Mobile Matters

Using crowdsourced data to assess people's experience of using mobile networks

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Overview

Being able to use a smartphone over a high quality, reliable mobile connection is essential for most people in the UK. To better understand the experience of using mobile data services, Ofcom has analysed crowdsourced data collected between October 2023 and March 2024 from mobile devices across the UK.

In this report, we focus on the cellular technologies people are connected to when using data services (2G, 3G, 4G, 5G[1]), how often they could connect to data services when using their phone in a coverage area, the time to download and upload different sized files, the response times of different cellular technologies, and the distributions of download and upload speeds. We also look at how these vary by mobile network operator (MNO) and location.

Our report is based on test data provided by Opensignal, which we have analysed using our own statistical methodology. In a change from last year's report, we have excluded tests run on Apple iOS devices and those where the device operating system was not identified and, as a result, the findings in this report are not directly comparable to those published in the 2023 Mobile Matters report.

The analysis in this report is conducted at the MNO retail customer level, i.e. customers using mobile virtual network operators (MVNOs) are excluded from the analysis. The sample distribution broadly matches both the population distribution of the UK, and the relative operator shares, and we have ensured that the sample sizes are sufficient to ensure the robustness of the findings.

For a more detailed description of the data collection and analysis, please see A1. Technical methodology and A2. Statistical methodology. An interactive dataset can be accessed is available.

Mobile network performance is only one factor that people may wish to consider when making decisions about their mobile service. Price, handset model, quality of customer service, coverage and contract terms are other relevant aspects that should be considered.

The data in this report relate to network performance where coverage is available from an operator. Coverage is a measure of signal strength (as shown by the 'bars' on a mobile phone) and sufficient coverage is required to run the various performance quality tests which are used to obtain the data presented in this report.

This research is part of a wider programme of work by Ofcom to research and provide information regarding mobile quality of experience. Ofcom's Broadband and mobile coverage checker maps mobile coverage levels (signal strength) as predicted by each MNO. This information is not directly comparable to the crowdsourced data presented in this report.

[1] In this report, we include connections to both 5G non-standalone (NSA) and standalone (SA).

What we have found – in brief

Share of cellular network connections

- **5G and 4G accounted for 97.6% of cellular network connections**. Our analysis shows that 78.0% of cellular network connections were to 4G networks over the 6-month period we looked at, with 19.6% of connections being on 5G networks, 2.3% over 3G and just 0.1% were on 2G.

Comparison of cellular technologies

- **The proportion of cellular data connections that were successful was highest on 5G.** Where a 5G network was available from their mobile network operator, mobile users were able to access data services on a 5G network on 98.4% of occasions. This compared to 97.2% over 4G and 85.0% over 3G.
- **The time taken to download a 2MB file was much longer over 3G than 4G and 5G.** Downloading a smaller (2MB) file can be representative of many typical activities undertaken on mobile devices, for example downloading photos or short low-resolution video clips in messaging apps or social media usage. On average, it took 4.3s to download a 2MB file over 3G, compared to 0.8s on 4G and 0.3s over 5G.
- **Larger file downloads highlight the benefit of 5G over 4G.** While 2MB downloads took an average of 56% less time over 5G than 4G, 5MB downloads took 65% less time on 5G than over 4G.
- **Upload times for 1MB files were shortest on 5G.** On average, it took 0.5s to upload a 1MB file over 5G, a significantly shorter amount of time than the 0.8s average over 4G and the 3.8s average recorded on 3G.
- **5G networks offer faster downstream connectivity than 4G and 3G.** We analysed data connection speeds using tests that consume as much data as possible over the duration of the test. The results of these show that 47% of 5G connections had an average download speed of 100 Mbit/s or higher (vs 11% on 4G and 4% on 3G) and 1% had an average speed of under 2 Mbit/s (vs 5% on 4G and 22% on 3G).
- **The same is true for upload connection speeds over 5G.** The results of similar timed upload tests show that 29% of 5G uploads had an average speed of 20 Mbit/s or higher (compared to 15% on 4G and 3% on 3G) and 11% were less than 1 Mbit/s (compared to 20% on 4G and 44% on 3G).
- **Response times on 3G are around double those on 4G and 5G.** Average response times (latency) recorded over 3G connections (42.3ms) were around twice of those on 4G (21.9ms) and 5G (18.9ms).

MNO comparison

- **Three customers had the highest proportion of cellular network connections that were on 5G.** Over the period we looked at, 21.4% of Three cellular network connections were on 5G. Vodafone had the lowest proportion of connections that were on 5G (15.0%) and the highest average share of connections on 4G, at 82.7 %. O2 customers had the lowest 4G proportion, at 73.9%.
- **EE had the highest average data connection success rates over both 4G and 5G.** However, the differences observed between the MNOs' 5G and 4G data connection success rates were very

small (with there being less than 0.5 percentage points between the lowest and highest recorded values for each technology).

- **File downloads took longer on O2 than on the other MNOs' networks.** This was true of 2MB, 5MB and 10MB file downloads over both 4G and 5G mobile networks.
- **Three had the fastest average response time (latency) over 5G.** Over 4G, EE had the fastest average response time (18.3ms), while O2 customers had the slowest average response time on 5G (21.4ms) and Vodafone had the slowest response time on 4G (23.7ms).
- **Three had the highest share of 5G download speeds at 100 Mbit/s or higher (60%).** The proportion of O2 connections with a 100 Mbit/s+ download speed over both 5G (32%) and 4G (3%) was much lower than the other MNOs and O2 also had the highest proportion of 5G and 4G download speed measurements that were under 10 Mbit/s.
- **EE had the highest proportion of 5G and 4G upload speed tests that were 20 Mbit/s or higher.** EE also had the lowest proportion of upload speeds under 1Mbit/s over 5G, while Vodafone customers had the lowest proportion under 1 Mbit/s on 4G. O2 had the lowest proportion of 5G and 4G speed tests at 20Mbit/s or higher, and the highest proportion under 1Mbit/s over both cellular technologies.

