for businesses.

- Leased lines, offering fully scalable uncontended symmetric capacity, by providing a dedicated fibre connection from the customer's premises to the communications provider's Ethernet core network.

- Services such as Generic Ethernet Access (GEA) and Ethernet in the First Mile (EFM) which bridge the gap between broadband services and full Ethernet solutions. EFM uses between two and eight copper pairs to deliver symmetrical speeds from 2Mbit/s to 35Mbit/s.

4.22 However, we are aware that for some SMEs these options may either provide insufficient speeds and reliability (ADSL), lack symmetric download and upload speeds (ADSL and NGA) or may not be affordable (leased lines).[74]

4.23 Installation times are also an important factor for SMEs. Businesses and communications providers have raised concerns with us about Openreach's quality of service in the delivery of wholesale Ethernet leased lines to new customers on a timely basis. Openreach is engaged in a number of initiatives to improve performance and the Office of the Telecoms Adjudicator has been facilitating industry discussions. We are reviewing these developments as part of the Business Connectivity Market Review (BCMR) and considering whether there is a need for regulatory intervention to address them.

Improving urban coverage

4.24 There are gaps in superfast coverage in some inner city areas due to a range of factors discussed at 3.31. BT is assessing options for extending superfast coverage to gaps in some urban centres. This includes technical trials of new approaches where the existing network topology makes NGA roll-out more challenging. Extending coverage would enable the provision of superfast services through a range of products from different providers.

4.25 Another option for many may be the Government's Superconnected Cities project, which offers funding for SMEs towards installation of infrastructure to deliver faster internet services. The funding can be used with a range of providers in 22 cities across the UK. This project has already helped many SMEs get high speed broadband. In some cases, however, the use of the funding is limited by current network roll-out and SMEs can still face significant installation costs and lead times.

4.26 In some cities, alternative providers are beginning to roll out ultrafast fibre networks offering speeds of up to a gigabit per second. For example:

- **CityFibre**. ISPs use Cityfibre's fibre-optic network to serve business customers in York, Aberdeen and other cities (see case study below)

- **Hyperoptic**. FTTP network providing 1 Gbit/s broadband in London, Reading, Cardiff and Bristol and now expanding to Leeds, Manchester and Liverpool.

[74] The Federation of Small Business discussion paper explores communications services for SMEs including speeds, reliability and affordability: http://www.fsb.org.uk/policy/assets/FSB-The-Fourth-Utility.pdf

- **Nottingham Ultraband project**. Nottingham City Council is piloting a project which connects three business sites - Broadway Cinema and Media Centre, Antenna and Mercury House - in the city centre with a gigabit network.

4.27 These kinds of networks can be suitable for SMEs with bandwidth requirements higher than those offered over the residential NGA network.

4.28 There are also further options beyond fixed networks. In some areas, new approaches to securing business connectivity are emerging that do not rely on laying fibre. These include: fixed-wireless and 4G based services provided by companies like Bluebox Broadband, Call Flow Solutions, MLL Telecom, Optimity, Relish and others.[75]

Improving rural coverage

4.29 SMEs in rural areas have low superfast broadband coverage. The continuation of Phase 1 and Phase 2 of the BDUK programme to extend coverage to 95% of the country will increase coverage for SMEs as well residential consumers, especially as a proportion of SMEs are home-based. BDUK is now also considering options to address the "final 5%", discussed in section 3.

4.30 In some areas business coverage is being explicitly considered in roll-out plans. The superfast broadband roll-out projects in Cornwall and North Yorkshire are not yet complete and both incorporate ambitions to provide coverage to businesses as well as residential customers.

4.31 Non-major NGA providers are providing business connectivity in some rural areas. For example, Gigaclear provides a range of gigabit business broadband packages in rural villages in Oxfordshire and is expanding its FTTP network in other rural areas.

Business Parks

4.32 Some business parks lack fibre connectivity and are outside current NGA upgrade plans. In its report the FSB called for the Government to "prioritise the delivery of fibre-optic broadband to new and existing business parks and ensure that enterprise zones and clusters are fully connected. The aim should be to equip all businesses in these areas with high-speed broadband, with guaranteed speeds and a symmetrical service."[76]

4.33 We will consider the factors affecting business park connectivity as part of our further work on SMEs. It may be that business park connectivity is better provided by dedicated leased line (shared across businesses) or other network options than by superfast broadband delivered over FTTC or cable. The case study examples from Tech City and Titanic Quarter show the role bespoke solutions can play in serving business parks.

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[75] http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/infrastructure-2014/next-gen/

[76] http://www.fsb.org.uk/policy/assets/FSB-The-Fourth-Utility.pdf

Case study - Titanic Quarter, Belfast

The Titanic Quarter provides an example of how connectivity provision can be integrated into the development of a business site to serve a range of residential and business consumers, including SMEs.

Titanic Quarter is a regeneration project in Belfast's docklands on the edge of Belfast City Centre. Around 4,000 people work and 1,000 live in the estate. Key tenants include the Northern Ireland Science Park, Titanic Belfast visitor centre, Belfast Metropolitan College, Citi, the Public Records Office and the Titanic Studios, currently home to the production of HBO's series 'Game of Thrones'.

The Science Park is a business support initiative offering office space facilities across six buildings within Titanic Quarter to knowledge-based enterprises of all sizes. It is currently home to 125 companies, mostly SMEs, working in areas as diverse as software development, mobile technology, renewable energy, digital media and financial engineering.

Both Titanic Quarter and the Science Park operate separate private, managed, high-capacity fibre and copper network infrastructures on a transparent, open-access, carrier-neutral basis. The networks offer managed extension circuits and dark fibre connections for voice and data, providing a single style of infrastructure within the estate.

Telecoms providers can connect to this infrastructure at common gateway points and are carried to the end customer within Titanic Quarter. Under Titanic Quarter's agreement with its local infrastructure management partner – Atlas Communications – the rates of access, charging and Service Level Agreements are the same for all telecoms providers. The Science Park has a similar but separate arrangement which can offer tenants 5GBit/s connectivity through a range of providers.

Direct international connectivity is also available from Titanic Quarter via Project Kelvin – Northern Ireland's fibre-optic link to North America. Good connectivity has proved crucial to Titanic Quarter's tenants. It has helped the Science Park attract technology-focused overseas companies and also develop its SMEs by easily relocating growing tenants within the park. Citi currently handles one tenth of its daily global Foreign Exchange business from its Titanic Quarter operation.

Further analysis

4.34 Further work is required on the question of connectivity for SMEs to quantify the issue more precisely and understand the extent to which gaps in superfast broadband coverage are affecting SMEs.

4.35 As part of our SME plan, we have issued a Call for Inputs (CFI) to ask small businesses and communications providers for their views on current levels of availability as well as choice and quality of communications services for SMEs. Responses are due by 2 January.[77] We encourage interested parties to respond in order to highlight issues in relation to the provision of communications services to SMEs.

4.36 Responses to this CFI will inform a report on how the market is serving SMEs in relation to fixed and mobile connectivity. This will be published in spring 2015. This initial report will outline any further work we plan to undertake. We will also assess

[77] http://stakeholders.ofcom.org.uk/consultations/smes-cfi/

whether adequate protection is in place for SMEs, if we found there are specific barriers and problems faced by SMEs.

4.37 Alongside this, we have recently launched a business portal on our website with advice specifically tailored for businesses. It includes information on choosing or switching to a new provider, navigating and negotiating contracts, and resolving complaints with a provider.[78]

[78] www.ofcom.org.uk/adviceforbusinesses

Section 5

Mobile networks and Wi-Fi

Overview

5.1 Mobile services are now at the heart of how most people stay in touch, at home or out and about. In the UK, 95% of households use mobile phones and 16% have no voice landline at all. Mobiles are also vitally important to business: 79% of SMEs use mobile phones.

5.2 In this section we provide an update on:

- The levels of coverage provided by 2G, 3G and 4G mobile networks;
- The increasing and changing use of mobile data services, including video and over the top messaging services;
- The increasing number and usage of public Wi-Fi hot spots;
- Emerging developments in the Internet of Things sector and next generation 5G mobile services.

5.3 A short summary of the key developments in each of these areas is provided below, which are then set out in greater detail later in this section.

- **The variety of ways in which consumers use mobile devices has led us towards a more refined approach to measuring mobile coverage**: A consequence of increasing mobile usage is that consumers increasingly expect to be able to reliably use mobile phones in more locations than ever before – indoors, outdoors, on the move, in cars, and in more rural areas. To provide mobile coverage estimates that are likely to more representative of the consumer experience of using mobile services we have made two adjustments to our reporting of mobile coverage in this year's report:
  - We have assumed a higher average mobile signal level, -86dBm, is needed to make a reliable voice call on a 2G network. This increased level takes into account the higher operational signal levels required by some more recent smartphones. It also accounts for the signal levels we have found from drive tests to be needed in practice to make reliable voice calls in vehicles fitted with external mobile aerials;
  - We have provided estimates of in-building mobile coverage and coverage in vehicles without an external aerial, based on an assumed additional propagation loss factor of 10 dB. In practice the actual in-building loss factor is subject to large variations depending on the building type and the construction materials used.[79] Similarly different types of vehicle are likely to reduce in-vehicle signal levels by different amounts. Given this, the in-building and in-vehicle coverage estimates provided in this report should be viewed as indicative.

[79] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/buildingmaterials/

5.4 Based on these adjustments the headline levels of 2G, 3G and 4G coverage are:

- **2G voice and low data rate coverage:** 99% of premises are covered outdoors by at least one MNO and 97% are covered by all three of the MNOs that operate 2G networks. Rural coverage is lower, with 98% of premises covered outdoors by at least one MNO, and only 82% covered by all operators. Indoor premises coverage in the UK by all three 2G networks is 83%.

- **3G high speed data coverage:** 84% of UK premises are covered outdoors by all four MNOs, although this falls to 75% of premises in Scotland, 65% in Wales and 63% in Northern Ireland. Indoor premises coverage in the UK by all four 3G networks is 71%.

- **4G very high speed data coverage:** The current major technological development in mobile is the ongoing roll-out of fourth generation (4G) networks. Good progress is being made with 35% of premises now having coverage by Vodafone, EE and O2, and 72% of premises have coverage from at least one of them. Initial analysis suggests that between June and October 2014, these three MNOs have increased coverage by between 2 and 14 percentage points.

5.5 **We are supporting a number of initiatives to improve mobile coverage:** To help improve mobile coverage and support competition Ofcom is taking steps to increase the amount of lower frequency spectrum, which has good outdoor and indoor propagation characteristics, for use by mobile networks. This included the recent award of the 800 MHz band which formed part of the 4G auction, and future plans to enable the release of the 700 MHz band. In addition the Government's Mobile Infrastructure Project is aiming to extend mobile coverage to up 60,000 premises that are in mobile 'not-spots' locations. The Government is also consulting on a range of options to ensure mobile coverage is available from more than one MNO in 'partial mobile not-spots' locations. These options include: national roaming, whereby a consumer unable to access their normal network could roam to another operator's to make a call; increased infrastructure sharing; "virtual network" arrangements; and, extended coverage obligations. Ofcom is providing technical support to this programme. In addition, technological developments may also help: for example, MNOs are increasingly using femtocells to improve mobile coverage in some areas.

5.6 **Mobile data usage continues to grow rapidly but SMS messaging has reduced:** The growth in consumer demand for mobile data has been rapid: at the time of our first Infrastructure Report in 2011, only 32% of adults were using their mobile to access the internet. Three years later, 57% of adults do. Total data throughput has increased by 53% this year, which is similar to the increase in 2013. This has been driven to a large degree by the continued growth in both the numbers and use of smartphones and tablet PCs. Video continues to represent a significant proportion of mobile traffic at 39%. In contrast the number of SMS messages sent in 2013 fell from 172 million in 2011/12, to 130 million. This is likely to be due to a substitution of SMS messaging by over the top messaging applications such as Whatsapp and Kik. The number of reported users of over the top messaging services grew by over a third over this period[80].

[80] CMR 2014

5.7 **There are is already significant interest in moving beyond 4G:** LTE advanced, sometimes known as 4G+, has been launched in some cities, increasing both capacity and speeds of mobile broadband. Looking further ahead, research is underway to establish the capabilities of future 5G networks, which could be available for deployment from 2020 onwards. In addition to providing enhanced mobile performance, high speed 5G technology may also potentially be used in the future to provide fixed wireless ultrafast broadband connectivity to homes (see the Fixed Broadband section).

5.8 **The Internet of Things is starting to become reality:** The number of applications and devices communicating with each other without human involvement are expected to grow. Existing examples include home management sensors, smart meters, vehicle traffic management and wearable technologies such as fitness bands. The capacity requirements of these first generation services are relatively modest and can be most likely met by existing, mobile, and license exempt bands. However, they are likely to raise a new set of network security and reliability, consumer privacy, and ubiquitous coverage requirements.

Measuring and predicting mobile coverage

5.9 Currently, there are four mobile network operators (MNOs) operating across most of the UK:[81]

- EE (previously known as 'Everything Everywhere');
- O2 (owned by Telefonica UK);
- Three (owned by Hutchinson Whampoa); and
- Vodafone.

5.10 These four MNOs operate using two infrastructure sharing arrangements. EE and Three share infrastructure under the 'MBNL' joint venture, whilst O2 and Vodafone share infrastructure as part of an extended joint venture and commercial agreement referred to as Cornerstone/Project Beacon.

5.11 In our previous our Infrastructure Report and updates we have reported on the mobile coverage provided by MNOs in terms of:

- **Outdoor premises coverage:** this indicates the proportion of residential and small business premises where there is a strong enough mobile signal to make a call outside the building. This metric does not provide an indication of the in-building coverage.
- **Geographic coverage:** this indicates the total land area where there is a strong enough mobile signal to make a call outdoors. This provides a better indication of coverage away from built up areas than outdoor premises coverage.
- **Roads coverage:** this indicates the parts of the national road network where there is a strong enough mobile signal to make a call outside vehicles or inside vehicles fitted with an external antenna.

[81] A number of other communications providers have radio spectrum allocations that allow mobile services to be provided but currently are not operating commercially, or only on a very restricted basis. These include BT, TalkTalk and UKBroadband.

5.12 These measures provide an important but only partial measure of the mobile coverage experienced by consumers during their typical day-to-day activities because:

- They do not include the ability to achieve mobile coverage in some specific use cases such as in buildings and in vehicles which are not fitted with an external aerial;
- They do not account for variations in handset receiver performance. In particular some more recent multi frequency band, multi-standard smartphones often require a stronger signal to operate than earlier generation phones[82];
- The planning models used to predict mobile coverage are statistical in nature and can only provide an estimate as opposed to exact prediction of mobile coverage in a given location.

5.13 To help address these issues we conducted a series of drive tests to help determine the average level of signal typically required to enable a voice call to be reliably made on a typical current generation smartphone. The scope and results of this study are described below.

We have undertaken drive-testing to validate MNO coverage estimates

5.14 Periodically, we test the accuracy of the coverage data provided by MNOs. This year we undertook a series of drive-testing exercises to collect:

- **Signal strength measurements**: this involved scanning all spectrum frequency bands and mobile technologies (2G, 3G and 4G) to find the strongest signal in any given location for each MNO and technology. We recorded received signal strengths using a specialist measurement device.
- **Voice call success rate measurements:** this involved continually making test calls on each network from handsets mounted within the vehicle so that we could establish the relationship between signal strength and call success rates.

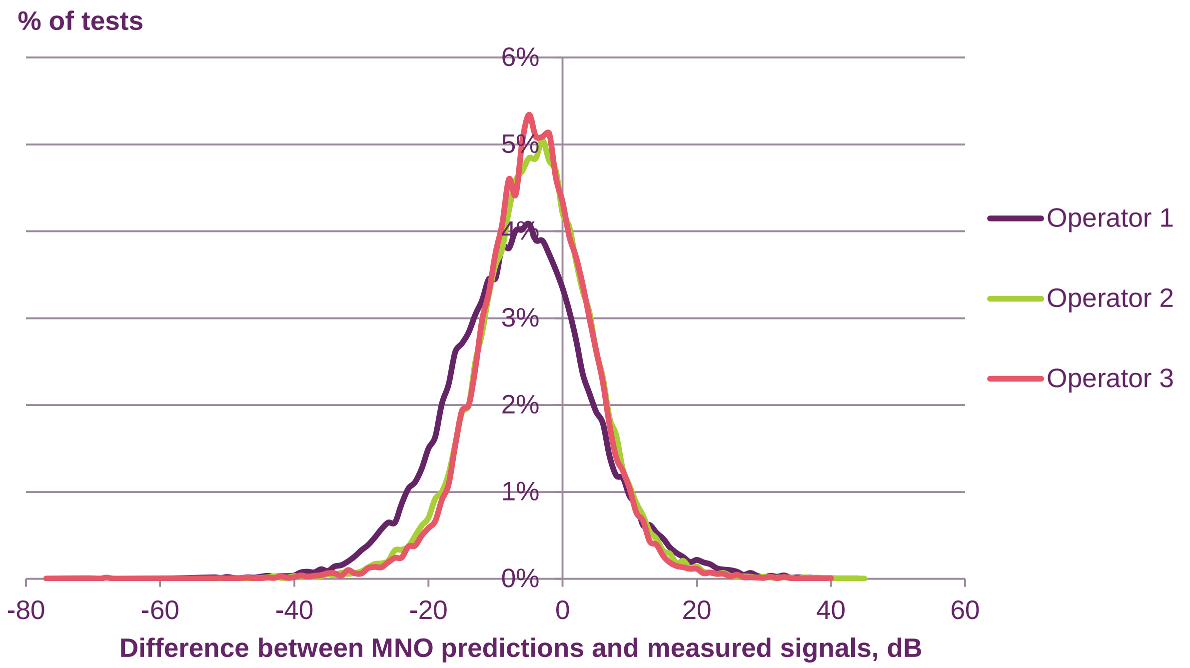
5.15 These measurements were undertaken by two independent and well-established mobile network performance consultancies, Real Wireless and P3 Communication, during September 2014 in various locations in England and Wales.

Results of the exercise

5.16 Figure 37 shows the distribution of the differences between the measured and predicted signal strengths (i.e. measured minus predicted) of the three 2G networks for 32,000 different outdoor locations in urban areas of the Midlands and rural areas in the Welsh borders.

[82] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/RFHandsets/

Figure 37 - Distribution of differences between MNO 2G signal strength predictions and measured signals



Source: Ofcom analysis of MNO data and test results

5.17 The results indicate that on average the predicted signal levels are approximately 5dB higher than the measured signals. As all three networks show a similar average difference, this may result from a calibration error in the test equipment used which has introduced a systematic offset in the data. The data does however indicate that the differences between the predicted and measured signal levels are similar for all three 2G networks.

5.18 Despite the average difference between measurements and predictions being close to zero, the width of the curve indicates that there can often be large disparities. These differences appear to follow the bell shaped distribution typically associated with localised variations in signal levels caused by shadowing by buildings and trees. These variations are typically modelled on a statistical basis in the coverage prediction models used by MNOs, and hence would be expected to show up in the chart above as a bell shaped distribution when compared with measurements made at precise locations.

5.19 The predictions and measurement presented in the chart above represent the mean (average) values over a 100m x 100m square ‘pixel’ of land. In reality there will also be variations in the signal strength within the pixel. As a result, even where the measured mean signal exactly matches the predictions, users within the pixel may experience different levels depending on their exact location. In areas of weak signal, there may be some parts of a pixel where a call is possible, but others where it is not.

5.20 As well as allowing us to compare operator predictions with real world measurements, the drive test results have also allowed us to consider the relationship between the signal measurements and call success rates.

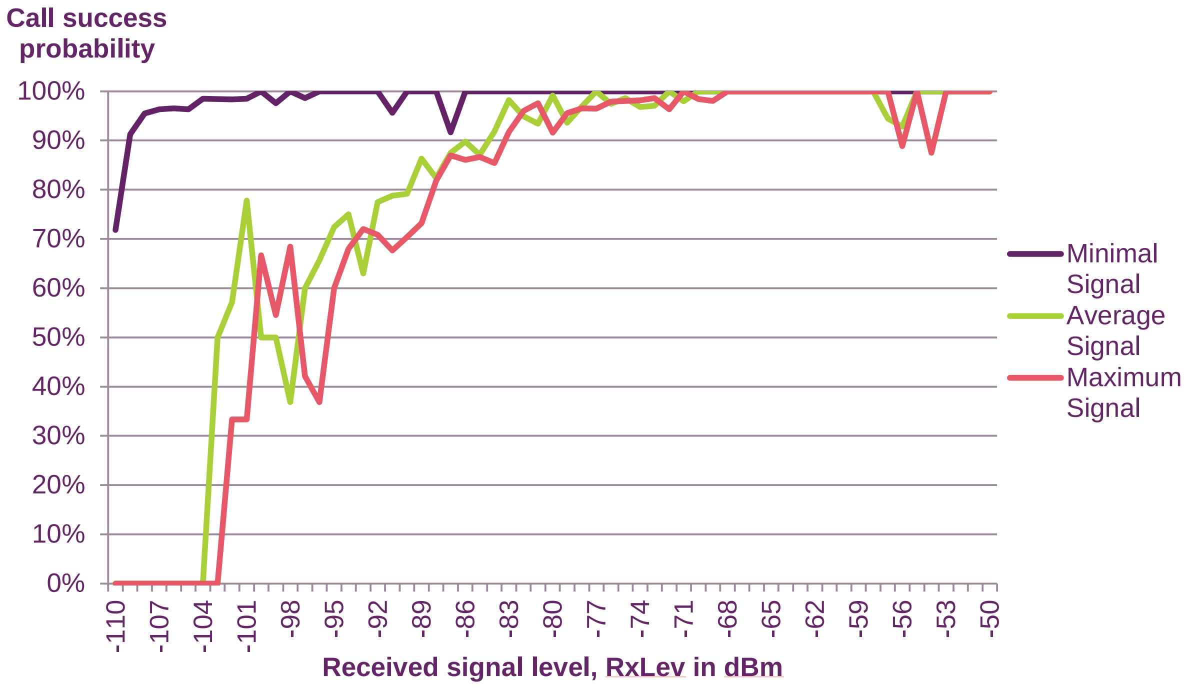
5.21 Figure 38 shows the minimum, average and maximum signal strengths measured by handsets during successful test calls placed on the 2G networks in the West Country and Shropshire. Call failures due to problems unrelated to signal strength, such as network contention, have been excluded. Because actual measured signal levels are used in these test the differences between the measured and predicted results described above do not affect the conclusions we can draw from them.

5.22 From Figure 38 it can be seen that[83]:

- As the average signal strength reduces the likelihood of being able to successfully make a call reduces. Typically calls can be maintained during brief periods of very low signal, although the user may experience periods of interrupted speech.

- The average minimum signal strength needed to achieve a call success rate of 90% is approximately -86dBm.

Figure 38 - Signal strength vs. call success, 2G networks, West Country & Shropshire



Source: Ofcom analysis of test results

5.23 Given these results, we have assumed in this report that a minimum signal strength of -86dBm is needed to achieve outdoor 2G coverage, including coverage in vehicles fitted with external aerials. This is consistent with the minimum signal level assumed to be needed in our 2012 Infrastructure Report Update and means that in the areas predicted to have 2G coverage, there is likely to be at least a 90% chance of consumers being able to successfully make a voice call (due to signal strength issues).

5.24 Some MNOs have argued that lower 2G signal threshold of -93 dBm should be used.[84] Whilst we recognise that a lower signal threshold may be sufficient to make a

[83] To predict call success rates using operator signal predictions requires the probability curves associated with figures 37 and 38 above to be combined. We are currently undertaking this analysis with a view to reporting on predicted call success rates in future.

call in some use cases such as stationary use outdoors away from buildings and trees, the measurements we have made to date suggest that a higher level of -86 dBm is required for the use case of using a mobile device in a vehicle fitted with an external aerial. For this reason we have used a signal level of -86dBm for the purposes of reporting outdoor levels of 2G coverage in this report. However, we recognise that further work is needed to establish the signal levels required to provide mobile coverage for different use cases and will be a major priority for Ofcom's work on mobile coverage over the coming months.

5.25 To provide a first order estimate of network coverage in buildings and in vehicles (not fitted with external aerials) we have assumed that a 10dB higher minimum signal level is required than for outdoor mobile coverage. For indoor 2G coverage this means that a level of -76 dBm is assumed to be needed to provide indoor coverage. In practice the additional signal strength required to provide indoor coverage is dependent on the type and construction on the buildings and the types of vehicles used. This means that estimates of indoor and in-vehicle coverage provided in this report should be treated as indicative.

5.26 For the purposes of reporting outdoor 3G coverage we have used the same signal level threshold criteria as used in our previous infrastructure reports. This is a different methodology to that established for the 3G coverage licence obligations.

5.27 As highlighted above, we are planning to continue to refine and develop coverage and other performance statistics with the aim of reflecting as closely as possible what consumers are actually experiencing.

Levels of 2G, 3G and 4G mobile coverage

5.28 In this year's report we report for the first time individual coverage results for all MNOs, with the exception of the coverage of Three's 4G network. In the time available it was not possible to resolve differences between Three's data and our field measurements on 4G coverage, leading to its omission from this report. Our overall coverage figures for 4G also exclude Three's coverage and therefore only represent 4G coverage from EE, Vodafone and O2. However, our analysis of the data received indicates that at this point in time Three's 4G coverage is lower than that of other MNOs.

5.29 In addition to individual MNO specific data, we also present coverage results on an aggregated basis for the following categories:

- **'complete not-spots':** areas or premises unable to receive mobile coverage from any MNO.
- **'partial not-spots':** areas or premises able to receive mobile coverage from some but not all MNOs.
- **covered by all three MNOs:** areas or premises able to receive mobile coverage from all MNOs.

5.30 These are also presented for the following different use cases:

[84] Annex 3 sets out estimated 2G coverage in the UK based on different signal thresholds to demonstrate how choice of signal threshold affects estimated coverage.

- **Outdoor premises coverage:** this indicates the proportion of residential and small business premises where there is a strong enough mobile signal to make a call outside the building.
- **Indoor premises coverage:** this indicates the proportion of residential and small business premises where there is a strong enough mobile signal to make a call inside the building.
- **Outdoor geographic coverage:** this indicates the total land area where there is a strong enough mobile signal to make a call outdoors.
- **Motorway coverage:** this indicates amount of the national motorway network where there is a strong enough mobile signal to make a call outside vehicles or inside vehicles fitted with an external antenna.
- **A and B road coverage:** this indicates the amount of the national A and B network where there is a strong enough mobile signal to make a call outside vehicles or inside vehicles fitted with an external antenna.

5.31 In addition, we report on mobile coverage levels at a UK, urban and rural, as well as a nations' level.

Coverage of voice and low speed data services over 2G

There is some variation in voice coverage between MNOs (over 2G) which creates *partial not spots*

5.32 For the first time this year, we are publishing the MNOs' individual coverage data. Voice services are delivered over 2G networks by EE, O2 and Vodafone. 2G networks also support low speed data communications and short messaging services (SMS). Voice is also carried over 3G networks by Three and by the other MNOs but 3G coverage is overall lower than 2G. We therefore report on 2G coverage as a proxy for overall voice coverage in the remainder of this chapter.

Figure 39 - 2G network coverage by MNO

	O2	Vodafone	EE
Outdoor coverage			
Premises	99%	99%	98%
Geographic	78%	82%	78%
National roads coverage			
Motorways	100%	100%	100%
A & B Roads	91%	93%	91%
Indoor/In-car coverage			
Premises	94%	92%	90%
Motorways	98%	98%	97%
A & B Roads	74%	78%	78%

Source: Ofcom analysis of MNO data

5.33 Figure 39 above shows that whilst in high level terms the three 2G MNOs provide broadly similar in terms of coverage across the various metrics, there are differences which create partial not spots where a mobile signal is available from some but not all three 2G networks.

Figure 40 - Urban and rural 2G network coverage

	O2 (2G)	Vodafone (2G)	EE (2G)
Outdoor premises coverage			
Rural	91%	91%	91%
Urban	>99%	>99%	>99%
Indoor premises coverage			
Rural	67%	67%	69%
Urban	98%	97%	93%

Source: Ofcom analysis of MNO data

5.34 Figure 40 above shows that across all 2G operators coverage is better in urban than rural areas.

UK coverage of 2G mobile networks

5.35 A summary of 2G mobile network coverage in the UK is shown in Figure 41.

Figure 41 - Summary of 2G mobile network coverage

	Complete not-spots	Partial not-spots	Covered by all three MNOs
Outdoor coverage			
Premises coverage	<1%	3%	97%
Geographic coverage	11%	21%	68%
National roads coverage			
Motorways	0%	<1%	>99%
A & B Roads	3%	13%	84%
Indoor/In-car coverage			
Premises	2%	16%	83%
Motorways	0%	6%	94%
A & B Roads	9%	33%	59%

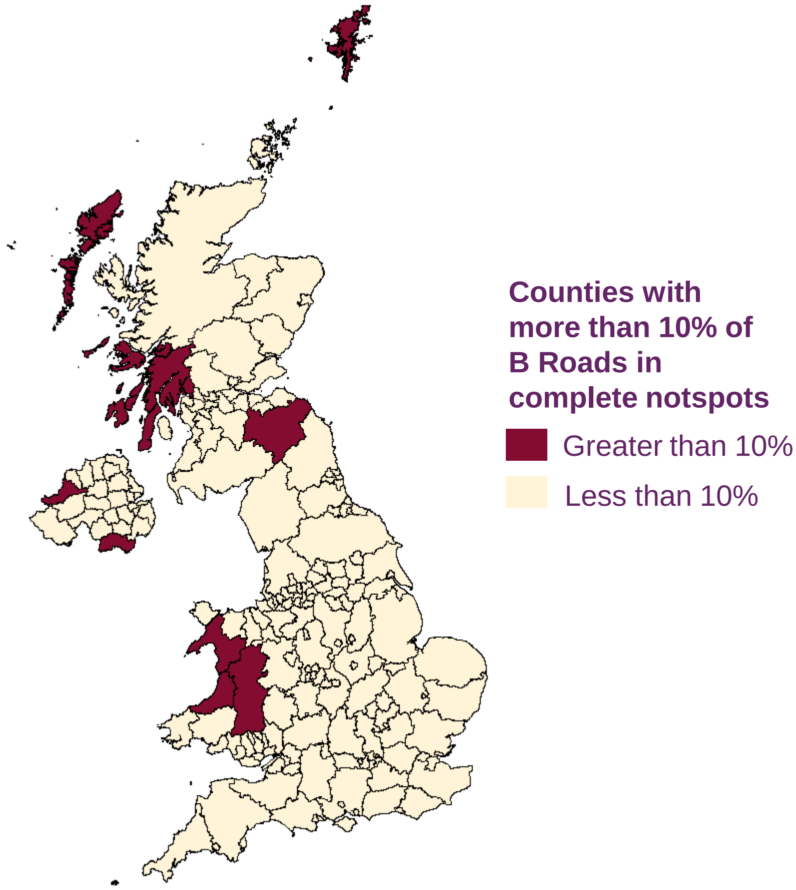
Source: Ofcom analysis of MNO data

There is good 2G coverage on motorways and major roads but there is less coverage on minor roads

5.36 Motorways are almost completely covered by 2G networks. 99% of A roads are covered by at least one MNO. 3% of A & B roads, however, have no mobile voice coverage and 13% of A & B roads only have mobile voice coverage provided by one or two of the MNOs.

5.37 B roads with very low 2G coverage are primarily rural and mostly in Scotland, Wales and Northern Ireland.

Figure 42 - Local Authorities with % B Roads (roadside coverage) in complete not-spots



Source: Ofcom analysis of MNO data

Coverage of 2G networks in the nations

5.38 A comparison of 2G coverage in England, Scotland, Wales and Northern Ireland is shown in Figure 43.

Figure 43 - 2G mobile network coverage by nation

Covered by	England		Scotland		Wales		Northern Ireland	
	No MNO	All MNOs	No MNO	All MNOs	No MNO	All MNOs	No MNO	All MNOs
Outdoor coverage								
Premises coverage	0%	98%	1%	95%	1%	90%	1%	91%
Geographic coverage	4%	82%	24%	47%	14%	57%	5%	72%
National roads coverage								
Motorways	0%	100%	0%	100%	0%	100%	0%	99%
A & B Roads	1%	92%	7%	70%	6%	69%	4%	78%
Indoor/In-car coverage								
Premises	1%	85%	3%	78%	4%	71%	5%	64%
Motorways	0%	95%	0%	92%	9%	93%	0%	81%
A & B Roads	4%	68%	18%	43%	14%	44%	14%	40%

Source: Ofcom analysis of MNO data

Rural and urban 2G coverage

5.39 A summary of 2G rural and urban UK mobile network coverage is shown in Figure 44. This shows that the effect of full and partial coverage not spots is lower for urban than rural areas.

Figure 44 - Urban and rural 2G network coverage

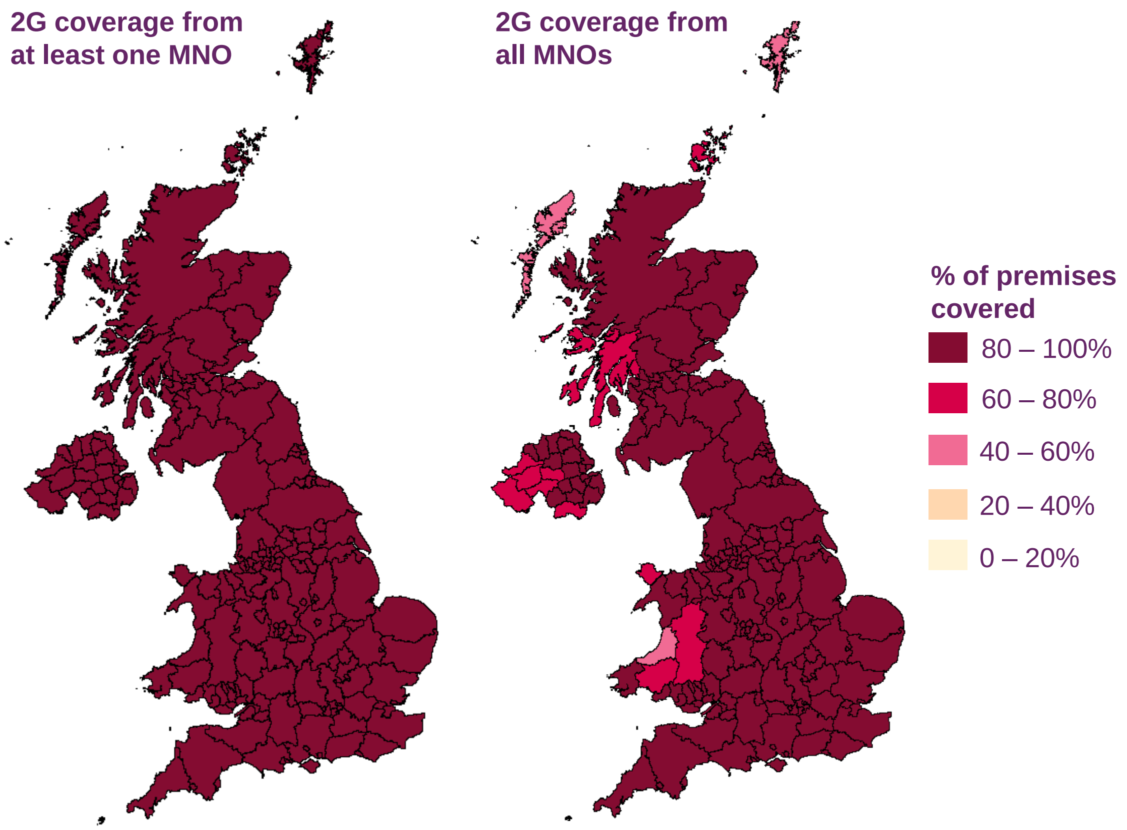
	Complete not-spots	Partial not-spots	Covered by all three MNOs
Outdoor premises coverage			
Urban	0%	<1%	>99%
Rural	2%	17%	82%
Indoor premises coverage			
Urban	0%	11%	89%
Rural	11%	46%	43%

Source: Ofcom analysis of MNO data

2G outdoor premises coverage in different UK local authorities

5.40 The map below shows how 2G outdoor premises coverage varies across the local authorities in the UK.

Figure 45 - 2G outdoor premises coverage by local authority



Source: Ofcom analysis of MNO data

2G call failure and completion rates can be more relevant to the consumer than basic coverage metrics

5.41 Looking beyond the coverage predictions set out above, it is also worthwhile to examine call failure and completion rates. There are two metrics that can be used to measure call failure rates:

- dropped calls: calls that cut out unexpectedly having been originally connected; and
- blocked calls: calls that fail to connect with the recipient.

5.42 We combine these metrics to calculate call completion success rates (CCSRs). In January 2014, we gathered dropped and blocked call data from the four MNOs. Comparative analysis was made difficult by the fact that the MNOs do not use consistent methodologies for deriving these failed calls statistics. There are also other key limitations with the data:

- The MNOs are unable to gather data on call attempts made by users in areas with no coverage; and

- there was no split made between urban and rural network performance.

5.43 We therefore used data from a third party data provider, RootMetrics, to better understand the consumer experience. Their research was carried out by collecting call failure and success rates using application software installed on a set of standard phones that were used in a wide variety of locations.

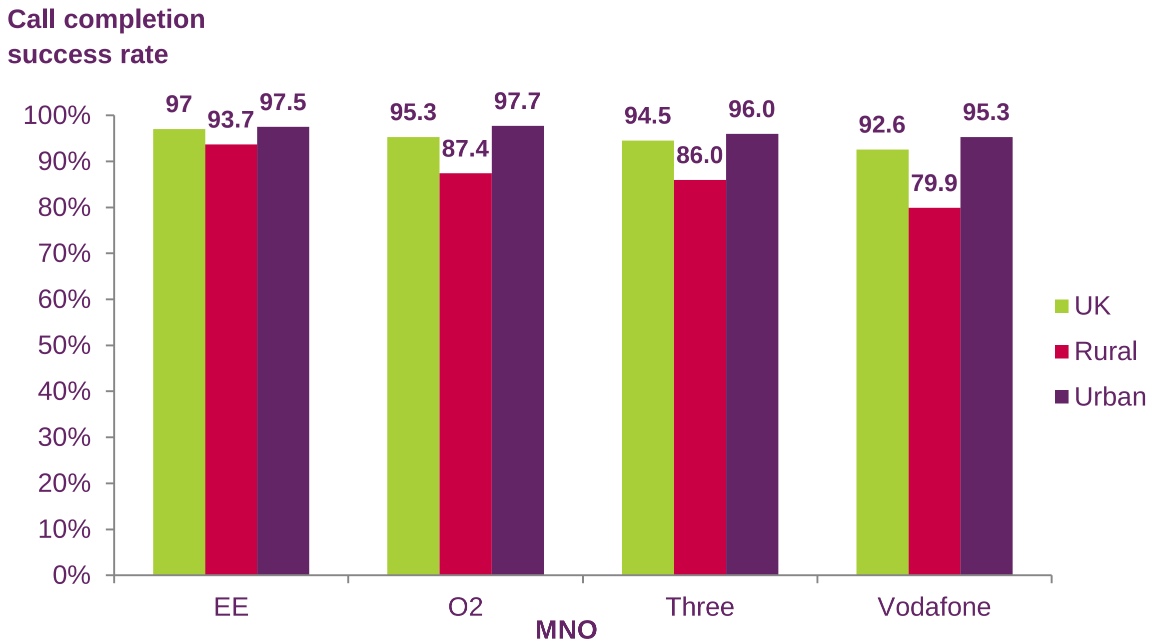
5.44 This methodology does have its limitations. It does not specifically differentiate between areas where MNOs do not claim to have coverage and areas where they do; nor does it reflect the success rate of incoming calls. Even so, there are distinct advantages to this method in terms of reflecting what consumers experience, because:

- the same tests are run on all networks, so we can compare results between the MNOs;
- call attempts made by users in areas with no coverage are measured; and
- the same fixed line number is called to ensure consistency across tests, with no variation attributable to differing end network or lack of mobile network coverage for the called party.

