Connected Nations 2023

Methodology Annex

19 December 2023
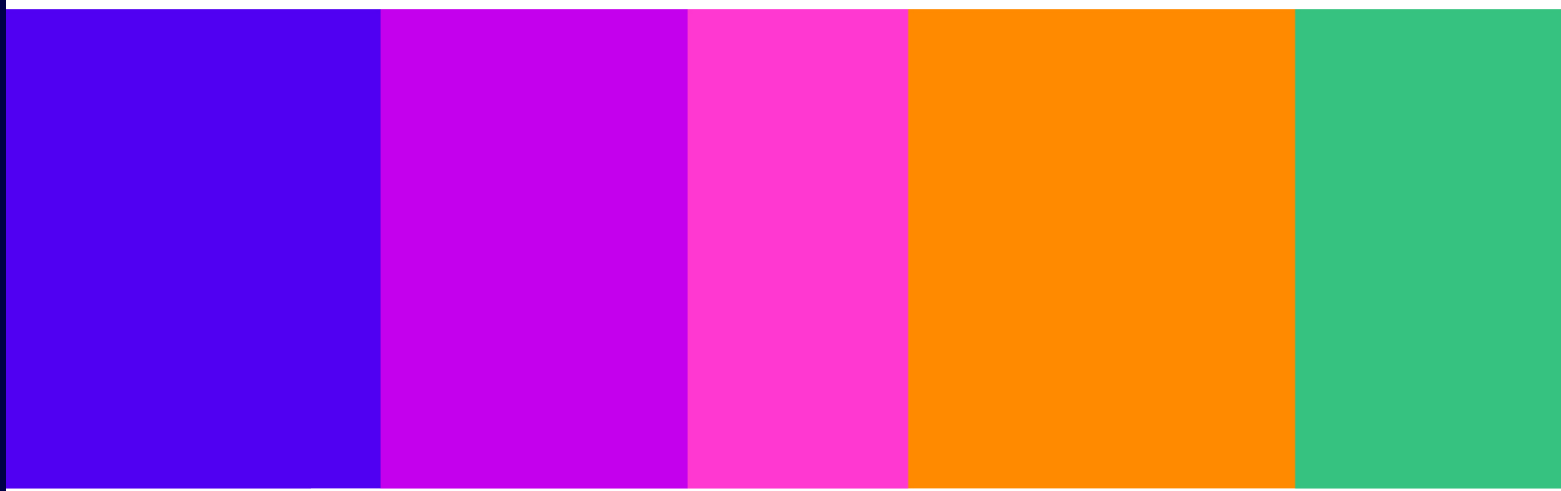
Contents

A1 Methodology

A1.1 This annex explains our approach to obtaining and analysing information from operators for the purposes of our Connected Nations reporting.

A1.2 The report uses data gathered from the providers in each sector, as well as information already held by Ofcom.

Calculating the 'premise base'

A1.3 This section explains how we identify, include, and categorise properties. In summary:

- We use property information from the Ordnance Survey's AddressBase® database including both Royal Mail postal addresses and additional property details from Local Authority sources. This ensures our 'premise base' is comprehensive and allows us to measure how network expansion is affecting all sections of the UK.
- We consider the sub-properties within a building regardless of the number of postal delivery points serving them. This ensures our overall report, as well as our published maps and apps, better reflect coverage at individual premises across the UK and are consistent with coverage information from providers.
- In the reporting we normally focus on coverage figures for residential properties. We will also highlight distinctions between residential and commercial premises where appropriate.

A1.4 The addressing products used in the annual Connected Nations include:

- Ordnance Survey AddressBase® Premium Epoch 104
- Ordnance Survey AddressBase® Islands Epoch 104

A1.5 Both products were released on 1 September 2023 and contain address information valid up to August 2023.

A1.6 Since the last full Connected Nations reporting in December 2022, we have provided two additional updates which used:

- Ordnance Survey AddressBase® Premium and Islands January 2023, Epoch 98 for the Spring Update
- Ordnance Survey AddressBase® Premium and Islands March 2023, Epoch 100 for the Summer Update

Ordnance Survey AddressBase®

A1.7 Ofcom uses the Ordnance Survey AddressBase® Premium product to provide the base dataset used to assess broadband coverage for residential and commercial premises.

A1.8 AddressBase® includes information about 44 million addresses, properties, and land areas where services are provided, by combining 3 datasets:

- Local Government National Land and Property Gazetteer (NLPG)
- Ordnance Survey MasterMap address layer
- Royal Mail Postal Address File (PAF)

A1.9 Each record in AddressBase® refers to a Basic Land and Property Unit (BLPU) and is defined in the British Standard for Addressing (BS7666) as an:

- Area of land in uniform property rights or, in the absence of such ownership evidence or where required for administration purposes, inferred from physical features, occupation or use.

A1.10   Each BLPU has a Unique Property Reference Number (UPRN), a spatial reference and one or more Land and Property Identifiers (LPI).

Method

A1.11   Our approach to identifying the 'premise base' includes three stages:

- Identifying 'Service delivery addresses': the address locations that are indicative of where a service would be provided.
- Data cleansing: for use in reporting, the premise list is linked to other attributes to identify statistical or administrative geographic units, or rurality categories. Timing of data may impact on how many records may be linked.
- Reporting definition: the inclusion of all records based on property classification or status may change dependent on the specific focus of a report.