Comparison by nation and rurality

- **The share of cellular network connections that were on 5G was twice as high in urban areas than in rural areas.** In urban areas of the UK, 20.9% of cellular network connections were on 5G, compared to 10.4% in rural areas. In rural areas, the proportions of connections on 4G and 3G were higher than in urban areas.
- **Differences in 5G and 4G data connection success rates across the UK nations were only small.** Our analysis showed bigger differences over 3G, with Northern Ireland having the highest and Wales the lowest average success rates. Connection success rates were higher in urban areas than in rural areas at a UK level over 3G, while the opposite was true for 4G and 5G (although the differences were small).
- **There was minor variation in 2MB file download times over 5G and 4G across the UK nations.** The observed differences were larger over 3G, with England recording shorter average time to download a 2MB file (4.3s) than Northern Ireland and Wales (4.8s and 4.6s respectively). The average time to download a 2MB file was longer in rural areas than in urban areas over all three cellular technologies at a UK level.
- **Northern Ireland had a lower-than-average proportion of 5G and 4G download speed measurements of 100 Mbit/s or higher and a higher proportion under 10 Mbit/s.** Urban connections had a higher proportion of faster connections and a lower proportion of slower connections than in rural areas over all three cellular technologies at a UK level.
- **Northern Ireland also had the lowest proportion of 5G upload speeds at 20 Mbit/s or higher (25%) and the highest proportion under 1 Mbit/s.** Over 4G, Northern Ireland and Wales had a lower-than-average proportion of upload speed tests with speeds of 20 Mbit/s or higher, and a higher-than-average proportion under 1 Mbit/s. The proportion of upload speed tests at 20 Mbit/s or more was higher (and the proportion under 1 Mbit/s lower) in urban areas than in rural areas across all three cellular technologies.

Share of cellular network connections

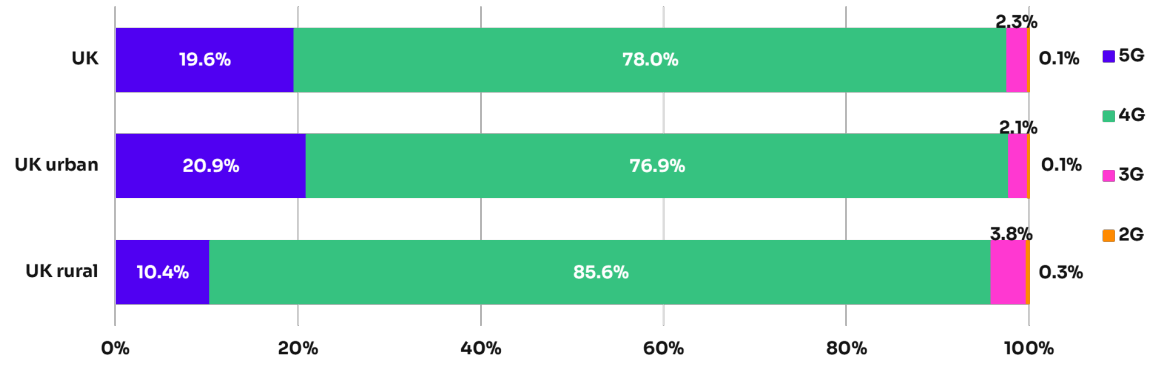
Analysing the cellular technology that people connect to gives an indication of the experience they will get when using mobile services, as advances in cellular technology are associated with better performance in relation to responsiveness and throughput speeds.

The analysis in this section is different to the network share metric published in last year's report, as it uses the technology split of cellular data connection attempts when a user's device was already connected to a cellular network (they were in a coverage area with an active service plan and had the appropriate handset capability for the technology in question), rather than the proportion of time spent connected to different cellular technologies.

Our analysis shows that 78.0% of cellular network connections were to 4G networks over the six-month period we looked at, with 19.6% of connections being over 5G. An average of 2.3% of cellular network connection was to a 3G network, and 0.1% to 2G networks.[2]

The proportion of cellular network connections that were on 5G was twice as high in urban areas (20.9%) than in rural areas of the UK (10.4%). In rural areas, the proportion of connections on 4G (85.6%) and 3G (3.8%) networks were higher than in urban areas (76.9% and 2.1% respectively).

Figure 1: Proportion of cellular network connections by cellular technology and rurality



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Data is not directly comparable to the findings published last year due to a change in the methodology Ofcom used to derive these figures; data only relates to areas where there was cellular network coverage.

[2] 2G and 3G may be under-represented as we do not get crowdsourced data from featurephone users, who are more likely to be 2G or 3G only.

Network changes

With 5G and/or 4G mobile services being available across most of the UK, the four UK mobile network operators (MNOs) have said that they will not offer 2G and 3G services beyond 2033.

BT/EE and Vodafone have already switched off their 3G networks, while Three started this process in April 2024 and Virgin Media O2 (O2's parent company) plans to switch off its 3G services in 2025.

As some of the providers have started their 3G switch-off process in our analysed period (October 2023 – March 2024), we have not included 3G performance results at an MNO level in this report, however, each MNO's cellular network connection share on 3G is shown below.

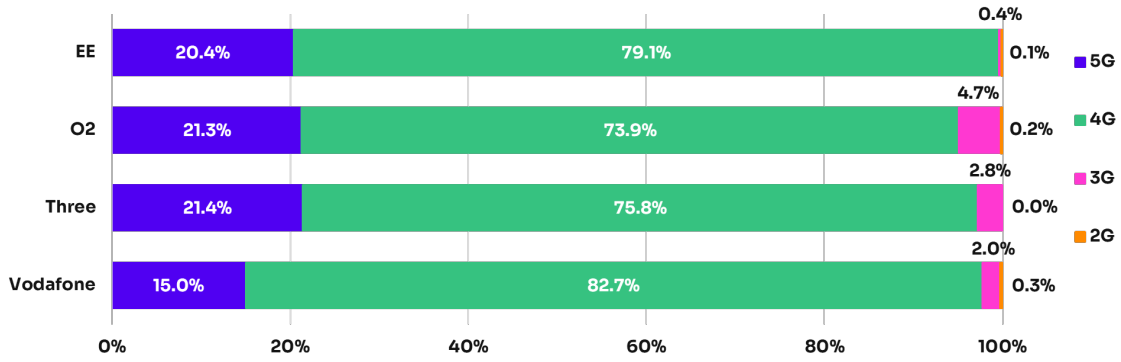
While Ofcom does not have a formal role in the switch-off process, we want to ensure that customers are treated fairly and can continue to access the services they need.

Currently, almost all 5G in the UK is offered using 5G non-standalone access (5G NSA), which uses a 5G radio access network, but relies on 4G core network. While 5G NSA uses a 4G LTE core, standalone 5G (5G SA) replaces this with a 5G core and can deliver much lower latency than 5G NSA. In this report, our analysis of 5G services combines both 5G NSA and 5G SA connections.

UK mobile providers have started to deploy 5G SA services: Vodafone launched its commercial 5G SA service in mid-2023, while Virgin Media O2's 5G SA network went live in February 2024. BT has suggested EE's 5G SA services will launch later in 2024, while Three has not announced its plans yet.

Three customers had the highest average proportion of cellular network connections that were on 5G networks (21.4%), while Vodafone customers had the lowest proportion of connections that were on 5G across the MNOs (15.0%). Over 4G, Vodafone customers had the highest average share of connections, at 82.7%, and O2 customers had the lowest 4G proportion, at 73.9%. The proportion of cellular network connections that were on 3G networks was highest among O2 customers, at 4.7%, while the proportion of cellular connections that were on 2G networks was low for all MNOs.