Results of the exercise

5.45 The results of the testing suggest that rural areas suffer significantly more from dropped and blocked calls than urban areas. The difference in CCSRs between urban and rural areas was at its smallest for EE customers and was largest for Vodafone customers.

Figure 46 - Voice network call completion success rates, UK, June-December 2013



Source: RootMetrics

5.46 Lower rural CCSRs are consistent with the fact that 2G coverage in rural areas is worse than in urban areas.

Coverage of 3G mobile broadband services

3G coverage is lower than voice coverage

5.47 All four MNOs provide 3G service. 3G networks provide high speed data transmission and multi-media applications, which enable consumers to watch, listen and read media content on the move. The MNOs also deliver voice services on 3G networks. A summary of 3G mobile network coverage is provided in Figure 47 below.

5.48 84% of premises are in areas of outdoor coverage from all four MNOs and 99% are covered by at least one MNO. Geographic coverage is significantly lower than premises coverage: 22% of the UK's land area has no coverage from any MNO.

5.49 3G coverage is relatively high on motorways: 83% of the length of UK motorways covered by all four MNOs. There is no motorway area without any coverage at all. 9% of A and B road length is in a complete not-spot for roadside coverage, compared to 17% for in-car coverage.

Figure 47 - Summary of 3G mobile network coverage, June 2014

	Complete 'not-spots'	Partial 'not-spots'	Covered by all four MNOs
Outdoor coverage			
Premises	1%	15%	84%
Geographic	22%	52%	26%
National roads coverage			
Motorways	0%	17%	83%
A & B Roads	9%	46%	45%
Indoor/In-car coverage			
Premises	3%	26%	71%
Motorways	0%	38%	61%
A & B Roads	17%	54%	30%

Source: Ofcom analysis of MNO data

3G coverage varies by nation

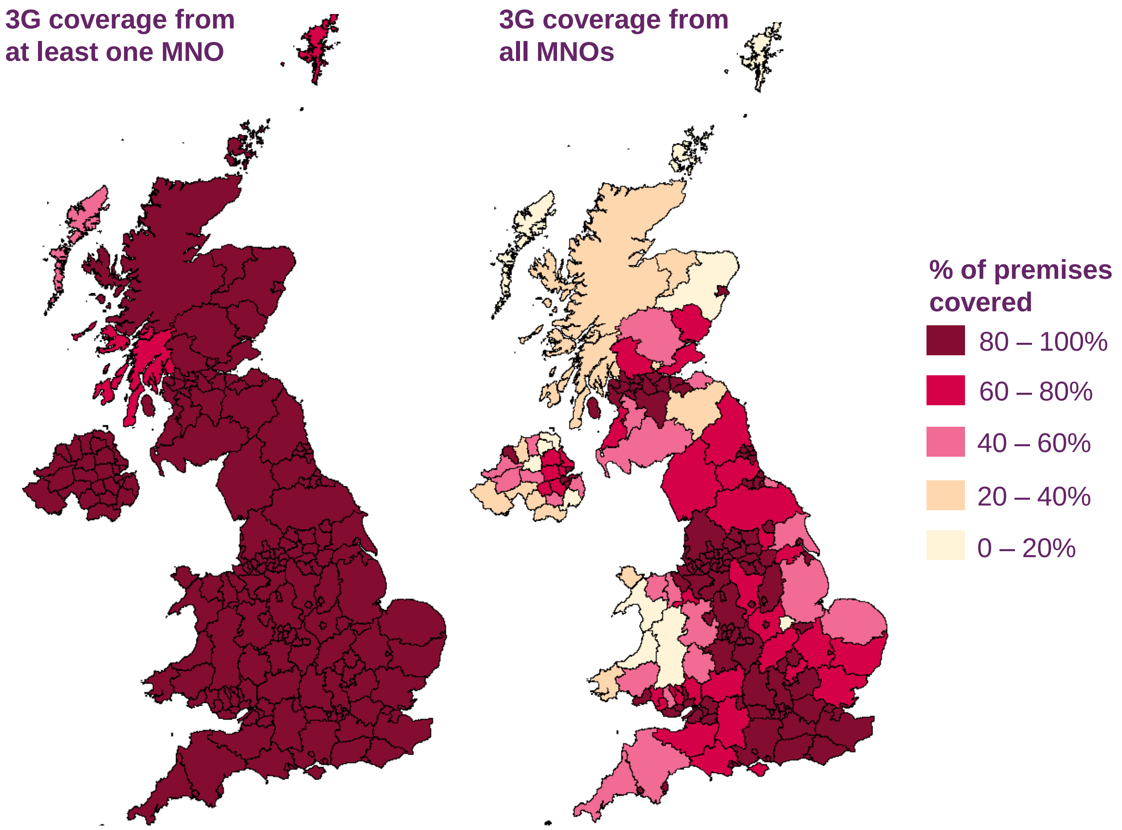
Figure 48 - 3G mobile network coverage by nation

Covered by	England		Scotland		Wales		Northern Ireland	
	No MNO	All MNOs	No MNO	All MNOs	No MNO	All MNOs	No MNO	All MNOs
Outdoor coverage								
Premises	<1%	87%	3%	75%	2%	65%	1%	63%
Geographic	7%	41%	49%	7%	21%	15%	8%	17%
National roads coverage								
Motorways	0%	86%	0%	67%	0%	92%	0%	70%
A & B Roads	3%	59%	27%	19%	11%	26%	5%	23%
Indoor/In-car coverage								
Premises	2%	74%	6%	64%	6%	43%	6%	47%
Motorways	0%	64%	0%	51%	0%	60%	1%	49%
A & B Roads	8%	39%	40%	12%	22%	14%	16%	11%

Source: Ofcom analysis of MNO data

5.50 The map below shows how 3G coverage varies across the local authorities of the UK.

Figure 49 - 3G outdoor premises coverage by local authority



Source: Ofcom analysis of MNO data

3G network coverage

5.51 Over 99% of premises in urban areas are covered by at least one MNO's 3G network outdoors, compared to 95% of premises in rural areas. There is a larger difference in the number of networks available, however. 92% of urban premises can access all four MNOs' networks outdoors compared to 38% of rural premises. 56% of rural premises are in partial not-spots of 3G networks compared to 17% of 2G networks.

Figure 50 - Urban and rural 3G network coverage

	Complete 'not-spots'	Partial 'not-spots'	Covered by all four MNOs
Outdoor premises coverage			
Urban	<1%	8%	92%
Rural	5%	56%	38%
Indoor premises coverage			
Urban	1%	20%	80%
Rural	18%	66%	16%

Source: Ofcom analysis of MNO data

5.52 Once again, there is a worsening of coverage when a user moves from outdoors to indoors.

3G coverage varies between MNOs

5.53 The reported coverage varies by MNO.

Figure 51 - 3G coverage by MNO

	O2	Vodafone	EE	Three
Outdoor coverage				
Premises	91%	87%	98%	98%
Geographic	44%	33%	74%	68%
National roads coverage				
Motorways	91%	87%	100%	100%
A & B Roads	61%	51%	88%	87%
Indoor/In-car coverage				
Premises	84%	76%	93%	93%
Motorways	76%	72%	99%	98%
A & B Roads	44%	37%	78%	73%

Source: Ofcom analysis of MNO data

5.54 EE has the highest geographic 3G coverage of the four MNOs, with 74% of the country's land covered. Vodafone has the lowest geographic 3G coverage at 33% of UK land area. However, when considering the number of premises that are covered (outdoors), all MNOs have levels of coverage exceeding 85%, ranging from 87%[85] to 98% of premises in the UK.

5.55 This pattern is repeated on roads, where motorways are fully covered by EE and Three's 3G networks. O2 and Vodafone cover only 61% and 51% of UK A and B roads respectively. Indoor premises coverage of 3G networks is 93% for both EE and Three, but 84% for O2 and 76% for Vodafone.

Rural 3G coverage is significantly lower than urban coverage for all MNOs, especially Vodafone

5.56 All four MNOs have outdoor 3G coverage of over 90% of all urban premises. Rural coverage is more varied: O2 covers 62% of rural premises (outdoors), much less than the 90% rural coverage achieved by EE and Three. Vodafone has the lowest rural coverage, at 47%. Indoor premises coverage is significantly lower for all MNOs in rural areas.

Lower frequency 4G spectrum is likely to help extend mobile broadband coverage

5.57 The majority of the spectrum used to deliver 3G services is in the higher frequency 2.1 GHz band. The use of these higher frequencies makes it harder to achieve wide

[85] As described earlier, we have used a different methodology for this Infrastructure Report and figures should therefore not be interpreted in the context of MNOs' licence obligations

area coverage. The use of lower frequency 800 MHz spectrum by 4G services will help address this. In particular there is a coverage obligation in one of the 4G licences to provide 98% indoor coverage by the end of 2017.

Figure 52 - Urban and rural 3G premises coverage by mobile network operator

	O2	Vodafone	EE	Three
Outdoor premises coverage				
Urban	96%	93%	>99%	>99%
Rural	62%	47%	90%	90%
Indoor premises coverage				
Urban	92%	84%	97%	97%
Rural	36%	26%	71%	67%

Source: Ofcom analysis of MNO data

Coverage of 4G mobile broadband services

4G roll-out is progressing well

5.58 As with 3G, 4G is capable of support mobile data services but generally provides higher download and upload speeds. EE was the first MNO to launch 4G services in late 2012 using spectrum previously used for 2G services. This was followed by the auction by Ofcom of additional 4G spectrum in April 2013, which saw all four MNOs and BT awarded spectrum.

5.59 Over the last few years there has been a concern that the UK is lagging behind other EU countries in terms of 4G rollout. However, as we set out below good progress is now being made with the practical rollout of 4G services and the UK is catching up fast.

5.60 Given the rapid pace of change, we have collected data for both June 2014 and October 2014 in order to report the most up-to-date 4G coverage at the national level. The recent growth in coverage for each MNO’s 4G premises coverage is shown in the table below:

Figure 53 - 4G premises (outdoor) coverage, June 2014 and October 2014

	O2	Vodafone	EE	Three
June 2014	43%	37%	68%	N/A
October 2014	51%	51%	70%	N/A
Increase in coverage (percentage points)	8%	14%	2%	N/A

Source: Ofcom analysis of MNO data

UK 4G Coverage

5.61 A summary of 4G mobile network coverage is provided in Figure 54 below. For the reasons explained earlier, the following tables exclude 4G coverage provided by Three.

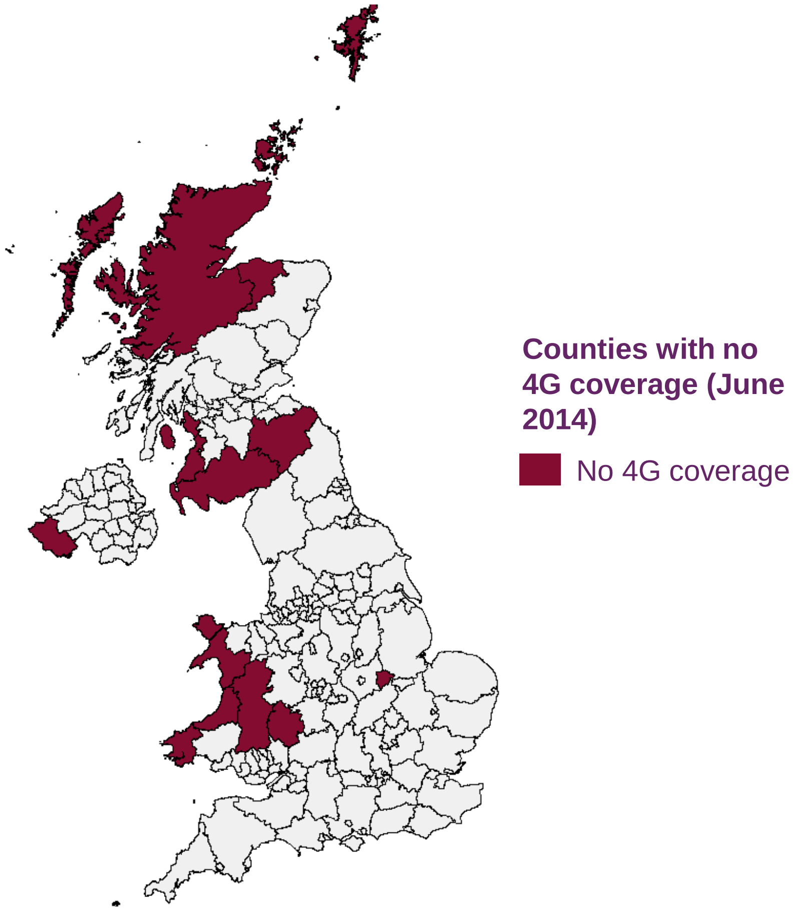
Figure 54 - Summary of UK 4G mobile network coverage, June 2014

	Complete 'not-spots'	Partial 'not-spots'	Covered by Vodafone, O2 and EE
Outdoor coverage			
Premises	28%	37%	35%
Geographic	77%	17%	5%
National roads coverage			
Motorways	25%	47%	28%
A & B Roads	63%	25%	12%
Indoor/In-car coverage			
Premises	37%	34%	30%
Motorways	36%	43%	21%
A & B Roads	71%	20%	9%

Source: Ofcom analysis of MNO data

5.62 4G has now reached 35% of UK premises (outdoors) for Vodafone, O2 and EE combined. In some rural counties, 4G has not yet been rolled out (as of June 2014). These are shown in the map below.

Figure 55 - Counties where no premises are covered by 4G networks (June 2014)



Source: Ofcom analysis of MNO data

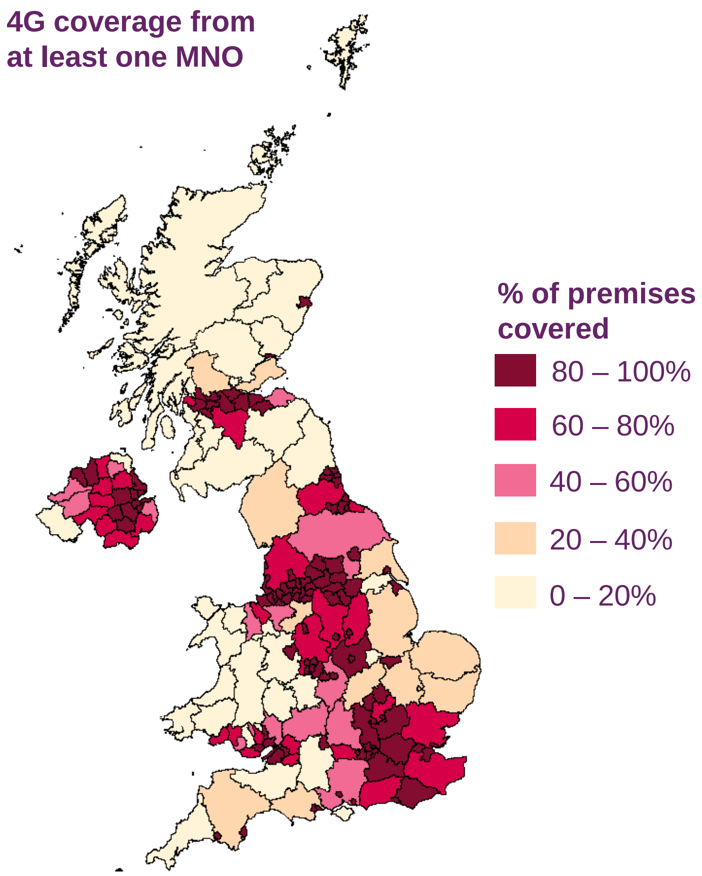
Figure 56 - 4G mobile network coverage by nation, June 2014

Covered by	England		Scotland		Wales		Northern Ireland	
	No MNO	3 of 4 MNOs	No MNO	3 of 4 MNOs	No MNO	3 of 4 MNOs	No MNO	3 of 4 MNOs
Outdoor coverage								
Premises	25%	39%	44%	34%	56%	0%	21%	0%
Geographic	67%	9%	95%	2%	91%	0%	59%	0%
National roads coverage								
Motorways	25%	32%	46%	26%	10%	0%	8%	0%
A & B Roads	53%	18%	87%	6%	85%	0%	50%	0%

Source: Ofcom analysis of MNO data

5.63 The map below shows how 4G outdoor premises coverage varies across the local authorities.

Figure 57 - 4G outdoor premises coverage by local authority, June 2014



Source: Ofcom analysis of MNO data

4G networks are better developed in urban areas

5.64 The difference between urban and rural 4G coverage is bigger than for 3G and 2G networks. This is because 4G roll-out is ongoing and operators have tended to focus on urban areas first. 78% of urban premises can receive a signal from at least one MNO outdoors compared to 33% of rural premises. As of June 2014, only 7% of rural premises can access EE, O2 and Vodafone's 4G networks (outdoors).

Figure 58 - Urban and rural 4G network coverage, June 2014

	Complete 'not-spots'	Partial 'not-spots'	Covered by O2, Vodafone and EE
Outdoor premises coverage			
Urban	22%	38%	40%
Rural	67%	26%	7%

Source: Ofcom analysis of MNO data

4G coverage varies between MNOs

5.65 There are currently significant differences in 4G coverage between MNOs (as of June 2014):

Figure 59 - 4G coverage by Mobile Network Operator, June 2014

	O2	Vodafone	EE	Three
Outdoor coverage				
Premises	43%	37%	68%	N/A
Geographic	9%	7%	19%	N/A
National roads coverage				
Motorways	37%	32%	70%	N/A
A & B Roads	18%	14%	33%	N/A
Indoor/In-car coverage				
Premises	38%	32%	59%	N/A
Motorways	29%	24%	59%	N/A
A & B Roads	14%	10%	26%	N/A

Source: Ofcom analysis of MNO data

5.66 EE currently has the highest level of 4G coverage. Its network covers 19% of the UK's land area and 68% of its premises (outdoors). Roll-out by the other 4G MNOs has started relatively recently, resulting in a limited coverage of less than 50% of premises for each of those MNOs.

5.67 EE's 4G roll-out is more mature than that of the other three MNOs. As of June 2014, it covers 75% of urban areas and 28% of rural areas (outdoors). O2 and Vodafone cover 14% and 8% of rural premises and 47% and 41% of urban premises respectively.

Figure 60 - Urban and rural 4G premises coverage by mobile network operator, June 2014

	O2	Vodafone	EE	Three
Outdoor premises coverage				
Urban	47%	41%	75%	N/A
Rural	14%	8%	28%	N/A

Source: Ofcom analysis of MNO data

5.68 We will continue to monitor the roll-out of 4G networks and will report on progress in next year's Infrastructure Report update.

Enabling further improvements in the mobile coverage

5.69 It has been clear for some time that market-led developments in mobile infrastructure alone will not satisfy all demand and intervention is necessary to achieve sufficient coverage. As This section highlights developments in public sector interventions, as well as technological developments, that may improve the coverage of mobile services.

Our spectrum policy aims to improve competition and coverage

5.70 Mobile coverage is a major work area in Ofcom's current Annual Plan[86], and is likely to remain a priority area of focus. Some recent policy decisions and initiatives on spectrum are helping to improve both indoor and outdoor coverage, by:

- **strengthening coverage obligations for mobile licences**. We have included more extensive coverage obligations in particular licences. For example, O2's 4G licence awarded last year (in the 800 MHz band) included a requirement to provide 98% indoor coverage.

- **making additional sub-1 GHz spectrum available**. Low frequency spectrum is targeted because it has good propagation characteristics. The last significant release of low frequency spectrum was the 800 MHz band, sold in the 4G auction following digital television switchover. We recognise that demand for mobile broadband continues to grow, meaning more spectrum is needed for both coverage and capacity reasons. Hence we are looking at further spectrum releases: for example, we are aiming to make the 700 MHz band currently used for DTT available for mobile broadband use from 2022.[87]

The Government has set out initiatives to increase coverage

Mobile Infrastructure Project

5.71 The Mobile Infrastructure Project[88] is a Government initiative to increase mobile coverage in areas that are poorly served. It is spending £150 million to deliver mobile voice services for up to 60,000 premises that have not previously had this option from any MNO. It also aims to improve coverage on at least ten of the UK's busiest A-roads.

5.72 We reported last year on the first site that went live in September 2013 in Weaverthorpe, North Yorkshire. It provides mobile coverage to 200 premises in what was previously a complete not-spot. In September 2014, the Government announced that a further 200 premises in North Molton, Devon, and a large section of the neighbouring Exmoor National Park, are now receiving a mobile signal following another new site being activated in the area. The remaining sites in the project are due for completion by 2016.

Improvement of train coverage

5.73 The Department for Transport (DfT) is working with Network Rail to improve mobile services on railways. Under its plan, Government aims to improve coverage to 70% of the travelling public. The DfT is also planning to invest £53m to improve Wi-Fi access on trains.[89]

Tackling partial not-spots in mobile phone coverage

5.74 The Government is considering plans for those areas of the UK where consumers receive coverage from some, but not all, of the four MNOs. In early November 2014,

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86 http://www.ofcom.org.uk/about/annual-reports-and-plans/annual-plans/annual-plan-2014-15/
87 See http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/discussion/ftv.pdf
88 https://www.gov.uk/government/news/mobile-reception-around-uk-to-get-massive-boost
89 https://www.gov.uk/government/news/plans-unveiled-to-boost-wi-fi-on-trains

Government launched a consultation on various legislative proposals to achieve these aims.[90] The options focus on:

- **National roaming:** this allows consumers' mobile devices to roam on other MNOs' networks, if their own provider's network is not available.
- **Increased infrastructure sharing:** this allows MNOs to attach their equipment to other MNOs' masts. Some level of infrastructure sharing is already taking place and is described earlier in this chapter.
- **Broader based virtual networks:** MVNOs currently agree wholesale access terms with a single MNO. The Government proposes that MVNOs could be able to offer devices that access all four MNOs. More detail on MVNOs and wholesale access is described later in this chapter.
- **Coverage obligations**: MNOs would have to cover an increased percentage of the UK in total, but the MNO would have freedom to decide exactly how this enhanced coverage would be delivered. The advantage of this approach is the MNO can choose the most efficient combination of network options, such as more commercial site sharing, increased mast height or higher transmitter power. Coverage obligations, based on premises coverage, have already been attached to all four 3G licences, and to O2's 4G licence.

Alternative network technology can also improve coverage

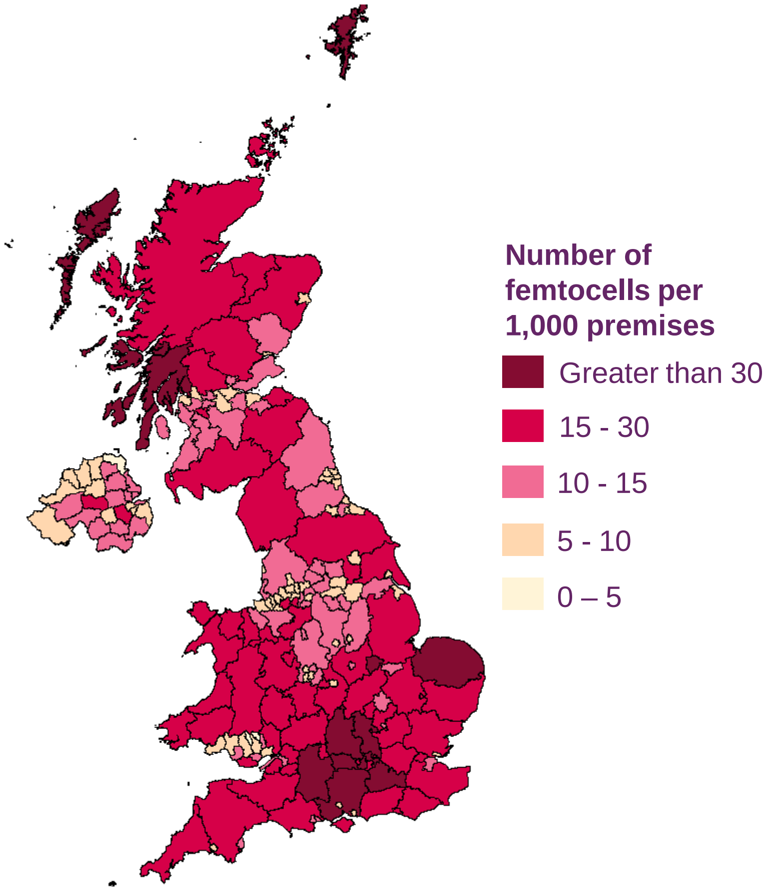
Femtocells

5.75 Femtocells are small, low-powered base stations, installed indoors to improve mobile coverage in the home. They are short-range devices and work by connecting to the host mobile operator network via a fixed broadband connection. They can be a technically robust way to extend indoor coverage in remote areas with poor coverage.

5.76 Vodafone, EE and Three offer femtocells to their customers and their number is increasing. Our data shows that between 2013 and 2014, the number of femtocells in the UK has risen from 300,000 to over 400,000.

[90] https://www.gov.uk/government/news/eliminating-poor-mobile-coverage

Figure 61 - Number of femtocells per 1,000 premises by local authority



Source: Ofcom analysis of MNO data

5.77 The use of femtocells to address poor coverage in rural areas has generally grown and in England and Scotland specifically has quadrupled in comparison to urban areas. The greatest concentration per premises is in the Shetland Isles, with 113 femtocells per 1,000 premises.

5.78 In addition to the benefits of residential femtocells MNOs are using similar technology to provide localised coverage in public spaces. For example, Vodafone's Rural Open Sure Signal has provided 3G connectivity to rural areas as a community-led trial in 12 communities, including one in the Shetland Isles. In July 2014, Vodafone announced that it will extend the trial to 100 communities in rural areas.

5.79 Early in November 2014, Minchinhampton in Gloucestershire became the first of these communities to benefit. The Open Sure Signal femtocells can be installed in any area where a fixed connection is available. This includes telegraph poles, shops and pubs.

Repeaters

5.80 Mobile cellular repeaters (also called 'boosters' and/or 'coverage enhancers') are devices which receive, amplify and re-transmit the signals from mobile base stations. Their purpose is to enhance mobile signals in areas where they are weak, such as indoors, in sports stadia and in shopping centres.

5.81 MNOs also use ‘smart repeaters’, which are different from cellular repeaters. They can be remotely controlled and configured. For example they can be remotely turned off if they are causing interference.

5.82 Repeaters can be a useful means of extending coverage. However, repeaters can also cause interference and therefore their use has to be closely controlled. In the UK, the use of a repeater must be either licensed by Ofcom, or specifically exempted from such licensing under section 8 of the Wireless Telegraphy Act 2006 (WT Act 2006). The use of any such device other than under and in accordance with a licence is liable to be a criminal offence, unless an exemption applies (and the use complies with the terms of any exemption).

5.83 We issued a call for inputs earlier this year on the availability of suitable devices. The key purpose of the call for inputs was to find out whether, and in what circumstances, repeaters may form part of the solution in improving coverage without having adverse effects, alongside other solutions for improving coverage and, if so, would it be appropriate to allow consumers to buy and deploy smart repeaters rather than MNOs. We are currently considering the responses we received with a view to deciding whether our current policy position needs to be reviewed.

Infrastructure Sharing and Wholesale Access

Infrastructure is shared under two major commercial arrangements in the UK

5.84 There are two network sharing arrangements between the four Mobile Network Operators in the UK. EE and Three have a joint venture called MBNL. Vodafone and O2 have a site sharing arrangement called Cornerstone which has been extended by Project Beacon into a broader based joint venture. These projects help MNOs to reduce the costs of network roll-out and maintenance.

5.85 The MBNL joint venture was formed in 2007 by T-Mobile (now part of Everything Everywhere) and Three. They have a national Radio Access Network (RAN) sharing agreement, sharing both passive and active network equipment. Each MNO maintains control of their spectrum for 3G services. This allows for efficiencies in network deployment and maintenance, while retaining the scope of service differentiation between the MNOs.

5.86 In February 2014 EE and Three announced a change in the sharing arrangement for the roll-out of their 4G networks. Rather than extending their RAN sharing agreement for their 4G roll-out, the two networks will only share passive infrastructure such as masts and backhaul links from the site. This arrangement means the network operators have more flexibility in their 4G network roll-out strategy.

5.87 Vodafone and O2 have a similar sharing arrangement to EE and Three, but applying to their 4G networks as well. They have created a joint venture for shared passive infrastructure. They have split the responsibility for network deployment into geographic areas. Vodafone is responsible for the west of the UK and O2 maintains the network in the east of the UK and in Northern Ireland. They share use of the network, which one or the other is responsible for maintaining.

MVNOs access the national networks through wholesale access

5.88 The four MNOs provide wholesale access to other mobile service providers. These are called Mobile Virtual Network Operators (MVNOs). Examples include supermarkets offering mobile services (Tesco, Asda); fixed communication providers offering 'quad-play' (fixed broadband, TV, fixed phone line and mobile) such as Virgin Mobile, TalkTalk and BT; and MVNOs focussed on international calls such as Lycamobile and Lebara. The MNOs have reported a total of 41 direct MVNO customers. Most of these MVNOs provide a similar service of voice, SMS and data, though some are more specialised.

5.89 The proportion of voice minutes used by MVNO customers has not changed since 2011, at 16% of total mobile voice minutes. However, the proportion of total mobile data used by MVNOs has fallen to 7% (from 14% in 2011). This suggests that MVNO networks are more targeted at voice call markets, or that their service propositions, including a sometimes more limited set of options with respect to bundled handsets lead to a higher proportion of such customers. SMS used by MVNO customers made up approximately 7% of all SMS on mobile networks.

The use of mobile broadband data continues to grow but SMS messaging has reduced

5.90 The take-up of mobile service subscriptions has been relatively static over the last three years.

Figure 62 - Mobile communications summary

	Q1 2014	2013	2012	2011
Active mobile subscriptions (millions) (average over the year)	83.2	83.1	83.4	82.4
Annual Mobile voice call minutes (billions)	134.2*	134.1	132.3	131.5
Annual SMS messages sent (billions)	125.1*	129.9	171.9	171.7

*Source: Ofcom, Communications Market Report 2014 (*Annual Q1 2013 to Q1 2014, Ofcom, Telecommunications Market Data update Q1 2014)*

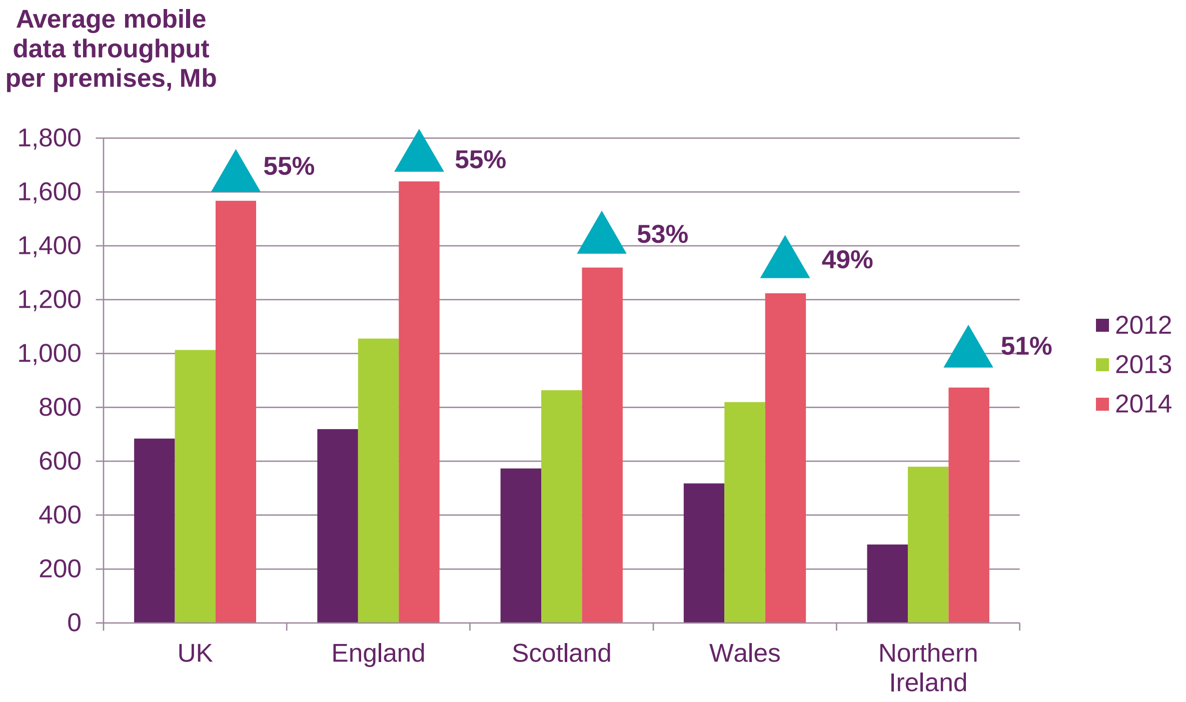
5.91 The number of active mobile subscriptions fell for the first time in 2013, but only slightly: down from 83.4 million in 2012 to 83.1 million in 2013. The number of mobile voice call minutes has risen slightly from 132.3 million to 134.1 million in 2013.

5.92 The number of SMS messages sent between 2011 and 2012 remained steady at 172 million. In 2013, only 130 million SMS messages were sent, most likely due to substitution by IP-based messaging programmes such as Whatsapp and Kik.

5.93 The MNOs provided information on mobile data use gathered from the throughput measured on their mobile transmitters. The numbers include data consumption by both residential and business customers. They also include customers of Mobile Virtual Network Operators (MVNOs), who operate retail mobile services through wholesale access provided by the MNOs.

5.94 The numbers do not include data ‘offloaded’ by mobile device users onto private and public Wi-Fi. This is because when consumers use mobiles over Wi-Fi, the connection is not provided by the mobile network provider.

Figure 63 - Average mobile data throughput (downloaded and uploaded data) per premises



Source: Ofcom analysis of MNO data

5.95 There has once again been a significant increase in the amount of mobile data downloaded and uploaded. The average data throughput per premises increased by 55%, to 1,567Mb per premises in the UK. Data use continues to be lower on average in Scotland, Wales and Northern Ireland, but all three nations experienced growth in data use of more than 49% in the last year.

Figure 64 - Data throughput per active connection

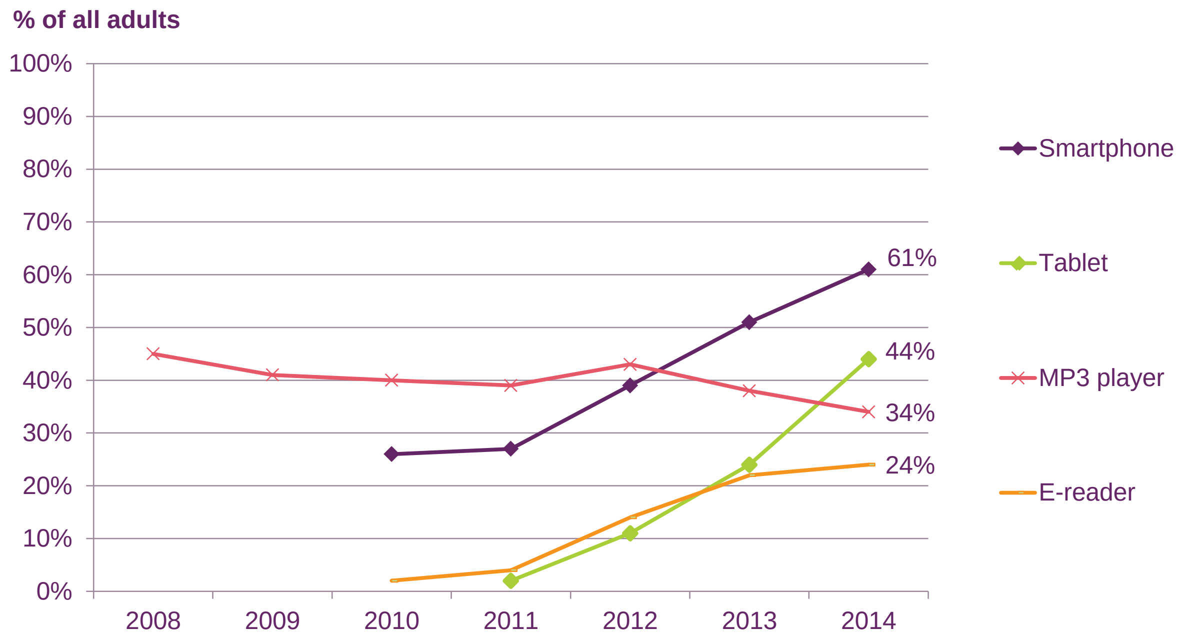
	June 2014	June 2013	June 2012	March 2011
Active connections (millions)	83.2*	82.7	82.2	81.1
Total data uploaded/downloaded (GB, millions)	44.3	28.9	19.7	9.0
Data per active connection (GB)	0.53	0.35	0.24	0.11
Percentage of data transferred between 6pm and midnight	33%	31%	31%	32%

*Source: Ofcom analysis of MNO data (*latest available, March 2014)*

5.96 Overall data usage has increased from 28.9 million GB to 44.3 million GB (53% increase). The data throughput per active connection has increased from 0.35GB per active SIM to 0.53GB per active SIM. This is due to a large increase in data use from 28.9 million GB in June 2013 to 44.3 million GB in June 2014. However, there was no significant change in the proportion of data downloaded and uploaded in the peak period.

5.97 The growth in mobile data use is correlated with the increasing popularity of smartphones over the last three years. 27% of adults had a smartphone in 2011, with less than 2% of adults owning a tablet. This year, 61% of adults own a smartphone and 44% own a tablet. As more devices that are able to connect to mobile networks become more popular, more data use on mobile networks seems inevitable.

Figure 65 - Take-up of mobile devices



Source: Ofcom, Communications Market Report 2014

Traffic mix has remained fairly stable since last year, despite roll-out of 4G

5.98 The proportion of total data use made up of web browsing and online video is similar to 2013. MNOs are still in their initial phase of 4G network roll-out. Around 8% of all active mobile subscriptions are 4G[91]. Therefore it is too early for 4G customers to have a significant impact on the overall traffic mix on mobile networks.

5.99 Consumers' use of data is not only limited by the network technology choice. MNOs can also impose caps on package, which constrain how much mobile data consumers will use.

[91] Ofcom, Communications Market Report 2014

Figure 66 - Traffic mix on mobile networks, June 2014

Traffic type	% of data in 2014	% of data in 2013
Video including streaming applications	39%	40%
Web browsing	42%	42%
Peer to Peer including Bit Torrent applications, file transfers and newsgroups	2%	8%
Other including VoIP, online gaming and email.	17%	10%

Source: Ofcom analysis of MNO data

Roadmap for future developments

Newer 4G technology is being rolled out

5.100 MNOs are currently working to improve mobile broadband download speeds by deploying "LTE Advanced" 4G technology. This can significantly improve on the original 4G, meaning peak download speeds of 150 Mbit/s and beyond.

5.101 In October 2014, two MNOs announced the roll-out of LTE Advanced (sometimes called 4.5G or 4G+). EE has rolled out this newer technology to areas of Central London, with a plan to cover Greater London and other cities in 2015.[92] Vodafone also planned to roll out the technology to Birmingham, Manchester and London over November, with other cities expected to receive the upgrade during the rest of the year and in 2015.[93]

5.102 The underlying approach used is known as 'carrier aggregation' and uses spectrum from two bands (as opposed to one) simultaneously. For EE, this means that customers' devices use 2600 MHz spectrum as well as 1800 MHz. For Vodafone customers, their devices will use both 800 MHz and 2600 MHz. In both cases, this means increased capacity allowing, according to EE, peak download speeds of up to 150Mbit/s. The theoretical maximum is 300Mbit/s, but this requires the use of large amounts of spectrum.

More research is developing the next generation of mobile technology

5.103 Looking further forward, research on the fifth generation of mobile technology is underway, although it is not clear at this stage what the outcome in technology standards or implementable systems will be. The world's first dedicated 5G centre (5GIC) is located at the University of Surrey, which won a funding programme to establish the centre[94]. It is working in partnership with a range of industry stakeholders, including three of the UK's MNOs, in order to develop solutions and standards for 5G networks.