A1.12   A Service delivery address can be defined as a premises that:

- Is able to receive mail either directly or indirectly (via a parent, sibling or holding address).
- Is not a 'parent-shell' address.
- Does not have a parent address OR parent address is classified as a 'parent-shell'. [1]

A1.13   For the identification of all UPRNs that are considered valid for analysis the following source tables are used:
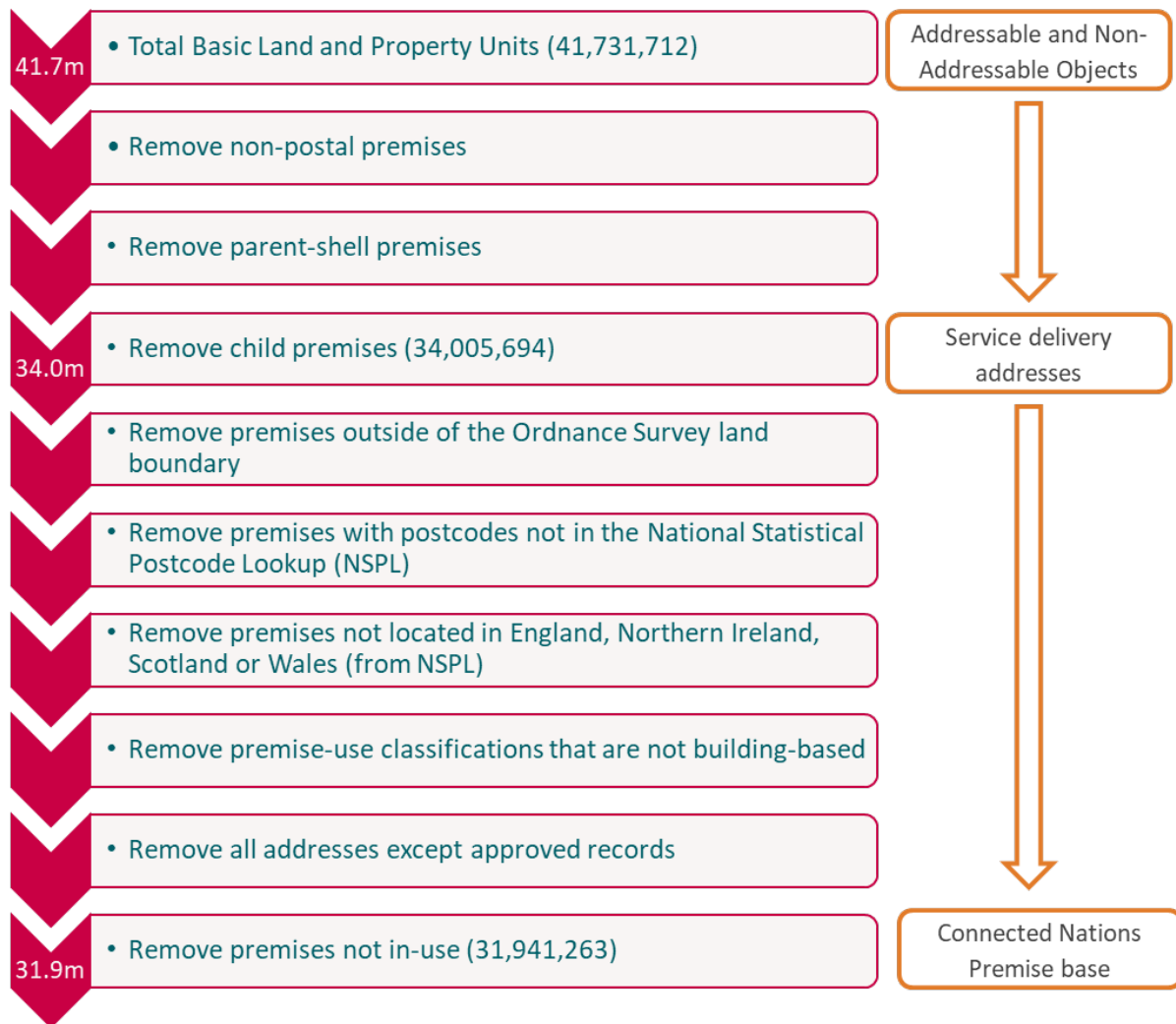
- [AB BLPU Table] AddressBase® Basic Land and Parcel Unit (BLPU) Table
- [AB Classification Table] AddressBase® Classification Table
- [NSPL Postcode Table] National Statistics Postcode Lookup Table[2]

Figure 1 shows the conceptual steps used to build the premise base.

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[1] In the Methodology Annex of our Connected Nations 2019 report we provided a number of examples of how a Service delivery address is defined.
[2] We used the 2021 Census NSPL from August 2023 to build the premise base for the Connected Nations 2023 report.

Figure 1: Conceptual steps to calculating the premise base (Epoch 104 counts)

41.7m	• Total Basic Land and Property Units (41,731,712)	Addressable and Non-Addressable Objects
	• Remove non-postal premises	
	• Remove parent-shell premises	
34.0m	• Remove child premises (34,005,694)	Service delivery addresses
	• Remove premises outside of the Ordnance Survey land boundary	
	• Remove premises with postcodes not in the National Statistical Postcode Lookup (NSPL)	
	• Remove premises not located in England, Northern Ireland, Scotland or Wales (from NSPL)	
	• Remove premise-use classifications that are not building-based	
	• Remove all addresses except approved records	
31.9m	• Remove premises not in-use (31,941,263)	Connected Nations Premise base