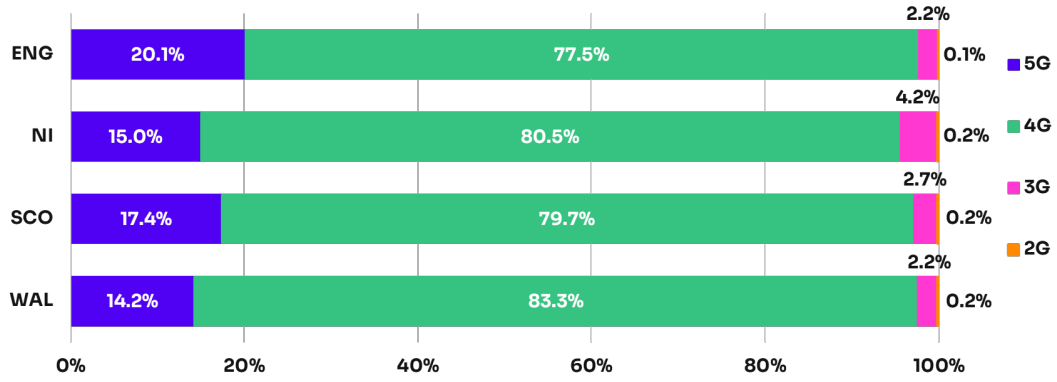
Figure 2: Proportion of cellular network connections by cellular technology and MNO



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Data is not directly comparable to the findings published last year due to a change in the methodology Ofcom used to derive these figures; Three does not operate a 2G network; BT/EE and Vodafone switched off their 3G networks during our data collection period; data only relates to areas where there was cellular network coverage.

Across the UK nations, England had the highest proportion of cellular network connections that were on 5G (20.1%), while Wales had the lowest proportion of 5G connections (14.2%). Conversely, Wales had the highest share of 4G connections (83.3%) and England the lowest (77.5%). The proportion of connections that were on 3G was highest in Northern Ireland (4.2%) and joint-lowest in England and Wales (both 2.2%). Our analysis found that the proportion of connections that were on 2G networks was low across all four UK nations.

Figure 3: Proportion of cellular network connections by cellular technology and nation



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Data is not directly comparable to the findings published last year due to a change in the methodology Ofcom used to derive these figures; data only relates to areas where there was cellular network coverage.

Across all four UK nations, the proportion of connections on 5G networks was higher in urban areas, while on 4G and 3G networks it was higher in rural areas.

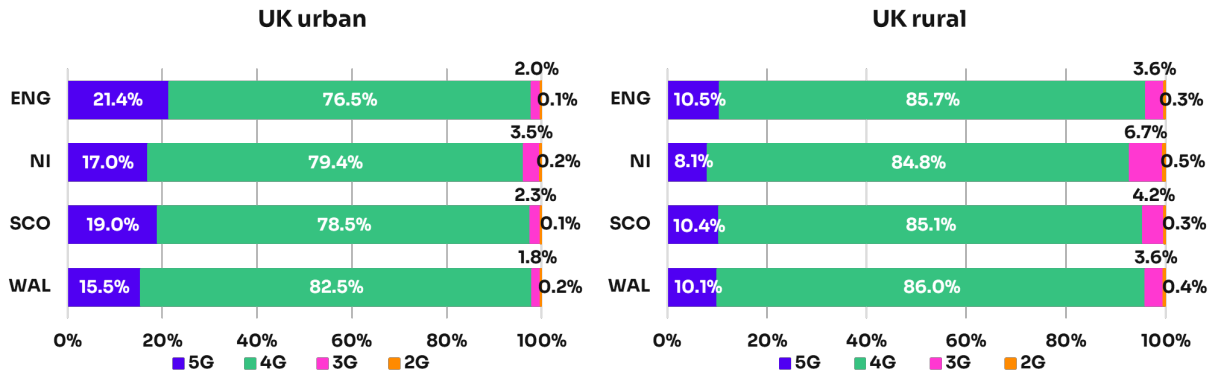
In urban areas, England had the highest proportion of cellular network connections on 5G (21.4%), while Wales had lowest proportion, at 15.5%. Conversely, Wales had the highest proportion of connections on 4G networks (82.5%), while England had the lowest proportion, at 76.5%. The

proportion of connections that were on 3G networks was highest in Northern Ireland amongst the four UK nations, at 3.5%, while Wales had the lowest proportion, at 1.8%.

In rural areas, England and Scotland had the joint-highest proportions of 5G connections (10.5% and 10.4% respectively), while Northern Ireland had the lowest proportion, at 8.1%. The proportion of rural connections on 4G networks was highest in Wales (86.0%) and lowest in Northern Ireland (84.8%). On 3G networks, the proportion of connections was highest in Northern Ireland (6.7%) and joint-lowest in England and Wales (both 3.6%).

In both urban and rural areas, the proportion of 2G connections was low across all four UK nations.

Figure 4: Proportion of cellular network connections by cellular technology, rurality, and UK nation



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Note: Data only relates to areas where there was cellular network coverage.

Data connection success rate

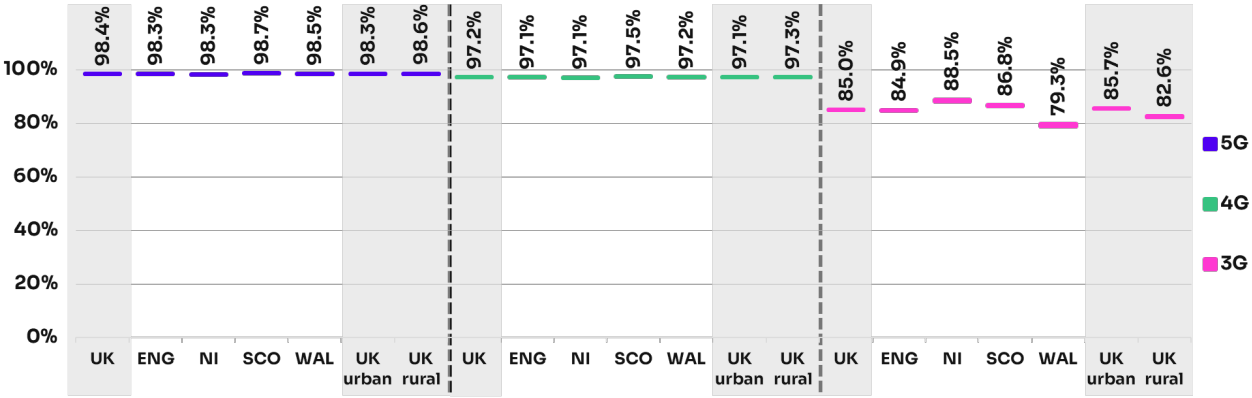
Analysis of data connection success rates shows the frequency with which individuals could access data services while actively using their phones within areas where there is mobile network coverage. This is not a measure of mobile coverage. For information on the coverage provided by the UK's four mobile networks, please see Ofcom's Broadband and mobile coverage checker and Connected Nations reports.