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[92] http://ee.co.uk/our-company/newsroom/2014/10/30/ee-switches-on-next-generation-of-4g-worlds-fastest-mobile-speeds-now-available-in-london

[93] http://www.vodafone.co.uk/cs/groups/configfiles/documents/assets/vftst056351.pdf

[94] http://www.surrey.ac.uk/5gic/

5.104 5GIC has developed a core research programme with the aim of finding efficient solutions for the following:

- higher spectral efficiency;
- low latencies;
- energy efficiency;
- reduced cost of ownership of the network; and
- ensuring that network and spectrum resources are dynamically deployed so that all users have the impression that there is always sufficient capacity in the network to meet their needs, whatever they may be doing.

5.105 As well as focusing on the consumer, the research will also investigate human-to-device, device-to-device, and human-to-human communications. The centre is establishing a test bed which is expected to go live for trials from April 2015 onwards. Other initiatives focussing on 5G include the European 5G Public-Private Partnership, 5GPPP, and the global initiative, Next Generation Mobile Networks (NGMN).

5.106 There are still uncertainties about the likely timing for the commercial roll-out of 5G. However, both the European Commission[95] and the Government are targeting 2020. Huawei has also set out a roadmap that estimates deployment of 5G from 2020 onwards.[96]

5.107 We will continue to consider the implications for spectrum and physical infrastructure required for the development of new mobile technology.

5.108 In addition to providing potentially improved mobile performance, 5G technology may also open up new wireless access network solutions for providing ultrafast broadband connectivity to homes and business as an alternative to fibre to the premises solutions.

‘The internet of things’ is becoming a reality

5.109 As seamless connectivity becomes a reality it is likely that more devices will connect wirelessly to each other without direct user intervention. ‘The internet of things’ (IoT) is a term that describes how devices can be connected to a network and communicate with each other without human intervention. This is also referred to as machine to machine (M2M) communications.

5.110 IoT is being driven by the falling cost of sensors, processors and bandwidth. There is no single standardised approach; IoT devices currently use a range of technologies to communicate, from data (on mobile networks shared with other users) to dedicated networks rolled out for IoT applications only.

Examples of IoT

5.111 IoT is already with us.

[95] http://europa.eu/rapid/press-release_IP-13-159_en.htm
[96] *5G: a technology vision,* Huawei

- One common use is in wearable technologies such as fitness bands and smart watches.

- Devices within homes are also becoming connected for energy control and security devices. Smart thermostats have the ability to switch a home's heating on or off remotely by using a smartphone, and sensors could be used to learn when a user wakes up or leaves the house.

- Smart energy metering is also the focus of a major IoT undertaking. Around 53 million smart electricity and gas meters are to be rolled out to residential and small businesses around the UK, with the promise of making billing easier and energy use easier to manage.

- Motoring is also seen as an area for IoT growth, with applications in parking meters, traffic control and car parks. For example, BT is trialling the use of smart parking in Milton Keynes.[97] It has installed small sensors in parking spaces that can detect if vehicles are parked over them. The data they gather can then be sent back to a central server, to present live information about available parking spaces to drivers in the city.

Infrastructure requirements

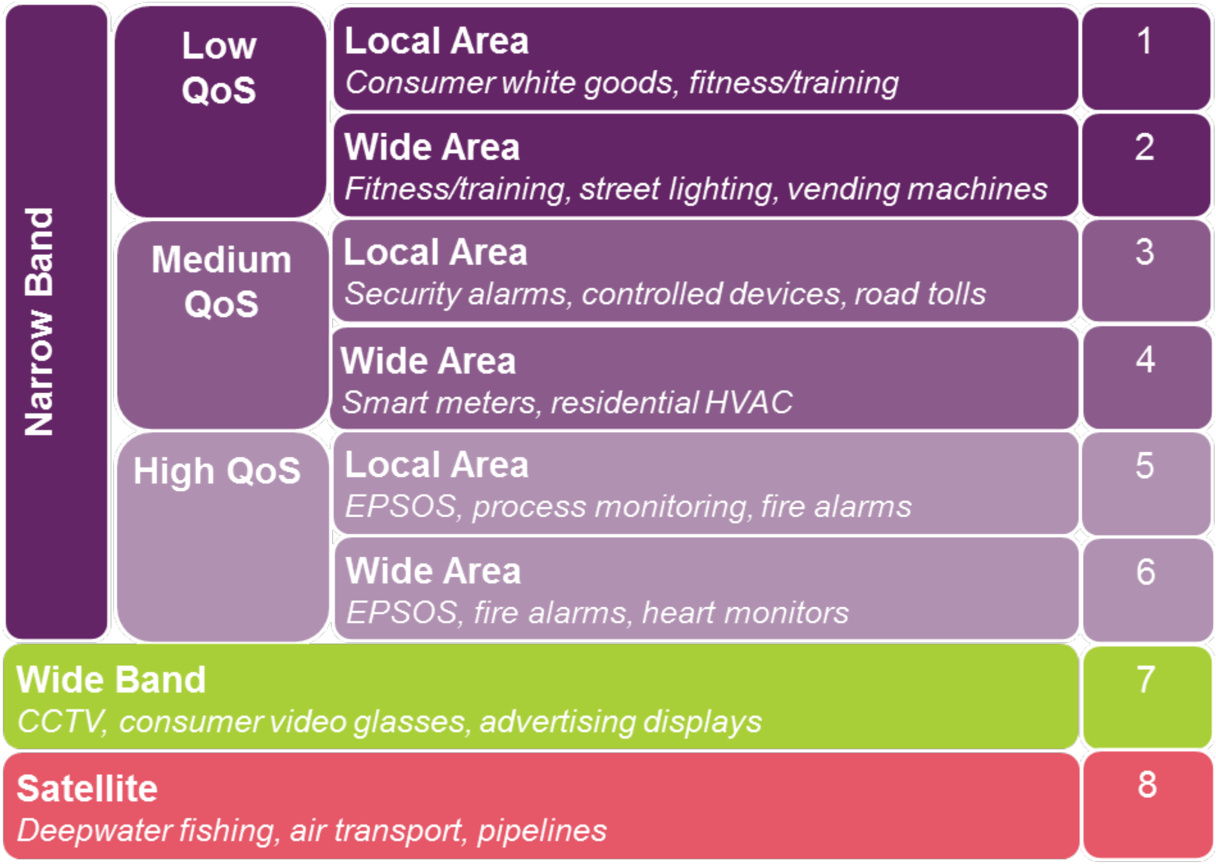
5.112 Although most IoT devices will need only a small amount of bandwidth, in order to succeed they will require reliable, low-cost, low-energy connections. Otherwise, they will be too impractical and expensive to achieve widespread adoption.

5.113 Each type of IoT application has its own network demands. Aegis Systems, working with Machina Research, reported for Ofcom on spectrum requirements and summarised these applications into eight categories (below).[98]

[97] http://www.mksmart.org/blog/2014/05/23/mksmart-helping-to-deliver-the-internet-of-things-in-milton-keynes/

[98] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/M2M_FinalReportApril2014.pdf

Figure 67 - M2M application groupings.



Source: Aegis Systems/Machina Research

5.114 Figure 67 shows that the vast majority of IoT applications require very low bandwidth. Within these narrowband applications, there are a variety of service requirements. They range from applications with low-reliability needs, such as fitness monitoring, to applications where reliability is critical, such as a fire alarm system, or the outputs of a heart monitor.

5.115 Other IoT applications have higher bandwidth requirements. Typically, these involve streaming video, such as for CCTV or a live advertising display. The need for a range of different types of infrastructure is emphasised by IoT infrastructure providers such as Arqiva, who told us that no single access technology will support all solutions, and that its customers are instead opting for a mixed set of access technologies.

Networks for the IoT

5.116 There are a number of networks that can provide IoT services:

- **Wi-Fi, and other networks using licence-exempt spectrum.** Applications requiring short-range connectivity can use existing technologies that do not need licensed spectrum, such as Zigbee, Bluetooth and Wi-Fi.

- **Mobile networks.** Mobile network operators can use their existing networks to provide coverage for IoT services. Some dedicated IoT providers buy wholesale data services from mobile operators to provide this connectivity. In order to operate on a mobile network, each device usually needs a SIM. Less than 5% of SIMs issued by mobile operators are known by the operator to be used for an

IoT application. Since most IoT devices have very low bandwidth applications, operators typically reported that less than 0.2% of data and SMS on their networks was being used for IoT applications. Therefore, they do not currently have a significant impact on the capacity of the network.

- **Non-mobile networks.** IoT connectivity is also available from operators that do not have a mobile network. For example, Arqiva has partnered with a connectivity provider, SIGFOX, to build a network for IoT (see box). Arqiva already provides much of the infrastructure behind TV, radio and wireless communications in the UK, so the fact that it is moving into the provision of IoT infrastructure underlines the area's potential for growth. Others, including BT's trial in Milton Keynes, mentioned above, are making use of locally unused resources such as 'white space' spectrum. Other non-mobile technologies include 'weightless[99]' and wireless mesh networks; some of which are designed to operate in dedicated spectrum bands, such as the 868MHz and 870-876MHz bands. These dedicated networks have been designed to minimise power consumption so that the costs of maintaining the devices can be reduced.

A new nationwide network for IoT

Arqiva is already a major provider of M2M communications services; it won one of the three UK contracts for the installation of smart meters, and is running a dedicated VHF network to track stolen vehicles.

Arqiva has partnered with a French network and connectivity provider, SIGFOX, to build new UK infrastructure for IoT. SIGFOX networks are already deployed in France, the Netherlands and Spain, and from 2015 a network will begin rolling out in the UK. Arqiva intends to focus initially on large cities: Birmingham, Bristol, Edinburgh, Glasgow, Leeds, Leicester, Liverpool, London, Manchester and Sheffield.

It sees growth in IoT implementation driven by a number of factors including public policy (e.g. smart meters), the falling cost of IoT sensors and modules, leading to their inclusion as standard in devices, and by the provision of new services built on the data from sensors

The aim is to build a low-cost, low-power network that can relay small amounts of information from sensors; the network will also connect the UK to SIGFOX's global IoT network. The solution is likely to be suitable where sensors transmit small amounts of information, and could be suitable for property applications, smart cities, logistics, manufacturing and consumer electronics. Arqiva told us that the new network will make it commercially viable for the first time to connect together small, low-bandwidth sensor devices, which Arqiva sees as the part of the IoT market with the greatest growth potential.

Ofcom's role

5.117 The introduction of IoT devices has the potential to deliver significant benefits to citizens, consumers and businesses across a wide range of industry sectors. Therefore, Ofcom is keeping under review the extent to which there may be barriers preventing the roll-out of IoT technologies and, where appropriate, considering how such barriers may be lessened or removed in the areas where we have direct responsibility (such as the availability of spectrum, numbering, addressing and

[99] Weightless refers to a low power, wide area network technology standard designed to work in many different spectrum bands

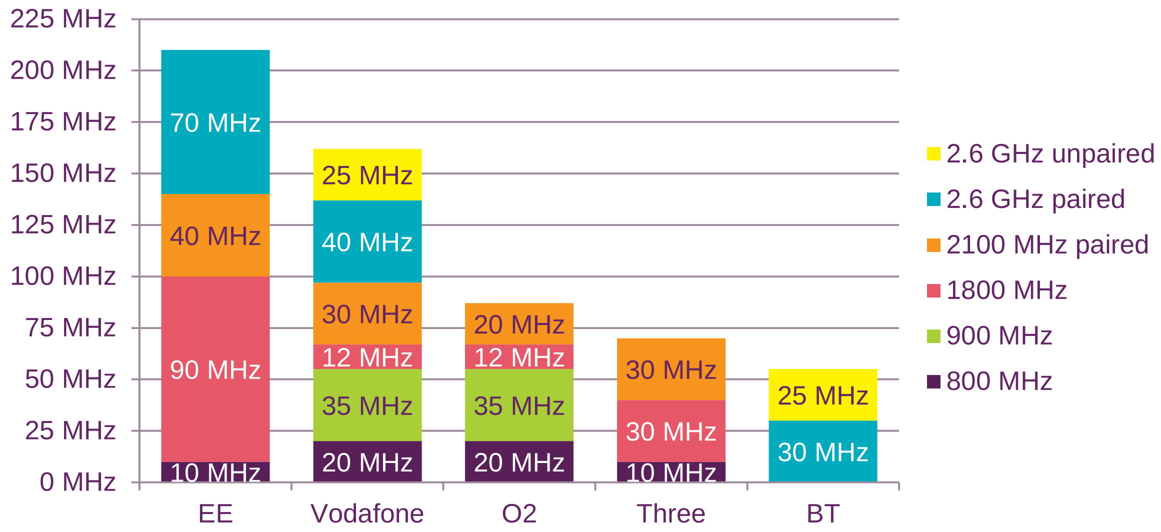
resilience). We also intend to consider those areas where it may be appropriate for Ofcom to work with other regulators and public bodies.

5.118 We recently published a Call for Inputs[100] asking for views about the likely IoT requirements for: spectrum, numbering and addressing, consumer privacy, and network security and Ofcom's potential role in this area. This consultation recently closed and, subject to the responses received, we expect to publish details of our next steps early in 2015.

Mobile spectrum use

5.119 This section sets out the state of spectrum use in the UK. The holdings of spectrum as of June 2014 are set out in Figure 68 below:

Figure 68 - UK spectrum holdings (bands currently in use for mobile services)



Source: Ofcom (BT is included as a mobile network operator on the chart as it was awarded the spectrum indicated in the chart in the 2013 4G award process. BT is currently not yet using this spectrum to offer mobile services to consumers.)

5.120 EE began rolling out 4G mobile services in November 2012 using 1800 MHz spectrum previously used for 2G services. Other MNOs and EE were awarded spectrum in the 800 MHz and 2600 MHz bands in March 2013 following the 4G mobile spectrum auction in order to roll out 4G networks.

5.121 The table below shows the networks operated within the spectrum owned by MNOs (bold indicates significant operations):

[100] http://stakeholders.ofcom.org.uk/consultations/iot/intro

Figure 69 - Mobile network operations by spectrum band and mobile network operator

	Spectrum bands							
	800	900	1000 - 1700	1800	1900 - 2000	2100	2200 - 2500	2600
2G		**Vodafone** **O2**		**EE** O2 Vodafone				
3G		O2 Vodafone				**O2** **Vodafone** **Three** **EE**		
4G	**O2** **Vodafone** EE* Three*			**EE** **Three**				EE Vodafone BT*

Source: Ofcom (asterisks indicate planned use of spectrum)*

5.122 As 4G roll-out progresses, we will monitor use of the spectrum allocated through the 4G mobile auction. While operators will continue to improve their networks, extra spectrum may also be required. We will auction additional spectrum in the 2.3GHz and 3.4GHz bands in 2015/16 and will make the 700MHz band available for mobile data from 2022 or earlier if possible. We are also considering a number of other longer-term spectrum options, and are working to ensure that the necessary international agreements are in place to enable their use.

Wi-Fi

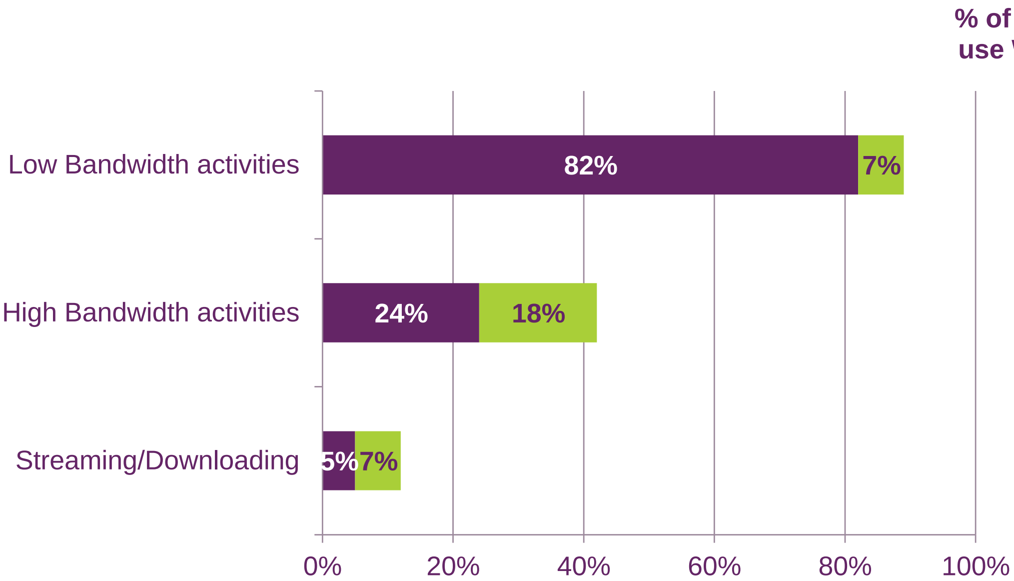
5.123 Wi-Fi is a local area wireless technology that enables devices to connect to the internet using high frequency spectrum. It is increasingly common as the in-home means of connection to a fixed broadband service. It is often also available publicly (sometimes free of charge) at Wi-Fi 'hot-spots'.

5.124 As streaming video onto mobile devices (including tablets) has become more popular in recent years, Wi-Fi has become increasingly important as a way to "offload" data use without breaching caps on download data imposed by MNOs. In the CMR we reported that 81% of consumers use Wi-Fi, with the majority using Wi-Fi at home.[101] Therefore, some mobile operators are using the ubiquity of Wi-Fi to improve access to mobile voice and SMS services. Both O2 and Three offer an app which allows their customers to make and receive calls and SMS. EE is due to launch a similar tool later this year.[102]

5.125 11% of consumers use Wi-Fi in a public place.[103] 12% of them use a smartphone to access public Wi-Fi, with just 2% and 3% using a laptop and tablet respectively. The most common locations were cafés and bars, which accounted for 64% of those who use public Wi-Fi.

[101] Figure 5.19, Communications Market Report 2014.
[102] http://ee.co.uk/our-company/newsroom/2014/06/20/EE-announcing-live-trials-of-phone-calls-over-Wi-Fi-and-4G-as-part-of-275-million-pound-voice-investment
[103] Ofcom, Communications Market Report 2014

Figure 70 - Activities carried out by those who use Wi-Fi out of the home



Source: Ofcom, Communications Market Report 2014

5.126 The majority of activities carried out by those who use Wi-Fi out of the home (public as well as transport-based, work and abroad) are low bandwidth. This includes activities such as checking emails, social networking and browsing websites. On the other hand, streaming and downloading of multimedia content such as video and audio is less common, with only 12% of those who use Wi-Fi out of the home ever undertaking it.

5.127 The number of hotspots counted for public Wi-Fi has increased by 23% from last year. Our data gathered from the major Wi-Fi network providers shows that 2.3 million GB of data was uploaded and downloaded on the public hotspots in June 2014. This is an increase compared to June 2013 but at a lower growth rate than the previous year, slowing from almost 100% increase last year to a 49% increase this year.

Figure 71 - Public Wi-Fi hotspots

	June 2014	June 2013
No. of public Wi-Fi hotspots	41,798	33,851
Total data uploaded/downloaded (GB)	2,262,049	1,514,630
Data per Hotspot (GB)	54	45

Source: *Ofcom analysis of operator data*[104]

5.128 Access to public Wi-Fi spots can be:

- free of charge: e.g. Wi-Fi access on Westminster Public Wi-Fi;

[104] An operator provided us with updated data for June 2013 after the publication of the Infrastructure Report update 2013. As a result the average total and average data used on Wi-Fi hotspots has been revised following this update

- bundled with mobile or broadband subscription: e.g. access to Wi-Fi on the London Underground is free for Virgin Media, EE, O2, Vodafone customers and Three customers;

- chargeable by time period: e.g. use of BT Wi-Fi is £4 for a 1 hour or £39 for 30 days

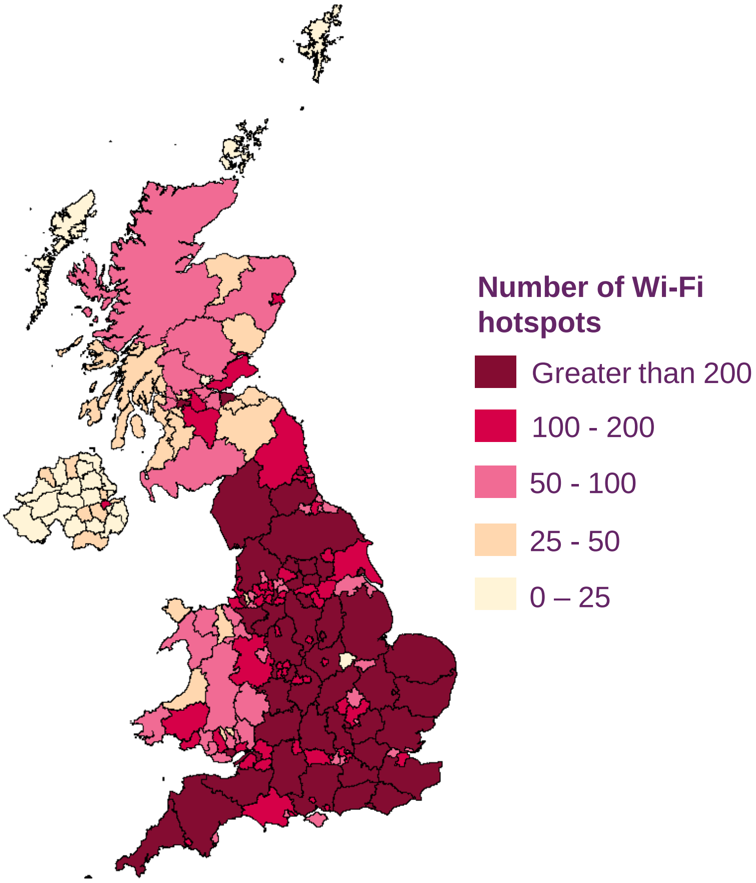
5.129 The data we collect shows a significant increase in the number of public Wi-Fi hotspots, from 34,000 last year to around 42,000 this year. For this report, we gathered data from the main fixed and mobile operators that provide public Wi-Fi hotspots in the UK.[105]

5.130 While this may represent a significant proportion of public Wi-Fi hotspots, there is a long tail of Wi-Fi providers not included in this analysis. For example, public Wi-Fi provision in cities such as Derby, as a part of the 'Super Connected Derby'[106] initiative, and Mansfield[107] is not included, as these are provided and maintained by other operators. Other schemes include those in Glasgow, Cambridge, Birmingham and Newry. Our data also does not include Wi-Fi hotspots provided on buses and trains.

5.131 Other data sources indicate that the number of Wi-Fi hotspots when other commercial and public sector providers are included may be in the region of 200,000 in the UK.[108] However, even these numbers do not include the BT FON[109] network, which are public Wi-Fi access points shared via residential and business customers' Wi-Fi routers. BT claims there are around 3.5 million of these across the UK.[110]

[105] BT, Sky, O2, Virgin Media, EE, and Arqiva
[106] http://www.superconnectedderby.co.uk/
[107] http://mansfield-Wi-Fi.ukmobilemedia.com/
[108] http://www.ipass.com/Wi-Fi-growth-map/ Wi-Fi roaming service provider, iPass, provides such an estimate on public Wi-Fi locations in cafes, hotels, shops, airports, transport and other locations on its website.
[109] https://www.btfon.com/
[110] https://www.btfon.com/support

Figure 72 - Number of Wi-Fi hotspots by local authority



Source: Ofcom analysis of operators' data

5.132 Most public Wi-Fi hotspots are in urban areas, predominantly in high street locations such as fast food chains, hotels and coffee shops. Our analysis suggests that over 16% of all public Wi-Fi hotspots are in London. Only 10% of all public hotspots are in rural areas (compared to 7% in 2013) with around 12% of the overall data consumed via these rural hotspots.

<u>Seamless connectivity between hotspots</u>

5.133 There have been initiatives from the industry to enable seamless connectivity between Wi-Fi hotspots. Passpoint[111] is a standard which is being promoted by global Wi-Fi network provider association, Wi-Fi Alliance, to achieve this objective. One of the operators has reported that they plan to introduce Passpoint technology on their hotspots, but only once some technical issues are resolved. Other providers are already deploying alternative authentication technologies which also allow users to automatically log on to the network when Wi-Fi is available, for example via a Wi-Fi app.

Use of unlicensed spectrum for Wi-Fi

5.134 Wi-Fi is provided over two licence-free spectrum bands, at 2.4 GHz and 5 GHz. The spectrum band at 2.4 GHz is more widely used as it has been available for longer and there are more compatible devices. However the popularity of this band also

[111] http://www.Wi-Fi.org/discover-Wi-Fi/Wi-Fi-certified-passpoint

causes congestion as many users try to use this limited resource at the same time. The unlicensed band at 2.4 GHz is also shared with other applications which may lead to interference.

5.135 To meet the increasing demand for data, Wi-Fi is also available at 5 GHz and there are an increasing number of devices and routers enabled to use it. At this higher frequency, faster data rates are available and there is a lower risk of interference with other 5 GHz Wi-Fi sources or with other devices which share the same frequency at 2.4 GHz. A number of fixed broadband providers, including BT, KCOM, TalkTalk and Virgin Media are beginning to provide their customers with Wi-Fi routers which are able to use both 2.4 GHz and 5 GHz Wi-Fi. Around 26% of residential fixed line users are using an operator--provided Wi-Fi router with this capability.

5.136 Public Wi-Fi hotspots are also making greater use of the 5 GHz band. Wi-Fi at both 2.4 GHz and 5 GHz are available from some of the main providers of public Wi-Fi, such as BT, O2 and Sky. Some of these providers were not able to provide a breakdown of the proportion of traffic that was carried over the 5 GHz band compared to the 2.4 GHz. Of those that were able to report on this breakdown, one suggested that approximately 25% of the Wi-Fi data was carried over the 5 GHz. Another, providing information about Wi-Fi use at a number of major train stations, reported that over 60% of data was carried over the 5 GHz band.

Section 6

Broadcast networks

Overview

6.1 At first glance, fixed and mobile telecommunications have seen more significant developments in recent years than the UK's broadcast infrastructure.

6.2 Most TV and radio continues to be consumed through traditional linear[112] broadcasting platforms. The number of channels, and the main platforms used to deliver them, (i.e. terrestrial, satellite and cable), are largely the same.

6.3 However, this relatively quiet period may now be changing. This section highlights three underlying trends that are increasingly affecting how consumers access and use TV and radio services. We also consider the future implications for TV delivery infrastructure. These trends include:

- **A migration towards increasingly higher-resolution TV.** The penetration of high-definition (HD) TV has reached 69% of TV households, supporting a greater use of high-definition TV services. Indeed, the focus now is moving to the next generation of HD ('4K') which will ultimately offer four times the resolution of HD, higher frame rates, and even-better picture contrast and colours.

  The first 4K trials took place in the UK in 2014, and research and development has already begun on 8K TV. Although these higher-resolution picture formats require more bandwidth, this is being offset by more efficient transmission video compression technologies, and the availability of higher-speed broadband connectivity.

- **Growth in broadband delivery of TV services.** A wide range of IPTV and over-the-top (OTT) services[113] is now available in the UK, ranging from linear channels delivered over operator-managed IP networks (such as BT Sport over BT YouView) to on-demand content that is provided over the top of a broadband network (e.g. BBC iPlayer). These services are placing both increased capacity and speed requirements broadband infrastructure. The extra demands are being met by the roll-out of superfast broadband and the use of content delivery networks (CDNs), device caching and multicast technologies.

  Over time, more consumers may come to regard broadband TV services as a replacement for broadcast TV. For example, it is interesting that the proportion of UK households with TVs is decreasing, albeit slowly, and that there are now nearly one million UK households that are broadband-only homes.[114]

- **The increasing consumption of TV and video over mobile networks.** High-capacity mobile video services are driving much of the increased consumer demand for mobile data capacity. To help meet this demand, mobile operators are using a combination of more sites, more spectrum and more efficient LTE (4G) technology, as well as offloading traffic onto fixed broadband networks

[112] Linear refers to the live broadcasting of the same content to multiple users.
[113] OTT services are delivered over the general internet
[114] http://www.barb.co.uk/resources/tv-facts/tv-ownership

using Wi-Fi. A further development is a new LTE broadcast solution, trialled in the UK in 2014, with the potential to deliver live linear TV services more efficiently in high-demand locations such as sports stadia.

6.4 We also discuss developments in listening to radio and other audio services, and how in some respects this is changing faster than TV viewing.

6.5 This chapter is structured as follows:

- Consumer context
- Coverage of different TV platforms
- Capacity of different TV platforms
- Emerging trends in how TV is viewed
- Developments in radio listening

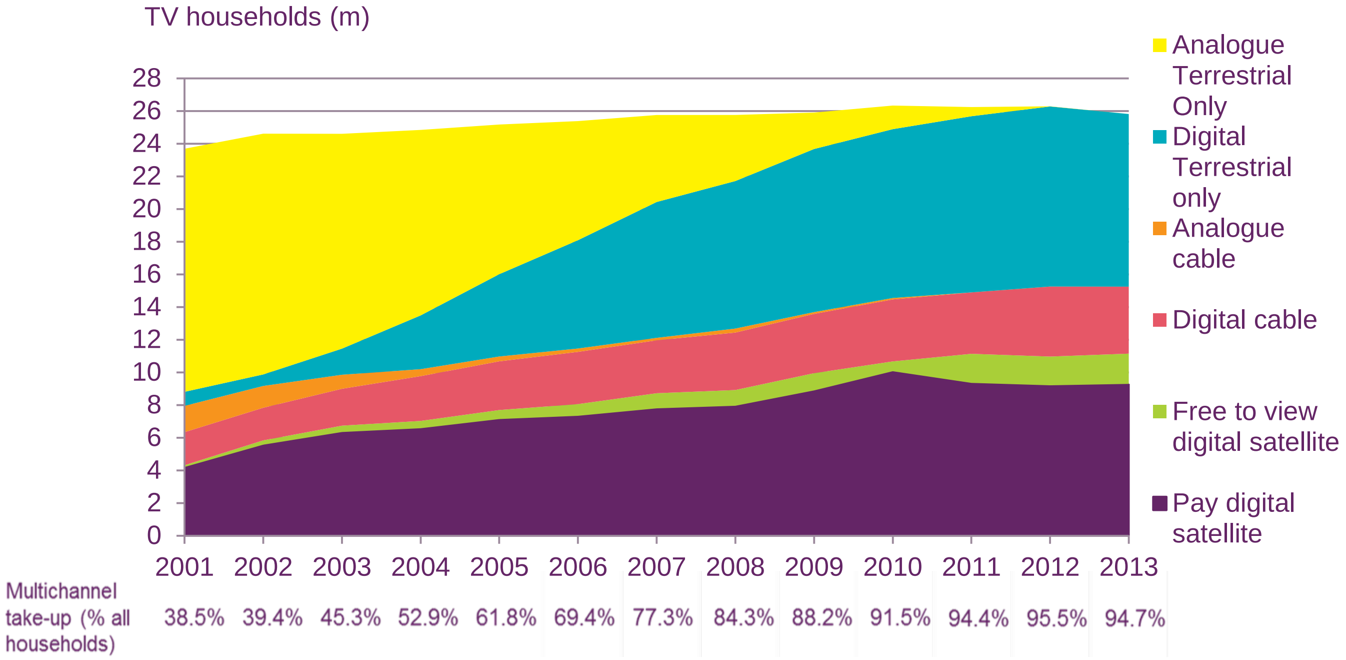
Consumer context

TV platform take-up

6.6 When we published our previous full infrastructure report in 2011, digital TV switchover was almost complete. The task was concluded in October 2012, a landmark moment when digital terrestrial TV (DTT) coverage was extended to more than 98.5% of UK households.

6.7 This not only led to a greater choice and competition in digital TV delivery platforms, but also released valuable UHF spectrum for mobile broadband use. Some is now being deployed to support the roll-out of 4G mobile broadband (LTE) services in the UK (see section 5).

Figure 73 - Platform take-up: 2001-2013

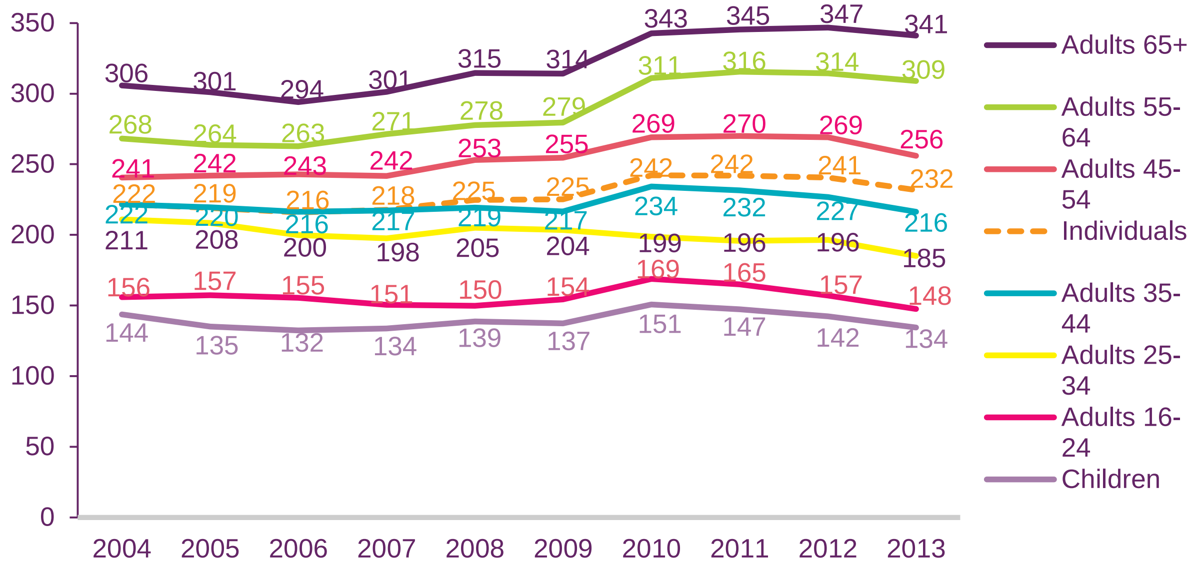


Source: BARB Establishment Survey. Note: Data points are based on Q4 data for each year

6.8 Figure 73 (above) charts the growth of digital TV since 2001, and the past and current breakdown in consumer take-up of different TV platforms. This shows that DTT, satellite and cable delivery platforms all play a significant role in delivering digital TV services.

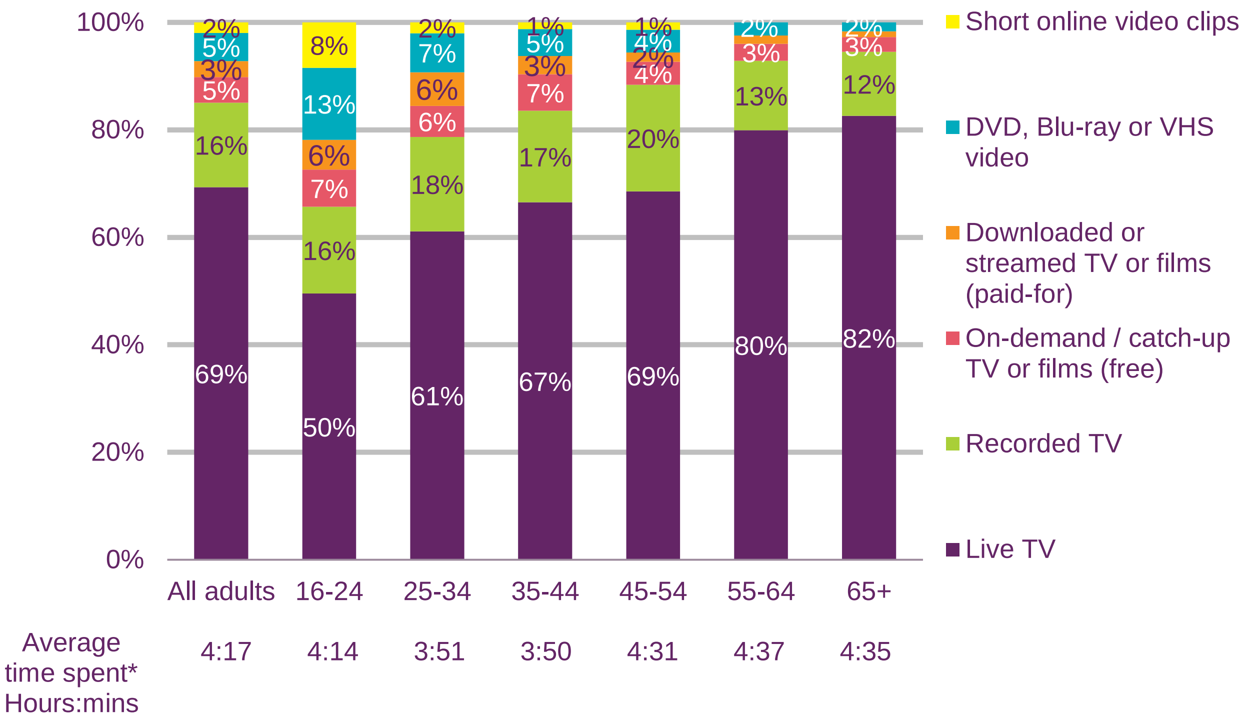
6.9 On average, people in the UK watch around four hours of television a day, with live linear viewing remaining the main way of consuming TV. Although the level of TV viewing reduced by approximately 4% in 2013, it is not yet clear whether this was the beginning of a longer-term trend or merely a temporary variation. Younger people watch less TV than the older age groups in total, and only half of viewing by 16-24s is live linear TV (see below). We don't yet know whether younger people will continue these habits as they grow older (i.e. whether this is a cohort effect) or whether they will eventually adopt similar viewing habits to present-day older groups.

Figure 74 - Average minutes of television viewing per day, by age, all homes



Source: Ofcom, Communications Market Report 2014

Figure 75 - Proportion of watching activities, by age group



*Source: Ofcom CMR 2014, Digital Day 7 day diary Base: All watching activity records for adults 16+ (25272), 16-24 (1583), 25-34 (3390), 35-44 (5362), 45-54 (6012), 55-64 (4905), 65+ (4020)*Average time spent is the total average daily time spent watching media, including simultaneous activity*

Coverage of different TV and radio delivery platforms

6.10 Figure 76 shows the estimated levels of coverage achieved by different broadcast platforms. These have not changed significantly for the DTT, satellite and cable digital TV delivery platforms since our last infrastructure report. However, as we set out in the box below, we now know more about the practical levels of coverage achieved by DTT and satellite.

Figure 76 - Estimated levels of broadcast platform coverage

	UK	England	Scotland	Wales	N Ireland
Virgin Media (cable)	**44%**	47%	35%	21%	26%
Satellite	**98%**	no data	no data	no data	no data
DTT PSB muxes	**99%**	99%	99%	98%	97%
DTT 6 muxes	**89%**	91%	87%	71%	72%
DTT 7 muxes	**76%**	79%	77%	45%	54%
BBC DAB	**95%**	96%	95%	88%	84%
Digital One DAB	**90%**	92%	83%	65%	79%

Source: Ofcom from operator data and UK planning model, CMR 2014 % of households. UK figures are aggregated from local authority level data - hence there may be slight variations compared to other sources of DTT and DAB coverage information.

Comparing the practical extent of DTT and satellite coverage

In assessing the practical extent of digital terrestrial and satellite coverage, caution is needed. In particular, the satellite coverage figures shown in Figure 76 should be viewed as the maximum theoretical level achievable.

These estimates are calculated using a number of assumptions about the typical receiver installation used by consumers. In practice, both DTT and satellite coverage can generally be improved by using a higher-gain and/or higher-height antenna installation.

Following digital switchover, coverage of DTT is estimated at over 98.5% of households. This assumes that a standard-gain DTT aerial at a height of up to 10m is used by all DTT households. In practice, higher-gain, higher-height aerials are used by some households to improve reception in weaker signal strength areas; this has the effect of increasing the proportion of households potentially able to receive DTT to more than 98.5%.