A1.14   The following SQL code is used to construct the premise base. A separate process is undertaken to link operator data to individual addresses.

```
SELECT
     * -- all fields
FROM
     [AB BLPU Table] b
     LEFT JOIN [NSPL Postcode Table]  n ON UPPER(replace(b.postcode_locator,' ','')) =
UPPER(n.postcode) -- join to NSPL on postcode
     LEFT JOIN [NSPL Country Table]  nc using (ctry) -- join to the country lookup
     LEFT JOIN [AB Classification Table] c ON b.uprn = c.uprn --join to classifications on
uprn
     LEFT JOIN [AB Classification Table] cp ON b.parent_uprn = cp.uprn --join to
classifications on parent_uprn
WHERE
     b.addressbase_postal IN ('D','C','L') -- is an addressable object (postal address)
AND
     left(c.classification_code,1) != 'P' --not a parent shell
AND
```

```
        (
        b.parent_uprn is null --does not have a parent
        OR
        left(cp.classification_code,1) = 'P' --has a parent, but that parent is a parent-shell
        )
AND
        b.country !='J' --uprn is within Ordnance Survey Land Boundary
AND
        n.postcode is not null --postcode exists in nspl
AND
        UPPER(nc.country_name) IN ('ENGLAND', 'NI', 'SCOTLAND', 'WALES') --UPRN in
Eng,NI,Scot,Wal (excludes Channel Islands and Isle of Man)
AND
        (
        left(c.classification_code,1)='C' -- Commercial
        OR left(c.classification_code,1)='R' -- Residential
        OR left(c.classification_code,1)='X' -- Dual Use
        OR left(c.classification_code,2)='ZS' -- Object of Interest->Stately Home
        OR left(c.classification_code,2)='ZW' -- Object of Interest->Place of Worship
        OR c.classification_code = 'OR04' -- Additional Mail / Packet Addressee
        )
AND
        b.logical_status = 1 --approved addresses only
AND
        (
        b.blpu_state IS NULL
        OR
        b.blpu_state = 2
        ) --in use premises
```

Data matching

A1.15   The availability of address-level data allows us to create a comprehensive data set describing the characteristics of all available services and operators present at premises across the UK. Many providers included a UPRN, a common identifier available for use in the UK. Other providers gave address information that would need to be processed and linked to our premise base. We received over 110 million records from fixed operators and 99.8% of our uniquely identified premise base was matched to at least one operator using the UPRN or building address reference, which forms our basis for coverage reporting.

A1.16   Our approach to address matching involves comparing records using:

- Direct matches based on the UPRN hierarchy.
- Confident matches using addresses that have an identified building number or name, street address and postcode.
- Approximate matches using addresses that have a street address and postcode.

A1.17   Figure 2 shows that just over 31 million premises (97.1%) were matched to operators only using the UPRN. Some premises were matched using different methods for each operator,

but the UPRN was the principal method for matching more than 31.8 million premises overall. Just under 10,000 premises (0.03%) were matched using address information only, compared to 26,000 premises in the December 2022 analysis.

Figure 2: Address match results to the premise base from all operators
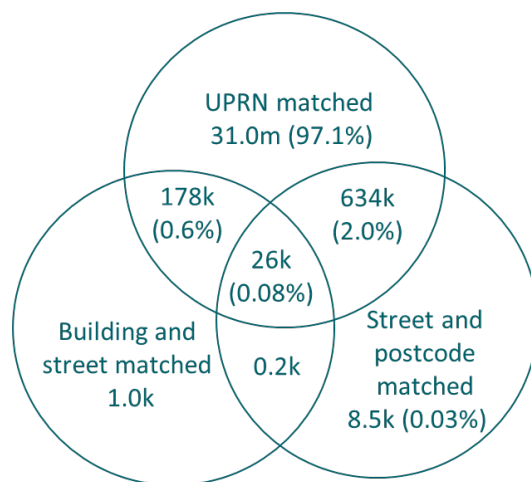
A1.18   Of the remaining 83,000 (0.3%) of premises not initially matched by UPRN or building address information, nearly 7,000 could be subsequently linked to a premise via the UPRN parent-child relationship, leaving a net total of 76,000 premises where no confident match could be used.

Postcode estimates

A1.19   Across the 110 million records received from all fixed operators, just under 145,000 (0.13%) could not be assigned to a geographic location and 74,000 records (0.07%) could only be matched to a postcode.

A1.20   As the number of non-used records is a small volume, and operator overlaps reduce the number of premises for which no information is available to 0.2% of the premise base, we have not used any postcode estimate results to ensure that we are reporting as accurately as possible at the address level.

Fixed broadband networks

Coverage

A1.21   Our data on coverage of fixed broadband services is collected from 60 fixed network providers (see our section on Data collection from providers). Operators were asked to provide data for each address where a service was provided or available to be provided, with a reference date of 1 September 2023.

A1.22   Fixed broadband coverage is calculated against the Connected Nations premise base described above. For September 2023 we have used a premise base of 31.9 million, derived from the Ordnance Survey AddressBase® Premium and Islands Epoch 104 products.

A1.23   The AddressBase® data was combined with additional geographic classifications from the ONS 2021 Census National Statistics Postcode Lookup from August 2023, and Urban and Rural categories derived from the Locale classification (see also A1.80).

Calculating availability

A1.24   Each operator provides information on the technology available together with predictions of download and upload speeds. After the address matching process, these characteristics are assigned to each premise to enable further detailed analysis to be undertaken. We apply thresholds in our analysis to investigate different patterns of provision. For coverage we have used the maximum predicted download speed available at a premise to determine in which broadband category a premise is represented.