Our analysis shows notable disparities in the performance of all three cellular technologies. On average, 98.4% of attempts to access 5G data services were successful when a smartphone's screen was on in an area of 5G network coverage. This was higher than the 97.2% success rate for 4G data services and the 85.0% recorded for 3G.[3]

Across the UK nations, there were only minor differences in the average proportion of successful data connections over 5G and 4G, while on 3G networks, Northern Ireland had the highest and Wales the lowest average data connection success rate.

Connection success rates were higher in urban areas than in rural areas at a UK level over 3G, while over 4G and 5G, the rural success rates were higher, although the differences were very small.

Figure 51: Average proportion of successful 3G, 4G and 5G connections while the screen was active, by cellular technology, UK nation, and rurality



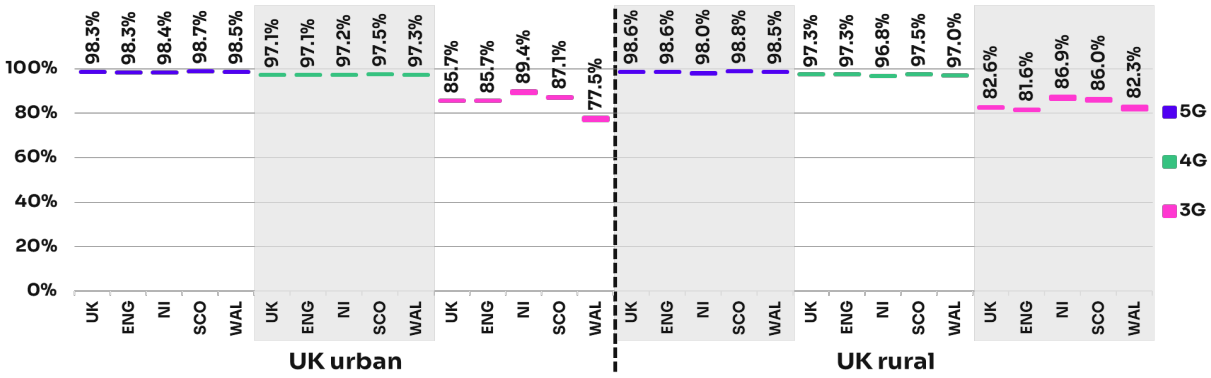
Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: The chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Our research shows that within each of the UK nations, there were minor differences between the average urban and rural data connection success rates over 5G and 4G. On 3G networks, average data connection success rates were higher in urban areas, except in Wales where it was higher in rural areas.

[3] As most UK 5G is 5G NSA, the observed differences between 5G and 4G data connection success rates may be due to network management.

In both urban and rural areas, there was minor variation in the average data connection success rates over 5G and 4G across the UK nations. Looking at urban 3G networks, Northern Ireland had the highest average data connection success rate, while Wales had the lowest success rate. In rural areas, Northern Ireland and Scotland had the joint-highest, while England and Wales had the joint-lowest average 3G data connection success rate.

Figure 62: Average proportion of successful 3G, 4G and 5G connections while the screen was active, by cellular technology, rurality, and UK nation

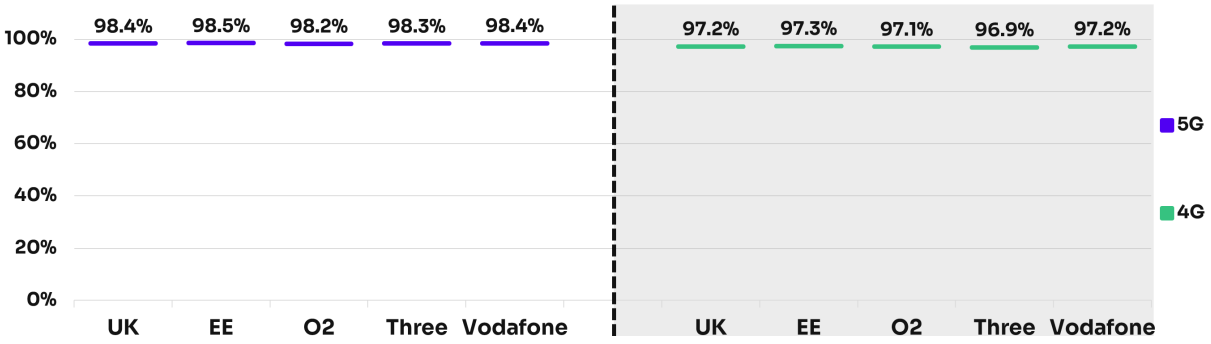


Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: The chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Across both 5G and 4G networks, the differences observed in average data connection success rates among MNOs were small.

EE had the highest average success rate for 5G connections, while O2 had the lowest. Similarly, over 4G, EE also had the highest data connection success rate, whilst Three had the lowest success rate. We have not included 3G figures here due to the ongoing closure of 3G networks.

Figure 7: Average proportion of successful 4G and 5G connections while the screen was active, by cellular technology and MNO



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: The chart bars show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Time to download files

People use their smartphones for a variety of purposes, some of which are more demanding in terms of connectivity than others. To understand file download times, we looked at the average time taken to download different sized files over 3G, 4G and 5G cellular technologies. Due to the ongoing 3G network switch-off, we only compared the 5G and 4G performance at an MNO level.

Time to download a 2MB file

Downloading a smaller (2MB) file can be representative of many typical activities undertaken on mobile devices, for example downloading photos or short low-resolution video clips in messaging apps or social media usage.[4]

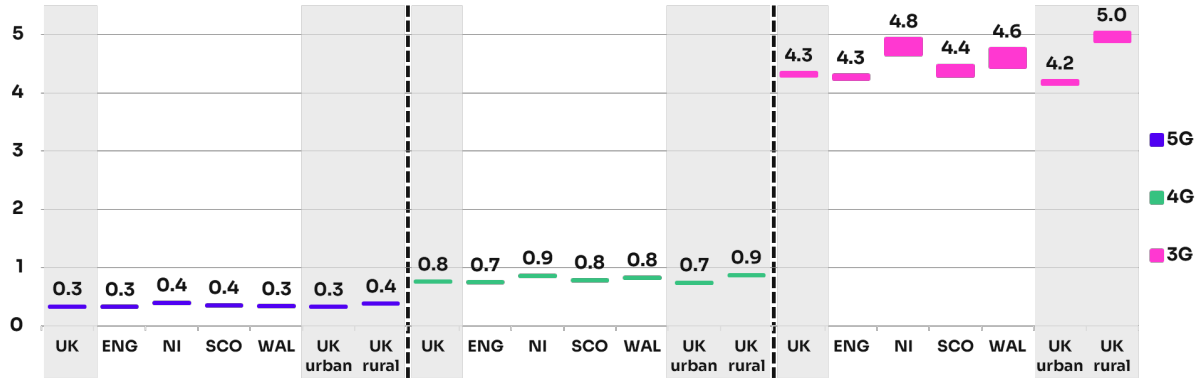
Our analysis shows that, on average, it took over twice as long to download a 2MB file on a 4G network than on a 5G network (0.8s and 0.3s respectively), and almost six-times longer on a 3G network (4.3s) than over 4G.