If satellite coverage was also based on the use of standard satellite installations, the predicted level of satellite coverage would probably be lower than that in the table above. This is because the higher frequencies used to deliver satellite services require a clear line-of-sight path to the satellite, and can be blocked by hills, buildings or trees. To overcome them, a higher satellite dish installation, or locating dishes away from buildings and trees, may be required. These non-standard installations may also be needed to reduce the visual impact on listed buildings, in conservation areas, and in national parks, and can increase costs for consumers.

Flats, or multiple dwelling units (MDUs), present another potential problem for satellite reception. Less than half of the 5.8 million households in MDUs are estimated to have access to an internal distribution system configured for satellite reception, although most do have one for DTT reception. While an increasing number of MDUs are now being fitted with an internal satellite distribution system and many of the individual flats can install their own satellite dish, they may be constrained by cost, planning, landlord or line-of-sight issues – again, lowering the practical level of satellite coverage.

In conclusion, the difference between the current level of coverage achieved by DTT and satellite is likely to be greater than shown in the table above if we assume that standard installations are used for both, and if access to services in MDUs are taken into account. However, it should be noted that there are places that cannot get DTT reception but can use satellite (as well as *vice versa*) – showing the important complementary role played by all TV platforms in providing digital TV coverage across the UK.

6.11 As we discuss later, there have been increases in DAB (digital audio broadcasting) radio coverage during this year, with further increases planned. As well as via DAB, digital radio services are available on digital TV platforms that reach 99% of UK households. Digital radio over the internet is available to virtually all[115] broadband customers.

Capacity of different platforms

6.12 Over 500 TV channels are broadcast in the UK. Cable, satellite and DTT each have different constraints on capacity for these channels. As we show later, the demand for broadcast capacity is growing, not only due to an increasing number of TV

[115] As an audio-only format, streaming radio can cope with very low bit-rates, and therefore can be streamed even on slow broadband connections.

channels (such as time-shifted channels) but also because HD is becoming more important.

6.13 By gaining the efficiencies of new broadcast transmission and compression technologies, more capacity has been made available on broadcast TV platforms in recent years. For example, when HD services launched on DTT in 2009, there was only sufficient capacity for three HD channels on the relevant multiplex (PSB3), using the more efficient MPEG 4 and DVB-T2 compression and transmission technologies. With continual improvements in MPEG 4 compression equipment efficiency, this multiplex is now able to support five HD channels. Further increases are likely in the future.

6.14 Five of the other DTT multiplexes (PSB1 and 2 and COM4, 5 and 6) currently use the older MPEG 2 and DVB-T compression and transmission standards. As a result they only have capacity for between seven and 14 standard-definition (SD) channels, depending on the amount of capacity devoted to each channel.

6.15 Since 2013, additional DTT capacity has been provided by a new interim multiplex ('COM7' in the table below). This multiplex operates in the 600MHz spectrum band that was freed up as a result of digital switchover (another interim multiplex, COM8, has been licensed but is not yet in service). COM7 operates using DVB-T2 and MPEG4 and can be received by households with Freeview HD equipment, which supports both these standards. This has the effect of extending the range of services accessible on receivers that support DVB-T2 and MPEG 4, such as BBC Four HD and 4Seven HD. We expect that this will encourage more consumers to adopt Freeview HD equipment. This in turn could help create a virtuous circle whereby an increasing number of DVB-T2 and MPEG4-compatible receivers makes it more attractive for other DTT multiplexes to use these standards.

6.16 Ofcom has also licensed a new DTT multiplex for use by local TV channels across the UK. In total, 30 local TV services hold licences and some are also available over satellite and cable TV.

6.17 We summarise the capacity of the different DTT multiplexes in the table below.

Figure 77 - DTT capacity and coverage

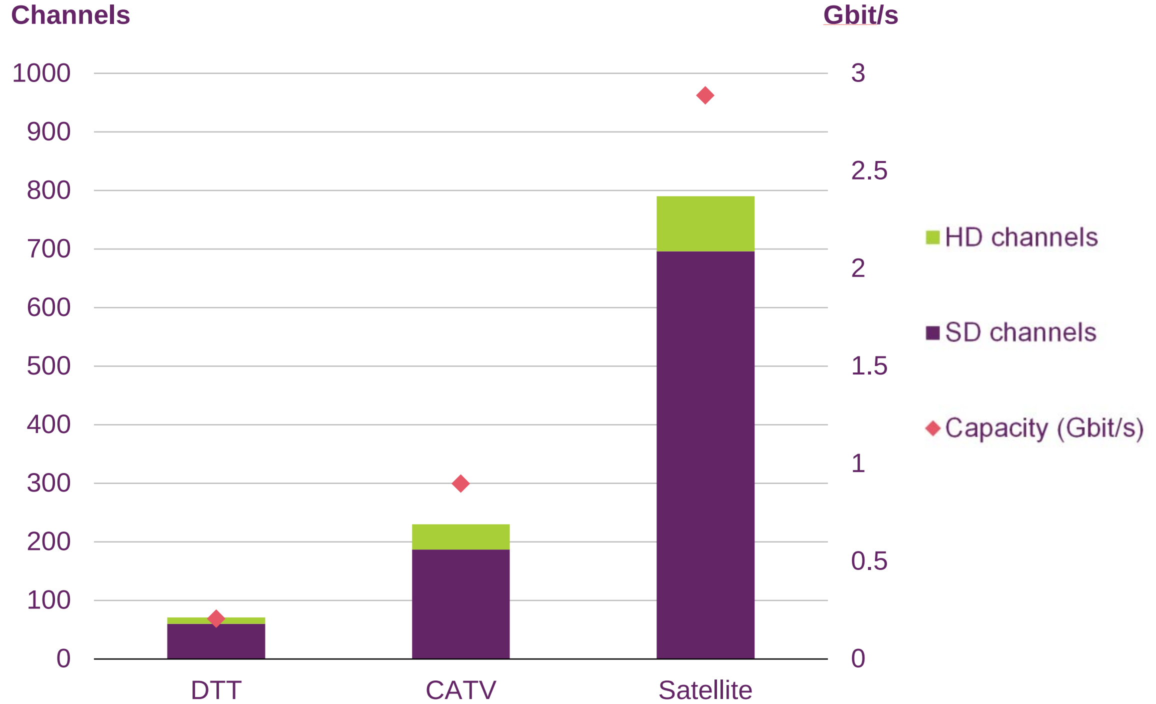
Multiplex	Standards	Bit rate (Mbit/s)	Coverage (% households)	Transmitters	Concurrent TV channels
PSB1	MPEG2/DVB-T	24	99%	1156	7 SD
PSB2	MPEG2/DVB-T	24	99%	1156	9 SD
PSB3	MPEG4/DVB-T2	40	99%	1156	5 HD & 1 SD
COM4	MPEG2/DVB-T	27	~90%	80	14 SD
COM5	MPEG2/DVB-T	27	~90%	80	14 SD
COM6	MPEG2/DVB-T	27	~90%	80	14 SD
COM7	MPEG4/DVB-T2	40	76%	30	6 HD & 2 SD
COM8			Licensed but not currently in use		
Local TV	MPEG2/DVB-T	10	Localised	20	3 SD
N Ireland	MPEG4/DVB-T2	10	N Ireland	3	3 SD

Source: Ofcom estimate based on operator data

6.18 It is more difficult to estimate the capacity of satellite and cable TV delivery platforms. At present there are four main satellites that currently provide TV coverage in the UK to homes with Sky or Freesat receivers. But new satellites, or ones with higher capacity, could be added in the future. For cable, new capacity could be added by implementing network improvements such as by splitting localised transmission nodes or by rebalancing the amount of bandwidth used for TV and the internet. The report by Analysys Mason, published alongside this report, contains more detail about the capacity of different platforms.[116]

6.19 A high-level comparison of the TV channel capacity of satellite, cable and DTT delivery platforms is shown in Figure 78. This reveals that satellite currently has the greatest platform capacity, followed by cable and then DTT.

Figure 78 - Comparison of network capacity for linear TV and channels, by platform[117]



Source: Analysys Mason, DTT channel list and MUX capacity, Digital UK; Virgin and Sky websites, King of Sat for satellite transponder capacities; estimated split of bandwidth for cable capacity, 2014 Please note, these calculations are indicative. Virgin Media capacity is representative of the capacity used for traditional broadcast only (based on 187 SD and 43 HD channels, 2.5Mbit/s per SD channel, and 10Mbit/s per HD channel), overall capacity of the cable network is around 3-4Gbit/s

6.20 Cable and satellite operators generally have greater control over consumer equipment used to receive their services than does the DTT platform, which relies on the horizontal receiver market. This potentially makes it easier for satellite and cable platforms to upgrade to more efficient transmission and compression standards to increase their capacity. This, coupled with their greater underlying levels of physical capacity, has helped ensure that satellite and cable platforms have been able to provide a sufficient amount of capacity to meet demand, including the demand for HD

[116] Analysys Mason report *"New service developments in the broadcast sector and their implications for network infrastructure".* Available at: http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf

[117] Source Analysys Mason: report *"New service developments in the broadcast sector and their implications for network infrastructure".* Available at: http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf

channels. In contrast, the DTT platform is more capacity constrained and carries many fewer channels.

Emerging trends in TV consumption and future infrastructure implications

6.21 The conventional DTT, satellite and cable TV delivery networks we describe above are continuing to play an important role in delivering broadcast TV content. In this section, however, we highlight changes that are starting to affect how TV is used by consumers and the implications for future infrastructure. These changes are:

- a move to higher-resolution formats, including high definition (HD) and ultra high- definition (UHD) ‘4K’ TV;
- greater use of broadband to deliver both linear and non-linear content; and
- consumption of TV content across a greater range of devices, including mobile devices.

6.22 Ofcom commissioned a report by Analysys Mason to assess these trends in more detail, and we have published their report alongside this one. This is available at: http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf

Adoption of higher-resolution formats

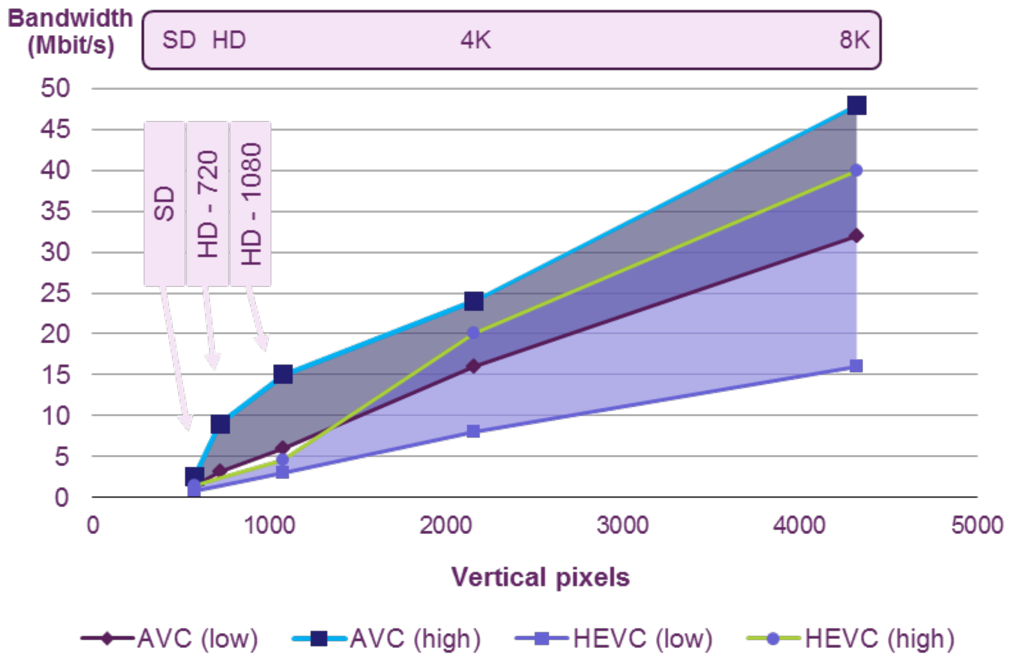
6.23 HD services were first made available in the UK over cable TV in 2005, and subsequently on Sky in 2006. HD became available on DTT in 2009 following the conversion of one DTT multiplex (PSB 3, operated by the BBC) to more efficient DVB-T2 and MPEG4 transmission and compression technologies.

6.24 HD pictures generally require more broadcast capacity than SD. The diagram below shows that an HD picture transmitted at a constant bit rate in MPEG 4 (also known as AVC) currently needs around 6-10Mbit/s of bandwidth and an SD picture 2-4Mbit/s when using MPEG2. On a broadcast platform, this creates the need for a trade-off between the numbers of channels that can be delivered, and picture quality. Over broadband, meanwhile, HD channels need more bandwidth and higher connection speeds; this means fewer people are able to receive them, since not everyone will have a fast enough connection.

6.25 The improvement in digital compression efficiency delivered by new compression standards (shown in Figure 79 below) is helping to lower demands on networks. For example, the new HEVC (high efficiency video coding) compression standard makes it possible to deliver an HD service with a similar amount of bandwidth to an SD service using MPEG 2.

6.26 HEVC will also make transmission of even higher-definition pictures a practical reality. Looking beyond current HD, higher-definition TV formats such as Ultra HD (UHD), also known as 4K, are set to place new demands on network capacity. 4K TV offers four times the picture resolution of HD, as well as other potential features including higher frame rates, better dynamic range and colour rendition, and enhanced audio, to provide a more realistic viewing experience. Using HEVC, it seems likely 4K TV will need to be transmitted at approximately 13-15 Mbit/s. The BBC conducted the first UK trial of 4K TV in 2014 using both DTT and IPTV distribution. Other providers such as Netflix have also made 4K content available to some of their customers in the UK.

Figure 79 - Capacity requirements for different TV screen formats using different compression technologies



Source: Analysys Mason

6.27 In their report, Analysys Mason concluded that the introduction of 4K TV is likely to be staggered across different platforms. While 4K services are already available as over-the-top, on-demand broadband services, the report suggests that satellite and managed IPTV providers are the most likely to deploy 4K over the next two to three years, followed by cable. Launch of 4K on DTT would probably come much later, given the capacity constraints on the platform.

Growth in broadband TV

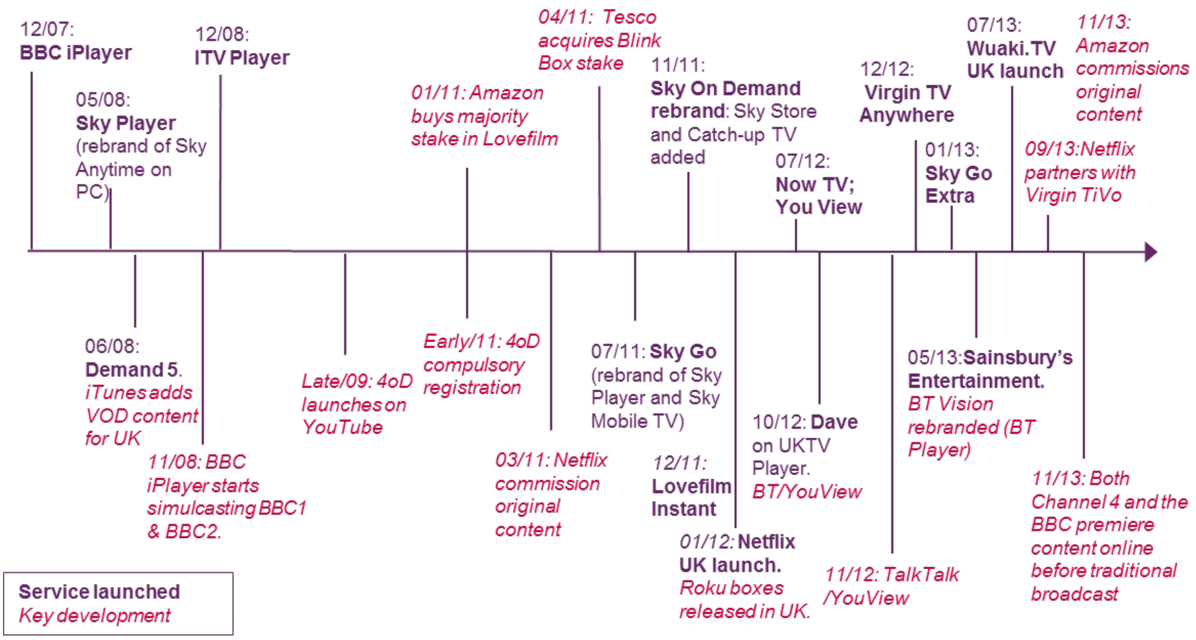
6.28 Broadband TV services are becoming increasingly popular with consumers, and a wide range is now available in the UK. These services can be split between those that are managed by operators (e.g. to control quality of delivery), and those that are delivered over the internet or over the top (OTT) via broadband connections. See Figure 80 below, while Figure 81 shows the historical timeline for the evolution of broadband TV services.

Figure 80 - Types of broadband TV services

	Operator-managed IPTV	OTT
Linear		• TVCatchup • TVPlayer • VuTV
Non-linear (on-demand)	• Sky+ / on-demand • Virgin on-demand	• BBC iPlayer • Amazon Prime Instant Video / Instant Video • Netflix • iTunes Store • YouTube • Blinkbox • Wuaki.TV
Both	• BT (YouView) • TalkTalk(YouView) • EE TV (pre-launch)	• NowTV • Sky +/on-demand/Go • Virgin TV Anywhere • BT Sport App / Online

Source: Analysys Mason: New service developments in the broadcast sector and their implications for network infrastructure

Figure 81 - Evolution of broadband TV services



Source: Ofcom CMR 2014

Operator-managed IPTV services

6.29 Operator-managed IPTV services generally support the delivery of both linear broadcast channels and on-demand content in both SD and HD formats. Operators use different approaches to manage capacity, and both BT and TalkTalk have invested in their own ‘multicast’ networks.[118]

6.30 The use of multicast has helped to reduce demands on broadband infrastructure by linear broadcast channels. This approach allows the same content to be delivered to multiple homes using the same backhaul video stream, rather than having to send out individual streams to each user. This significantly reduces the traffic on the backhaul connections and the risk of congestion. The ISP controls the whole process and can manage its network to offer a more reliable quality of service. This avoids the glitches often experienced when watching video online. It provides a broadcast-quality consumer experience to the TV, using a set-top box provided by the ISP.

OTT services

6.31 Most of the main OTT services only offer on-demand access to TV content and films. A small number of services, such as TVPlayer and TVCatchup, provide linear content, including delivery to connected Freeview sets.

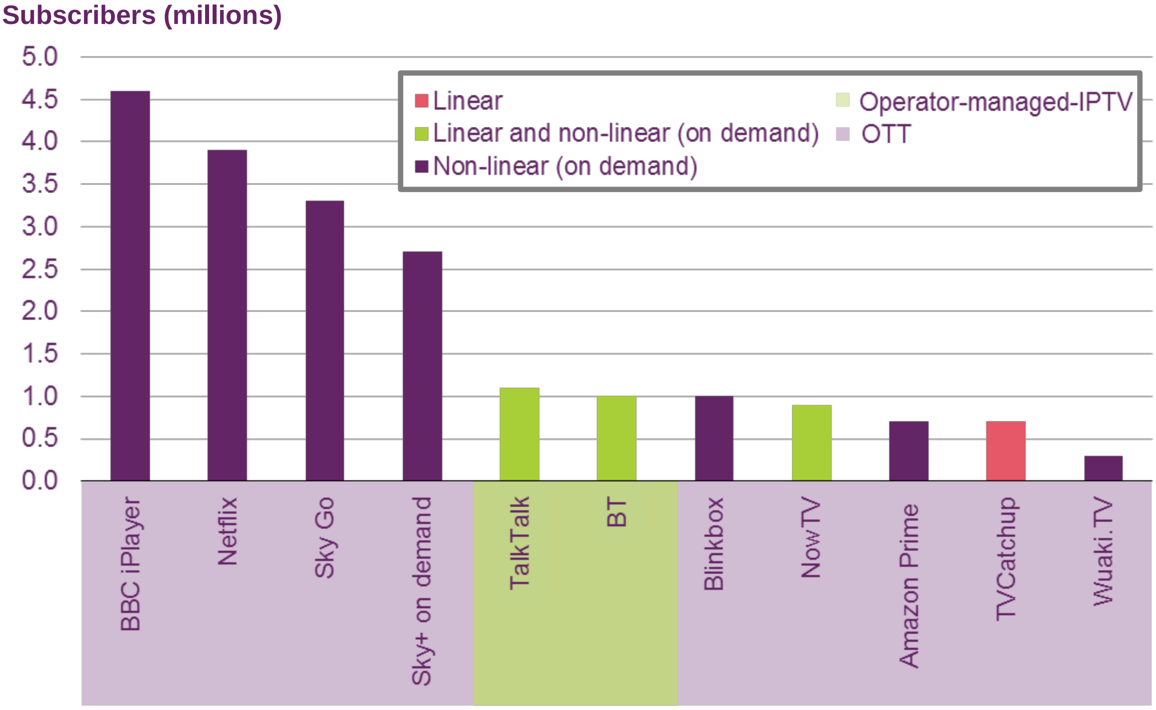
6.32 An OTT approach relies on sufficient capacity being available on the broadband network to deliver a good customer experience. Most OTT services therefore choose to buffer part of the video stream in the receiving device before it starts to play, and use an adaptive bit rate approach that adjusts the quality of the user’s stream to match the speed and capacity of their connection. Because an OTT service is delivered over the general internet, rather than using an ISP’s multicast system, it can place greater demands on broadband backhaul network capacity than a managed IPTV approach. In section 7 we discuss the resilience of IPTV services and mention a few cases where high demand for live streamed content has led to capacity problems.

6.33 Figure 82 shows that much of the growth in broadband TV is being driven by OTT on-demand services, with BBC iPlayer being the most popular, although Netflix has also grown rapidly in recent years. Over the next few years it is likely that there will be further growth in these services, placing increased demand on broadband network capacity.

6.34 Take-up of smart TVs is likely to continue growing, and new connected-TV devices are likely to appear, including a Freeview-branded connected TV service.[119] Momentum behind this service is now building with agreement on technical specifications and the awarding of initial contracts. As this, and other connected TV services proliferate, it is likely that the majority of UK households will be equipped to view OTT content on their main TV sets within the next few years. Whether this leads to more fundamental changes in consumers’ viewing habits remains to be seen.

[118] BT and TalkTalk both use multicast to provide content to their TV customers. BT provides BT Sport and a number of other channels to BT Infinity and TV customers using its own multicast product, as well as using a separate ADSL multicast service to customers who do not receive BT Infinity. TalkTalk provides SD pay-TV content on its own ADSL multicast network, and buys a wholesale multicast product from BT to provide content to its fibre customers.
[119] http://www.digitaluk.co.uk/industry/news/connected_tv_service

Figure 82 - Number of users of different broadband TV services



Source: Analysys Mason: New service developments in the broadcast sector and their implications for network infrastructure

6.35 Another form of on-demand content delivery that may become more common with the falling cost of digital storage is the use of cached content, either in the home or further upstream in networks (in 'the cloud'). This approach has the advantages of allowing content to be delivered outside periods of peak demand and for consumers to download and store content even if they have slow broadband speeds.

Implications of growth in broadband TV on broadband infrastructure

6.36 Currently a broadband connection speed in the range of 1-2Mbit/s is needed to deliver an SD video stream, and 6-8Mbit/s to deliver an HD stream using MPEG 4. In practice, higher speeds than these are likely to be needed to provide household access to other broadband services at the same time.

6.37 The new and more efficient HEVC compression standard (described earlier) will help to reduce the connection speeds needed to deliver broadband TV services. For example, an HD video stream might be delivered in the future using HEVC, requiring a connection speed in the range of 3-5Mbit/s; and a 4K stream using less than 15Mbit/s. However, many ADSL broadband customers' lines would still be unable to support these speeds; they would need to upgrade to VDSL, fibre or cable to access HD and 4K video services.

6.38 As we described above, the growth in broadband TV services will also place increased demands on ISP backhaul networks. On managed IPTV networks this can be minimised using multicasting, but this is not currently applicable to OTT services. One option is to use caching: here, on-demand content is stored closer to the user to avoid the need for transmission at peak times, and to reduce the amount of data that needs to be transmitted over the core network. One particularly attractive future option would be to make use of the increasing storage capacity of consumer set-top boxes and personal video recorders, which now commonly have 1 TB or more. For example, EE's planned IPTV services will auto-cache up to six TV channels selected by the viewer, enabling catch-up and restarting of programmes at the beginning.

6.39 Another element of broadband infrastructure for TV is in-home networks, especially Wi-Fi. The growth of broadband TV is also likely to place increased demand on these in-home networks. For example, Wi-Fi routers may need to be upgraded to support broadband TV services where a lack of a reliable Wi-Fi connection could cause the video to glitch or stop. This is less likely to be an issue for catch-up on-demand content, which can use buffering in the receiver. But for linear services, the lack of reliable Wi-Fi can give an inferior experience.

6.40 On this point it is notable that YouView[120] set-top boxes do not incorporate Wi-Fi as standard and instead use wired Ethernet or Powerline connections.[121] However, not all households may want to use wired connections between their TVs and their broadband routers, in which case in-home Wi-Fi performance may become an increasingly important factor in the future growth of broadband TV services.

Wider range of devices used to consume audio-visual content, especially mobile and tablets

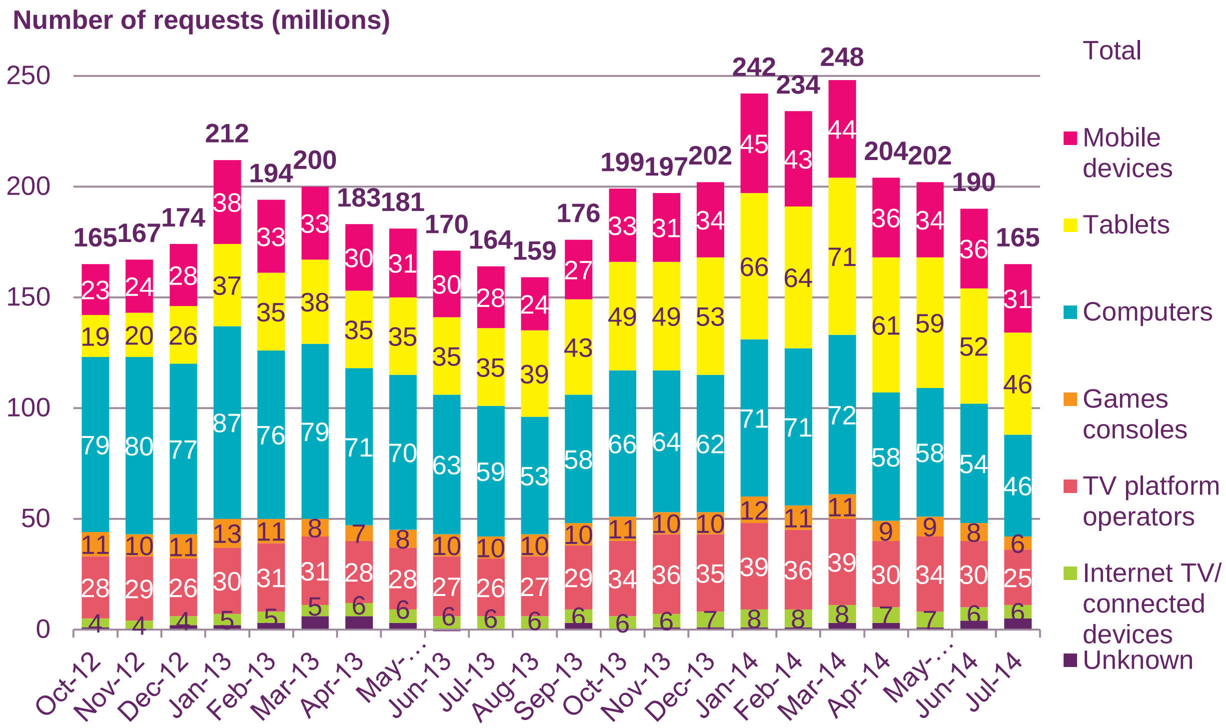
6.41 TV is increasingly being consumed on devices other than TVs. In particular, catch-up content is growing in importance and is being consumed inside and outside the home on everything from mobiles, tablets and games consoles to connected TVs and computers.

6.42 We can gain some insight into how consumer behaviour is changing from the data published by the BBC on the devices that request TV iPlayer content. As seen in the chart below, there has been significant growth in viewing iPlayer content on smartphones. In July 2014, 47% of requests for iPlayer content were sent from tablets and mobiles, compared to just 25% in October 2012. Conversely, the proportion of requests from computers fell from 48% to 28% over the same period.

[120] http://support.youview.com/articles/Self_Service_FAQ/Can-I-connect-my-YouView-box-wirelessly-1370864306799

[121] While it is possible to connect YouView boxes wirelessly this is a more complex connection and requires the purchase of additional equipment.

Figure 83 - BBC iPlayer use by device type



Source: BBC. Note: Internet TV / connected devices include Freeview and Freesat smart TVs, set-top-boxes and devices like Roku and Blu-ray DVD players. TV platform operators include Virgin Media and BT Vision. Games consoles comprise Sony PS3, Nintendo Wii and Microsoft XBox 360. An update in iStats AV meant that PS3 devices were incorrectly classified as unknown devices between 18 Feb and 21 May 2013. On mobile networks, data traffic is growing, specifically for TV and video. Forecasts suggest a four-fold increase in traffic carried over mobile networks in the UK over the period 2013 to 2018, driven by traffic on 3G and 4G handsets as well as devices such as tablets and e-readers.[122]

6.43 On mobile networks, data traffic is growing, specifically for TV and video. Forecasts suggest a four-fold increase in traffic carried over mobile networks in the UK over the period 2013 to 2018, driven by traffic on 3G and 4G handsets as well as devices such as tablets and e-readers.[123]

6.44 A wide range of OTT mobile video and TV services is currently available, but in future it will be possible to use mobile networks for one-to-many transmission as mobile broadcast systems are developed.

6.45 A 4G multicast system, known as eMBMS (Evolved Multimedia Broadcast Multicast System) has now been standardised. It was recently trialled and demonstrated during Glasgow's Commonwealth Games by the BBC in co-operation with EE, Huawei and Qualcomm. It is unclear at this stage when this approach will move from trials to full implementation. One possibility is that it could be deployed in locations where there is a high demand for mobile TV services such as sports stadia, giving spectators access to TV feeds.

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[122] Analysys Mason report *"New service developments in the broadcast sector and their implications for network infrastructure".* Available at: http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf

[123] Analysys Mason report "*New service developments in the broadcast sector and their implications for network infrastructure*"

6.46 Meanwhile, the increasing take-up of smartphones and tablets is driving video consumption on mobile devices. In Q1 2014, smartphone penetration in the UK was 61% of adults, and 44% of households owned a tablet.[124] Statistics from Three suggest that video currently represents 50% of data traffic[125] over its mobile network. EE expects 70% of network traffic to be video by 2017. To help meet this increased demand, mobile operators are using a combination of more cells, more spectrum, more efficient LTE (4G) technology and Wi-Fi offloading.

The effect of new TV consumption models on infrastructure

6.47 In summary, changes in TV technology, and consumer and supplier behaviour, are under way and are already having consequences for the UK's communications infrastructure. In particular, the growing use of broadband TV services and the use of higher-resolution picture formats are placing increased speed and capacity demands on fixed and mobile broadband infrastructure.

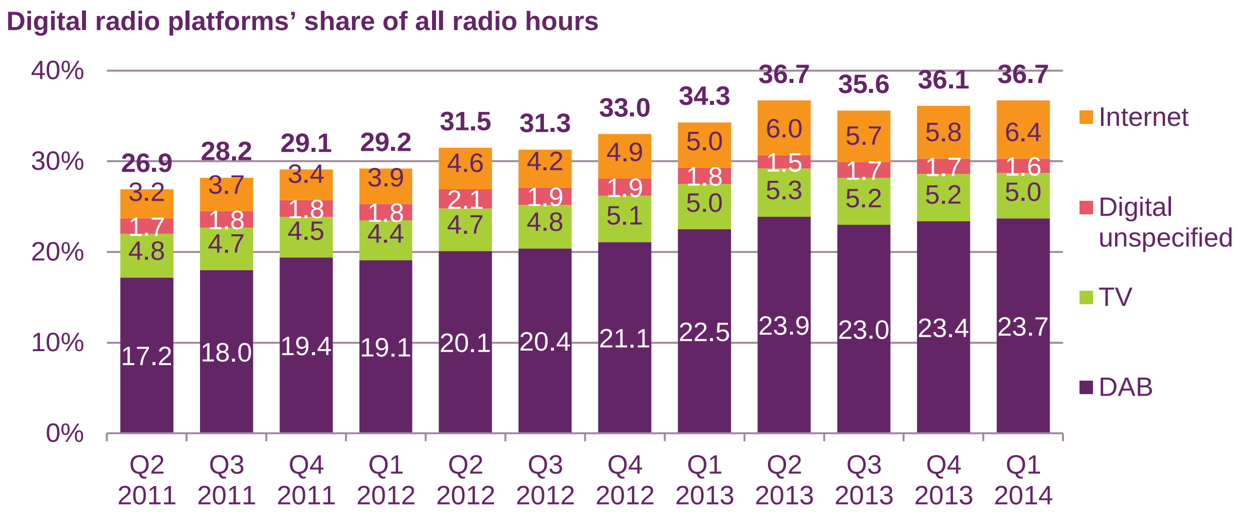
6.48 Despite these changes, conventional linear broadcast TV platforms are likely to continue to represent the majority of consumer viewing for the foreseeable future. However, viewers will probably supplement this with increasing demands for broadband-delivered TV, both linear channels and on demand, as well as mobile and tablet viewing. Indeed, many consumers already watch TV in this way.

Radio platforms

Digital listening is continuing to grow

6.49 Radio services are available on a wide range of delivery platforms including analogue FM and AM, DAB, digital TV platforms and fixed and mobile broadband. Most radio listening remains through analogue, but over a third is now via digital platforms. These include DAB, digital TV and the internet, as seen in the chart below.

Figure 84 - Digital radio's share of radio listening: Q1 2014



Source: RAJAR Note: 'Digital unspecified' relates to listening to digital-only stations where the survey respondent has not specified the listening platform used. From Q1 2012 'Internet' has been reclassified as 'Online/Apps'

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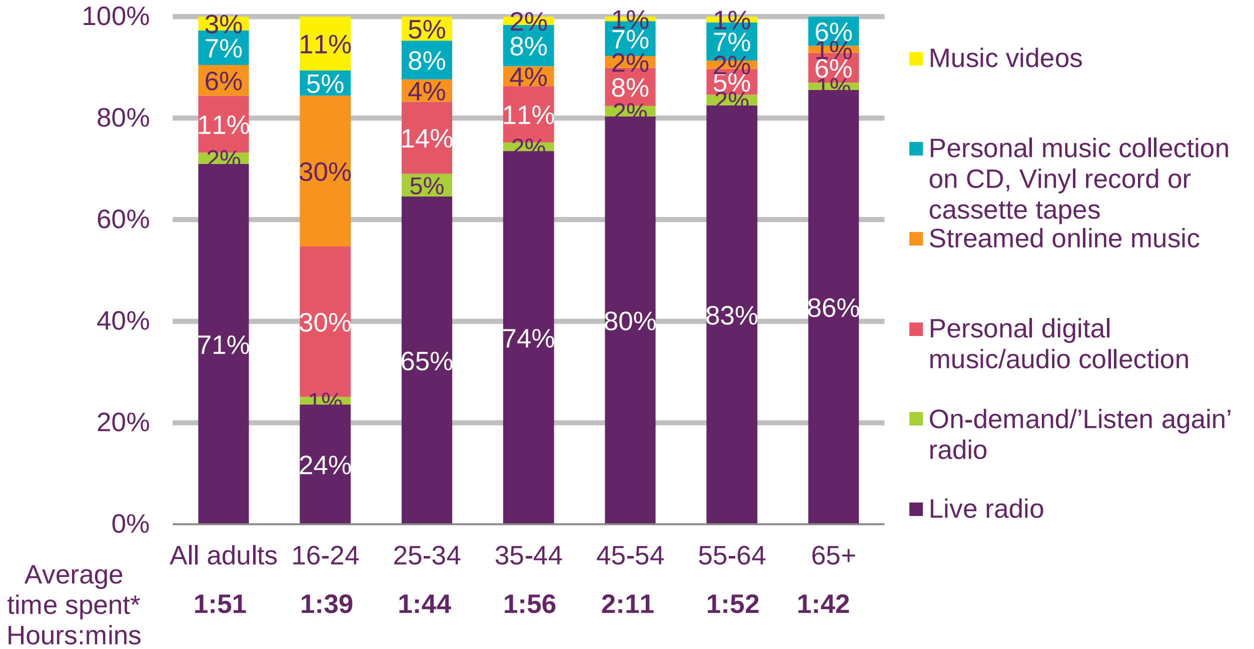
[124] Ofcom, *Communication Market Report* 2014.
[125] Analysys Mason report *"New service developments in the broadcast sector and their implications for network infrastructure".* Available at: http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf

6.50 There are significant differences between younger and older age groups, as seen in the chart below. For listeners aged 16-24, it is notable that more listening is carried out through digital and online than via linear broadcast platforms. This is not true of any other age group. As with the differences in TV viewing discussed earlier, it remains to be seen whether or not this is a cohort effect.

Figure 85 - Proportion of listening activities, by age group



Source: Digital Day 7 day diary
Base: All listening activity records for adults 16+ (17290), 16-24 (999), 25-34 (2342), 35-44 (4113), 45-54 (4334), 55-64 (3284), 65+ (2218)
**Average time spent is the total average daily time spent listening to media, including simultaneous activity*

Digital coverage and capacity is also growing

6.51 As part of the TV licence fee settlement with the Government in 2010, the BBC agreed to "enhance its national DAB coverage in the period of this agreement and to match FM coverage". As a first phase in this enhancement, the BBC is set to expand its national DAB coverage to around 97% of UK households by March 2017.

6.52 Incremental extensions to the coverage of local and national commercial DAB multiplexes are also currently under way. In addition, the BBC and commercial radio operators are working together to extend the coverage of local DAB multiplexes so that in each local area the DAB coverage is equivalent to the FM coverage of the largest local commercial radio service. This will increase the aggregate coverage of local DAB to over 90% of households by 2016.

6.53 Alongside these plans to extend existing national and local DAB coverage, new local DAB multiplexes continue to be launched, bringing local DAB services to some parts of the UK for the first time. In 2014, new services came to Somerset and Derbyshire, with further launches to come in North Yorkshire and North Wales.

6.54 Ofcom has also advertised the licence for a second national commercial DAB multiplex.

Section 7

Security and resilience

Overview

7.1 As we increase our dependence on the nation's communications infrastructure, the security and resilience of fixed, mobile and broadcast television networks and services become ever more important.

7.2 A major failure would have the potential to affect large numbers of people and businesses; it could also have repercussions for the wider UK economy. At the same time, the interconnected and global nature of communications services brings with it challenging vulnerabilities which we must identify and address.

7.3 This section discusses security and resilience in the communications industry. It includes:

- Ofcom's framework for engaging with the communications industry on security and resilience matters.
- An analysis of the security incidents that were reported to Ofcom between September 2013 and August 2014 and which had a significant impact on the operation of public electronic communications networks and services. This shows that the most commonly reported security incidents[126] affect consumer telephone access to the 999[127] emergency services and are more likely to occur in large population centres. The most common causes of service loss are the failure of hardware components and the loss of power.
- A study into the impact of the winter floods on fixed and mobile sector networks and services. This shows that there was an increase in the average incident duration, but that, in general, providers are apparently well prepared for severe weather and able to minimise the impact on consumers.
- The measures taken by providers in the fixed, mobile and broadcast sectors to ensure the availability of their networks and services. This section examines how site planning considerations, back-up sites, diverse routing, specialist incident response teams and cyber-attack defences all play a part in providing secure and resilient services.
- A summary of the measures being taken by providers to counter the growing threat of cyber-attack. Although cyber-crime accounts for a very small proportion of the incidents reported to Ofcom, providers highlight this area as a growing trend and are taking the threat seriously.
- Security and resilience in broadcast networks and services. This section examines the cause of outages in the past year and shows that services are

[126] We set thresholds for such reports, based on the numbers of customers affected and incident duration. Because of "safety of life" considerations, the thresholds for incidents that affect emergency services access are lower than any other, which explains the apparently high incidence.
[127] This also applies to the single European emergency call number "112". For ease of reference, however, we refer just to the UK national emergency call number "999" in this section.

normally fully available. We consider providers' concerns that the extremely high demand for online content may lead to capacity problems in the future, and look at how content delivery networks (CDNs) are helping to alleviate this growing concern.