- Since the first Connected Nations report in 2011, we have tracked the progress of superfast broadband rollout. We use 30 Mbit/s download speeds as the threshold for defining superfast services. We use the term 'Ultrafast' for services offering download speeds of 300 Mbit/s or higher.
- We also monitor the proportion of premises that do not have access to a decent broadband service, defined as a service capable of delivering a download speed of at least 10 Mbit/s and an upload speed of 1 Mbit/s. In this report we include all unmatched and unclassified premises when assessing their access to a broadband service.

Coverage for business enterprises

A1.25   Where we report on the availability of broadband services for small and medium enterprises (SMEs), we have used an address match process to link our Connected Nations premise base to a business classification system, the Dun and Bradstreet Business Universe. This data set provides 3.4 million records across classes of business, including agricultural, construction, financial, food, clothing, footwear, hotels, restaurants, pubs, local service, manufacturer, recreation, cultural, sporting activity, transport, motor, fuel and wholesale business locations. The data set is used subject to the following attributions:

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- © CACI 2023

A1.26   We linked 2.8 million (82%) records from this data set using building, or street, and postcode identification to records in the Ordnance Survey AddressBase® Premium and Islands Epoch 104 products to identify the Unique Property Reference Number (UPRN) for each business record. A further 549,000 (16%) could only be matched to postcodes, and 54,000 (2%) records could not be matched.

A1.27   Due to the reliance on building, or street, and postcode identification, there is ambiguity in the matching process. We undertook further analysis to remove business records where we were not confident in the matching result. Finally, we constrained the analysis to the 2.23 million records that are within our Connected Nations premise base.

A1.28   The definition of small and medium enterprises is based on the number of employees at the specific site. The categories of SME are:

- Micro: Sole trader and fewer than 10 employees.
- Small: 10 to fewer than 50 employees.
- Medium: 50 to fewer than 250 employees.

A1.29   It should be noted that our coverage data does not include networks deployed specifically to connect businesses (in particular, we do not gather data on leased lines specific networks). Therefore, these business sites may be able to get good connectivity, albeit via leased lines rather than broadband products.

Take-up of fixed broadband services, line speeds, and data use

A1.30   We gathered data from many, but not all, of the fixed broadband internet service providers (ISPs) listed in our section on Data collection from providers, on both their retail services and the services they provide to other ISPs as a wholesale service. This was provided with a collection period of 1 to 31 May 2023.

A1.31   We collected data on average and maximum measured speeds and data usage on all active lines.

A1.32   We also gathered supplemental data from fixed broadband providers in relation to take-up of full-fibre and gigabit-capable services, and changes to fixed voice services in the last twelve months (with a collection date chosen by providers in the period from 17 August to 7 September 2023).

Estimating take-up

A1.33   Take-up is estimated from the lines reported as discussed above (as of May 2023) as well as the total premises as of May 2023 to ensure consistency. Table 2.7 in the Connected Nations Report was derived from examining all premises with full-fibre take-up as of May 2023 and identifying in which 4-month coverage submission full fibre was first identified as being available to the property.

A1.34   For superfast take-up we included all lines where the maximum measured speed was at least 30 Mbit/s.

Measured line speeds

A1.35   Our analysis of active broadband speeds is based on the per-line average measured download and upload speeds provided by the ISPs.

A1.36   Only lines that could be assigned to a geographic location at postcode level and with a measured speed greater than zero were used in the line performance calculations. These criteria were met by 24.5 million records.

Data use

A1.37   Our analysis of data use is calculated from the amount of data downloaded and uploaded on each line as reported by the ISPs. Our analysis considers all lines used in the average speed calculations and with total data use greater than zero. These criteria were met by 21.7 million records.

Fixed voice services

A1.38   We asked the providers of fixed broadband communications to share a breakdown of the technology used to delivery voice services over the access network as of 30 June 2023. Some broadband providers do not offer voice services, and many internet voice service providers do not deploy fixed broadband networks and were therefore not approached to provide data to us, so the results obtained are indicative only.

A1.39   We also asked about the number of customers that migrated from a PSTN-based voice service to a Voice over Broadband service in the 12 months up to the collection date, and the number of customers that had moved to a broadband only service during the same period.

A1.40   Finally, we asked for a breakdown of the number of customers that had taken a Voice over Broadband service with respect to those that were new customers to the provider, existing customers that had initiated the change (for example, through a service or package upgrade) and those for which that the change was initiated by the provider.

Fixed Wireless Access

A1.41   Fixed Wireless Access (FWA) services can be provided on a mobile network by Mobile Network Operators (MNOs), where the capacity is shared with mobile users, or on a dedicated wireless network by Wireless Internet Service Providers (WISPs).

A1.42   We asked both MNOs and WISPs for a list of the properties that could be served with FWA by their network without the installation of new access points, and to specify whether this service is at least a decent broadband service. An explanation of the use of FWA to deliver a decent broadband service is available in our statement on Delivering the Broadband Universal Service.

A1.43   Our analysis of FWA coverage by WISPs uses data from 21 providers relating to their network as of September 2023, providing us with a list of premises based on their modelling of their network. The list of WISPs included in our analysis is provided in our section on Data collection from providers.

A1.44   The data from both MNOs and WISPs was matched against our premise base in the same way as fixed broadband coverage.

A1.45   We have also carried out research looking into the speeds that can be delivered to consumers using WISP networks. Using the same approach as our home broadband performance research on fixed networks[3], we conducted measurements on five WISP networks in March 2023 and present the results in our interactive report. Our results show that WISP networks can deliver decent and superfast speeds.