The average download time recorded over 5G connections was less than half that over 4G, and while the difference between the two averages was less than half a second, this could impact the user experience by being the difference between content feeling as though it is being accessed "instantaneously" or with a short delay.

There was minor variation in the average time to download a 2MB file over 5G and 4G across the UK nations. There were larger differences across the UK nations over 3G networks, with England recording a shorter average time to download a 2MB file (4.3s) than Northern Ireland and Wales (4.8s and 4.6s respectively). The average time to download a 2MB file was longer in rural areas than in urban areas over all three cellular technologies, at a UK level.

[4] As the test is a single file download, it is only indicative of the performance of these types of services, rather than an exact representation.

Figure 83: Average (median) time to download a 2MB file, by cellular technology, UK nation, and rurality (seconds)

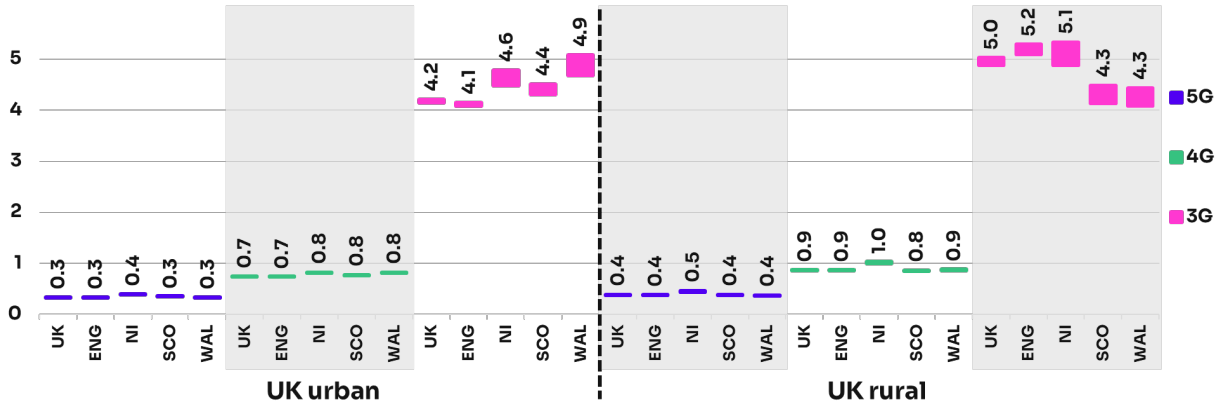


Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Within each of the UK nations, there were only minor differences in the average urban and rural times to download a 2MB file over 5G and 4G. Over 3G networks, rural areas had a longer average 2MB file download time in England and Northern Ireland, while in Wales, urban areas had a longer average download time, with no significant difference in urban and rural average 2MB file download times in Scotland.

Similarly, there were only slight differences in 2MB download times across the UK nations within urban and rural parts of the UK over 5G and 4G. There was greater variation over 3G networks, with England having the shortest average 2MB download time in urban areas, while in rural areas, the average time to download a 2MB file was shorter in Scotland and Wales than in England and Northern Ireland.

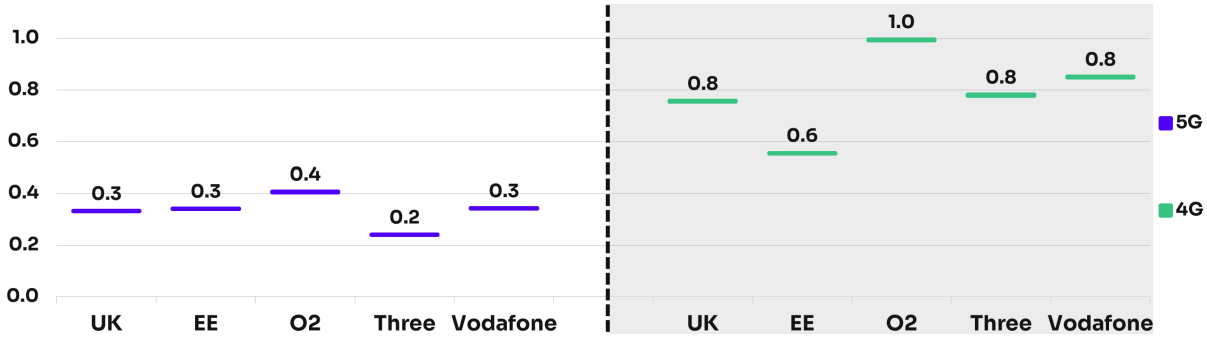
Figure 9: Average (median) time to download a 2MB file, by cellular technology, rurality, and UK nation (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

O2 customers had the longest average time to download a 2MB file over 5G and 4G networks. Three customers had the shortest average 2MB download time over 5G networks, while EE customers had the shortest average 2MB download time over 4G.

Figure 10: Average (median) time to download a 2MB file, by cellular technology and MNO (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Time to download a 5MB file

A 5MB file download can be representative of opening a photo in an email, opening a longer low-resolution video via instant messaging, or downloading a short audio file.[5]

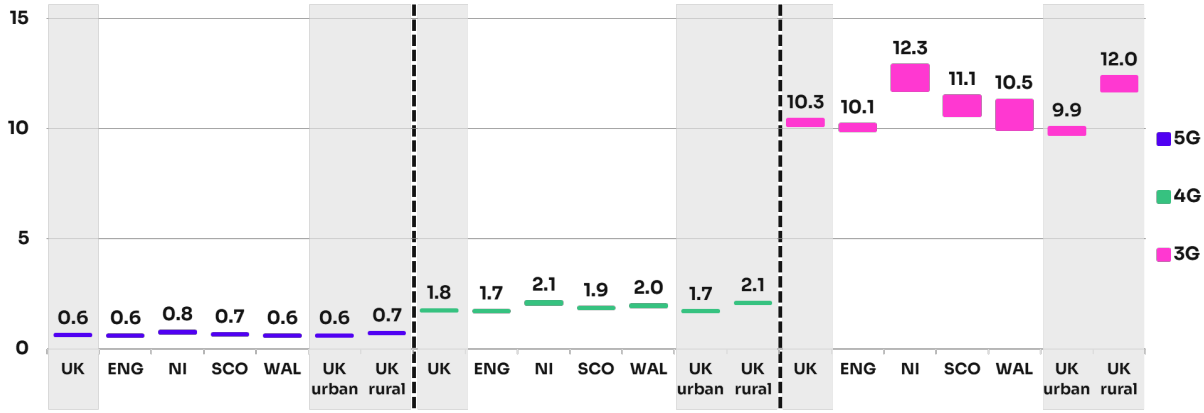
Downloading a larger file gives a data connection more time to ramp up to the maximum available connection speed, meaning that a greater proportion of the download takes place at higher speeds.