Framework

The respective responsibilities of Ofcom and providers regarding security and resilience

7.4 In accordance with Article 13a of the Framework Directive[128], sections 105A-D of the Communications Act 2003, place requirements on providers and Ofcom regarding the security and resilience of communications networks and services.

7.5 These requirements help to mitigate risks to security and resilience by setting out the following:

- Network and service providers must take appropriate measures to manage risks to security, in particular to minimise the impact on consumers and interconnected networks.
- Network providers must take all appropriate steps to protect, as far as possible, network availability.
- Network and service providers must report to Ofcom breaches of security or reductions in availability which have a significant impact on the network or service.
- Ofcom must, where it thinks it appropriate, notify regulators in other Member States, and the European Network and Information Security Agency (ENISA) of any reports.
- Ofcom may inform members of the public of details of any reports received, or require a network or service provider to do so.
- Ofcom must prepare an annual report summarising details of all reports it has received and send it to the European Commission and ENISA.

7.6 Ofcom first published guidance on these security requirements in May 2011 and updated that guidance in August 2014.[129] 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.

7.7 In order to help achieve the goals set out in sections 105A-D of the Communications Act 2003, Ofcom works closely with providers and industry bodies, both in the telecommunications and broadcasting industries; with the Government, including the Department for Business, Innovation & Skills, the Department for Culture, Media & Sport and the Cabinet Office; and with our counterparts in other European regulators via ENISA.[130]

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[128] Directive 2002/21/EC of the European Parliament and Council on a common regulatory framework for electronic communications and services.
[129] http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/security-resilience/ofcom-guidance.pdf
[130] http://www.enisa.europa.eu/

7.8 Aside from the requirements under sections 105A-D of the Communications Act, digital television (DTT) multiplex operators have an obligation to meet high standards of reliability and to provide Ofcom with an annual report on transmission performance. These specific requirements are set out in the Television Technical Performance Code.[131]

Fixed and mobile networks

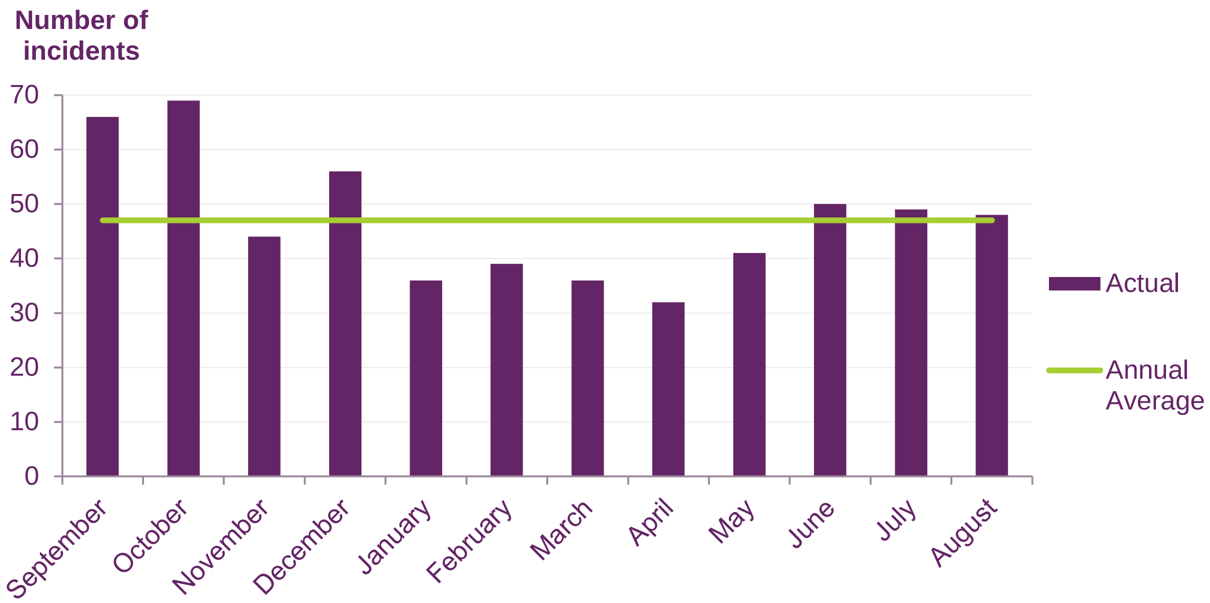
The majority of security incidents reported relate to voice services, often affecting consumer access to the 999 emergency services

7.9 In the past year, 566 security incidents were reported to Ofcom by fixed and mobile providers.

7.10 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.

7.11 Figure 86 summarises the number of incidents reported each month between September 2013 and August 2014. The monthly variation can be as great as 20% of the average and could be the result of seasonal factors such as weather or school holidays. Ofcom will continue to monitor for trends over time.

Figure 86 - Incidents reported to Ofcom: September 2013 to August 2014



Source: Ofcom analysis of data provided by operators

Scope of Ofcom reporting guidance/ framework

7.12 Ofcom's guidance provides qualitative and quantitative criteria, against which a provider can gauge the impact of an incident and determine if it should be reported.

[131] http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/tech-guidance/tv_tech_platform_code.pdf

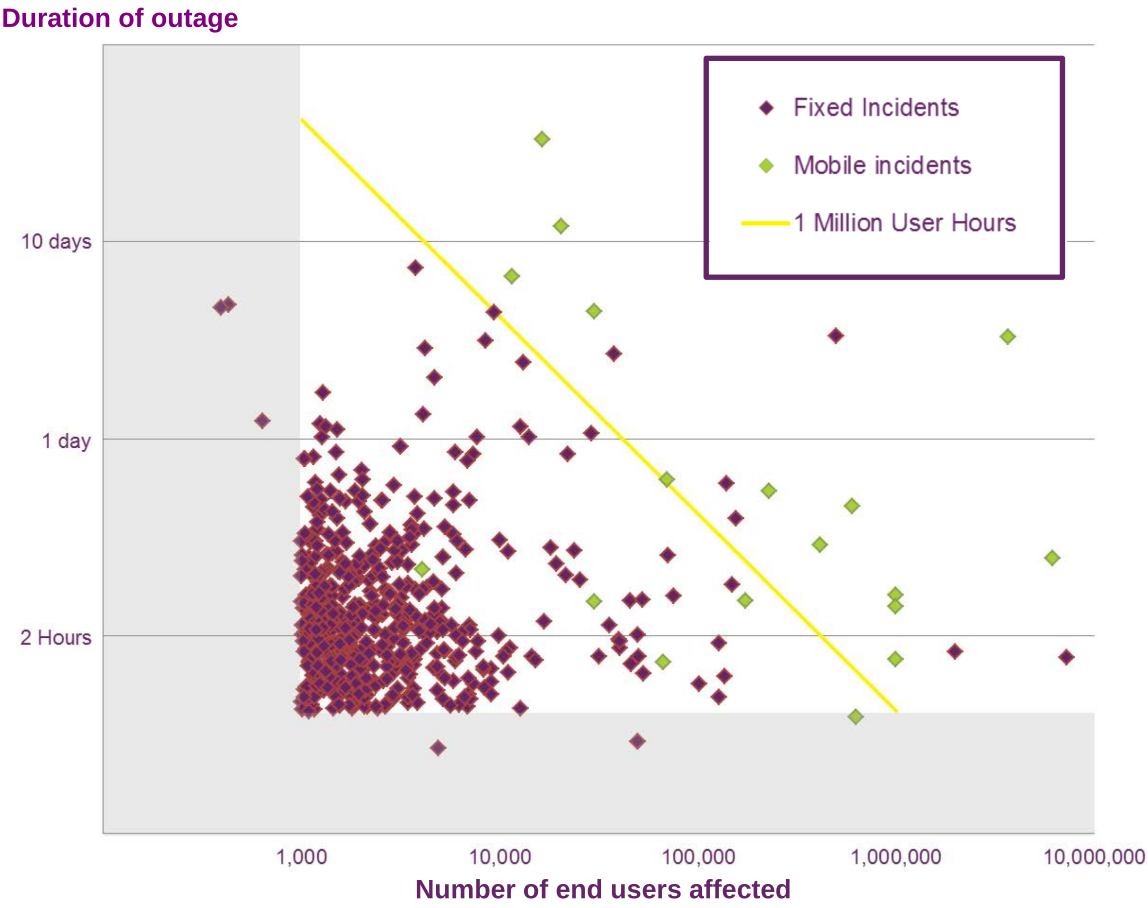
7.13 Quantitative criteria take the form of numerical thresholds. The lowest and most critical is the 'emergency services access' threshold which applies to incidents that affect voice access to the emergency services for 1000 customers, for one hour. Thresholds for incidents which affect telephony services, but not emergency services access, and for incidents which affect data services, are significantly higher.

7.14 The application of these thresholds means that there will be incidents that occur but which are not reported to Ofcom. Since they do not have "significant impact", this is in line with the relevant legislation.

7.15 Although the new guidance is now in effect, the summary of incidents presented in this section is based on reports received between September 2013 and August 2014, under the thresholds specified in our previous guidance.

7.16 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 comparative discussion. Figure 87 shows the customer-hours impact of the 566 incidents reported to Ofcom.

Figure 87 - Impact of incidents reported to Ofcom: September 2013 to August 2014



Source: Ofcom analysis of data provided by operators

7.17 The majority of incidents have a relatively low customer-hours impact and are reported under the 'emergency services access' threshold. Significantly fewer incidents were reported under the higher non-emergency services access thresholds.

Of the 566 reported incidents, 548 affected fixed networks and 18 affected mobile. This can be explained by two key differences between fixed and mobile networks.

7.18 First, the data show that 97% of the fixed-line incidents reported to Ofcom affected voice access to the emergency services. This was the case for just 39% of mobile incidents because UK mobile operators have an emergency roaming agreement. When a mobile network is unavailable, the handset will still have access to the emergency services via a rival's network, if coverage is available. This means that a low customer-hours voice outage on a mobile network is unlikely to result in a loss of emergency services access and therefore will not be reported to us. This type of co-operation agreement is not technologically feasible in fixed networks so we receive significantly more incident reports against the 'emergency services access' threshold.

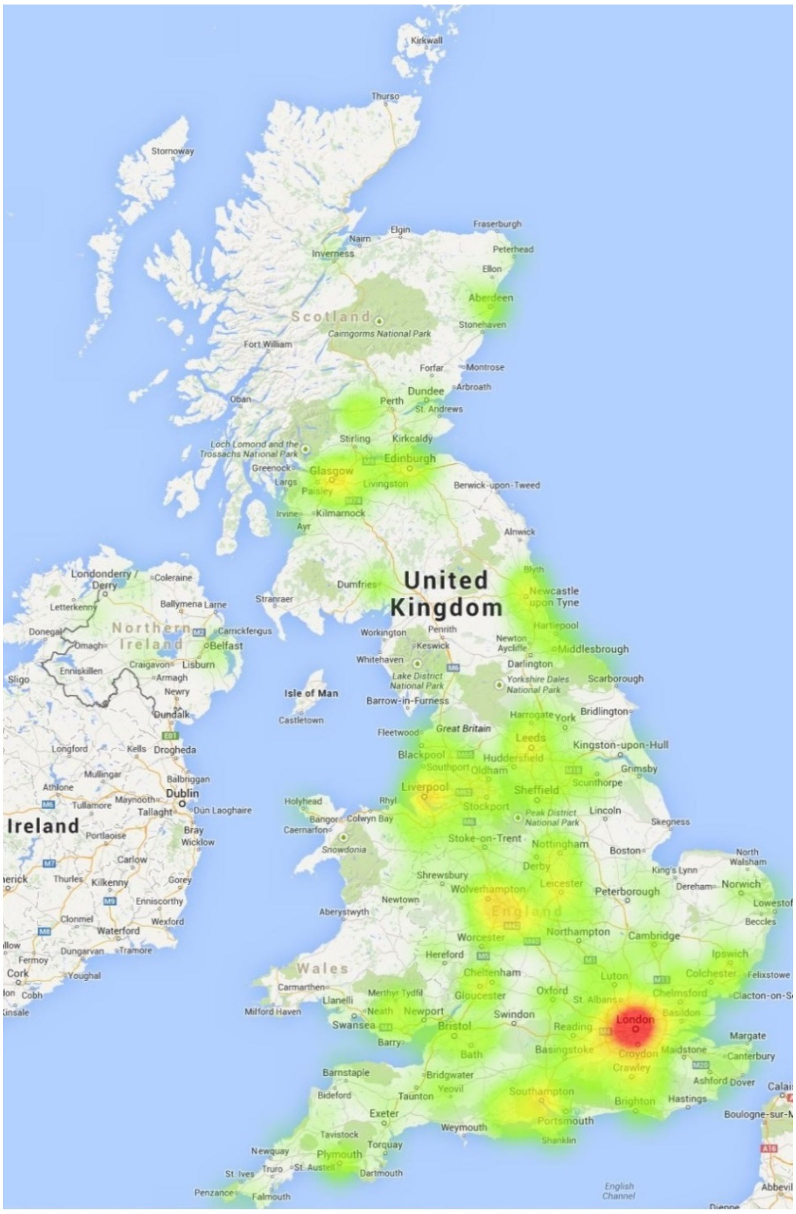
7.19 Second, the topology of mobile networks means that network failures have a relatively low impact. Overlapping cell coverage, and a UK average of around 300 consumers per cell, means that the failure of a single or small number of cell sites would rarely meet our minimum threshold. In contrast, a fixed network's local exchange or street cabinet can be a single point of failure for thousands of consumers.

7.20 These inherent differences between fixed and mobile explain why significantly more fixed network incidents are reported to Ofcom. These are concentrated in the lower left quadrant of Figure 87.

7.21 The yellow line indicates where an incident will have an impact of one million customer-hours. This type of incident will generally be the result of a core network failure and there is a more equal distribution of fixed and mobile incidents in this space. Ofcom is required to report incidents which have an impact of greater than one million customer-hours to ENISA.

7.22 Figure 88 below shows how the 566 incidents are geographically distributed in the UK, and reveals that there is a correlation between incident frequency and population density.

Figure 88 – A heat map showing the frequency of outages reported to Ofcom, by location



©2014 Google – Map data ©2014 GeoBasis-DE/BKG (©2009), Google

7.23 Where densities are higher, a higher concentration of network assets is required to provide services. It is logical to expect that where there are more assets, there is a greater likelihood of incidents.

7.24 However, our minimum incident threshold of 1,000 end-users affected may result in some rural incidents not being reported. The geographical location and the extent of the impact of incidents is covered in our new guidance, and we aim to investigate this pattern further in the coming year.

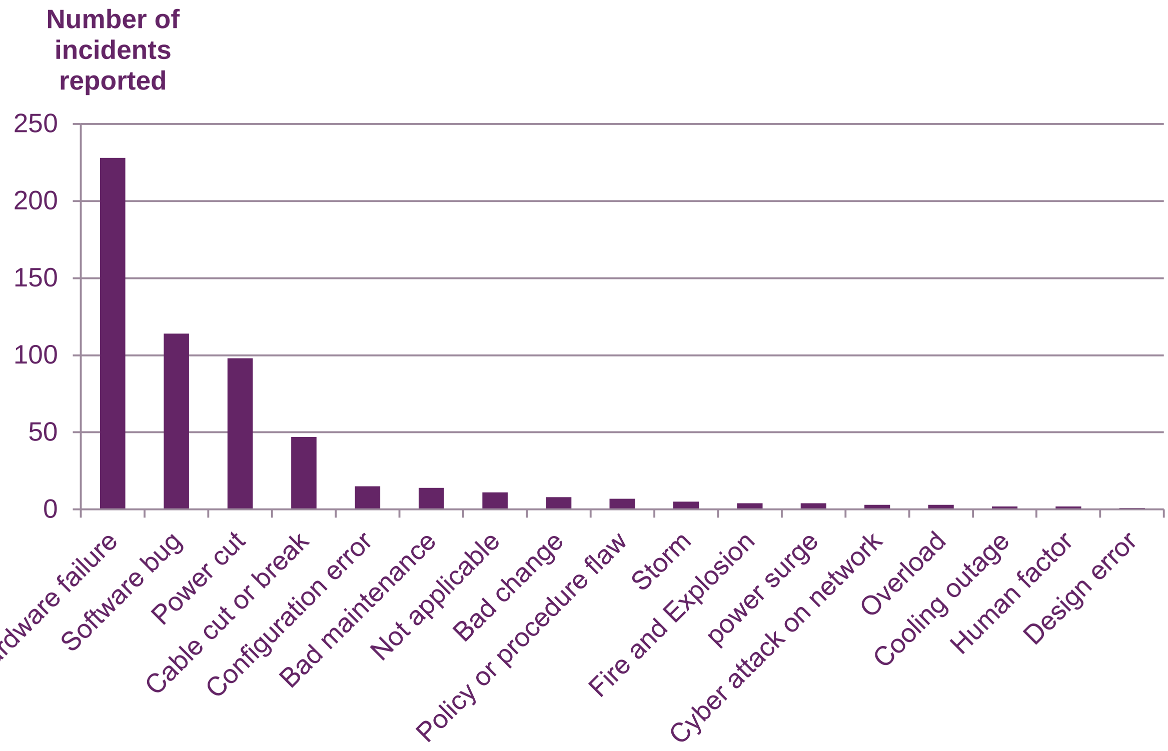
The majority of incidents are caused by the failure of hardware components, the loss of power supply or by software bugs

7.25 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; some 95% of the 566 reported incidents fall into this category. This includes hardware and software failures, and the failure of systems, processes and procedures.

7.26 The remaining categories are human error, natural phenomena (which includes severe weather) and malicious actions, which were responsible for 3%, 1% and <1% of the reported incidents, respectively.

7.27 Ofcom categorises the root and primary cause of reported incidents according to the taxonomy provided in the ENISA Article 13a Technical Guideline on Threats and Assets.[132] The primary cause category provides further detail regarding the exact issue which led to an incident. Figure 89 shows that incidents were reported against a wide range of primary causes.

Figure 89 - Primary cause of incidents reported to Ofcom: September 2013 to August 2014



Source: Ofcom analysis of data provided by operators

7.28 The 'power cut' category indicates a loss of electricity from the grid. This type of incident often has an impact that is restricted to the local area, but is likely to affect both voice and data services.

7.29 'Hardware failure' is the most common primary cause. Interestingly, 99 of the 228 hardware failure incidents were power-related hardware issues. Examples included the failure of a fuse, battery, inverter circuitry and backup generator. Therefore, 197 incidents, or 35% of the 566 reported incidents, were the result of some form of power failure (grid-distributed power or on-site hardware-related power failure). The impact of a hardware failure is often restricted to the local area where there is limited network resilience; for example, in exchanges or street cabinets. Due to the resilient

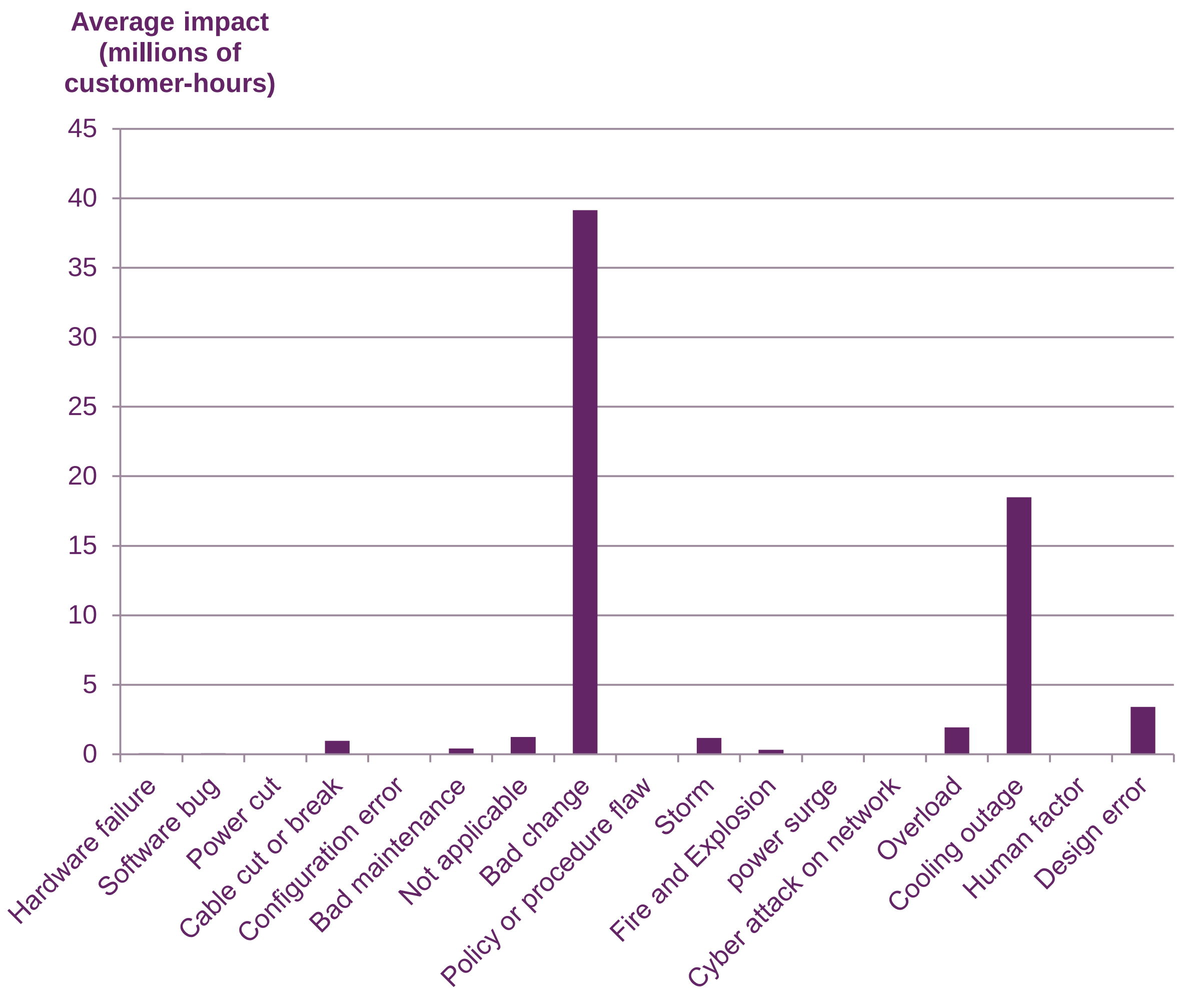
132 https://resilience.enisa.europa.eu/article-13/guideline_on_threats_and_assets

nature of core network design, hardware failure in core network assets rarely leads to a loss of network availability.

7.30 ‘Cable cut or break’ is often the result of a procedural failure, human error or criminal activity. Often, cables are cut by people with no connection to telecoms – it could be an accidental cut under the sea, or by road or utility workers. In the case of fibre cables, their very high capacity means that many customers may be affected, and such incidents can take a considerable time to resolve.

7.31 The ‘software bug’ category includes network failures where a network asset (such as a server, switch or router) must be turned off and on again to resolve the incident. As with hardware failure, the impact of a software failure is often restricted to the local area, where there is limited network resilience.

Figure 90 – Impact of incidents reported to Ofcom: September 2013 to August 2014



Source: Ofcom analysis of data provided by operators

7.32 Figure 90 shows the average impact of primary-cause incident categories. When compared with Figure 89 it is clear that the most frequent incidents have a lower than average impact; conversely, incidents with the highest average impact are less frequent.

7.33 The more frequent primary causes are likely to be captured by the providers' incident management processes, and are therefore more quickly diagnosed and managed by their response teams. Also, the more frequent primary causes, such as power cut and hardware failure, are more likely to occur in the access layer of the network, where the number of consumers affected is constrained by the network topology.

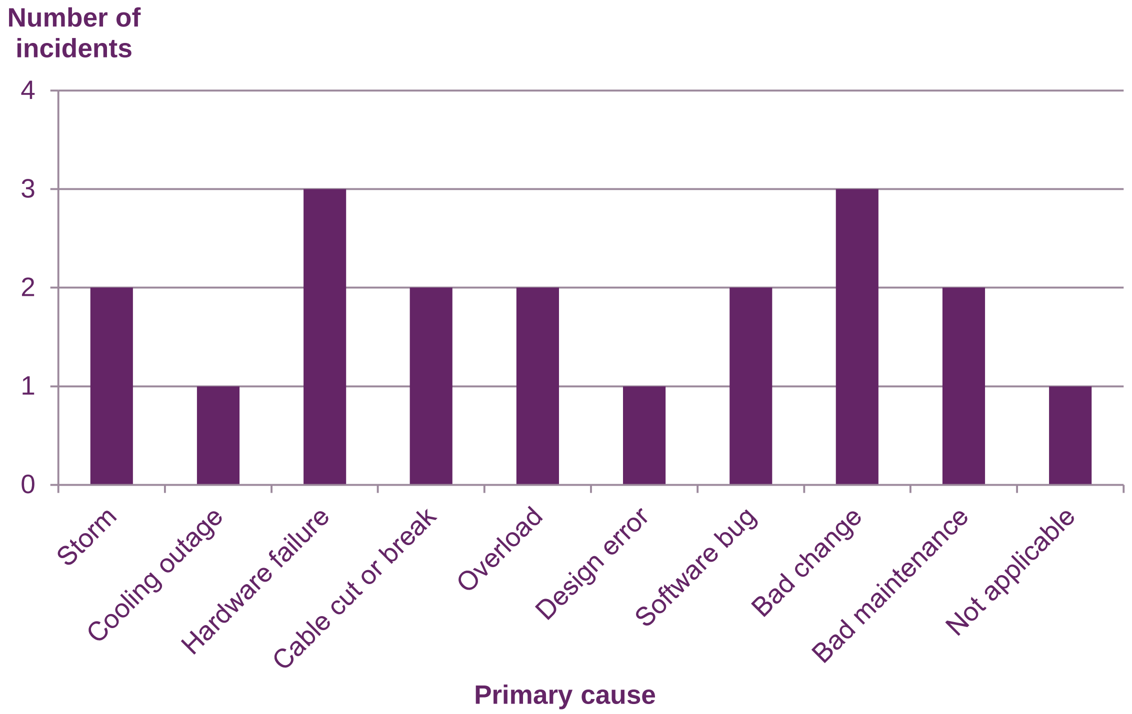
7.34 Conversely, the less frequent failure modes may not be understood by providers and can require a complex fault diagnosis and resolution process. Additionally, incidents with a relatively high impact are those that occur in the core of the network.

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

7.35 Figure 91 summarises the primary root causes of these outages and shows that there is no dominant issue behind incidents with an impact of more than one million user hours.

7.36 Although power failure is a significant cause of incidents overall, it does not appear in Figure 91. For an incident to have an impact of over one million user hours it is extremely likely that the network fault is in the core or distribution layers of a network. Typically, these parts of a network will have an extremely resilient power supply.

Figure 91 - Summary of the primary root causes of incidents meeting the ENISA reporting threshold



Source: Ofcom analysis of data provided by operators

7.37 The largest single impact on a fixed network in the last year was caused by an attempted bank robbery. In February 2014[133], criminals cut through 11 cables in a failed attempt to disable a bank's alarm systems. In doing so, they severed cables containing hundreds of fibres, causing major disruption to the voice services of BT,

[133] BBC, 2014. Thousands hit as vandals cut BT phone cables. http://www.bbc.co.uk/news/uk-england-london-26341324 [Accessed 26 February 2014]

TalkTalk and Sky customers in the London area. The complex restoration effort required by Openreach took over three days, over which time the combined impact reached over 40 million customer-hours.

7.38 No provider is immune to unexpected and significant network failures, and indeed, EE[134], Vodafone[135], O2[136], Three and Virgin Media[137] all suffered incidents with an impact above one million customer-hours during the reporting period.

7.39 Most recently, on 22nd November, Vodafone suffered a network incident[138] that caused a number of high profile "Non-Geographic Call Services"[139] that it provides to large public and private sector customers to fail. These included both the 101 and 111 non-emergency accesses to national Police and NHS services. Services were restored relatively quickly but the incident demonstrated how a failure in a single network element can have a significant national impact.

7.40 Guidance from ENISA[140] sets out that national regulatory authorities of Member States should include incidents with an impact above one million user hours in their annual reports to ENISA. In the reporting period of September 2013 to August 2014 there were 19 incidents which met this threshold: 13 affected mobile networks and six affected fixed networks. System failure is still the main root cause, at 68%.

7.41 ENISA's *Annual Incident Reports 2013* provides a summary and analysis of the incidents reported by EU Member States during that year.[141]

Case study – The impact of severe weather and flooding

Providers take considerable steps to ensure service availability during periods of severe weather

7.42 The risk that flooding poses to major switching sites is a prime planning criterion, and sites are positioned, and sometimes repositioned, as a result. Examples of these sites suffering as a result of river or coastal flooding are therefore very rare.

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[134] The Inquirer, 2014. EE suffers a major network outage, blames gremlins. http://www.theinquirer.net/inquirer/news/2335283/ee-suffers-a-major-network-outage-blames-gremlins [Accessed 20 March 2014]

[135] The Independent, 2014. Vodafone 'working hard' to resolve intermittent outages of its mobile phone services. http://www.independent.co.uk/life-style/gadgets-and-tech/news/vodafone-working-hard-to-resolve-intermittent-outages-of-its-mobile-phone-services-9065562.html [Accessed 28 October 2014]

[136] The Telegraph, 2014. O2 customers suffer wide-scale network outage. http://www.telegraph.co.uk/technology/news/10354066/O2-customers-suffer-wide-scale-network-outage.html [Accessed 28 October 2014]

[137] The Register, 2014. http://www.theregister.co.uk/2014/07/08/virgin_media_suffers_yet_another_dns_outage/ [Accessed 8 July 2014]

[138] http://www.theregister.co.uk/2014/11/28/nhs_and_police_nonemergency_services_outage_due_to_switch_failure_source/

[139] These services use numbers starting with 08 or 09, or are accessed via a three digit code, and are often used to provide call centre services.

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

[141] ENISA, 2014. Annual Incident Reports 2013. http://www.enisa.europa.eu/activities/Resilience-and-CIIP/Incidents-reporting/annual-reports/annual-incident-reports-2013/ [Accessed 28 October 2014]

7.43 Prolonged flooding can damage some types of underground cable, although many are actually designed to be submerged during normal operation. A more significant problem during temporary floods is that damaged cables cannot be repaired until flood water subsides. Occasionally, flooding can damage cable routes, for example due to ground movement and resultant duct damage.

7.44 Most fixed line exchanges were built many years ago, and although flood risk was taken into account at the time, flood patterns do change over time. Defences are strengthened and relocation of higher risk sites occurs. But exchanges need to be located near the population they serve and, as a result, some remain at direct risk from flooding.

7.45 In the mobile sector, extreme weather events and flooding invariably result in a higher than usual number of base station failures. The most common causes are power failure, the failure of microwave backhaul links, or infrastructure and equipment damage. Severe weather can also hamper safe access to mobile infrastructure and therefore prolong the duration of the incident.

7.46 Figure 92 below shows a remote mobile base station site where there was a long-running incident this year. Restoring the service took a long time because bad weather prevented engineers from reaching the site; they eventually needed a ski lift to gain access. Although this incident did not meet one of our numerical thresholds it is an example of reporting under the qualitative criteria.

Figure 92 - Example of a remote location which led to an extended incident

Source: An operator

7.47 Providers' incident response teams are prepared for mobilising in severe weather. When bad conditions are forecast they will often take preventative measures such as allocating additional engineers and increasing stocks of back-up fuel for emergency generators. During incident response activities, field engineers often need to draw on specialist training, all-weather kit and special vehicles to reach and repair damaged network assets in extremely challenging environments.

Figure 93 - An amphibious vehicle used by EE to access remote parts of the country

Source: EE

7.48 During the winter of 2013-14 an anticipated increase in the average incident duration was noted, but generally providers were well prepared for severe weather and succeeded in minimising the impact on consumers

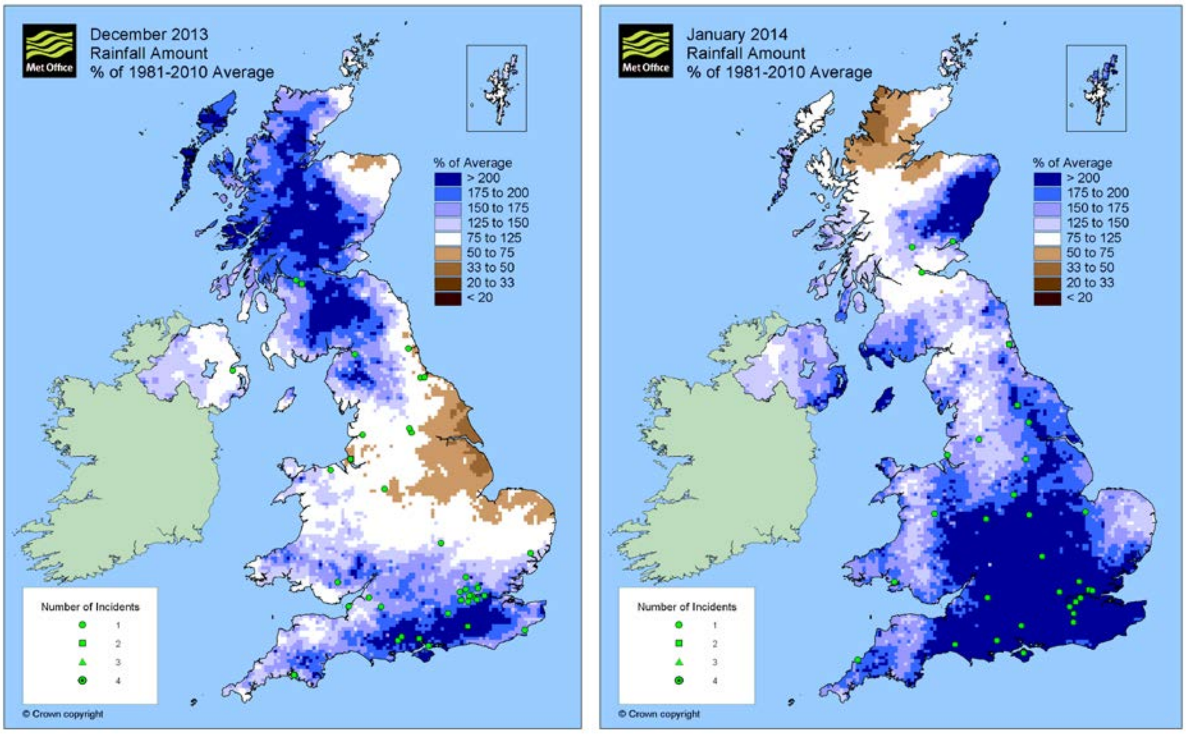
7.49 The preparations and responses of UK providers during the 2014 floods meant that severe weather was responsible for only five of the incidents reported to Ofcom in the reporting period. This represents less than 1% of the 566 incidents reported.

7.50 The winter of 2013-14 included the wettest December-January period since records began.[142] The charts below show that during that time, some parts of the UK received rainfall over 200% greater than the expected average.

7.51 However, the charts also show that there is no obvious correlation between the locations of incidents (plotted in green) and levels of rainfall.

[142] Met Office, 2014: A global perspective on the recent storms and floods in the UK. http://www.metoffice.gov.uk/research/news/2014/uk-storms-and-floods [Accessed 28 October 2014]

Figure 94 - Rainfall maps comparing rainfall levels and incident locations: December 2013 and January 2014

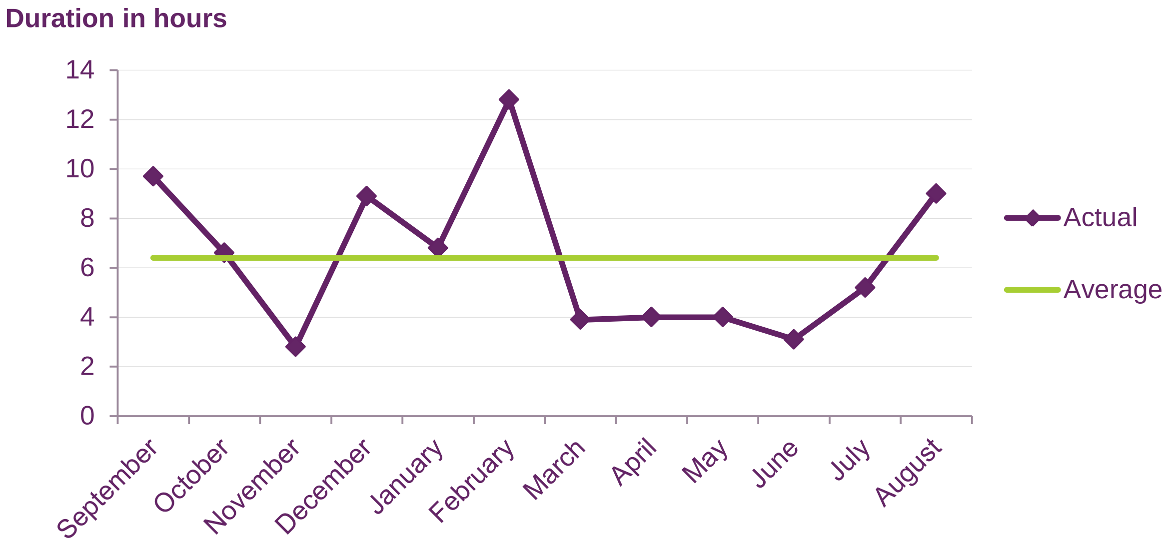


Source: Ofcom/Operators/Met Office

7.52 Figure 86 (on page 126) shows that the number of incidents reported in January was below the average for the period. This suggests an improved performance by providers during those weeks of severe weather. The maps also show that the location of incidents during the period does not deviate from the annual geographical distribution shown in Figure 88.

7.53 Furthermore, Figure 95 shows that the average duration of an incident for a given month increased during the winter months. This is consistent with our understanding of providers' incident response operations and the challenges their engineers face during severe weather.

Figure 95 - Average duration of incidents reported to Ofcom: September 2013 to August 2014



Source: Ofcom analysis of data provided by operators

7.54 Throughout the wettest December and January period on record, the UK's providers prevented a significant increase in the average number of incidents. We noted an (anticipated) increase in average incident duration, but in general providers demonstrated that they are well prepared for severe weather and for minimising the impact on consumers.

Ofcom engages with a wide range of organisations and industry bodies to ensure that the resilience of networks and services is constantly improving

7.55 The resilience of networks and services is largely linked to the level of focus and investment by providers.

7.56 Collective activity by groups of providers, government agencies and regulators can also help. Joint actions, such as information-sharing to protect against possible incidents, and co-ordinating resources to respond to actual ones, bring tangible benefits.

7.57 The Electronic Communications Resilience and Response Group (EC-RRG) continues to be the major instigator of these collective activities. Its members include most of the providers which have significant amounts of communications infrastructure, and they work together to improve the resilience of the sector as a whole. Recent areas of focus have included the potential impact of space weather events and fuel shortages. The group is responsible for the National Emergency Alert for Telecoms (NEAT) process for information and resource-sharing during major incidents affecting the sector.

7.58 During both the Commonwealth Games and the NATO summit in Wales this year, the group used a process for network status reporting that was developed during the Olympics. This enables providers to file daily reports of any issues affecting their networks or services during major events. It gives the event organisers a valuable snapshot of how the communications networks are performing, and keeps them informed about any problems even if these are not significant enough to trigger the use of NEAT.

7.59 Even when providers submit nil returns, as is often the case, this provides important reassurance and keeps lines of communications open.