Satellite coverage

A1.46   Our analysis of the satellite coverage in the UK is currently limited to a single provider that offers Low Earth Orbit (LEO) satellite broadband services directly to the consumer.

A1.47   LEO satellite constellations have the capacity to deliver coverage and broadband services to all parts of the UK. We have focused our analysis on the take-up of these services and their geographic distribution.

A1.48   We have mapped geographical coordinates of customer premise equipment (latitude and longitude) to the nearest UPRN and compared these locations against other network technologies that are available at those locations.

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

Mobile

Coverage

A1.49　Our data on the coverage of mobile networks was collected from the four mobile network operators (BT/EE, Three, Virgin Media O2 and Vodafone) as 100m x 100m pixels referenced against the Ordnance Survey Great Britain (OSGB) grid system. Coverage for all networks was as of 1 September 2023.

A1.50　Premises coverage is calculated against the Connected Nations premise base for September 2023 (see A1.3 – A1.14). This is combined with additional geographic classifications from the ONS 2021 Census National Statistics Postcode Lookup from August 2023, and Urban and Rural categories derived from the Locale classification (see also A1.80).

A1.51　Roads data is taken from Ordnance Survey and Northern Ireland Land & Property Services open data sources.

A1.52　We apply the technology-specific thresholds to each of 100m x 100m pixels to determine whether a sufficiently strong signal is available to successfully make a phone call or send or receive data. These pixels are aggregated to provide an estimate of either the landmass or the number of premises that are covered by the corresponding mobile technology.

A1.53　In 2018 measurement work was undertaken by Ofcom to identify the minimum coverage level (the technology-specific threshold) required to deliver a good quality of experience to consumers on the 4G network. We also identified minimum coverage levels for 2G and 3G networks, which allows us to present a consistent view of coverage on all these networks to consumers.

A1.54　For 2G, 3G and 4G networks, we define coverage based on the minimum signal strength required to at a minimum deliver a 98% probability of making a 90-second telephone call successfully. In the case of 4G specifically, our definition also delivers a 95% chance of getting a download speed of at least 2Mbit/s. We use the signal strength thresholds shown in Figure 3 when estimating coverage.

Figure 3: Mobile strength thresholds

Service		Metric[4]	Outdoor	Indoor and in-car
2G		RxLev	-81dBm	-71dBm
3G		RSCP CPiCH	-100dBm	-90dBm
4G/enhanced data		RSRP	-105dBm	-95dBm
Voice	2G	RxLev	-81dBm	-71dBm
	3G	RSCP CPiCH	-100dBm	-90dBm
	4G	RSRP	-105dBm	-95dBm
Basic data	3G	RSCP CPiCH	-100dBm	-90dBm
	4G	RSRP	-115dBm	-105dBm
5G high confidence		SS-RSRP	-110dBm	N/A
5G very high confidence		SS-RSRP	-100dbm	N/A

A1.55 For 5G networks, we define availability of coverage based on the minimum signal strength (SS-RSRP) required for devices to establish a reliable 5G connection. This definition supports a reporting framework suitable for different variants of 5G in low, mid, and high frequency bands, without inferring a typical service or performance (although where a reliable connection is established, we would expect core data services to be supported, subject to available capacity).

A1.56 We provide a view of outdoor 5G coverage availability across a range that provides increasing confidence of a reliable 5G connection, from high confidence (where a signal strength of -110 dBm or better is predicted) to very high confidence (where a signal strength of -100 dBm or better is predicted). We associate the High Confidence level with at least an 80% probability of coverage being present in the predicted location, and the Very High Confidence level with around a 95% probability.

A1.57 Noting that operators supply predictions to Ofcom based on a 50% confidence level across a pixel, to establish these higher confidence levels we have worked back from the on-the ground thresholds typically used as the limit for maintaining a 5G connection. We have then accounted for the overall effectiveness of operators' 5G predictions (prediction error statistics) and local level variability, as well factoring in the differences between handset

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[4] **RxLev:** the Received Signal Level in 2G networks.
  RSCP CPiCH: the Received Signal Code Power on the primary Common Pilot Channel for 3G networks.
  RSRP: the Reference Signal Received Power in 4G networks.
  SS-RSRP: the Synchronization Signal reference signal received power in 5G networks.

performance. The consequential combined standard deviation across these effects (which we have taken to be in the region of 12 dB), enabled us to establish signal strengths at which predictions supplied to us on a 50% reliability basis from a reasonable prediction model were likely to align with high (-110 dBm @80%) and very high confidence (-100dBm @95%) of coverage in a given location.

Mobile prediction models

A1.58   The mobile coverage figures provided in this report rely on the accuracy of coverage prediction data supplied by the mobile operators. We note that operators continue to update and improve their prediction models, which is welcome.

A1.59   We take the accuracy of the data supplied to us seriously given its importance to policy making and to ensuring people are well informed about available coverage. We will continue to monitor, through drive testing, the accuracy of all operators' coverage predictions.

A1.60   We are aware that operators continue to work on refining their predictions and Ofcom will continue to engage and encourage operators to focus on an approach that provides consumers with confidence in coverage being reliably available where it is predicted.

Data use

A1.61   This data was collected in May 2023 and included information on the amount of data uploaded and downloaded on each mobile cell in these networks. The geography of data traffic is defined by the location of the associated mobile cell base station.

Mobile performance and crowdsourcing

How crowdsourcing works

A1.62   Mobile crowdsourcing works by collecting anonymous measurement information from consumer mobile devices to provide a view of network performance from a user perspective. To achieve significant scale and a broad distribution of samples, the mobile crowdsourced data is collected through partnerships with popular mobile applications with a considerable number of users. These partners embed the crowdsourcing software (known as a software development kit, or SDK) in their own apps to collect performance measurements.