For this reason, while a 5MB file is 2.5 times as large as a 2MB file, the average 5MB file download times for all cellular technologies were less than 2.5 times those of a 2MB file. Over 3G, a 5MB download took 2.4 times as long than a 2MB download, over 4G 2.3 times as long, and over 5G 1.9 times as long. The benefit of 5G is therefore more marked when downloading a larger file, and this was evident when comparing 4G and 5G download times: a 5MB download over 5G was 65% shorter than over 4G, compared to a 2MB download over 5G being 56% shorter than over 4G.

Across the UK nations, Northern Ireland had the longest average 5MB download time over all three cellular technologies. Over 5G networks, average 5MB download times were shortest in England and Wales, while England had the shortest average time to download a 5MB file on 4G.

Urban areas recorded a shorter average 5MB download time relative to rural areas for all three cellular technologies, with the largest difference over 3G.

Figure 11: Average (median) time to download a 5MB file, by cellular technology, UK nation, and rurality (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

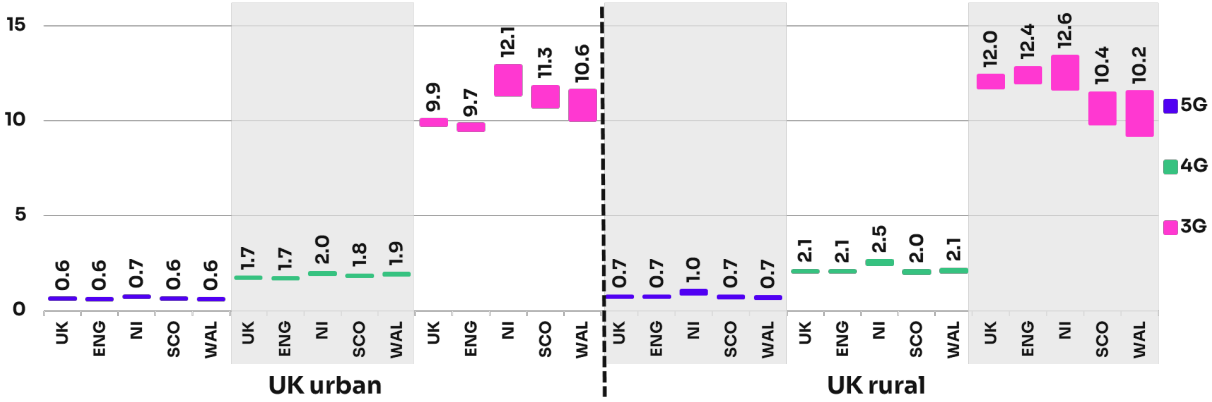
Across the UK nations, urban areas had a shorter average 5MB download time than rural areas over both 5G and 4G networks. Over 3G networks, there was no significant difference between 5MB download times in urban and rural areas across the UK nations, except for England, where the average 5MB file download time was shorter in urban areas.

[5] As the test is a single file download, it is only indicative of the performance of these types of services, rather than an exact representation.

In urban areas, there were only minor differences across the UK nations over 5G networks, however, England had the shortest average 5MB download time over 4G and 3G.

Across rural areas, Northern Ireland had the longest average 5MB download time over 5G and 4G networks. Over 3G networks, the average time to download a 5MB file was shorter in Scotland and Wales than in England and Northern Ireland.

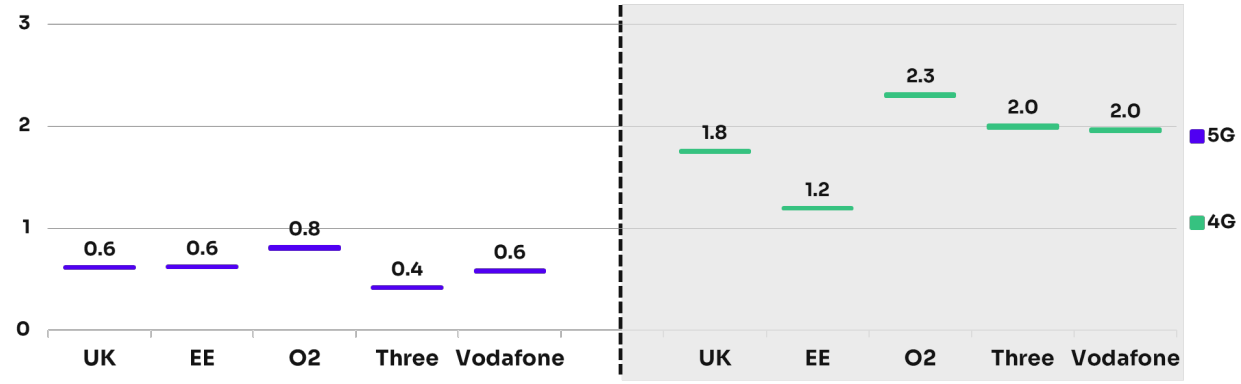
Figure 12: Average (median) time to download a 5MB file, by cellular technology, rurality, and UK nation (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

O2 customers had the longest average time to download a 5MB file over 5G and 4G. Three customers enjoyed the shortest average 5MB download time on 5G networks, while EE customers had the shortest average download time over 4G.

Figure 13: Average (median) time to download a 5MB file, by cellular technology and MNO (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Time to download a 10MB file

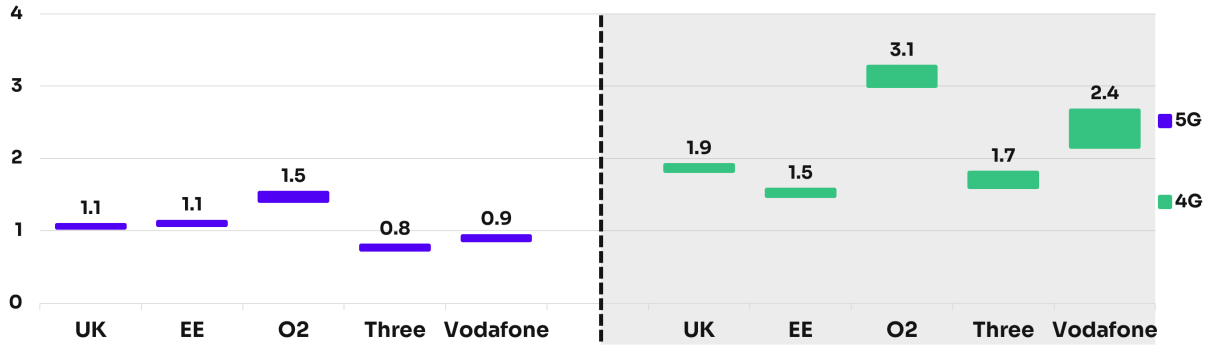
Downloading a 10MB file can be representative of activities such as downloading higher quality short-form video.[6]

While we included 3G networks in our download time tests for 2MB and 5MB files, time to download tests using a 10MB file were only run on 5G and 4G connections.