7.60 Another example of the industry working together is NICC, the UK's technical interconnect standards group.[143] In May 2014 a new working group was formed with the objective of updating the ND1643 'minimum security standard'. Ofcom looks for certification against this standard as evidence that a provider is complying with its obligations to manage security risks arising from connecting with other networks. The working group aims to develop the standard further, to include more traditional circuit switched network technologies and to ensure that the standard is suitable for both large and small providers.

7.61 Ofcom contributes to both groups discussed above. We also work with other economic regulators to improve resilience across the UK's infrastructure sectors. Part of our work in the UK Regulators Network (UKRN[144]) is to lead a project looking at cross-sector resilience. Alongside our other duties, we are examining how the UKRN's members consider resilience, and are identifying opportunities to improve collaboration.

Case study: The impact of cyber-attacks on networks and consumers

The scale of cyber-attacks is growing but the impact on UK networks remains low.

7.62 Network and consumer equipment are vulnerable to cyber-attacks, when an attacker attempts to compromise networks and services by using malicious code, or by exploiting legitimate network functions. One such example is a distributed denial of service (DDoS) attack.

7.63 One common form of DDoS attack is to bombard a target network or server with traffic, leaving it with no spare computing or network capacity to carry out its normal function. In order to mount an attack, the attacker may control and exploit, *en masse*, malware-infected personal computers or vulnerable broadband routers. In this way, consumers' equipment may play a role in carrying out the attack without their knowledge. Due to the nature of these attacks, users may not suffer a complete loss of service, but they may experience significantly poorer internet access.

7.64 The impact of DDoS attacks can be hard to quantify. They may result in loss of service for a small number of targeted users, a degradation to services overall, or the failure of technologies on which the entire network is dependent, such as the domain name system (DNS) or authentication. We have received only a small number of incident reports of cyber-attacks. However, DDoS attacks are a growing threat, with providers reporting that it is becoming easier to launch attacks using simple to use and easily accessible tools.

[143] NICC, 2014. The home of network interoperability standards. http://www.niccstandards.org.uk/ [Accessed 28 October 2014]

[144] UKRN 2014. UK Regulators Network. http://www.ukrn.org.uk/ [Accessed 28 October 2014]

7.65 Attackers typically target larger organisations such as online businesses, web hosts, online storage and DNS servers. DDoS can also inadvertently occur during certain types of network failure.

7.66 Providers are also beginning to observe individual consumers being targeted. This can be for a variety of reasons, from competitive online gamers trying to seek an advantage to the exploitation of online casino games.

7.67 Attackers tend to exploit the properties of commonly used internet protocols, such as the user datagram protocol (UDP) or the transmission control protocol (TCP). They use these protocols to overload the target system's resources and, in many cases, the attackers remain untraced.

7.68 Organisations which monitor cyber-attacks, such as Arbor Networks and Prolexic, report that the number and scale of DDoS attacks on all types of target are growing. Arbor Networks reported that the number of attacks exceeding 20Gbit/s in the first half of 2014 was twice that detected in the whole of 2013.[145] In February, Cloudflare reported a large DDoS attack which peaked at 400Gbit/s.[146]

7.69 However, against this backdrop of increased attacks, providers have reported a very limited impact on residential consumers. They cite the low number of attacks, and sufficient spare capacity in their networks, as key reasons for this. The attacks that providers have observed have generally been the flooding attacks described above, or targeted attacks which exploit equipment or software vulnerabilities.

7.70 However, mindful of the evolving nature of DDoS attacks, most providers have introduced measures to protect their networks from this type of threat. They use automatic tools to manage and filter traffic at the edges of their network. These can be used to filter out known sources of attack and patterns of malicious traffic, or to control the volume of traffic that is allowed to enter their network. Additionally, there are specific preventative measures available to providers, often associated with understood attack vectors or known vulnerabilities.

7.71 The protection of networks and consumers against cyber-attack is a process of continuous development. Government-funded computer emergency response teams (CERTs) report daily on new vulnerabilities identified in commonly used software and systems. Attackers will continue exploiting communications networks to take advantage of these flaws.

Broadcast networks

Most networks used for broadcasting maintain high availability

7.72 Broadcast networks, such as the digital television (DTT) and the digital radio (DAB) networks, generally have high availability. All four DTT multiplex operators reported high availability of their services for 2013.[147] The two national DAB networks also reported availability above 99.9% between July 2013 and June 2014. Nevertheless,

[145] Arbor Networks, 2014. Worldwide Infrastructure Security Report: Volume IX

[146] Cloudflare, 2015, Technical Details Behind a 400Gbps NTP Amplification DDoS Attack, http://blog.cloudflare.com/technical-details-behind-a-400gbps-ntp-amplification-ddos-attack/ [Accessed 28 October 2014]

[147] DTT multiplex operators are required to provide an annual technical report to Ofcom summarising the availability of their transmitter sites. Data on DTT availability in this section are gathered from these reports and so reflect a different reporting period to the rest of the Infrastructure Report.

outages do occur and, like fixed and mobile networks, longer outages tend to be in rural areas where access to the transmitter is more difficult.

Broadcasters' responsibilities

7.73 Broadcasters are required to provide an annual summary of transmitter availability, in accordance with Ofcom's Television Technical Performance Code.[148] The Code sets out an availability target for each DTT transmitter site. The 80 main transmitter sites that provide coverage to 90% of households have an availability target of 99.8%. The public service broadcasting (PSB)[149] channels are transmitted from more than 1000 additional 'relay' sites and these have a target availability of 99.0%. Availability is reported to us on a site-by-site basis, and the vast majority of sites met or exceeded these targets in 2013.

7.74 Separate requirements under Sections 105A-D also apply to broadcast networks. However, the threshold we specify for significant incidents on broadcast networks is different to those for fixed and mobile networks.[150] The nature of our thresholds means that we receive few reports.

Outages on DTT networks are generally very short and affect only specific transmitter sites

7.75 Data from the DTT multiplex broadcasters show that most outages on transmitters are very short. Typically, they last for less than an hour, although there have been cases that took four to five days to resolve. One particularly lengthy example was the loss of television services in the Inner Hebrides and the Isle of Arran due to winter storms in March 2013.[151] The loss of power in the area meant that the transmitters were not functioning for between three to five days. The outages affected PSB-only relay transmitter sites, which generally serve small communities that are outside the reach of the larger main transmitters, and which carry only the PSB multiplexes. As the vast majority of relay transmitters pick up and re-broadcast signals from another transmitter, any outage at the 'parent' transmitter will cause a knock-on outage at its dependent relays.

7.76 Another type of incident is a failure at broadcasters' studios, playout centres or content aggregation sites. This can cause relatively widespread disruption because these centres provide video feeds to multiple transmitters and/or platforms. One such outage occurred on 1 December 2013 across a large part of the UK, temporarily affecting the distribution of ITV to viewers in Central and Northern England who were watching on standard definition Freeview, digital satellite or via cable on Virgin Media.[152] This was due to a loss of power at one of ITV's main playout centres,

[148] Television Technical Performance Code, http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/tech-guidance/tv_tech_platform_code.pdf Licensees are required to comply with this code, which contains the requirement to provide annual technical reports to Ofcom.

[149] There are five public service broadcasters in the UK which are guaranteed access to spectrum for broadcasting. These are carried on three PSB multiplexes, called PSB1, 2 and 3. PSB 1 and 3 are managed by the BBC and PSB2 is managed by Digital 3 and 4 (D3&4).

[150] The numerical threshold for a significant outage on broadcasting networks and services is an outage affecting at least 100,000 customers for at least 12 hours.

[151] STV 2013, Thousands of homes face night without power in wintry conditions http://news.stv.tv/scotland/218689-homes-in-arran-and-kintryre-facing-night-without-power-in-bad-weather/ [Accessed 30 October 2014]

[152] ITV News, 2013 ITV viewers see 'blank screens' http://www.itv.com/news/story/2013-12-01/itv-viewers-see-blank-screens-transmission-problems-x-factor/ [Accessed 10 September 2014]

caused by an electrical fault. Service was quickly restored to digital satellite viewers because a temporary reconfiguration of the signal distribution paths enabled content from another region to act as a substitute. However, viewers on standard definition Freeview were affected until power to the transmission centre was restored.

7.77 Like telecoms, broadcasting networks rely greatly on other sectors. For example, local power outages, particularly in smaller sites, can mean that service can only be restored once power has returned. There is also a reliance on incoming programme feeds to transmitter sites (telecoms circuits at larger transmitters). One outage of a programme feed caused a two-minute outage to almost 80 sites.

DAB networks also have high availability

7.78 The two providers of national digital radio (DAB) multiplexes, BBC and Arqiva, reported very high availability for their DAB networks, at above 99.9%.

7.79 However, adverse weather in December 2013 caused a number of significant outages. The BBC's DAB service in Guildford, Surrey, suffered a loss of service on 24 December for 17 hours when winter storms took out the electricity supply. In London, Arqiva reported losing its national DAB multiplex for over a day, beginning on 24 December, due to failures in the microwave radio distribution network between a number of sites in the area. There is no evidence of these incidents having a greater impact by occurring on Christmas Eve.

Extremely high demand for online content can lead to capacity problems

7.80 Consumers are increasingly turning to online services such as BBC iPlayer, ITV Player and Sky Go for live and on-demand content. Streaming live content can present some challenges for online distribution; the demand for extremely popular programmes at peak times may exceed the capacity available from content distribution servers. In the past year, there have been a number of high-profile examples when demand for shows exceeded expectations, and the user experience was degraded for some consumers. These included:

- the live stream of the opening match in this year's World Cup on ITV Player[153];
- a live stream of football on the final day of the Premiership season on SkyGo[154];
- the first episode of Game of Thrones on SkyGo[155]; and
- the live stream of the Scottish independence debate on STV Player. [156]

[153] Broadcast, 2014. ITV Player crashes during World Cup opener http://www.broadcastnow.co.uk/news/multiplatform/itv-player-crashes-during-world-cup-opener/5073146.article [Accessed 10 September 2014]

[154] Guardian, 2014. Sky Go and Now TV users complain after Premier League outage http://www.theguardian.com/media/2014/may/12/sky-go-now-tv-users-complain-premier-league-manchester-city-west-ham [Accessed 10 September 2014]

[155] Pocket-Lint, 2014, Games of Thrones success prompts Sky to simulcast 24: Live Another Day and Mad Men too http://www.pocket-lint.com/news/128338-game-of-thrones-success-prompts-sky-to-simulcast-24-live-another-day-and-mad-men-too [Accessed 10 September 2014]

[156] Independent, 2014 STV Player: Live stream of Scottish Independence debate fails, meaning viewers outside Scotland could not watch http://www.independent.co.uk/news/uk/scottish-independence/scottish-independence-stv-live-stream-of-debate-fails-meaning-potential-viewers-outside-scotland-cannot-watch-9650420.html [Accessed 10 September 2014]

7.81 The BBC suffered a lengthy outage on parts of its website in July, which affected its audio and video streaming services.[157] This was due to a number of faults occurring at the same time, which increased the load on its database that supports streaming services.

7.82 These examples show the importance of ensuring that there is sufficient capacity to serve peak demand. Using CDNs, which are covered in more detail in section 9, is one way to distribute content to ensure resilience. However, this only works for on-demand content which can be distributed to servers in advance.

7.83 Three of the four examples listed above related to the demand for live streaming. This is more challenging. However, there are solutions such as multicast, which can help ISPs manage the distribution of popular content. We explain this in more detail in section 9.

Improving the resilience of broadcasting networks

7.84 This year, for the first time, we have gathered information from all the main terrestrial multiplex, satellite, cable and IPTV[158] operators about their arrangements for maintaining and improving the availability of broadcast networks. All of the operators we contacted provided information on their resilience arrangements. They also told us about their processes for responding to an emergency and restoring normal operation.

7.85 In the following paragraphs, we report first on the arrangements of the terrestrial broadcasting networks, followed by the satellite, cable and IPTV operators.

Although DTT and most DAB broadcast networks rely on a single transmission service company, extensive procedures are in place for major incidents

7.86 The transmitter network infrastructure for the UK's DTT, and most DAB, broadcasters is owned and operated by Arqiva, a single integrated transmission service company. The broadcasters that use Arqiva's network identified its business continuity plans in their responses.

7.87 Extensive and generally robust procedures appear to be in place to deal with major incidents in Arqiva's network. [✂] DTT multiplex operators also have contractual agreements with Arqiva to ensure that network service levels meet the transmitter availability requirements set by Ofcom.

7.88 A number of specific architectural measures are also in place to ensure high levels of availability and resilience in broadcast networks. Most main transmitter sites (i.e. those serving relatively large populations) have at least two programme feed circuits. These use networks from separate providers and with diverse mains power feeds where these are available. The transmitter equipment chains at main sites are duplicated and operate in passive reserve configuration, meaning that the backup equipment chain is ready to take over if the main feed fails. In the event of an antenna fault, services are typically reconfigured automatically to operate from either another part of the antenna array, or from a reserve antenna.

[157] BBC, BBC Online outage on Saturday 19 July 2014
http://www.bbc.co.uk/blogs/internet/posts/BBC-Online-outage [Accessed 10 September 2014]
[158] Managed and live television services over broadband connections

7.89 Smaller TV transmitter sites, such as low-power 'relay' transmitters which tend to serve just a few hundred homes, do not usually have equipment or feed redundancy. They require an engineer to visit the site to repair equipment faults. [✂]

7.90 The BBC advised that its 'reference' DTT transmitting stations have two or three programme feeds with independent connectivity, to ensure that a fault on one feed would not affect the others. With the exception of those operating as part of a single frequency network[159], non-reference DTT transmitting stations use terrestrial re-broadcast for their programme feeds. These feeds are supplemented by other systems if they are unreliable, or are predicted to be so. The DTT network's resilience is tested as part of an ongoing programme. In addition, the core of the BBC's DAB transmission network (those sites serving the majority of the population) has multiple programme feeds with telecoms carrier independence.

7.91 [✂]

7.92 [✂]

7.93 [✂]

Cable, satellite and IPTV networks also have resilient network architecture

7.94 A large amount of TV content, including live content, is transmitted via satellite, cable and on fixed broadband networks. The resilience of these networks is maintained primarily through the 'mirroring' of key sites. If the primary sites fail, backup sites can take over to enable the network to maintain the service.

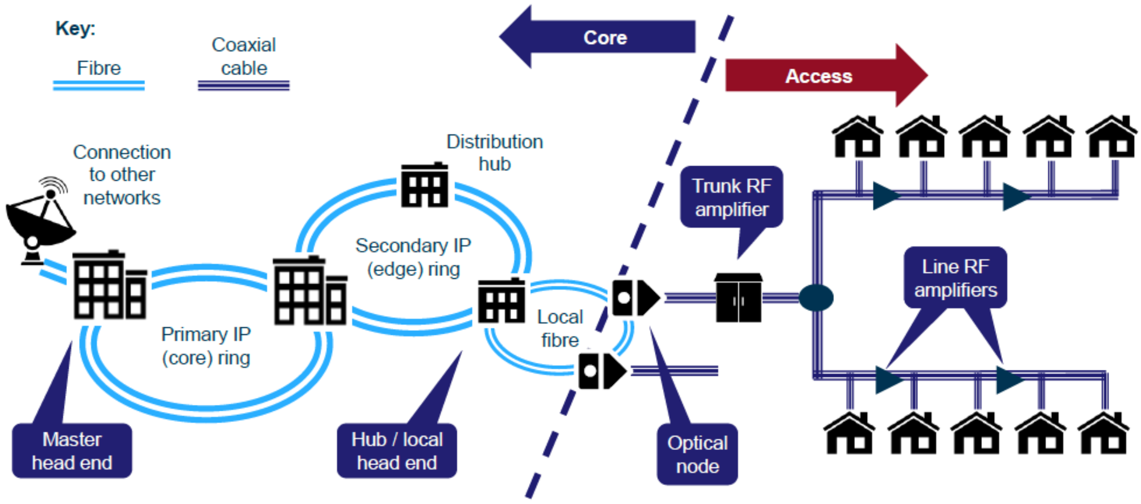
7.95 These network operators also use a number of other measures to improve the resilience of their networks. These include:

- diverse routing of data via separate physical paths;
- improving the physical security of sites by locating critical network equipment in areas with controlled access;
- controlling remote access to the equipment through logical security policies; and
- having processes in place to maintain business continuity, conduct incident response and implement disaster recovery.

7.96 A small number of key broadcast sites support the distribution of linear content on the cable, satellite and IPTV networks. All of the network operators reported arrangements to maintain a backup site in a geographically different location. If broadcast content from the primary site is interrupted, service can be maintained from the backup site. In some cases, there may be a short interruption in the service as the network is manually reconfigured. These sites also employ dual routes on geographically diverse paths, meaning that if there is a single cable break, traffic can be rerouted to an alternative cable.

[159] A single frequency network is a transmitter configuration used at a small number of DTT sites which allows neighbouring transmitters to use the same transmission frequencies in order to enhance coverage without consuming additional spectrum. Precise timing synchronisation has to be maintained between transmitters operating in SFN mode, and special programme feed arrangements are also required. All DAB networks use SFN techniques.

Figure 96 - Overview of a typical cable network

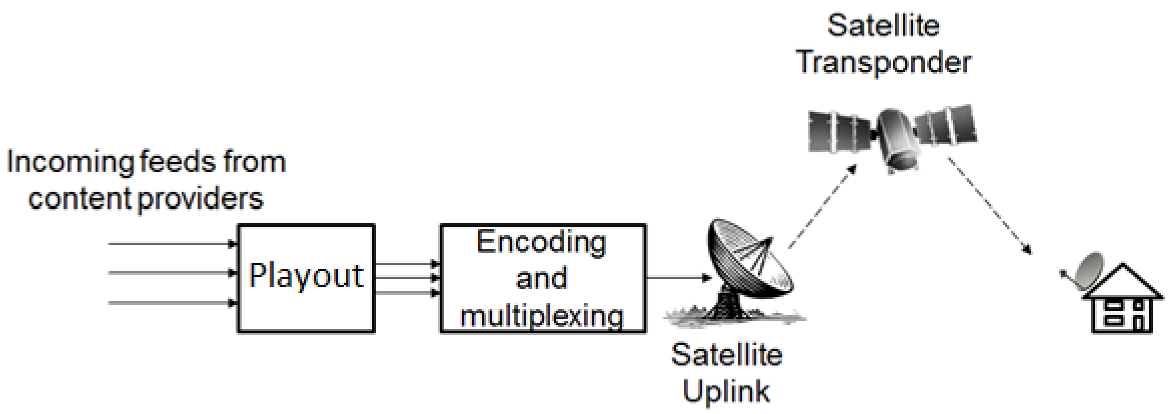


Source: Analysys Mason

7.97 Figure 96 shows the key components of a cable network. Live television content is aggregated at the master head end, where additional local content is injected. [✂]

7.98 Figure 97 sets out the key elements of the distribution of broadcast content for a typical satellite broadcaster. Satellite broadcasting requires the transmission of broadcast content to a satellite transponder via a satellite uplink. The consumer receives the content via a signal from the satellite transponder.

Figure 97 – Overview of typical satellite broadcast network



Source: Ofcom

7.99 [✂]

7.100 [✂]

7.101 BT and TalkTalk provide live content to their customers via their broadband network. Incoming content from television channels are dual-delivered to the data centres, via independent and resilient paths. [✂]

BT's media and broadcast network

7.102 [✂]

Arrangements for on-demand content

7.103 Unlike live programmes, on-demand content can be cached in a diverse range of servers.

7.104 This practice is mainly to reduce the costs of data carriage and to improve the customer experience, as explained in section 9. However, this also makes the distribution of content more resilient because the same content is available from a number of CDNs.

7.105 Because multiple copies of the same content are saved on different servers, a single server can fail without any impact on consumers.

Section 8

Convergence and seamless connectivity

Overview

8.1 Convergence is the growing phenomenon whereby a range of content types (audio, video, text, pictures) and services are distributed over different digital networks (fixed broadband, mobile, satellite, cable, digital terrestrial) to a variety of consumer devices (PCs, tablets, TVs and mobiles).

8.2 In a convergent world, a mobile handset can receive voice calls, data, pictures, audio, video and text, all delivered over a mobile network. Similarly, television and video content is accessed using satellite, cable and digital terrestrial TV, or indeed via a fixed broadband connection or mobile network.

8.3 Convergence has been changing the communications landscape for some years and is continuing apace. Some examples are obvious, such as the increasing use of internet-based TV services. Others are less obvious, particularly where they involve convergence between networks, but their implications for consumers are considerable; it is becoming increasingly possible to have seamless and ubiquitous access to communications services – a world of 'anything, anytime, anywhere'.

8.4 Consequently, convergence is making new types of communications network available to consumers, as well as creating wider coverage and more capacity. In this chapter we outline some of the ways this is happening, and cover:

- **Different types of convergence** and their implications for infrastructure. Increasingly, consumers are using different types of network and service interchangeably. In response, operators and service providers are having to ensure they can provide their services across multiple networks to multiple devices.

- **Fixed/mobile convergence,** which is leading to the continuing and seemingly inexorable decline in use of fixed voice services, as consumers use newer forms of communication such as voice over internet protocol (VoIP) and instant messaging (IM) instead.

- **Broadcast TV convergence**. Although the vast majority of viewing is broadcast TV, an increasing share is being consumed over the internet. (This is explored in detail in section 6).

- **Seamless connectivity**: how this is benefiting consumers and making new services possible, particularly as more devices link to each other using the 'internet of things'.

8.5 Our overall conclusion is that the divisions between different types of communications network, service and device are likely to continue to break down. Consumers will continue to benefit from new services, particularly over the internet, as the communications infrastructure develops. But these new developments also underline the benefits of wider coverage of fixed and mobile networks.

Network implications of convergence

Types of convergence

8.6 Convergence can take many forms. We tend to use the term in a number of distinct senses:

- **Device convergence**, where one device can be used for more than one type of service. For example, your mobile can give you access to the internet, TV and radio as well as telephony.
- **Service convergence,** where services that were once entirely separate become increasingly interchangeable in consumers' minds[160] and behaviour. Consider, for example, how consumers increasingly see fixed and mobile voice telephony as essentially the same type of service.
- **Network convergence,** which is happening as transmission and distribution are being used to transmit more than one type of service, such as TV platforms that also broadcast radio.

8.7 All these aspects of convergence – between traditional devices, services and networks – began with the introduction of digital technologies in the 1990s. They then accelerated hugely once the internet became a mass-market tool, and were given a further boost when multi-use devices such as smartphones and tablets emerged. More than anything, therefore, it is internet-based consumption which is driving the greatest challenge to existing business models and presenting new demands on infrastructure.

Implications for operators

8.8 The extent to which operators will have to evolve their infrastructure will depend on how consumers change their behaviour over time.

8.9 If consumers' use of communications services evolves slowly, perhaps because the innovations lack appeal or are too expensive, the fact that new services are available will not in itself lead to enduring changes in infrastructure.

8.10 3D TV is a case in point. A few years ago, TV platform operators, broadcasters and manufacturers experimented with offering 3D channels to consumers, and there were suggestions that more network capacity would be needed to accommodate them. Although some viewers continue to use, and value, these channels (particularly for sport), they have failed to become a mass-market proposition. Indeed, the BBC ended 3D broadcasts in 2013. With this in mind, current innovations such as ultra HD (UHD) broadcast content are appearing, but there is no guarantee that they will succeed.

8.11 For operators, meanwhile, convergence means continuous upgrades in infrastructure, such as adding bandwidth and adopting new technologies. It also means having to think about how to compete across a broader landscape, and consider offering services in multiple forms. Operators may be competing with new entrants such as 'over the top' (OTT) players (delivering a service over the general internet) who may not have their cost structure, or who can offer consumers the kind

[160] The underlying economic market, however, may not change for regulatory purposes

of flexibility – on-demand, anything, anywhere use – that traditional platforms find more difficult.

8.12 Below, we consider in more detail two main areas where operators are having to respond to convergence: the move from fixed to mobile telephony, and the growing use of internet services as a supplement, or even a replacement, for TV.

Fixed-mobile convergence

Fixed telephony is available to almost everyone

8.13 In the past, fixed telephony was the main route for phone calls. Because of the universal service obligation (USO)[161], coverage of fixed telephony is near-ubiquitous, and customer orders for new telephone lines are only declined when they are beyond a reasonable cost to provide.[162]

Take-up of fixed connections is now being driven by demand for broadband, rather than voice services

8.14 The total number of fixed residential and business connections has stayed approximately the same for the last three years, although there has been some growth in the number of residential fixed lines; from 23.9 million in 2011 to 25.0 million in 2013.

8.15 However, the main driver of residential fixed-line growth seems to be the customers wanting a broadband connection, rather than a fixed voice line. In fact, around 5% of UK homes have a fixed line but don't use it for voice services, while around 11% of households say they prefer mobile access exclusively for both voice and internet services.[163]

Figure 98 - Fixed telephone line summary

	2013	2012	2011
Fixed lines, including ISDN (millions)	33.4	33.2	33.3
Fixed lines, residential only (millions)	25.0	24.4	23.9
Fixed voice call minutes (billions)	91.6	102.5	111.1

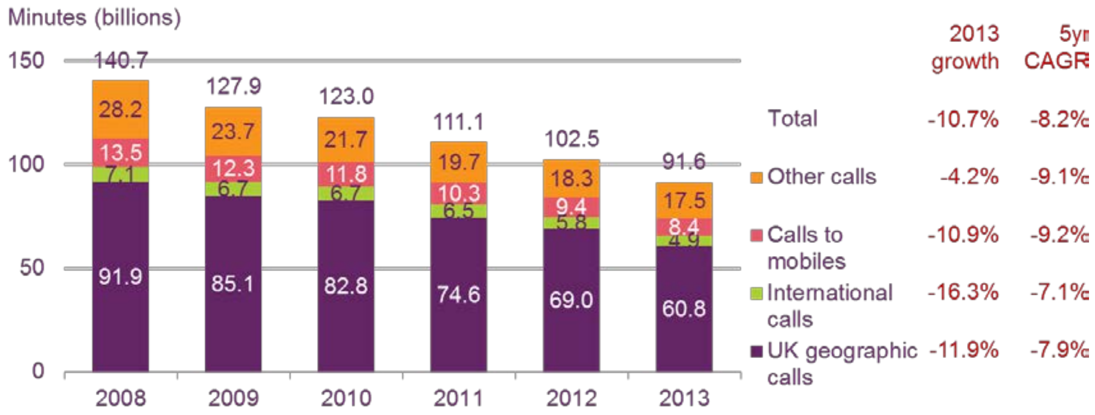
Source: Ofcom, Communications Market Report 2014

[161] As set out in the Universal Service Notification, 2003. See: http://stakeholders.ofcom.org.uk/telecoms/ga-scheme/specific-conditions-entitlement/universal-service-obligation/designation-of-bt-and-kingston
[162] Between January and June 2014, 164 orders were placed with BT for new telephone lines that would exceed the reasonable cost limit. Of these, 119 were cancelled by the user during the process, 31 are still in progress and 14 were completed. These were provided mainly to rural customers, but there were some instances of orders from urban customers building a second property on an existing site.
[163] Ofcom, *Communications Market Report 2014*

Use of fixed voice continues to decline

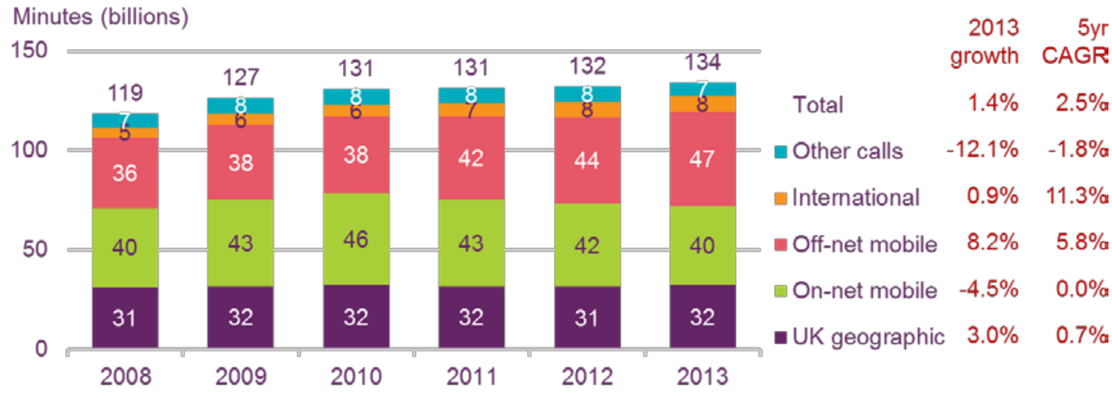
8.16 Consumer-led convergence is developing rapidly in voice telephony. The charts below show that fixed call volumes fell by over 10 billion minutes between 2012 and 2013, yet outgoing mobile call minutes only rose by 2 billion minutes over the same period. Nor are voice calls being replaced by SMS (texts); these are also falling.

Figure 99 - Fixed voice call volumes, by type of call



Source: Ofcom Communications Market Report 2014

Figure 100 - Outgoing mobile call minutes, by type of call



Source: Ofcom Communications Market Report 2014

8.17 Consumers are increasingly replacing fixed voice calls with other forms of communication such as VoIP, IM or social networking. Calls via OTT VoIP service providers can usually be made free of charge or by payment for the data used. Information from KCOM[164] suggests that whereas a third of its total calls were VoIP calls in early 2012, this has now risen to almost half.

New technologies are set to accelerate fixed-mobile convergence

8.18 Historically, operators have tried to offer services that combine the cost benefits of fixed voice with the flexibility of mobile. For example, handsets were introduced that used fixed networks within the home and mobile networks outside it, while retaining a single device and telephone number.[165] This wasn't sufficiently popular; the handsets

[164] KCOM provided information about the use of VoIP by customers across its broadband network. This is compared to information provided about the total minutes of calls across its fixed network.
[165] e.g. BT Fusion, discontinued in 2009.

weren't seen as attractive and there were reliability issues. However, this is now changing and a range of developments make it increasingly likely that fixed-mobile convergence will proceed further. These include:

- **Growing use of VoIP**. Figure 101, below, shows that there has been steady growth in the use of VoIP on mobile handsets. In most cases these come as OTT services provided as an app on a smartphone, such as Skype or Apple's FaceTime. Typically, the consumer needs a new user-ID specific to that service, but both fixed and mobile operators are now offering VoIP apps linked to a consumer's existing fixed or mobile telephone number. With the rising popularity of VoIP services, it's likely that other major operators will enter this space, potentially with features that OTT providers can't offer, such as quality of service guarantees. BT's One Voice (aimed at corporate users) is an example, and we expect others in the near future.

Figure 101 - Use of VoIP services

Source: Ofcom Communications Market Report

- **Wi-Fi calling**. Most VoIP services require consumers to use a specific app. This makes it clear to the user that VoIP calls are different from traditional voice calls. However, EE is planning to launch a Wi-Fi calling service later this year enabling calls to be made over a Wi-Fi connection without an app.[166] The latest Apple iPhone also has Wi-Fi call functionality; users can make calls in exactly the same way as they would over the mobile network.[167] These are both examples of service convergence, showing how users may not be aware of the network used for their calls.

- **Voice over LTE**. At the moment, 4G or LTE mobiles use 3G or 2G networks for voice services, but mobile operators are likely to launch voice over LTE (VoLTE) services in the next year. Here, voice calls will be converted into data packets to be carried over the IP LTE network.

8.19 Ofcom commissioned research into the possible evolution of both fixed and mobile voice networks.[168] This found that convergence between fixed and mobile services can significantly cut operators' costs as services migrate away from legacy networks. In addition, converged mobile services will depend more strongly on fixed networks

[166] http://ee.co.uk/ee-and-me/network/wifi-calling
[167] https://www.apple.com/iphone-6/connectivity/
[168] Analysys Mason report: *Roadmaps for the transition to new fixed and mobile voice technologies.* Available at http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/new-tech.pdf

to allow improved coverage and capacity. For this reason, the ability of networks to support voice and data, from both fixed and mobile devices and handsets using IP-based technology[169], is likely to become increasingly important over time.

Broadcast TV convergence

8.20 The degree of convergence in broadcast TV has been more limited to date, but it is growing. As we describe in section 6, broadcast TV viewing has remained steady and is being supplemented – rather than replaced – by viewing using IPTV, or via other devices such as mobiles and tablets.

8.21 However, largely unnoticed by consumers, some convergence is taking place in TV streaming. Historically, broadcast TV was delivered to, and consumed on, television sets at home, usually in a linear fashion (i.e. watched live, as broadcast). However, the growing use of broadband over the past decade has meant that tablets, smart TVs and computers are now commonly used for viewing catch-up content (such as the BBC iPlayer). Fixed broadband and content providers have introduced caches to store this content closer to the customer, both to reduce the load on the rest of the network and to improve the consumer experience of streaming video. We examine these techniques for internet interconnection in more detail in section 9.

8.22 Increasingly, consumers are also watching live IPTV content through services such as Now TV and YouView. Unlike catch-up programming, this content cannot be cached in advanced, so operators have to find a different way to manage the demand these services place on the network. Some fixed operators, such as BT and TalkTalk, are using an approach called ‘multicast’ for their IPTV services (see section 6). This is a more efficient use of network capacity: it allows the same content to be streamed to multiple users with minimal bandwidth provision (i.e. on a one-to-many basis). Multicasting also reduces the amount of duplicated traffic that needs to be carried to a local node, and providers have greater control, since content is not being delivered over the general internet. This enables a broadcast-quality service for consumers.

8.23 Because IPTV-delivered channels are listed alongside those on DTT, YouView consumers do not differentiate between programmes delivered through broadcast and broadband. As services such as YouView become more popular, it is likely that watching linear content on IP networks will continue to grow, provided the quality of the video stream can be maintained by operators.

Seamless connectivity

Wireless networks allow consumers to access anything, anytime, anywhere

8.24 As mentioned above, a major driver of convergence is the growing use of smartphones.

8.25 Consumers have become used to being able to access the internet wherever they are. As discussed in section 5, mobile data use continues to grow rapidly as consumers increasingly use their smartphones for data-hungry activities such as watching online video. In turn, providers of communications services are increasingly tailoring their services for mobile users and relying on mobile for revenues. Indeed,

[169] In the literature this is referred to as an IP-enabled multimedia subsystem (IMS)

two-thirds of Facebook's advertising revenue comes from mobile, which also accounts for 40% of YouTube viewing.

8.26 The fact that many consumers rely on having access to the internet anywhere underlines the importance of ensuring that mobile is available near-universally. It's also one of the reasons why Ofcom has included licence conditions in O2's licence requiring it to provide indoor 4G coverage to at least 98% of the population by the end of 2017.[170] The growing number of Wi-Fi hotpots also play an important role in ensuring consumers can access communications services on the move.

Consumers can move increasingly seamlessly between networks

8.27 Consumers are already using fixed and mobile networks interchangeably, with 'Wi-Fi offloading' the most obvious example: consumers use Wi-Fi hotspots when it is cheaper and/or more reliable.

8.28 New technology will make interaction between networks seamless, by improving the ways in which devices can migrate from one network to another. One example is 'soft SIMs'. Unlike traditional SIM cards, which have limited ability to connect to different networks, soft SIMs rely on software that allows consumers to move much more easily between mobile networks, wherever there is coverage. Apple has incorporated a soft SIM into its latest iPad Air.

8.29 Improved connectivity could also come through self-optimising networks (SON) that use technologies such as Passpoint 2.0. These allow the seamless authentication of devices across mobile networks, and automatic integration of Wi-Fi access points, allowing consumers to move onto, and between, Wi-Fi networks without logging on separately each time.

8.30 The architecture of mobile networks is also evolving. Although they will continue to rely on a core backbone of large macrocell transmitters and receivers, this architecture is being increasingly supplemented by a variety of other networks, including femtocells, Wi-Fi and small cells. Small cells already improve mobile coverage at low cost in indoor locations (e.g. shopping centres), and localised not-spots, and are likely to be deployed more extensively.

8.31 Future technologies such as soft SIMs in handsets will allow deeper integration between alternative small-cell networks, and facilitate switching between fixed and mobile networks. In turn, there are likely to be new forms of mobile network provision and changes in consumer propositions over time.

[170] http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

Section 9

Internet networks

Overview

9.1 Earlier sections of this document have focused on the access networks that communication providers (CPs) use to provide connections to customers, either as the direct physical line to the home via fibre or copper for fixed networks, or the radio coverage from masts for mobile networks. These connections are used to provide access to the internet and the vast range of internet services.

9.2 This chapter considers three topics associated with internet networks and connectivity: internet service providers' (ISPs') management of data use by consumers, ISPs' interconnection arrangements and IP addressing.

9.3 ISPs use various approaches to manage data use on their networks. They can apply caps to limit the amount of data a customer can use, or apply traffic management to limit customers' speeds or the applications they can use. We have found that:

- Managing consumers' data use plays an important role in increasing the efficiency of network capacity management.
- There has been increased pressure on ISPs to be as transparent as possible about their management practices. Broadly speaking, ISPs have simplified their packages and improved the information they provide to their customers, thereby improving transparency.
- All major UK fixed and mobile internet access providers have now signed up to the Broadband Stakeholder Group's Open Internet Code of Practice[171] and are committed to an effective self-regulatory model, a key part of Government policy on Net Neutrality.

9.4 In order to allow their subscribers to access internet content, ISPs must interconnect with other network operators. Increasingly, ISPs are also making such internet interconnection arrangements with the content delivery networks (CDNs) and individual content providers which are the source of significant volumes of the data traffic which subscribers consume. We have found that:

- Internet service providers are using a variety of different interconnection arrangements to manage the demand for content from their customers.
- There has been a significant shift of data traffic to content delivery networks and peering interconnections, on both fixed and mobile networks. The proportion of traffic provided by the top four interconnection partners (Google, Netflix, Akamai and Limelight) has also increased.
- The majority of peering traffic is still exchanged at locations in London, but this varies by the type of connection. For example, CDN traffic is distributed across the country more widely than peering and transit traffic.

[171] http://www.broadbanduk.org/2012/07/25/isps-launch-open-internet-code-of-practice/

9.5 Some ISPs' approaches to managing use and interconnection arrangements may impact on net neutrality. While some approaches are beneficial to the user experience, and contribute to efficient use of the network, inappropriate use of these tools can have a negative impact on consumers.

9.6 We also report on the use of IPv4 and IPv6[172] addresses. The internet relies on these addresses to route data across the globe, but IPv4 addresses are running out. There are a number of options for continuing to meet the demand for IP addresses:

- Trading and transfer of IPv4 addresses. Organisations with surplus IPv4 addresses can transfer their addresses to those who need them.

- Using the technique 'network address translation' (NAT) to share a single IP address between multiple users, so that the remaining allocation of addresses is used more efficiently.

- Introducing a new IP address system, IPv6, which uses a much larger address space to ensure that there will be enough addresses to meet the demand.

9.7 ISPs estimate that they will run out of IPv4 addresses in the next two to five years. Many are thinking of deploying IPv6, and some are also using techniques such as carrier-grade NAT, to use their remaining IPv4 addresses more efficiently.

Managing data use within ISP networks

Introduction

9.8 The growth of the internet has created an opportunity and a major challenge for network operators: they must consider how they will cope with the huge growth in data traffic. Networks must have the capacity to accommodate overall data volumes as well as peak instantaneous demand. Operators typically do this by:

- **Investing in new capacity** in their own networks and in their upstream links to service providers. Dedicated upstream links to particularly popular content enable operators to deliver a consistently high quality experience to consumers accessing this popular content.

- **Strategically managing existing capacity**, particularly during peak load conditions. ISPs have a number of ways to manage existing capacity over their networks.

9.9 The three main approaches to managing customers' use are:

- **Usage caps or data caps**: the user is limited to a certain amount of data consumption, for instance 10GB per month;

- **Traffic management (speeds)**: ISPs may impose speed limits on services and applications that place the most demands on the network and/or they may prioritise the types of traffic that are most affected by traffic congestion; for instance, real-time online services such as voice over IP (VoIP) and video streaming. Some ISPs may also limit the speeds of uploaded or downloaded data at peak hours. Even in the absence of data caps, such restrictions may

[172] The current, most widely deployed, version of internet addresses is IPv4. IPv6 is designed to be the successor to IPv4, with a much larger address space.

have the unintended consequence of reducing the amount of data uploaded and downloaded during those times; and

- **Traffic management (application and service restrictions)**: ISPs may manage use by restricting users from connecting devices, such as their smartphones to their laptops to share the internet connection (‘tethering’). ISPs may also restrict or block access to specific applications that place heavy demands on the network, such as video streaming or peer-to-peer file sharing.