A1.63   We are working with a mobile crowdsourcing data provider named Opensignal, who have provided us with access to a crowdsourced dataset. This allows us to assess the latest view of mobile network performance from the consumer's perspective.

A1.64   No personal identifiable data is passed on to Ofcom and throughout the crowdsourced data collection process. Opensignal have assured us that no personal identifiable data is collected and that all collected data are further anonymised in a way such as not to be able to identify any individual or individual usage patterns.

Measurement methodology

A1.65   With Opensignal's crowdsourcing platform, data is collected in places where people use their mobile devices all around the UK covering both rural and urban areas, as well as indoor and outdoor locations, and at all times of day, weighted towards the times that those devices are in use the most.

A1.66   Two types of tests are performed when collecting the data: active background tests and passive measurements. Active background tests are those defined and initiated by Opensignal to measure the device's network performance irrespective of the user's activity. Passive measurements refer to the collection of information regarding the current network environment, such as signal strength, from the device operating system. We are only using the data from active background tests for our current assessment.

A1.67   To ensure diversity and robustness of measurement data, active tests are conducted according to a set of triggers defined by Opensignal which are activated in a variety of situations, including changes to location and network configuration, app activity and when certain timers elapse. The combination of these triggers ensures measurements are performed throughout the day, providing a broad and representative set of network performance data.

A1.68   From the measurements calculated during the active background tests, we focussed on three Key Performance Indicators (KPIs), namely **Download throughput, Upload throughput and Latency**. These metrics are in line with activities performed in consumer mobile applications and are likely to closely reflect the perceived consumer quality of service. The way each of these metrics are calculated is further detailed below. [5]

Download throughput

A1.69   Download throughput tests are performed by downloading files of various sizes using the Hypertext Transfer Protocol (HTTP) [6] from content delivery networks (CDNs) File sizes of 2MB, 5MB and 10MB are used to perform download throughput tests and these simulate a typical user download activity i.e. downloading a webpage. Note that this measurement does not measure the maximum throughput of the network but is typical of customer interactions and can be used to measure relative performance between operators.

Upload throughput

A1.70   For upload throughput tests, Opensignal uses a 1MB file to perform an upload throughput test. The file is sent using HTTP to CDNs used by typical internet applications. This test simulates a user performing a typical upload activity i.e. uploading an image. As with download, the upload tests do not give the maximum upload throughput of the network but is representative of typical usage and can be used to compare relative performance between operators and devices.

Latency

A1.71   Latency is half of the round-trip travel time of each packet from the time the packet is sent from the SDK to when the same packet is received. These tests are performed over the User Datagram Protocol (UDP), a connectionless protocol. Unlike the Transmission Control Protocol (TCP), connectionless protocols such as UDP utilise minimum handshaking [7] and are used in latency sensitive applications such as video and VoIP calling. For latency tests, the closest test server is chosen based on geographical distance between test server and SDK device. One hundred packets are then sent from the SDK to the test server and the precise

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[5] More detailed information on KPI metrics can be found in Opensignal's website.
[6] HTTP is a set of rules that governs how communication is exchanged over the internet between a client, for example a user web browser, and a server such as a website. This set of rules enable the transfer of information such as text, images, sound, video, and other multimedia files over the web.
[7] The processes of setting up a communication link.

time that each packet is sent is recorded to millisecond precision. 20ms spacing is kept between each packet transmission. The test server receives the packets sent from the SDK and immediately echoes them back to the listening SDK device. The precise time that each packet is received is also recorded. The Latency KPI is then calculated based on the average measured latency from the 100 packets.

Data analysis methodology

A1.72　We set out below our methodology for processing this data to enable us to meet our objective of assessing the quality of network performance available to a typical user. These are:

a) We processed a dataset which had been gathered over a nine-month period,[8] recognising the need to maintain a good balance in terms of providing a recent view of the network performance (considering that networks evolve over time) but also ensuring that enough historical samples are included to be statistically significant for making an assessment.

b) Splitting the view of the data by geographical areas. In the case of this Connected Nations report, UK postcode districts have been used to provide detailed local insight while ensuring sufficient samples in most areas to provide statistical significance. [9]

c) Grading the consumer quality of service in each area into 4 main performance classes, namely **Basic, Good, High and Very high performance** based on whether all the Key Performance Indicators (KPIs) mentioned above meet or exceed all the thresholds defined for a given performance class as shown in Figure 4.

d) Assigning a postcode district's overall performance class is done by determining the highest performance class achieved by at least 80% of the crowdsourced data recordings that took place within it. For example, suppose 90% of all individual data recordings taken within a specific postcode district meet the criteria for 'good performance', 80% meet the criteria for 'high performance', and 70% meet the criteria for 'very high' performance. In that case, the postcode district will be classed as 'high performance'. If less than 80% of measurements meet the 'good performance' criteria, the postcode district will be classified as 'basic performance'. If there are not enough individual measurements recorded within a postcode district to make a statistically reliable assessment, then that postcode district will be classed as having 'unknown performance'.

e) Increasing the reliability of our performance assessment by setting out a minimum number of unique device types in our postal district sample (as well as a minimum sample count as in (d)) that must be met before a postcode district can be classified as having a particular performance class (see statistical confidence section). This is to avoid the case that a small number of users are responsible for a large number of measurements in a district, potentially disproportionately affecting the overall classification. If this threshold on the number of unique devices is not met, the postal district is classified as 'unknown performance'.