As was the case with 5MB file downloads, O2 customers had the longest average 10MB download time over both 5G and 4G. Over 5G networks, Three customers had the shortest time to download a 10MB file, while over 4G networks, EE customers had the shortest average 10MB file download time.

[6] As the test is a single file download, it is only indicative of the performance of these types of services, rather than an exact representation.

Figure 14: Average (median) time to download a 10MB file, by cellular technology and MNO (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

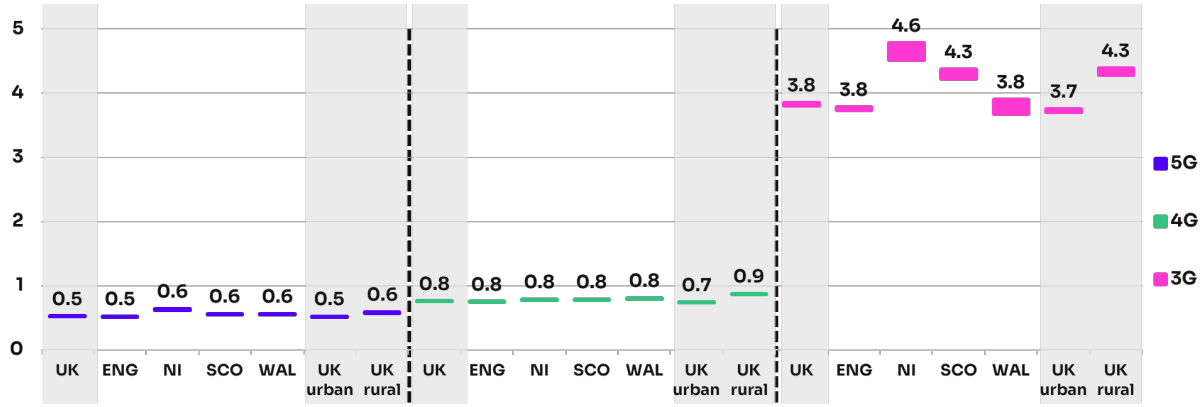
Time to upload files

Time to upload a 1MB file

Uploading a 1MB file can be representative of sharing photos or a short low-resolution video via messaging apps or social media.[7]

The average time to upload a 1MB file was shorter in urban areas compared to rural areas at a UK level across all three cellular technologies. Across the UK nations, differences in average 1MB upload times over 5G and 4G networks were minimal. However, over 3G networks, England and Wales had the shortest average 1MB upload time, while the average time to upload a 1MB file was the longest in Northern Ireland.

Figure 15: Average (median) time to upload a 1MB file, by cellular technology, UK nation, and rurality (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

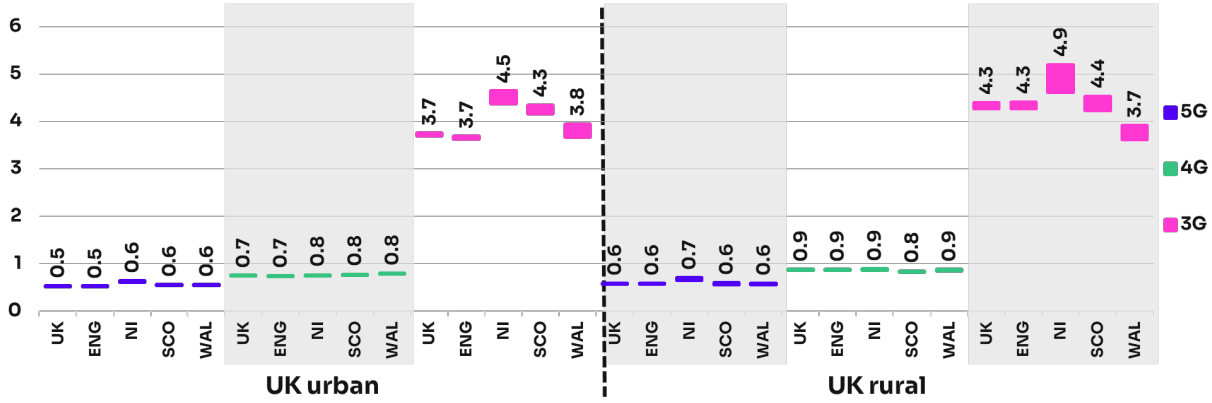
Across each of the four UK nations, there were only minor differences between the average 1MB upload time recorded in urban and rural areas on 5G networks. However, average 1MB upload times over 4G connections were significantly shorter in urban areas than rural areas in all four of the UK nations. On 3G networks, there were no significant differences between urban and rural areas except for England, where the average 1MB upload time was shorter in urban areas than rural areas.

In urban areas, England and Wales had the joint-shortest and Northern Ireland had the longest average 1MB upload time on 3G networks, while differences in average time to upload a 1MB file were comparatively small across the UK nations on 5G and 4G networks.

[7] As the test is a single file upload, it is only indicative of the performance of these services, rather than an exact representation.

In rural areas, any variations between the UK nations were also small over 5G and 4G. Again, the differences were greater on 3G networks, with Wales recording the shortest and Northern Ireland the longest average 1MB upload times.

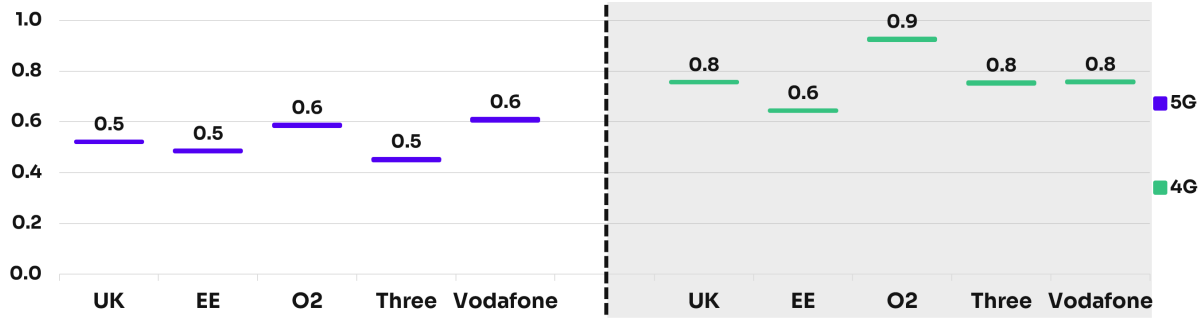
Figure 16: Average (median) time to upload a 1MB file, by cellular technology, rurality, and UK nation (seconds)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Differences in the average time to upload a 1MB file over 5G networks by MNO were only small. However, over 4G networks, EE customers had the shortest average 1MB upload time, while O2 customers had the longest average 1MB upload time.