9.10 ISPs may use these different approaches individually or in combination.

9.11 Managing consumers’ data use can play an important role in increasing the efficiency with which network capacity is managed. The various approaches to managing use are generally deployed to deliver a consistent and satisfactory experience for all users. Managing use is often intended to ensure that users pay for the demand they place on the network (e.g. mobile packages, where customers pay for the data they use). In these cases, lighter users pay less for their use and are not penalised for the heavy consumption of other users. Charging consumers according to their use also reduces the need for high minimum service charges, and enables affordable access to the internet for a wide range of users. Traffic management practices can also be used to protect safety-critical traffic, such as calls to the emergency services.

9.12 However, there may be other motivations behind some traffic management practices. In particular, it is possible that access providers might prioritise their own online services, or those supplied by a favoured partner, over equivalent services provided by others. The widespread adoption of such practices could damage online innovation and competition.

9.13 More generally, we think it is critical that network operators ensure that there is adequate capacity on their networks available for ‘best-efforts’ internet access, under which they aim to convey all traffic on more or less equal terms. If online service providers cannot rely on ‘best-efforts’ delivery being of adequate quality, this could diminish the level of innovation that has been fostered by the “open internet”. We would be concerned if network operators managed traffic and services to a degree that left insufficient network capacity for best-efforts traffic.

Approaches to managing data use

9.14 Operators have a number of approaches of managing use.

<u>Fixed broadband usage caps</u>

9.15 Usage caps are a traffic management tool used by network operators to limit data use. They are often used to design packages that fit consumers’ varying data needs.

9.16 Usage caps can be imposed in various ways. A typical cap will limit users to a certain amount of data per month. In other models, operators limit the amount of data use during specific times of the day (e.g. at peak periods).

9.17 Depending on the package and provider, broadband data caps can range from 2GB to 750GB of data per month. All the fixed broadband operators[173] now also offer at least one package with no data caps, while some providers exclusively offer

[173] BT, Virgin, TalkTalk, Sky, EE, KCOM and PlusNet all offer one or more unlimited fixed broadband packages among their broadband product choices.

'unlimited' broadband packages. Unlimited packages are popular: approximately 80% of fixed broadband customers are subscribed to uncapped packages.

9.18 Exceeding a fixed broadband data cap can affect a consumer in a number of ways, such as additional data charges or a temporary reduction in access speed.

Mobile usage caps

9.19 Most mobile operators impose data caps on some of their packages. Many have offered unlimited data packages in the past, notably Three and Giffgaff, although Three announced this year that it would introduce caps, limiting the amount of data that customers can access via tethering[174], even if their package includes 'unlimited' data.[175] Giffgaff announced that it would remove the 'unlimited internet' component from two of its top pre-pay monthly plans.[176]

9.20 The consequences of exceeding a mobile data cap are often similar to exceeding fixed broadband data caps. However, meeting a pre-pay tariff's data cap will generally result in a simple suspension of data services until more credit is added.

9.21 Network operators may allow their subscribers to access 'zero-rated' applications or services (also described as 'sponsored data services'). A subscriber's use of a zero-rated service will not count towards the data cap on their internet data package: for example, in Germany T-Mobile offers packages on which use of the music streaming service Spotify does not count towards the data cap. Although the data traffic of Spotify and competing music services may not be managed differently on the network, the traffic is treated differently in economic terms as the Spotify traffic does not count towards the customer's paid-for data allowance. In some circumstances, this may raise net neutrality concerns.

Traffic management: speed restrictions

9.22 Traffic management is used by operators to control the speed of data transfer for certain applications or services in order to manage network capacity use. It is most often used where congestion occurs - at particularly busy times, or busy parts of the network. This can mean giving priority to services that are time-sensitive (like VoIP) and de-prioritising and/or actively slowing down services that are less time-dependent, such as peer-to-peer (P2P) traffic.

9.23 The type of traffic management employed varies across ISPs. Many ISPs do not apply traffic management and may advertise their service as 'truly unlimited', both in terms of data use and throttling of certain services (i.e. reducing data speeds for certain services).[177] Others apply traffic management in some form, sometimes to different degrees across different broadband packages. In some packages, particular types of traffic are given greater priority, and consumers who particularly value a type of service can choose packages that prioritise such traffic.

[174] Tethering refers to connecting a device, such as a mobile phone, to another device (e.g. tablet or laptop) in order to use the first device's internet connection.

[175] http://thenextweb.com/uk/2014/03/18/uk-operator-three-will-limit-data-tethering-2gb-new-customers-even-plan-unlimited/

[176] http://www.ispreview.co.uk/index.php/2014/09/giffgaff-uk-scraps-cheaper-unlimited-mobile-broadband-data-plans.html

[177] Although network congestion may still mean that performance for customers can degrade, particularly during peak load periods.

9.24 A common form of traffic management is to place restrictions on P2P[178] services such as BitTorrent. This is because the design of some P2P software increases data use across a network to fill the available capacity. This can degrade performance for other applications or users sharing the same capacity. Furthermore, P2P downloads are not typically as time-dependent as other applications (such as music or video streaming, gaming and VoIP). In controlling P2P traffic, ISPs and operators can keep network infrastructure costs down without adversely affecting the typical user experience. However, the impact of traffic management on users of P2P services can be significant. In some cases speeds of P2P traffic can be reduced to a fraction of the speed of other traffic on the network.

Traffic management: application and service restrictions

9.25 ISPs and MNOs may also place restrictions on the types of applications and services that users can access. Rather than altering the speeds of certain applications and services in order to manage network capacity, this approach to traffic management completely blocks services, or entire classes of services, from a specific content or service provider. According to the Body of European Regulators of Electronic Communications (BEREC), the most frequently-reported restrictions are the blocking of P2P traffic on both fixed and mobile networks, as well as the blocking of VoIP traffic on mobile networks.[179]

9.26 However, this type of restriction does not necessarily limit demand or enable fairer network management.[180] Restricting access to services such as VoIP on mobile networks appears to consumers to be commercially-driven: its objective is to incentivise consumers to use the network operator's own voice service.

9.27 MNOs in particular have been known to impose restrictions on the use of VoIP. For example, in the past, Vodafone UK customers were able to use VoIP services only on the more expensive packages. However, traffic management policies and usage restrictions are evolving over time in response to changing customer behaviour and competition in the marketplace. VoIP and video-calling applications such as Viber, Google Hangouts, Skype and Facetime are becoming increasingly popular among consumers.[181]

9.28 UK MNOs now have stopped offering packages with VoIP blocks; Vodafone[182] and EE are now signatories to the Open Internet Code of Practice.[183] Virgin Media has also joined the Code, so all major fixed ISPs are also covered. We welcome these positive developments in transparency.

9.29 As discussed in the section below, it is crucial that consumers are provided with clear information on each operator's specific policies, so that they can reasonably compare the options available to them.

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[178] Peer-to-peer is a distributed application that uses end users' computers as nodes to deliver service applications.
[179] http://ec.europa.eu/digital-agenda/en/line-public-consultation-specific-aspects-transparency-traffic-management-and-switching-open
[180] Providers have sometimes argued that the high levels of data traffic generated by VoIP are difficult to manage. However, this type of restriction does not necessarily limit demand on the network, since VoIP calls do not necessarily consume a lot of bandwidth
[181] *Communications Market Report*, Ofcom, August 2014
[182] Vodafone has abandoned VoIP restrictions, but it continues to block VoIP on relevant legacy contracts that pre-date July 2014.
[183] http://www.broadbanduk.org/wp-content/uploads/2012/07/BSG-Open-Internet-Code-of-Practice-amended-October-2014.pdf

Transparency

9.30 In the past few years, there has been increased pressure on mobile and fixed operators to be transparent about the ways in which they manage consumers' data use.

9.31 ISPs are subject to an obligation[184] to be open with consumers about their traffic management practices. Under the auspices of the Broadband Stakeholder Group (BSG), and with Ofcom and Government support and encouragement, the ISPs published the *Voluntary Industry Code of Practice on Traffic Management* in 2011.[185] [186] Signatories to the Code publish the details of their traffic management practices. Each ISP must:

- Provide the necessary information to consumers about what traffic management takes place, why and with what impact;
- Provide customers with clear, easy-to-understand information on traffic management so that they can better compare broadband packages; and
- Publish a common Key Facts Indicator (KFI) table, summarising the traffic management policy for each package on offer. These tables have been available on signatories' websites since July 2011.

9.32 In 2013, Ofcom[187] investigated whether consumer information on traffic management was sufficiently clear to consumers, resulting in the publication of its *Consumer Guide to Traffic Management.*[188] The guide was developed following consumer research[189] to understand how consumers are buying and using fixed broadband services, and their knowledge of traffic management policies.

9.33 The research identified a number of ways in which the quality of traffic management information could be improved. Broadly, consumers participating in the research suggested that ISPs should communicate their traffic management policies in clearer and simpler language, use specific measurement criteria when 'fair usage' policies are applied, and explain succinctly how these policies affect their range of products.

9.34 Following the publication of this research in 2013, and in line with its commitments, the BSG worked with ISP signatories to change the ways in which ISPs present traffic management information to their customers. They now provide introductory information explaining their policies, and the impact of the policies on their services, and have updated their KFIs to include glossaries of technical terms.

9.35 We have reviewed the KFIs, and asked communications providers to confirm that they adhere to them. Our conclusion is that, broadly, transparency about traffic management practices has improved, and in general traffic management policies are less restrictive than previously. In particular, MNOs have dropped specific service blocks on mainstream packages.

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[184] General Condition 9.2e.
[185] 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
[186] As at May 2013, in addition to the founding signatories of the code (Sky, BT, O2, TalkTalk, Three, Virgin Media and Vodafone), the following ISPs have signed up to the code since its launch in March 2011: EE, Giffgaff, KCOM, PlusNet, and Tesco Mobile.
[187] In collaboration with the BSG and the ISPs
[188] http://consumers.ofcom.org.uk/internet/internet-traffic-management/
[189] http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/traffic/

Usage cap transparency

9.36 Transparency surrounding usage caps and 'fair-use' policies has been the subject of particular scrutiny. In the past, some ISPs advertised fixed and mobile broadband services as 'unlimited' when these services were in fact subject to a fair-use policy; in effect, a usage cap. Some consumers were being misled by the term 'unlimited', and many consumers signing up to such packages were not aware of the fair use policies.

9.37 Guidance introduced by the Advertising Standards Authority (ASA) in 2011[190] addressed this problem. The guidance says that fixed and mobile broadband services should only be advertised as 'unlimited' when there are genuinely no restrictions on the amount of data that can be used.[191]

9.38 Since the introduction of the guidance, the ASA has taken action against various broadband providers due to their usage cap advertising. For example, in 2013 the ASA banned Virgin Media from claiming: "Unlimited downloads. Download and browse as much as you like with no caps and no hidden charges", because there were restrictions in place that affected some customers' ability to download data and/or their downloads speeds.[192]

Net neutrality

9.39 As already discussed, the growth in the use of the internet creates a challenge for network operators, who must consider how best to meet their subscribers' demands. They are likely to do so partly by investing in new capacity, and partly by rationing their existing capacity, using the various approaches described above.

9.40 The different approaches to managing subscribers' data use may have different effects on users' experience of the openness of the internet – and these differences are at the heart of the net neutrality debate. Some argue that some network management practices by network operators and ISPs could be discriminatory, in particular by undermining the ease with which innovative services can launch and become successful.

9.41 The net neutrality debate has become a significant issue on the international telecoms policy agenda. In 2013 the European Commission published a draft legislative package: *Connected Continent: Building a Telecoms Single Market*[193] , which included proposals for net neutrality rules. Among the Commission's proposals were a prohibition on "discriminatory blocking and throttling", and rules for traffic management. At the time of writing, the Connected Continent regulation is still being negotiated, and the net neutrality provisions remain on the table.

9.42 Ofcom's approach to net neutrality, as set out in our statement published in 2011[194], recognises that widespread discriminatory behaviour by ISPs could put at risk the openness of the internet, and its continued operation as a platform for rapid and

[190] http://www.cap.org.uk/~/media/Files/CAP/Help%20notes/use%20of%20unlimited%20claims%20in%20telecoms%20advertising.ashx

[191] The guidance is intended to help advertisers, agencies and media owners interpret the CAP Code and the BCAP Code. The ASA Council has regard to the guidance when considering whether "unlimited" claims in telecommunications advertising comply with the relevant Advertising Code.

[192] http://www.asa.org.uk/News-resources/Hot-Topics/~/media/Files/ASA/Hot%20Topics/Broadband%20hot%20topic.ashx

[193] http://ec.europa.eu/digital-agenda/en/connected-continent-legislative-package

[194] http://stakeholders.ofcom.org.uk/binaries/consultations/net-neutrality/statement/statement.pdf

diverse innovation. However, in the first instance, Ofcom believes that effective competition among ISPs should ensure that consumers benefit from the open internet's diversity of services and innovation, as long as:

- Sufficient information is available to enable consumers to make the right purchasing decisions; and
- Consumers are able to act on this information by switching providers, where appropriate.

9.43 A key concern in relation to net neutrality is the risk that ISPs will seek to manage their subscribers' access to online services to further their own commercial objectives, to the detriment of end-users. For example, net neutrality concerns might arise in the case of a broadband provider blocking or restricting access to third-party video-on-demand (VoD) services such as Netflix to favour their own internet TV service. Similarly, an ISP might seek to charge online service providers for access to their subscribers, and block those who do not pay. The French ISP Free[195] briefly blocked Google's ads in early 2013, in what was seen as an effort to force Google to pay to access consumers.[196]

9.44 We consider that the widespread adoption of such practices could pose a risk to the operation of the internet as an open platform. This could limit its potential to support the rapid growth and broad span of innovation which has characterised it until now.

9.45 As outlined above, some traffic management can be beneficial if it improves the delivery of time-sensitive services such as streaming audio and video. It is therefore important to distinguish 'reasonable' from 'unreasonable' traffic management.

9.46 The phrase "unreasonable traffic management" is used to describe practices that aim to further the commercial interests of the network operator, but do not appear to benefit the consumer, such as selective blocking of VoD services (as above) or VoIP on mobile networks.

9.47 'Reasonable' traffic management practices are those which aim to improve the consumer's quality of experience; for example, managing network congestion or blocking access to content identified as unlawful. We are of the view that 'unreasonable' traffic management is highly undesirable.

9.48 While we maintain that unreasonable traffic management, such as blocking VoIP, is highly undesirable, we believe that there is currently no evidence that such practices are harming UK consumers' overall ability to access the open internet, or impeding innovation. Indeed, unrestricted service options are available from a number of competitive providers, both fixed and mobile. As a result, we do not think there is a need to intervene now to restrict or modify the traffic management practices adopted by the main access providers.

Net neutrality and interconnection arrangements

9.49 Historically, the net neutrality debate has focused on the management of access networks, and the potential constraints on innovation which this might cause. More

[195] http://www.economist.com/news/business/21569414-xavier-niel-playing-rough-internet-giant-france-v-google

[196] Free eventually backed down due to government pressure and restored full access to content on the internet, including Google ads. http://www.bbc.co.uk/news/technology-20943779

recently, concerns have been raised over the interconnection arrangements between content providers and access network operators – illustrated most clearly in the public dispute between Netflix and Comcast.[197] To some extent this wider focus is justified: interconnection arrangements can affect consumers' ability to access specific online services as much as traffic management in the access network. But it is important to use the appropriate frame of reference in examining commercial disputes over interconnection arrangements – the issues are not strictly the same as access network management, as interconnection is an essential aspect of internet operations, and interconnection agreements are primarily between network operators. Interconnection is discussed further below.

Interconnection with other networks

Introduction

9.50 In the section above we discussed the techniques ISPs use to manage traffic within their networks. The ways in which they connect to content outside their network also affects consumers' ability to access the online services of their choice.

Types of interconnection

9.51 Traditionally, there were two main ways in which ISPs connected to content, service providers and other ISPs:

- **Peering**: an agreement between two network providers to exchange traffic, either in private or via a public peering internet exchange; and
- **Transit**: the ISP pays for bandwidth from a provider of core internet connectivity. All ISPs need a transit connection to provide access to services hosted on networks with which they are not directly peered. Transit is often used to connect to services hosted in other countries.

9.52 More recently, content providers have begun using content delivery networks (CDNs) to store their content at locations closer to the end-user. The ISP connects to the CDN for a more direct, and potentially higher quality, route between the content and the end-user. For example, companies like Netflix use CDNs to place copies of their video library in multiple locations across the globe, making it easier to serve video to many customers simultaneously in multiple territories.

9.53 The use of a CDN may also offer bandwidth savings for the terminating ISP, which does not have to use internet connectivity for which it is paying (e.g. potentially via a paid-for transit circuit) every time a piece of content is requested by a customer. It benefits the content provider as the customer has a better experience of accessing that content.

9.54 Many CDNs are now being extended, to incorporate some or all of the data storage capacity that hosts end-users' content in 'caching servers'[198] in the access provider's own network. This further reduces transit or backhaul connectivity costs and improves the customer experience.

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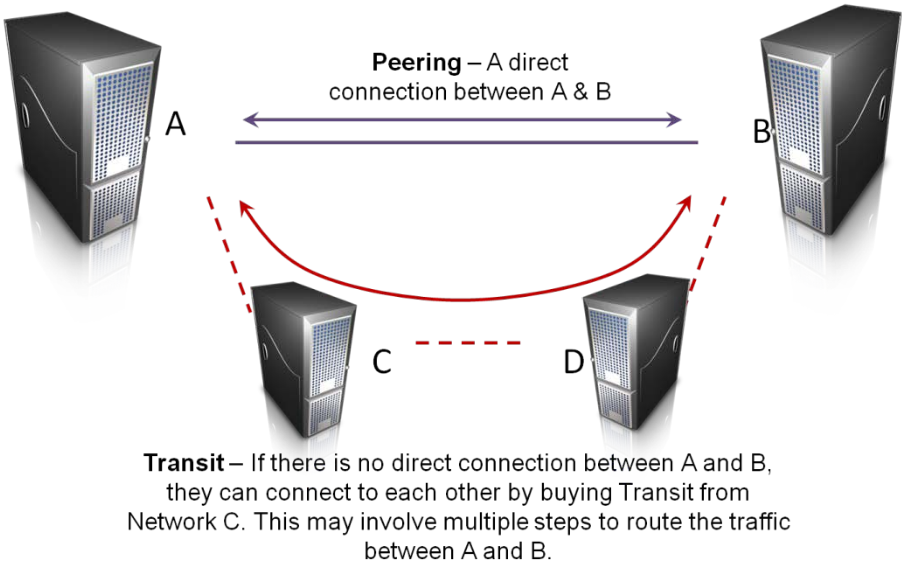
[197] http://www.cnet.com/news/netflix-ceo-criticizes-comcast-on-net-neutrality-data-caps/

[198] 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.

Figure 102 - The differences between peering and transit.



9.55 Peering takes place at a location agreed by both parties. In many cases these will be at internet exchange points (IXPs); locations built to facilitate peering. Each ISP installs a circuit from its network into a peering point and connects it to another network, allowing the exchange of traffic without incurring transit costs. As multiple networks all have a presence at the same physical location, it becomes cheaper for all these networks to interconnect with each other.

9.56 In the UK a large number of public peering points – 'internet exchanges' - are located in London. The London Internet Exchange (LINX) and London Network Access Point (LONAP) are two of the largest not-for-profit organisations providing these interconnect locations. Some exchange points are located elsewhere: Leeds, Manchester, Edinburgh, and soon, Cardiff.[199] A number of ISPs, often those with an international network footprint, also peer at other leading IXPs, such as AMS-IX in Amsterdam.

9.57 Traditionally, peering took place between broadly equivalent actors (hence 'peers') in the internet value chain; i.e. access providers or 'Tier 1' providers of core internet connectivity. These arrangements were predicated on roughly symmetrical traffic flows, broadly equivalent benefits and, consequently, the assumption that each party should bear its own direct costs.

9.58 Increasingly, however, peering arrangements are being put in place that involve actors in the value chain with highly asymmetric traffic flows. For example, the BBC has peering arrangements with a number of ISPs, so that its iPlayer services can be delivered over a peered link. This peering arrangement is advantageous to the ISP, as it frees up its transit connections for other traffic. This leads to improved speeds and reliability for the relevant services, thereby giving consumers a better experience.[200]

[199] The Welsh Government has been working with LINX, Cardiff County Council and other partners to bring an internet exchange to Cardiff. http://wales.gov.uk/newsroom/businessandeconomy/2014/8838915/?lang=en
[200] https://support.bbc.co.uk/support/peering/

9.59 The BBC and other large content businesses can also reduce costs[201] by adopting a peering-based interconnection strategy, as this is typically cheaper than transit for delivering content at larger data volumes. However, in some instances and in some markets, such asymmetrical interconnection arrangements can incur fees payable from one party to the other.

9.60 Content providers like Google, Netflix and Spotify are adopting a similar approach and are also embedding servers hosting their most popular and frequently-accessed content in ISPs' access networks, even closer to the end-users. Embedding servers in the ISPs' access networks may more properly be termed 'integrated CDN'; in other words, offering the same advantages as third-party CDNs such as Akamai and Limelight, but bringing the content even closer to the customer, so that transport costs are further reduced. This is, however, viable only for the largest content providers, whose scale makes the required investment economically viable.

9.61 The extensive use of peering, particularly for this type of content delivery, may lead to differentiated performance, with content services that use CDNs or peering interconnection potentially facing lower delivery costs and/or higher quality. It might even be argued that this is another deviation from a truly neutral internet. In principle, CDNs and direct peering may have benefits for consumers, as it can allow them to receive services, particularly time-sensitive ones like video streams, at more reliable quality, and typically reduce costs for content providers and network operators.

9.62 It remains to be seen, however, whether the adoption of lower cost or more efficient approaches to distribution – including CDNs and provider-specific peering arrangements - will lead to consumer detriment. Some of these arrangements may only be available to large-scale operators, allowing them to ensure high quality content delivery, while new providers may be unable to ensure that their services are accessible at satisfactory quality, and so may face difficulty in establishing themselves in the market. However, the extent of this risk is unclear, and may be mitigated by the fact that small content services can potentially access scale-appropriate CDN delivery, or can buy their connectivity from an ISP with good peering relationships.

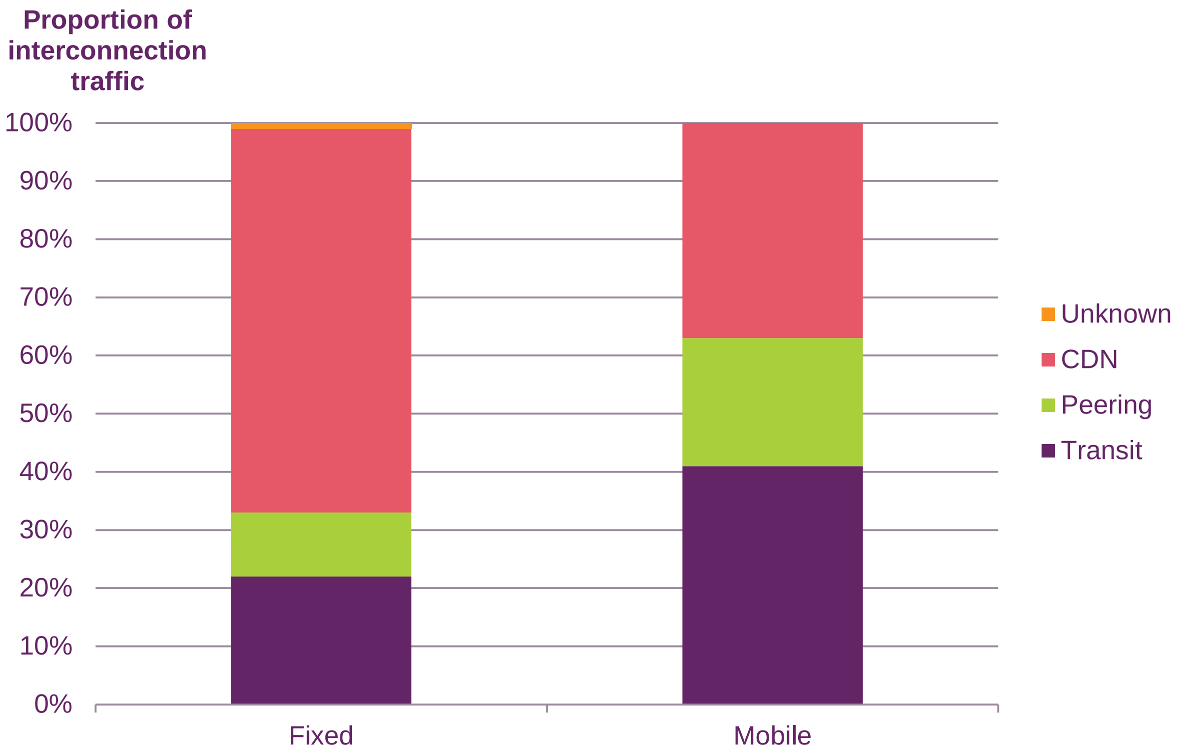
Internet interconnect arrangements in the UK

Types of interconnections

9.63 Figure 103 below shows that fixed operators use a larger proportion than mobile operators of CDN traffic. The proportion of traffic via a CDN has increased for both types of networks since last year.

[201] http://drpeering.net/FAQ/What-is-the-peering-breakeven-point.php

Figure 103 – Share of peering and transit interconnections for typical fixed and mobile operators



Source: Ofcom analysis of operator data

9.64 This year, we have seen a significant shift of data traffic to CDN and peering connections, for both fixed and mobile networks, compared to the same analysis in the 2013 report. This is unsurprising, as growth in data consumption has been driven by the increase in online streaming.[202] With the roll-out of faster mobile networks we expect the use of CDN and private peering to grow for mobile networks. Globally, Arthur D Little estimate that the number of CDN operators has grown significantly, from 25 providers in 2006 to 155 in 2013.[203]

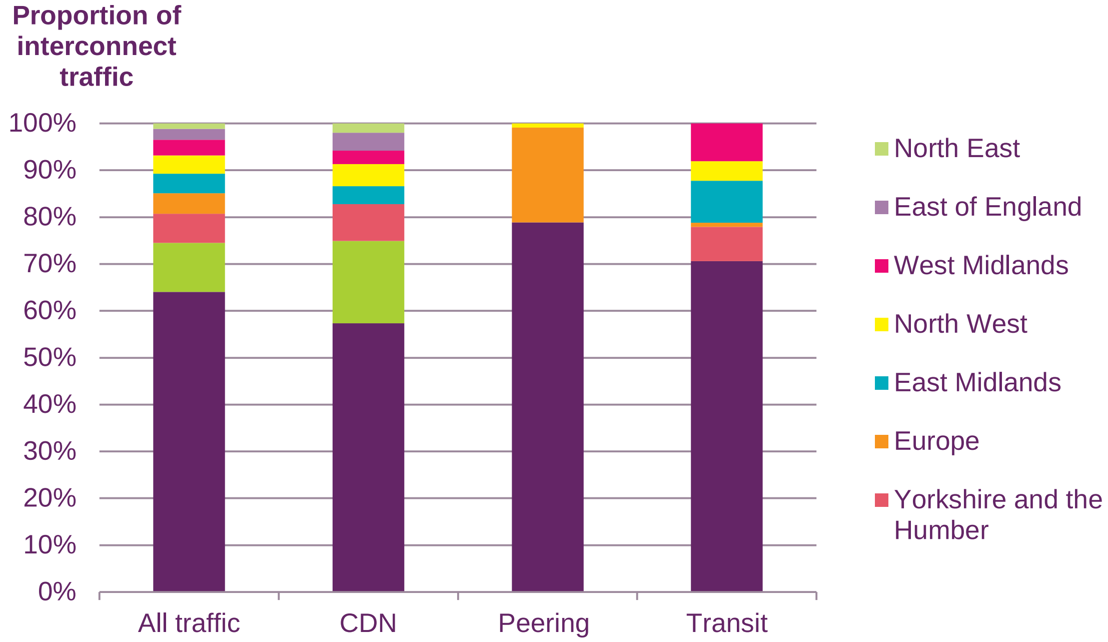
9.65 The proportion of traffic that is provided by the top four interconnection partners has also increased. For some fixed networks, the proportion of traffic delivered via Google, Netflix, Akamai and Limelight makes up around 60% of all interconnecting traffic. On mobile networks, this proportion is lower; between 30-40% of all interconnecting traffic. This shows that the source of internet data is increasingly consolidating into a small number of providers.

[202] In section 3 we report that video use on fixed networks has increased from 44% of all data downloaded in 2013 to 48% of all data downloaded.

[203] http://www.adlittle.com/downloads/tx_adlreports/ADL_LibertyGlobal_2014_FutureOfTheInternet.pdf

Location of interconnections

Figure 104 - Proportion of UK interconnect traffic exchanged in UK regions and Europe



Note: Some operators provided only an aggregate view of their CDN traffic, without specific information about the proportion of traffic through each location. These are classed as 'UK-wide'.

Source: Ofcom analysis of operator data

9.66 Figure 104 shows the distribution of interconnecting traffic by the location and type of interconnect. Over 60% of all interconnect traffic is shared via locations in London. This proportion varies by the type of interconnection.

9.67 Peering connections, including public and private peering, have the largest proportion of interconnect traffic exchanged in London. This is unsurprising, given that many operators are based in London. After London, around 20% of peering traffic is exchanged at other large co-location facilities in Europe, mainly in Frankfurt and Amsterdam.

9.68 Our data suggest that only a small proportion of traffic is carried across the other regional interconnections in the UK. This is probably due to the smaller number of networks currently present at these locations; these internet exchange points are relatively new. LINX reports that approximately 50 networks are present in the internet exchange in Manchester and 11 in Scotland.[204] By comparison, there are over 5000 networks at the internet exchanges in London.[205]

9.69 Figure 104 also shows that CDN traffic is somewhat more dispersed across the UK than peering traffic, although the majority of the traffic is handed over in London. This is because the role of CDNs is to bring content closer to a customer. Therefore, more of the traffic is handed over to the CP's network at an interconnection point nearer to the customer.

[204] https://indico.uknof.org.uk/materialDisplay.py?contribId=16&materialId=slides&confId=31
[205] https://www.linx.net/pubtools/member-techlist.html

9.70 It is likely that many mobile operators will consider rolling out their CDNs closer to the customer because it may reduce the costs of conveying data through the core network, and improve the customer experience. EE is trialling a new technology in association with Nokia Networks called Liquid Applications, which could bring CDN capabilities to the mobile base station, to store popular content nearer to the customer.[206] This type of local caching is already common in fixed networks. In some cases the servers are provided and managed by content providers such as Google (as discussed earlier).

9.71 We expect the use of CDNs on both fixed and mobile networks to grow, as streaming of video increases.

Internet addressing

Introduction

9.72 The internet relies on a numeric address scheme to route data across the globe. For data to be delivered, each device connected to the internet must have access to a publicly routable internet protocol (IP) address. The current, widely deployed, version of IP is version 4 (IPv4) and provides around 4 billion unique addresses. For example, the Ofcom website IPv4 address is 194.33.160.25. In this common notation, an IPv4 address is described as a 'dotted quad' notation.

9.73 The US-based Internet Assigned Numbers Authority (IANA) oversees the distribution of IP address resources to the five regional internet registries (RIRs). The RIRs allocate blocks of IP addresses to telecommunications companies and internet service providers within their operational areas.

9.74 IP address allocations in the UK are serviced by the RIR for Europe and the Middle East, Réseaux IP Européens Network Coordination Centre (RIPE NCC). This organisation is based in Amsterdam, and is established under Dutch law as a not-for-profit membership organisation. RIPE's diverse membership includes major telecommunications companies, internet service providers, academia, and commercial and public bodies.

9.75 The internet has its origins within research and academic networks. The modern internet can trace its roots to a small, informally arranged network of networks. The rapid growth of internet use around the world has resulted in the demand for addresses far exceeding the number available in the IPv4 format. Although IPv4 allows for approximately 4 billion IPv4 addresses, some of these are reserved for specific uses, e.g. private networks, carrier-grade network address translation or multicast.

9.76 In 2011, IANA declared that the central pool of IPv4 addresses was "exhausted". Each of the RIRs is, in varying degrees, running out of its final block of IPv4 addresses. Once a registry runs out, no further new IP addresses will be available. This may create a problem of scarcity for new entrants into the marketplace, because IP addresses will be limited.

9.77 In an effort to slow the depletion of its limited IPv4 stock, since September 2012 the RIPE NCC has limited its assignment of IPv4 addresses, to new and existing

[206] http://www.mobileeurope.co.uk/Press-Wire/nokia-networks-intel-launch-innovation-centre

members, to 1,024 addresses.[207] This is a very small allocation, and unlikely to be adequate for many potential communications service providers.

9.78 The Internet Engineering Task Force (IETF) has long been aware of the potential exhaustion of IPv4 addresses. In 1998 it standardised a successor to IPv4: internet protocol version 6 (IPv6).[208] Work has been ongoing to further refine and develop IPv6 and related protocols

9.79 IPv6 uses a much larger address space than IPv4: it allows for 340 undecillion[209] unique addresses. Many industry observers believe that the deployment of IPv6 is essential for the continued growth of the internet and is a key enabler for the 'internet of things'. However, the implementation of IPv6 will present some significant challenges: it requires investment in the network, by online service providers, and in updating or replacing consumers' equipment to handle the new-format IP addresses.

9.80 The remainder of this subsection describes the current position in the UK in relation to the availability and utilisation of IPv4 and IPv6 addresses.

Overview of current IP addressing in the UK

IPv4 allocation and use

9.81 In order for an IP network to connect to the public internet it must 'advertise' its existence on the internet. Ofcom commissioned an independent study to examine the levels of allocation and use of UK-assigned IPv4 and IPv6 address.[210] The study used software functionality provided by RIPE NCC, RipeStat, which allows the exploration of public IP networks and the addresses they use in the global routing tables of other networks. Using these tools, the report authors were able to determine how much of the UK IP address allocation is in use and how much is not visible to the internet at large. (Note that the multinational nature of communication provider businesses often means that a UK company may have subsidiary organisations active in other countries, with their own IP address allocations provided by other regional internet registries. Quantifying and estimating the holding and use by UK entities IPv4 and IPv6 addresses will therefore always have an element of uncertainty. We are confident, however, that the study presents a reasonably accurate picture of UK allocation and use.)

9.82 Figure 105 depicts the total number of IPv4 addresses allocated and reachable on the public internet. The UK has approximately 70 million IPv4 addresses allocated by the RIPE NCC. Of this figure approximately 56 million IPv4 addresses are deemed as being reachable on the public internet.

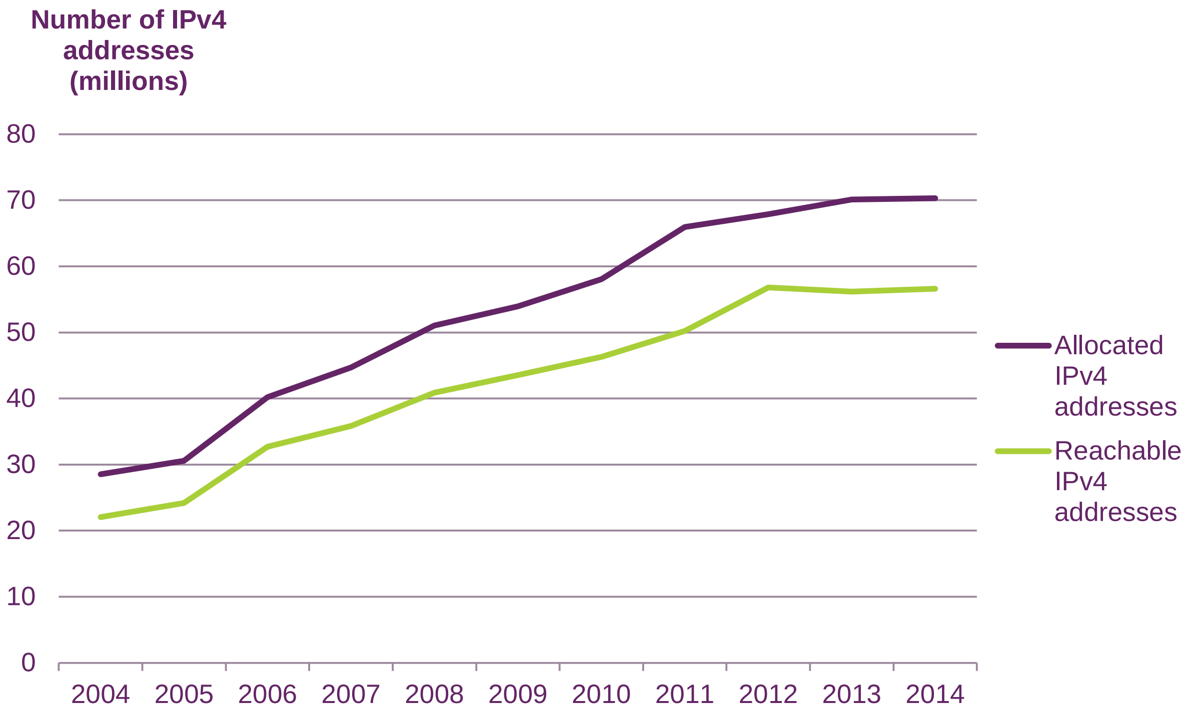
[207] IPv4 Address Allocation and Assignment Policies for the RIPE NCC Service Region — RIPE Network Coordination Centre: http://www.ripe.net/ripe/docs/ripe-623#51

[208] http://tools.ietf.org/html/rfc2460

[209] Undecillion is 10^{36}.

[210] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/rtfm.pdf

Figure 105 - RIPE UK-assigned IPv4 addresses



Source: RTFM LLC
** Note: reachability data is available from 2004 using RIPEStat API*

9.83 We asked CPs to estimate the likely date of IPv4 exhaustion for their networks. They gave varying estimates of when they would run out of IPv4 addresses. Their estimates were between two and five years, based on the current rate of use.

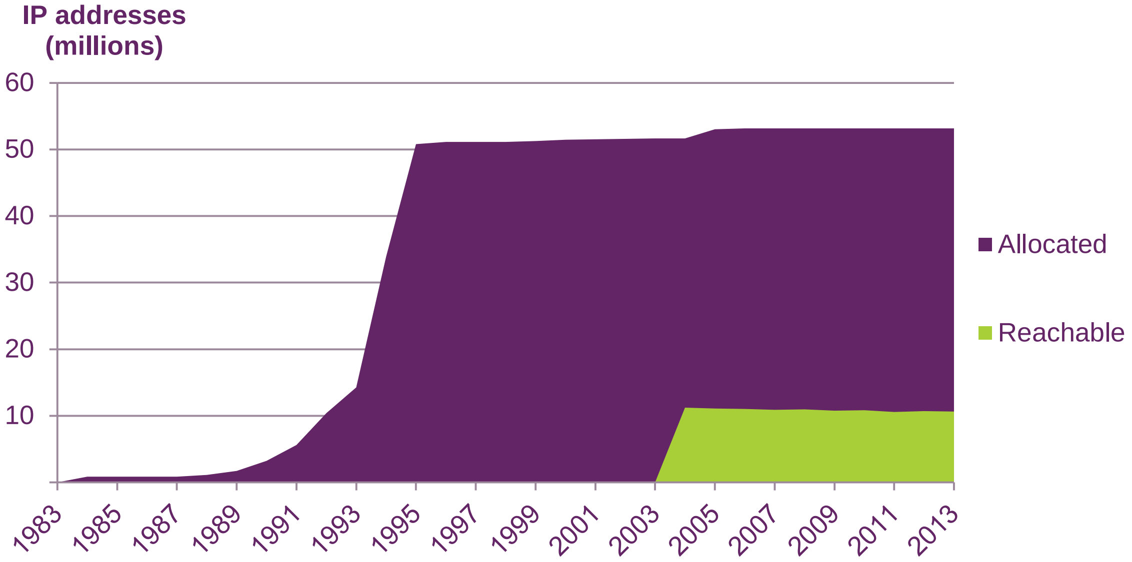
UK legacy address space

9.84 Although UK Local Internet Registries (LIRs) now receive their IP address allocation from RIPE NNC, some organisations in the UK have IP addresses that were allocated before the formal establishment of the RIR system in 1997. These addresses are known as legacy IPv4 addresses, and were typically issued to Government, educational and commercial organisations requesting IP addresses at that time. The study undertaken by RTFM for Ofcom has calculated that there are about 53 million UK legacy IPv4 addresses.