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[8] For this report we have used data from 1st January to 30th September 2023
[9] Postcode district means a geographical area indicated by the (alphabetical) letters and numbers in a postcode preceding the space in the code e.g. SE1.

Figure 4: Key Performance Indicator thresholds for each performance class

Performance class	Download throughput	Upload throughput	Latency
Basic	<2 Mbit/s	<0.5 Mbit/s	>100ms
Good	>=2 Mbit/s	>=0.5 Mbit/s	<=100ms
High	>=5 Mbit/s	>=1 Mbit/s	<=50ms
Very high	>=10 Mbit/s	>=2 Mbit/s	<=30ms

A1.73 We will continue to evolve our approach to ensure we provide the most accurate picture of network performance, even as networks and consumer devices continue to evolve, and new capabilities are enabled by crowd source platforms.

Statistical confidence

A1.74 To ensure that the sample data from each postcode district is statistically robust, we have only included a performance view for postcode districts that meet both the following criteria:

- o Minimum of 100 crowdsourced data recordings taken within the postcode district; and
- o Minimum of 15 unique device types contributing crowdsourced data recordings in this postcode district.

A1.75 These criteria ensure that the data recordings used to summarise the mobile performance of a postcode district come from a variety of individuals (rather than only one or two phones contributing all the measurements) and are from a sufficiently large sample of measures, reducing the margin of error around the percentage of data recordings meeting a performance class.

A1.76 For Connected Nations 2023 we have decided to remove a possible change to a postal district's performance classification based on a 10% margin of error and a 97% statistical confidence level, as was used in Connected Nations 2022. The purpose of this possible change to a postal district classification, based on the crowdsourced measurements within it, was to ensure that any postal district classification was statistically significant. Since we are using a threshold of 80% of a district's measurements (at a given level e.g. basic/good/high/very high) to classify a district, our certainty in that classification depends on

- (i) the number of samples in the district, and
- (ii) how close the measured proportion is to the 80% threshold.

A1.77 However, following a sensitivity analysis, we have concluded that our additional constraint of 100 measurements and 15 unique devices per district - failing this a district is classified as 'performance level unknown' - is in fact sufficient to ensure statistical significance in our district level classification. For this reason, we have decided to simplify our methodology and no longer apply a possible change based on the Margin of Error in Connected Nations 2023.

A1.78   Our use of statistical parameters is informed by analysis of the overall dataset and the distribution within, and our view on best practice approach to statistical significance, as well as consultation with Opensignal. As with our measurement methodology, we will keep this statistical approach under review as we develop our further assessment of mobile network performance.

Limitations

A1.79   As noted in our UK report, we recognise that no single tool is likely to provide a complete view of mobile network performance that distinguishes all influencing factors. For example, this approach does not currently enable us to provide insights across the entirety of UK, given the limited samples available in the many rural areas. It also aggregates samples from different device locations at the time of the test (e.g. whether a device was indoors or outdoors) and whether the test was conducted at a very busy period or not, such that additional, more granular insight may be possible over time. We will consider whether and how our approach can be refined as we make greater use of crowdsourced data in the future.

Urban and rural classifications

A1.80   We have used the Locale classification to identify premises as being in an urban or rural area. Locale is a third-party data source based on the analysis of 2011 census output areas (OAs). Each OA is assigned to one of seven Locale Groups using a combination of Government conurbation definitions, population density at the OA and postcode sector levels, urban sprawl boundaries, OS roadmaps and additional visual inspection

A1.81   We assign the Locale classifications to either Urban or Rural based on the following:

- Urban: Codes A to C relate to settlements with populations over 10,000 and codes D to E relate to settlements with populations over 2,000.
- Rural: F to G relate to settlements with populations under 2,000.

A1.82   For fixed broadband analysis, every premises is assigned to a census output area via its postcode. For mobile analysis, each pixel is assigned to a census output area through a spatial comparison of the pixel OSGB[10] coordinates to the corresponding census output area polygon. The Locale urban and rural classification is then matched to these records via the census output area.

Geographic boundary changes

A1.83   Our analysis and reports use the 2021 Local Authority boundaries and consequently do not reflect the changes from 1 April 2023. [11] We will use the 2023 Local Authority list from next year onwards.

A1.84   The 2021 Local Authority list consists of 374 Lower Tier authorities: 309 in England, 11 in Northern Ireland, 32 in Scotland, and 22 in Wales. The 2023 changes reduce the number of Local Authorities in England to 295 and the UK total to 360.

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[10] **OSBG:** Ordnance Survey Great Britain – see https://www.ordnancesurvey.co.uk/documents/resources/guide-coordinate-systems-great-britain.pdf
[11] https://blog.planningportal.co.uk/2023/03/24/local-authority-changes-from-1-april-2023/

A2 Data collection from providers

Ofcom requested data from communication providers using our powers under section 135 of the Communications Act 2003 and Regulation 17 of the Statutory Instrument 2016/607.

Under section 134A of the Act, Ofcom is required to prepare a report for "each relevant period" as defined in section 134A(4) of the Act; the matters on which we need to report are listed in section 134B of the Act.