9.85 It should be noted that these legacy allocations were made when the internet was largely the preserve of academic and research networks, and the legacy address space is not directly managed by the five RIRs. There are a number of very large-scale allocations in this 'legacy' address space that are largely, or completely, unused, and appear to be prime candidates for transfer or for trading to parties with IP address shortages.

9.86 This study concluded that around only 20% of the UK legacy address space is routable on the public internet. This means that the remaining 80% of addresses are not being used on the public internet. They may, however, be in use in a private network setting, and this raises questions about efficiency. This figure has remained largely static since 2004.

Figure 106 - Number of legacy IPv4 addresses allocated to the UK and the proportion that are reachable



Source: RTFM LCC

9.87 The UK legacy IP address space is dominated by two large assignments of addresses belonging to two UK Government departments, the Department for Work and Pensions (DWP) and the Ministry of Defence (MoD). These add up to over 33 million IP addresses. The study identified that neither the DWP nor the MoD IP address assignments were visible within global internet routing tables. It is reasonable to conclude that this address space is not in active use on the public internet. The figure below summarises the top five legacy IP address holders in the UK.

Figure 107 - The top five legacy address space holders by date

Organisation	Allocation	Size	Allocated Date
UK Government Department for Work and Pensions	51.0.0.0	16777216	01/09/1993
DINSA Ministry of Defence	25.0.0.0	16777216	01/01/1995
BP	149.177.0.0	1245184	13/05/1991
British Telecommunications plc	147.147.0.0	393216	01/01/1984
Global Crossing VHSDR service	171.28.0.0	196608	09/01/1995

Source: RTFM LLC

9.88 Figure 106 and Figure 107 show that other UK organisations are also holding considerable IPv4 address resources. There may be ways to bring these unused blocks of addresses into efficient use; for example, by recycling them to other UK-based access and service providers. This might be appropriate if there were concerns that the costs of IPv6 transition were prohibitive, and if IPv4 conservation methods caused significant problems.

Approaches to manage the demand for IP addresses

9.89 Although there remains a significant stock of unused IPv4 addresses, in the hands of UK institutions, demand for addresses continues to grow rapidly. In the absence of new supply, it will be necessary to consider how to access these unused stocks. There are three options:

- trading IP addresses;
- using the remaining allocation of addresses in a more efficient way; or
- adopting IPv6 addressing

9.90 To meet the demand for IPv4 addresses, an IPv4 address trading and transfer market has developed. Organisations with unused or surplus IPv4 address space[211] may effectively 'sell' or transfer it to entities seeking IPv4 addresses. This market incentivises owners of unused address ranges to make them available to others. We note that historically a value of up to $10 or more per address has been achieved. This may help alleviate any immediate shortfall currently being experienced, particularly by CPs or service providers which entered the market recently.

9.91 Previously in this section we explained that RIPE has in place a final IPv4 address allocation policy.[212] This policy limits the allocation of IPv4 addresses to 1,024 addresses for each LIR from the final pool of IPv4 addresses held by RIPE. RIPE's final allocation policy also requires that the requesting LIR has received an IPv6 allocation from an upstream LIR or the RIPE NCC to encourage the take-up of IPv6 addresses.

9.92 However, the allocation of 1,024 IPv4 addresses may not be sufficient for some organisations. There is a transfer mechanism which currently permits the transfer of IPv4 address blocks between LIRs within the service area of the regional internet registry. Transfers from/to UK LIRs within the RIPE NCC service region began in 2013; these are shown in the table below.

Figure 108 - IPv4 address transfers to UK LIRs within the RIPE service region

Size	Donors	Recipients	Date
32,7680	• Easynet Global Services Limited • Telefonica UK Limited	British Sky Broadcasting Limited	06/05/2013 - 05/08/2014
12,288	• Telecitygroup International Ltd	Linode, LLC	28/06/2013 - 14/08/2014

[211] Early adopters were often allocated large sets of IPv4 addresses, as there was no concern at the time about running out of addresses. Rules around the limited allocation of IPv4 addresses were only introduced more recently. RIPE currently issues blocks of 1,024 IPv4 addresses to its members.
[212] *IPv4 Address Allocation and Assignment Policies for the RIPE NCC Service Region* — RIPE Network Coordination Centre: http://www.ripe.net/ripe/docs/ripe-623#51

30,720	• Zytac Limited • NetServices UK Limited • Dark Group Ltd • PAV I.T. SERVICES PLC • Zytac Limited	Gamma Telecom Holdings Ltd	08/04/2013 - 23/04/2014
1,024	• Mailbox Internet Ltd	CentralNic Ltd	01/05/2014

Source: RTFM LLC

Efficient use of remaining addresses

9.93 Another way to manage the current availability of IPv4 addresses is to share the same address between multiple users using a technique called 'carrier grade network address translation (CGNAT). Typically, a CP can manage the sharing of a single address between multiple users by maintaining a register of the users of the common address, thereby 'translating' the public IP address to the correct end-user.

9.94 Under some scenarios, the implementation of CGNAT can lead to complications, particularly for two-way services or those initiated remotely - as the end-user's IP address is masked by the address presented to the public network. As noted in last year's *Infrastructure Report Update,* this practice looks set to grow in order to allow use of 'IPv4 only' user equipment until it reaches the end of its life.

Adoption of IPv6 addressing

9.95 Mobile operators are generally looking to introduce IPv6 addressing, as support for IPv6 is built into the standard for LTE, so 4G networks running on LTE handsets are already compatible. However, further software upgrades or configuration changes within the network and in consumer devices may be required before mobile operators can begin to use IPv6 addresses. In the meantime, CGNAT is already in widespread use on mobile networks.

9.96 Fixed operators are also considering CGNAT or a dual-stack approach, where IPv4 and IPv6 run in parallel. Unlike mobile, there are no upcoming changes in the technology incorporating IPv6, and therefore these have to be introduced separately.

9.97 None of the major CPs we contacted are currently offering IPv6 addresses for their residential/non-business users, although IPv6 services are available from some smaller fixed broadband providers, such as Andrews and Arnold. However, most major CPs told Ofcom they will be rolling out IPv6 addressing in the next 12 months.

9.98 As mentioned, a potential barrier to the introduction of IPv6 addresses is the availability of compatible equipment in the home. Most of the main fixed CPs that we contacted reported that the majority of the routers provided to customers were already IPv6-compatible. In aggregate, approximately 70% of consumer routers provided by these operators are IPv6-ready. For these routers, only a firmware upgrade was necessary. However, customers owning older routers will require new IPv6-compatible hardware.

9.99 Although residential CPs are deploying IPv6-ready equipment, there is some evidence that take-up of IPv6 is not progressing very quickly. Ofcom commissioned an independent study to examine the current state of UK-assigned IPv4 and IPv6 addresses among UK LIRs.

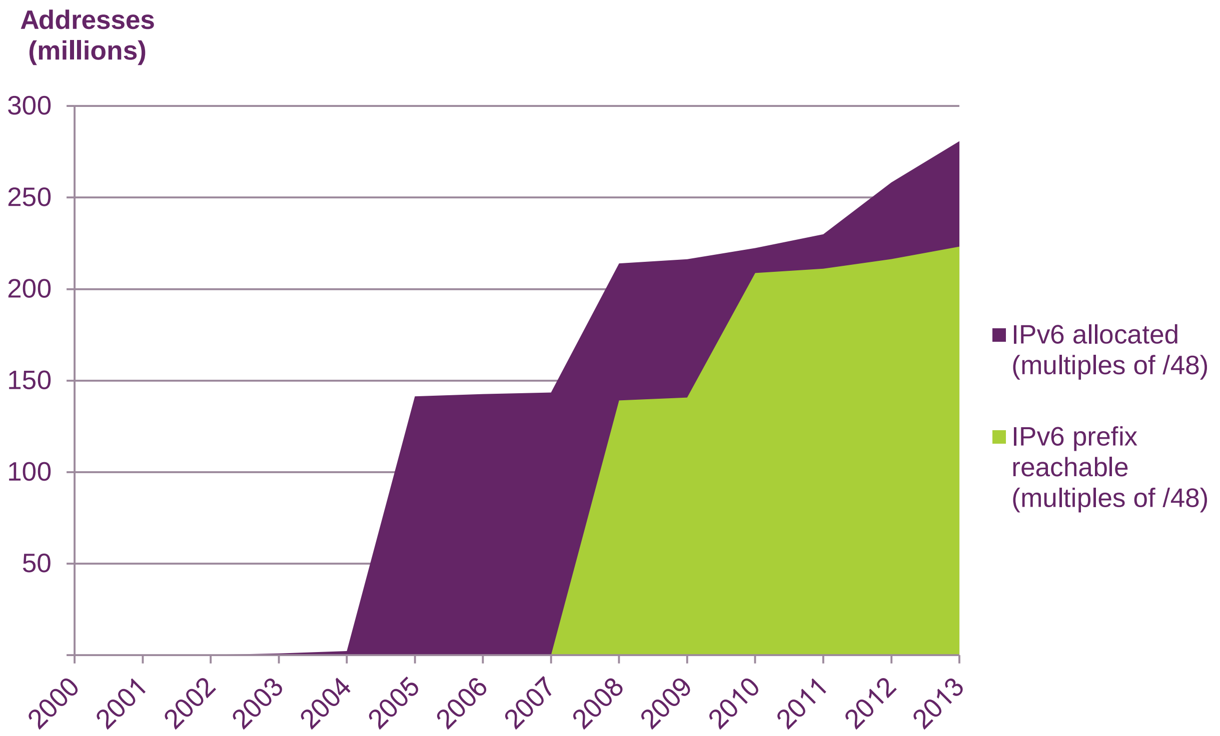
Figure 109 - Extent of IPv6 deployment in the UK

	Number of LIRs
LIR Total	1186
LIRs with IPv6 allocations	876
LIRs with no IPv6 allocations	310
LIRs with only IPv6 allocations (no IPv4)	20
LIRs with reachable IPv6	332
LIRs with unreachable IPv6	544

Source: RTFM LLC

9.100 Figure 109 above shows that nearly a quarter of UK LIRs[213] have been allocated with IPv6 addresses. However, only 38% of these (or 28% of all LIRs) have IP addresses which are publicly reachable. Therefore the vast majority of UK LIRs cannot be currently reached using IPv6 addresses.

Figure 110 - IPv6 addresses (multiples of /48) allocated to UK LIRs



Source: RTFM LLC

[213] This includes LIRs such as commercial, Government and educational organisations which need their own allocation of IP addresses as well as residential broadband providers.

9.101 The Ofcom-commissioned study also considers the take-up of IPv6 addresses since 2000. As shown in Figure 110, while the allocation of IPv6 addresses and the number of reachable addresses continues to grow, the rate of growth for both has slowed.

Domain name system – a UK perspective

Introduction

9.102 Although IP addresses are used to route data packets across networks, including the internet, internet users more typically use domain names in the form *www.ofcom.org.uk.* The domain name system (DNS) is needed to translate the domain name into an IP address, i.e. to convert *www.ofcom.org.uk* to *194.33.160.25.*

9.103 DNS is a globally distributed and hierarchical system and is primarily used to display a human-readable domain name for an IP address on internet-connected devices and systems. DNS also offers other service such as reverse IP address / DNS lookups, cryptographic key publishing and service discovery.

9.104 The US-based Internet Corporation for Assigned Names and Numbers (ICANN) currently coordinates the global co-ordination of DNS via its Internet Assigned Numbers Authority (IANA) function.

9.105 Aside from the familiar generic top-level domains (gTLD), such as .com, .net, .org etc., each country is assigned a two-letter country code - .uk is the country code top-level domain (ccTLD) for the United Kingdom. In 2014 new gTLDs were deployed into the global DNS system; examples of new UK-centric gTLDs are .cymru, .london and .scot.

9.106 Nominet is the .uk ccTLD DNS registry that oversees most of the .uk namespace. (.gov.uk and .ac.uk are managed by the Joint Academic Network (JANET)).This organisation supplied Ofcom with some contextual data and information for this report concerning DNS and IPv6. In this section we summarise these data, namely:

- take-up of domain name security extensions (DNSSEC);
- take-up of IPv6 among UK domain names;
- security enhancements within the .uk DNS namespace; and
- new generic topic-level domain names.

Domain name system security extensions (DNSSEC)

9.107 DNS is critical to the proper running of the internet, as users rely on the distributed servers to return the correct IP address for the website they wish to access. DNS is a critical service allowing internet users to remember only familiar domain names, rather than having to remember an IP address.

9.108 However, as the internet has evolved - from a small trusted community of research and university campus networks to the global scale we know today - malicious actors have started to seek to subvert and take advantage of systems at the heart of the internet, such as DNS. For example, cyber-criminals will attempt to subvert the local domain name system in an attempt to redirect traffic to malicious sites that they host, which they can use to infect end-user terminals with malware, or harvest sensitive personal information such as bank details.

9.109 In order to secure this critical system, the Internet Engineering Task Force has developed a cryptographic means of authenticating DNS query responses. Domain name system security extensions (DNSSEC) provide an authenticated 'chain of trust' from the global root DNS server to the CP DNS server. This means that CP DNS servers are able cryptographically to verify the DNS query response; in particular, that the IP address response is coming from a legitimate source. This gives a degree of assurance; ordinarily, this would mean that CPs' DNS services check the validity of the IP address within a DNS query response. This prevents tampering or fraudulent query responses which may lead to consumer harm.

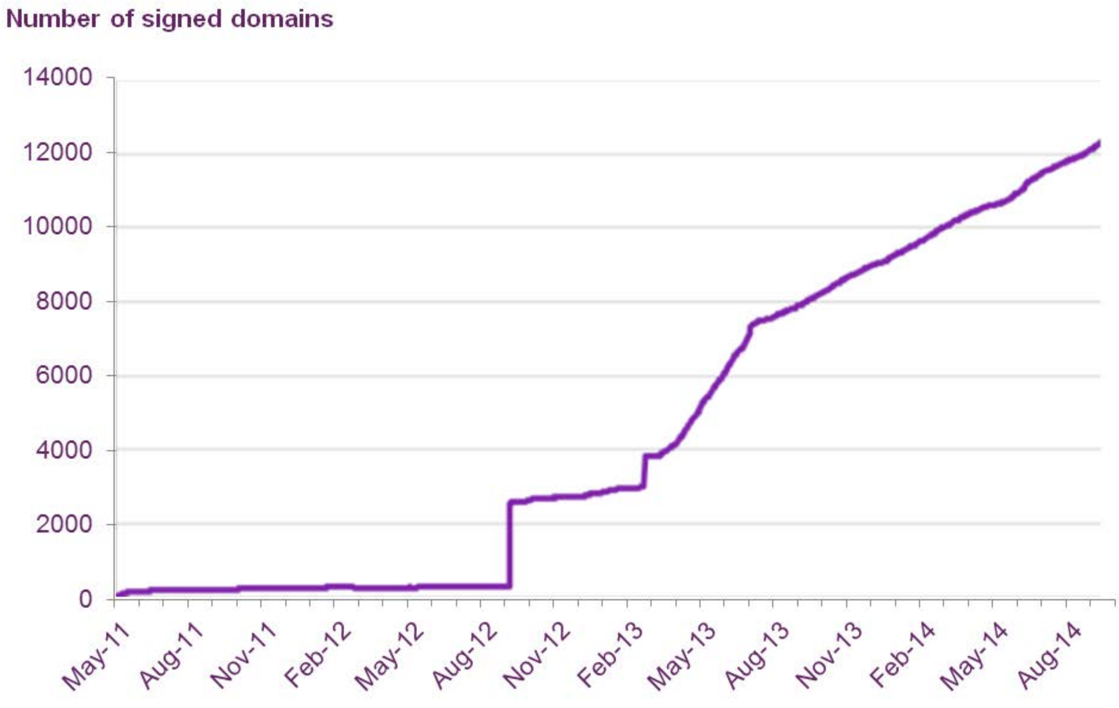
9.110 The UK's Nominet played a key role in the enhancement of DNSSEC.[214]

9.111 In 2011 Ofcom commissioned an independent study to examine the adoption rate of DNSSEC and the barriers to adoption.[215]

.uk DNSSEC growth

9.112 Nominet, the UK ccTLD DNS registry, confirmed that of the 10.5 million domain names in the .uk registry, a comparatively small, but increasing, number DNS domains are DNSSEC signed. In 25 September 2014 the number of DNSSEC-signed domains was 12,301 (up from 6,736 on 5 July 2013).

Figure 111 - DNS Signed domains in the UK



Source: Nominet

[214] http://tools.ietf.org/html/rfc5155
[215] http://stakeholders.ofcom.org.uk/binaries/internet/domain-name-security.pdf

IPv6 within the .UK DNS namespace

9.113 For the 2013 Infrastructure Report Nominet supplied Ofcom with details of IPv6 address adoption among its membership. This year, Nominet supplied updated indicative data. Nominet estimates that approximately 8.6% of Nominet domains can be reached via IPv6 addresses, a slight drop from last year. It should be noted that IPv6 traffic volume is indicative only. Nominet is unable to provide absolute figures on IPv6 adoption, as some registrar DNS name servers may be located outside the UK and not are readily visible to Nominet.

Security enhancement within the .uk DNS namespace

9.114 In addition to DNSSEC, Nominet has introduced a number of other features to enhance security:

- Domain locking. this is a service offered to Nominet registrars that allows registrants to choose to lock their DNS settings at the registry level.[216] Under this measure, the DNS details of a domain name, including the IP address of the website, cannot be changed unless unlocking is explicitly requested by an authorised representative; and

- Two-factor authentication. This provides increased security for Nominet registrars when accessing Nominet's systems.

New generic top-level domains (gTLDs)

9.115 In 2011 the board of ICANN voted to expand the range of suffixes, i.e the generic top-level domains (gTLDs) available within the global DNS system[217]. This has gone beyond the familiar DNS suffixes .com and .org to include a wider variety of domain endings. Examples of new endings include .accountants, .rentals and .vodka.

9.116 In April 2014 London launched its own top-level domain Dot London (.london), offering an alternative to existing domains such as .uk or .com. In the first five months following Dot London's launch in April 2014, close to 45,000 registrations have been received from businesses, organisations and individuals around the world.

9.117 The UK ccTLD Registry, Nominet, also operates the registry service for two new gTLDs: .cymru and .wales. The ICANN-accredited resellers, registrars contracted via Nominet, will offer both .cymru and .wales domains. DNSSEC is enabled, but not mandatory for .wales and .cymru gTLDs. The new .cymru and .wales domain will be available for registration in early 2015 and will support domains registered in both Welsh and English languages.

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[216] http://registrars.nominet.org.uk/namespace/uk/security-tools-and-protection/introducing-domain-lock

[217] ICANN Approves Historic Change to Internet's Domain Name System | Board Votes to Launch New Generic Top-Level Domains - ICANN: https://www.icann.org/news/announcement-2011-06-20-en

Annex 1

Methodology

This report uses new data gathered from the largest operators in each sector, as well as information already held by Ofcom. Where possible we have reused data already submitted to Ofcom by industry, in order to minimise the input required from stakeholders. In the main, we have only gathered data from the communications providers who make up a significant proportion of the residential market.

For fixed networks, we used input from the four networks making up over 80% of that market, and from KCOM for services in Hull. In the case of mobile networks and digital terrestrial broadcast networks, we gathered data from all the network operators

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

Our data on coverage of fixed broadband services is collected from the three main fixed network operators, BT, KCOM and Virgin Media.

For the overall coverage of fixed broadband, reported in section 3, coverage is reported on a base of residential and small business premises (where we refer to ‘premises’ or ‘households’ in this report we are referring to the sum of residential and small business postal delivery points). We have excluded PO boxes and large organisations.

In section 4, where we report on the availability of superfast broadband for SMEs, we use a base of only SME premises, for SMEs with at least one employee. This section also only reports on the coverage of networks provided by BT, KCOM and Virgin Media.

We use premises data from Ordnance Survey AddressBase[218] (June 2014 version), LPS OSNI Pointer[219] for Northern Ireland and National Statistics Postcode Lookup (NSPL)[220].

Where two network operators are present in the same postcode, our source data is unable to indicate the degree of overlap between these networks. We estimate the coverage value for each postcode based on the average of the ‘best case’ (where there is least overlap) and ‘worst case’ (where there is most overlap). This is the same methodology as by the consultancy IHS when compiling data for the European Commission’s Digital Agenda Scorecard.

Take up, speeds and data use

We gathered data from the main fixed broadband Internet Service Providers (BT, KCOM, Sky, TalkTalk and Virgin Media) on both their retail services and the services they provide to other ISPs as a wholesale service.

[218] http://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[219] http://data.gov.uk/dataset/lps-osni-pointer-download
[220] http://www.ons.gov.uk/ons/guide-method/geography/products/postcode-directories/-nspp-/index.html

Our analysis of broadband speeds is based on information provided by these ISPs on the sync speed of each active line. This gives a measure 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.

For cable networks, we have used the headline speed of the broadband package for each line. Due to the nature of the network, cable network providers have greater control of the speeds they can provide to customers on a line. They typically set a sync speed higher than the headline speed to ensure that end users can experience the advertised speeds.

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 is therefore not available to the end user. We do not apply a margin to 10Mbit/s or 30Mbit/s because these thresholds are derived differently.

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.

Along with information about the sync speed of each line, we also gathered information about the postcode of that line. This provides the source data for our geographic analysis.

Our analysis of data use uses information on the amount of data downloaded and uploaded on each line for June 2014. We also collected data on the total data use between the hours of 6pm – midnight, to assess data use at 'peak times'. Our analysis considers all lines where the amount of data downloaded in June was greater than zero.

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

Mobile

Coverage

Our data on coverage of mobile networks is collected from the four mobile network operators, EE, O2, Three and Vodafone as 100m x 100m pixels referenced against the OSGB[221] grid system for their coverage in March 2014 for 2G networks and June 2014 for 3G and 4G networks. As 4G coverage is progressing rapidly we provide an update on 4G coverage based on coverage in October 2014.

Premises coverage is calculated from a base of 28.3m postal delivery points taken from the Ordnance Survey AddressBase[222] (June 2014 version) and LPS OSNI Pointer[223] database for Northern Ireland. Roads data is taken from Ordnance Survey Meridian and LPS OSNI data sets. We set the following signal strength thresholds when estimating coverage.

[221] **Ordnance Survey of Great Britain (OSGB) Coordinate System**
[222] http://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[223] http://data.gov.uk/dataset/lps-osni-pointer-download

	Metric	Outdoor	In-car and in-door
2G	RxLev	-86 dBm	-76 dBm
3G	RSCP CPiCH	-100 dBm	-90 dBm
4G	RSRP	-113 dBm	-103 dBm

Data use

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

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

Femto cells and public Wi-Fi

Femto cells

Mobile network operators who have more than 1000 Femto cells on their network provided information on the postcodes where these Femto cells were issued.

Public Wi-Fi

Our data on public Wi-Fi was gathered from the main providers of this service (Arqiva, BT, EE, KCOM, O2, Sky and Virgin Media). These public Wi-Fi providers reported on the total data downloaded and uploaded at each of their public W-iFi access points and the postcode of these access points. Where they were able to do so, some operators also provided information on the proportion of data downloaded and uploaded on 2.4GHz and 5GHz Wi-Fi.

Broadcast

DTT and DAB coverage

Our coverage metrics for coverage of digital television (DTT) and digital radio (DAB) represents the coverage of the national DTT and DAB services only. The table below sets out the networks and the multiplex owners for each of the multiplexes which are included in this analysis.

Network	Operator/Name	Classification (DTT only)
DTT	BBC (BBC A) BBC (BBC B) Digital 3 and 4 (D34)	Public service Broadcast
DTT	SDN (SDN) Arqiva (ARQA) Arqiva (ARQB) Arqiva (COM7)	Commercial

DAB	BBC Arqiva (Digital One)	

Other networks

Cable – Cable television services are assumed to be available where cable broadband services are available (see fixed networks).

Satellite – Our reported figures for satellite coverage is the maximum theoretical level achievable. A variety of practical reasons mean that the availability of satellite services is likely to be lower. Please see our explanation in section 6 for further details.

Internet

Internet Interconnection

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 2014 and the physical location of that interconnection.

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.

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

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

Bit-rates The rate at which digital information is carried within a specified communications channel.

Bonding A technique which could be used in DSL networks to improve data speeds by using multiple copper lines between the cabinet and the customer's premises.

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

ccTLD Country Code Top-Level Domain. A top-level domain reserved for a country (e.g. .uk)

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.

Data packet In networking, the smallest unit of information transmitted as a discrete entity from one node on the network to another.

DCMS Department for Culture, Media and Sport.

DNS Domain Name System – a system that translates domain names into IP addresses.

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).

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.

FTTH Fibre to the Home. A form of fibre optic communication delivery in which the optical signal reaches the end user's home.

GPON Gigabit Passive Optical Network. A point to multipoint network (as opposed to a point to point network), where a single optical fibre is used to serve multiple premises using passive splitters at higher speeds.

GSM Global Standard for Mobile telephony. This is the standard used for 2G mobile systems.

Headline connection speed Marketed speed.

HFC Hybrid Fibre Coaxial. A combined optical fibre and coaxial cable (a cable made up of a conductor and a tubular insulating layer) commonly used in cable networks.

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.

Leased lines A transmission facility which is leased by an end user from a public carrier, and which is dedicated to that user's traffic.

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

LIR Local Internet Registry – A body that is responsible for the distribution of IP addresses at a local level.

LLU Local Loop Unbundling. LLU is the process where incumbent operators (in the UK this is BT and KCOM) make their local network (the lines that run from the customers' premises to the telephone exchange) available to other communications providers. The process requires the competitor to deploy its own equipment in the incumbent's local exchange and to establish a backhaul connection between this equipment and its core network.

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

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

Mobile Broadband Various types of wireless, high speed internet access through a mobile telephone or a mobile data dongle.

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

MVNO Mobile Virtual Network Operator. An organisation which provides mobile telephony services to its customers, but does not have allocation of spectrum or its own wireless network and instead, buys a wholesale service from a mobile network operator.

Narrowband A service or connection providing data speeds up to 128kbit/s, for example via an analogue telephone line.

NEAT National Emergency Alert for Telecoms – The telecom's industry's process for information and resource-sharing during an emergency.

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.

Point-to-Point A network topology where the end user is connected to the network via a dedicated fibre.

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

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.

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 The next generation of faster broadband services, which delivers headline download speeds of greater than 30 Mbit/s.

SLU Sub-Loop Unbundling. This is where the unbundling of the access line takes place at the street side cabinet (rather than the exchange as for LLU) for a communications provider to gain control of the access line to the customer.

Telecommunications Conveyance over distance of speech, music and other sounds, visual images or signals by electric, magnetic or electro-magnetic means.

Transmitter A device which amplifies an electrical signal at a frequency to be converted, by means of an aerial, into an electromagnetic wave (or radio wave). The term is commonly used to include other, attached devices, which impose a more simple signal onto the frequency, which is then sent as a radio wave. The term is sometimes also used to include the cable and aerial system referred to above, and indeed the whole electrical, electronic and physical system at the site of the transmitter.

UMA Unlicensed Mobile Access. A technology that provides roaming between GSM and 802.11 Wi-Fi

UMTS Universal Mobile Telecommunications System. The 3G mobile technology most commonly used in the UK and across Europe.

Unbundled A local exchange that has been subject to local loop unbundling (LLU).

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.

Vectoring A technique used in DSL networks to increase the data speeds by using real time digital signal processing techniques to reduce the interference on the line.

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.

Weightless A low power, wide area network technology standard designed to work in many different spectrum bands.

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.

WiMAX A wireless MAN (metropolitan area network) technology, based on the 802.16 standard. It can be used for both fixed and mobile data applications.

WLR Wholesale Line Rental. This is a regulatory instrument requiring the operator of local access lines to make services available to competing providers at a wholesale price.

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

Annex 3

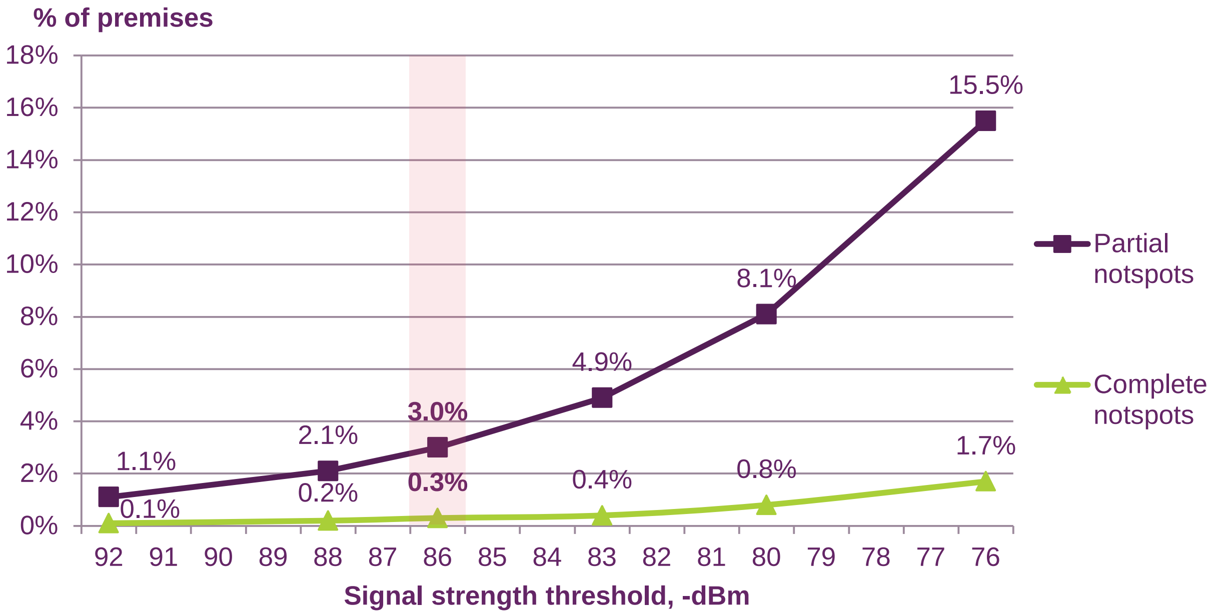
Mobile coverage scenarios

Mobile coverage estimates presented in this report are based on signal strength predictions provided by the MNOs using computer models. These models have been refined over time by comparing predictions with real world measurements.

While we have found the models to be broadly accurate, predicting signal strength at a specific location is highly complex and can be affected by a number of factors. These include the complexity of local topography (such as hills and valleys) and the presence of building and other obstacles, such as trees. As such, prediction is subject to a margin of error. When estimating outdoor coverage we have applied a signal strength threshold which we consider is sufficient to provide a reliable signal in the large majority of locations, taking into account the potential error margins associated with the MNOs signal strength predictions.

Mobile phone signals are weakened as they pass through solid objects such as the walls of buildings or the body of cars. Signal strengths are therefore generally weaker indoors and in-car than they are outdoors. We have reflected this in our analysis by applying a fixed signal loss of 10dB (this being the measure of mobile signal strength) to MNOs' outdoor signal strength predictions when estimating indoor and in-car coverage. The choice of appropriate signal threshold is a matter of judgment. We have undertaken sensitivity analysis to assess the impact on estimate coverage of applying different signal strength thresholds. The results are presented below. We currently use a signal strength threshold of -86 dBm for our 2G outdoor coverage figures, -76dBm for indoors and in-car.

Figure 112 - 2G mobile coverage of premises measured to be in partial not-spots under different signal threshold assumptions

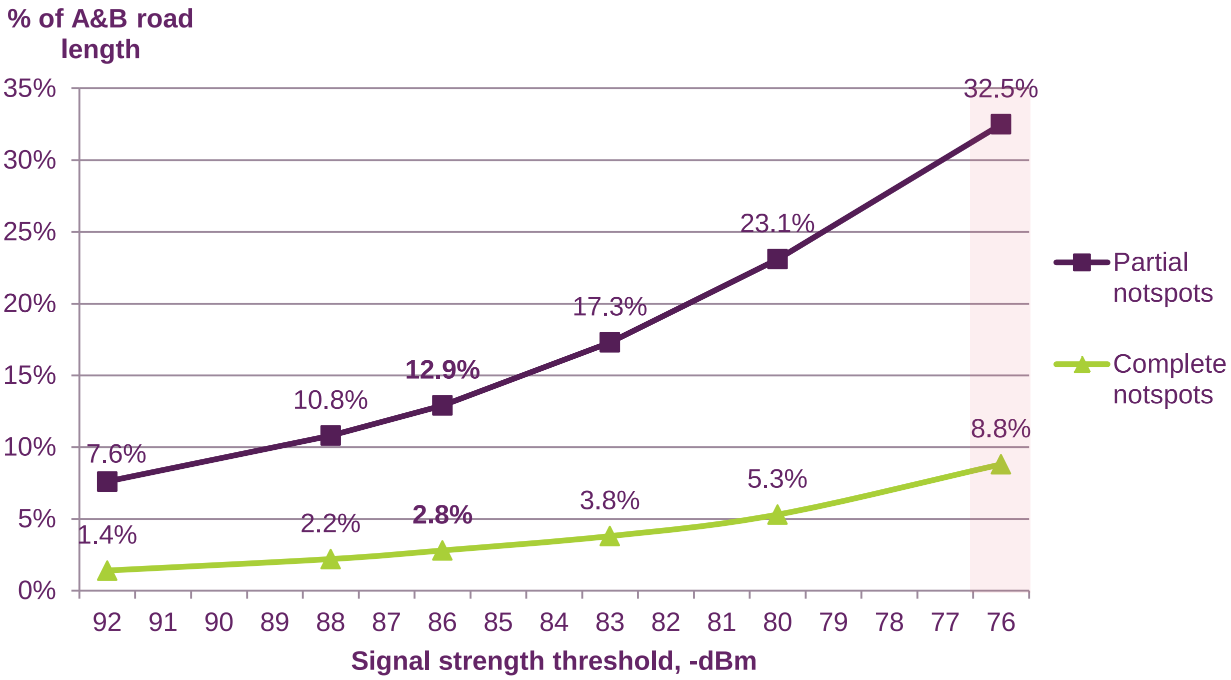


Our central case estimate of 3% of premises in partial not-spots and 0.3% of premises in complete not-spots is based on a signal strength threshold of -86 dBm.

The percentage of premises in not-spots is higher if we assume a signal strength threshold of -76 dBm. We believe that this could be a reasonable representation of indoor premises coverage, as signals are weakened by building material and thick walls. At this level,1.7% of premises are in complete not-spots and 15.5% are in partial not-spots.

The percentage of premises in not-spots is lower if we assume a signal strength threshold of -88 dBm or -92 dBm. These thresholds are considered by some MNOs to be more appropriate for the measurement of 2G mobile coverage. With these thresholds, the percentage of premises in complete not-spots is modelled to be as low as 0.1% and in partial hotspots, 1.1%.

Figure 113 - 2G mobile coverage of A- and B-roads under different scenarios

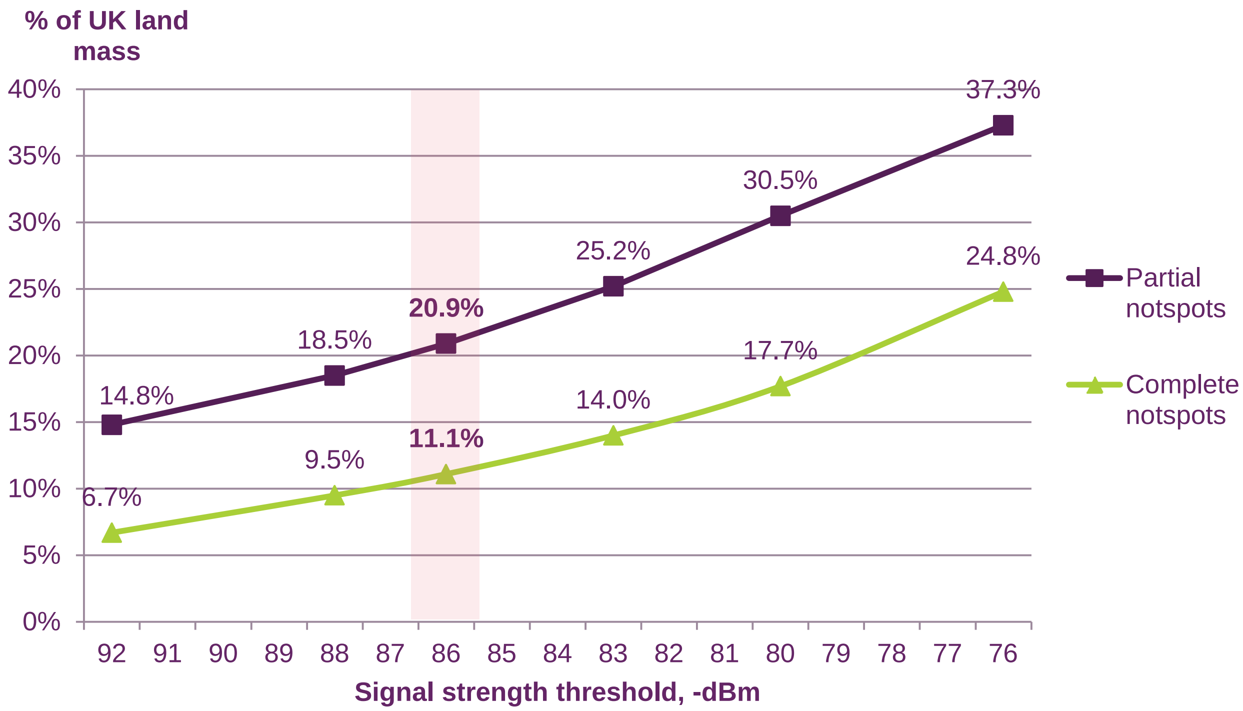


For roads coverage, our central case estimate is based on in-car coverage. For in-vehicle coverage, the 2G signal strength required could be as much as -76 dBm, similar to the case for buildings, as attenuation of signals through vehicles is higher than in an outdoor setting. In this situation, 33% of A and B road length could be in partial not-spots, with 9% in complete not-spots.

For 3G networks we have applied a signal strength threshold of >= -100 dBm RSCP CPiCH for outdoor coverage and -90dBm for indoor and in-car.

For 4G networks we have applied a signal strength threshold of >= -113 dBm RSRP for outdoor coverage and -103dBm for indoor and in-car.

Figure 114 - 2G mobile coverage of UK land mass under different scenarios



We estimated that the outdoor coverage of the UK land mass is 68%, with 11% of the UK's land area in complete not-spots and 21% in partial not-spots. When we use thresholds suggested by some MNOs, 15% of the UK's land area is in a partial not-spot and 7% is in a complete not-spot.

Annex 4

Research reports

In the process of compiling this report, Ofcom commissioned a number of external research reports to inform our analysis. The following reports are available on our website at the links below.

Report on Internet Performance Evaluation, Actual Experience	http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/performance-eval.pdf
'*Future capability of cable networks for superfast broadband*', Analysys Mason	http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/cable-sfbb.pdf
'*Roadmaps for the transition to new fixed and mobile voice technologies*', Analysys Mason	http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/new-tech.pdf
'*New service developments in the broadcast sector and their implications for network infrastructure*', Analysys Mason	http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2014/broadcast-dev.pdf
Study into UK IPv4 and IPv6 allocations, RTFM	http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/rtfm.pdf