Fixed network providers

The data for fixed networks was obtained, or continued to be used, from the following providers:

- 1310
- 4th Utility (Vision Fibre)
- Airband
- Ask4
- Atlas Communications
- Axione
- Bogons
- Borderlink (GoFibre)
- Box Broadband
- British Telecommunications plc
- Broadband for Rural North (B4RN)
- brsk
- CityFibre
- Community Fibre
- Connect Fibre / Fibre Asset
- Connexin
- Country Connect
- County Broadband
- ECom - Electronic Communities
- F&W Networks
- FACTCO
- FibreSpeed
- Fibrus Ltd
- Full Fibre
- G.Network
- Gigaclear
- Glide Business Limited
- Grayshott Gigabit
- Hampshire Broadband
- Hyperoptic
- ITS Technologies
- Jurassic Fibre
- KCOM
- Lightning Fibre
- LightSpeed
- Lothian Broadband Networks
- Modern Networks
- MS3
- MyFi
- Netomnia
- nexfibre
- Open Fibre Network Limited (OFNL)
- Openreach
- Orbital Net
- Persimmon Homes t/a FibreNest
- Quickline
- Sky
- Spectrum Internet Ltd (NSUK)/Ogi Wales
- Swish Fibre
- TalkTalk
- Technological Services
- Telcom
- Toob
- Trooli
- Truespeed
- Upp
- Velocity1
- Virgin Media O2
- Vodafone Ltd
- Voneus
- VX Fiber
- Wessex Internet
- WightFibre
- Wildanet
- York Data Services
- Zen

- Zzoomm

Fixed wireless access operators

The data for fixed wireless access networks was obtained, or continued to be used, from the following providers:

Wireless internet service providers

- Airband
- Borderlink (GoFibre)
- Connexin
- County Broadband
- Cromarty Firth Wireless
- Fram Broadband
- Highland Community Broadband
- Highland Wireless & IT Solutions
- IX Wireless
- Intouch
- Kencomp
- Lothian Broadband Networks
- Net1
- Orbital Net
- Quickline Communication + Boundless
- Secure Web Services Limited (SWS)
- Stixinternet
- Voneus/IRG Computers Ltd (ResQNet)
- Wessex Internet
- Wifi Scotland
- WildaNet

WISPs are removed from the list if we do not get new data or confirmation that previous data remains unchanged.

Mobile networks

- British Telecommunications plc/EE
- Hutchinson 3G UK Ltd (Three)

Satellite providers

- Starlink

Mobile network operators

The following mobile network operators supplied data for use in this report:

- British Telecommunications plc/EE
- Hutchinson 3G UK Ltd (Three)
- Virgin Media O2
- Vodafone Ltd

Neutral host providers

- Cellnex
- Britannia Towers 11
- Freshwave Networks
- Wireless Infrastructure
- Boldyn

IoT providers

- Connexin
- North SV

A3 Glossary

2G: Second generation of mobile telephony systems and the first digital mobile technology, launched in the UK in 1992. Uses digital transmission to support voice, very low-speed data communications, and short messaging services.

3G: Third generation of mobile systems, launched in the UK in 2003. Provides low-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, launched in the UK in 2012. It is designed to provide faster data download and upload speeds on mobile networks and can also support VoIP services.

5G: Fifth generation of mobile technology standards, launched in the UK in 2020 and used to deliver higher speed data services.

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'.

All roads: Motorways, A and B roads.

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.

Cloud computing: The provision of remote access to computing resources (compute, storage and networking) on demand and over a network (public internet or a private connection), instead of a personal computer or local server that are not part of the cloud.

Data (Mobile): The combination of 3G with lower speed 4G data services where either are likely to provide a connection speed of at least 200 kbit/s for nearly all connections. These connections are likely to be sufficient to support lower speed data services such as web-browsing, as opposed to higher resolution video.

Decent broadband: A data service that provides fixed download speeds of at least 10 Mbit/s and upload speeds of at least 1 Mbit/s or an indoor 4G mobile service with a connection speed of at least 2 Mbit/s.

Fibre to the cabinet (FTTC): A fixed access network technology that consists of a fibre optic cable from the exchange to a street cabinet, with copper cables used to connect the cabinet to the premises.

Fixed wireless access (FWA): A fixed broadband access technology that supports broadband services via a wireless network – either via a mobile network operator (MNOs) or wireless internet service provider (WISP).

Full fibre, also known as fibre to the premises (FTTP): A fixed access network technology that consists of a fibre optic cable from the exchange to the end user's home or office.

Gigabit capable: Broadband services that can deliver 1 Gbit/s download speeds.

Hybrid fibre coaxial (HFC) cable: A fixed access network technology that consists of a fibre optic cable to a street cabinet and coaxial cable from the street cabinet to the premises.

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

Low Earth orbit (LEO) satellites: satellite constellations that orbit at below 2,000 km and deliver satellite communications services, including lower latency broadband.

Major roads: Motorways and A Roads.

Mobile network operator (MNO): A provider which owns a cellular mobile network.

Not-spot: An area which is not covered by mobile networks.

Public Switched Telephone Network (PSTN): the UK's legacy landline network.

Superfast broadband: A data service or connection that can deliver download speeds of at least 30 Mbit/s.

Voice (Mobile): Mobile voice services that are managed by the mobile network (as opposed to a third party voice App on a handset). The criteria for the availability of mobile voice services is given in the Methodology section above.

VoBB (Voice over Broadband) A technology that allows users to make and receive calls using internet protocol, for which the quality of service is managed by the broadband provider.

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 (e.g. VoBB).

Wholesale services: Products and services made available to third party communications providers on a wholesale basis and which act as inputs to their Services.

Wireless internet service provider (WISP): Broadband service providers using a wireless link between a provider's mast site and an external antenna fixed to a customer's premise. These are dedicated networks for broadband customers only. These networks mostly use spectrum under licence exemption or light licence authorisation.