Figure 17: Average (median) time to upload a 1MB file, by cellular technology and MNO (seconds)



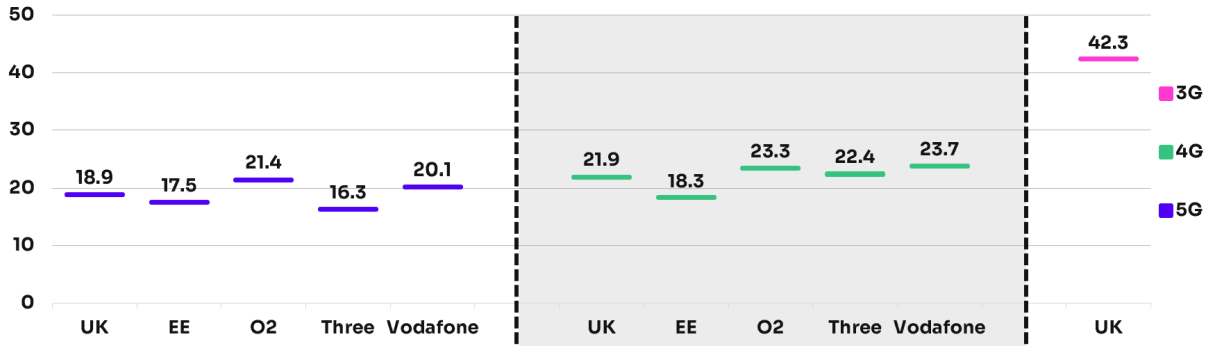
Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Response time (latency)

The time it takes the network to respond to a data request, known as response time or latency, can impact user experience. Lower response times will significantly improve the performance of real-time activities such as video calling, voice chat (VoIP) and online gaming, although other activities including web browsing will still have a satisfactory user experience with a slower response time. In general, most mobile activities need a network response time under 100ms to provide a good experience. For more demanding activities such as video calling, this drops to 50ms, while others, such as web browsing, may perform satisfactorily with a slower response time.

Our analysis shows that Three had the fastest average response time over 5G networks (16.3ms), with O2 customers recording the slowest time (21.4ms). Over 4G, EE had the fastest average response time (18.3ms) with Vodafone having the slowest time (23.7ms).

Figure 18: Average (median) response time, by cellular technology and MNO (ms)



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: Lower values indicate better performance; the chart bars/lines show that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown; data is not directly comparable to the findings published last year due to the omission of tests run on Apple iOS devices and those where the operating system was not identified; data only relates to areas where there was cellular network coverage.

Connection speeds

Distribution of download speeds

In addition to the fixed file size “time to download/upload” tests, Opensignal runs time-based connection speed tests. These differ from the fixed file size tests as they use as much, or as little, data as the connection can consume over the length of the test.

On faster connections, time-based tests can consume more data than the fixed file size tests and may provide a better measure of the typical download speeds available to the user as the connection has sufficient time to ramp up to its maximum usable speed.

The fixed file size and timed tests are therefore reflective of the performance received during different types of mobile use: the smaller fixed file tests replicate the experience delivered to users undertaking online activities that are more ‘bursty’ in nature and/or involve accessing smaller amounts of data, while the timed tests simulate activities that require larger amounts of data, such as downloading an app, TV programme, film or music album.

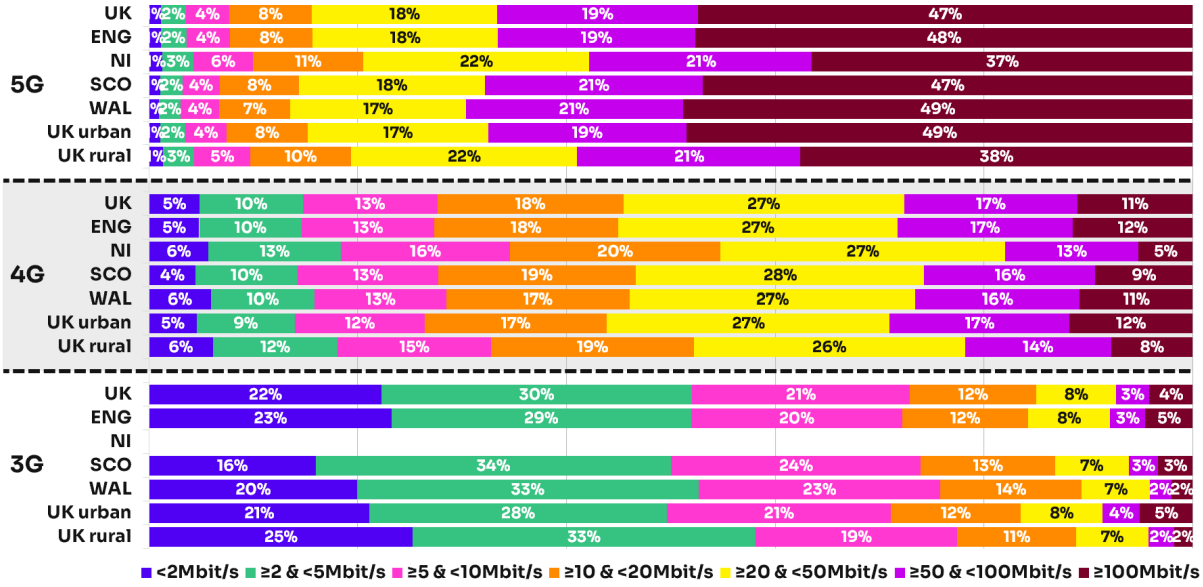
We have used the data from the time-based tests to understand the distribution of download and upload speeds received by mobile users.

Our analysis finds that 5G connections had a significantly lower proportion of download speed measurements that were under 10 Mbit/s (8%) than data connections on 4G (28%) and 3G (73%), and a significantly higher proportion of measurements of 100 Mbit/s or more (47%, compared to 11% on 4G and 4% on 3G). These reflect higher average download speeds over 5G.

Across the UK nations, Northern Ireland had a lower-than-average proportion of 5G measurements of 100 Mbit/s or higher (37%) and a higher proportion under 10 Mbit/s (10%). Northern Ireland also had lower-than-average speeds of 100 Mbit/s or higher over 4G, at 5% (less than half the UK average) and over a third of connections (35%) being under 10 Mbit/s (seven percentage points more than the UK average).

Across all three technologies, urban connections tended to have a higher proportion of faster connections and a lower proportion of slower connections, indicating that average download speeds are lower in rural areas.

Figure 19: Distribution of download speeds, by cellular technology, UK nation, and rurality



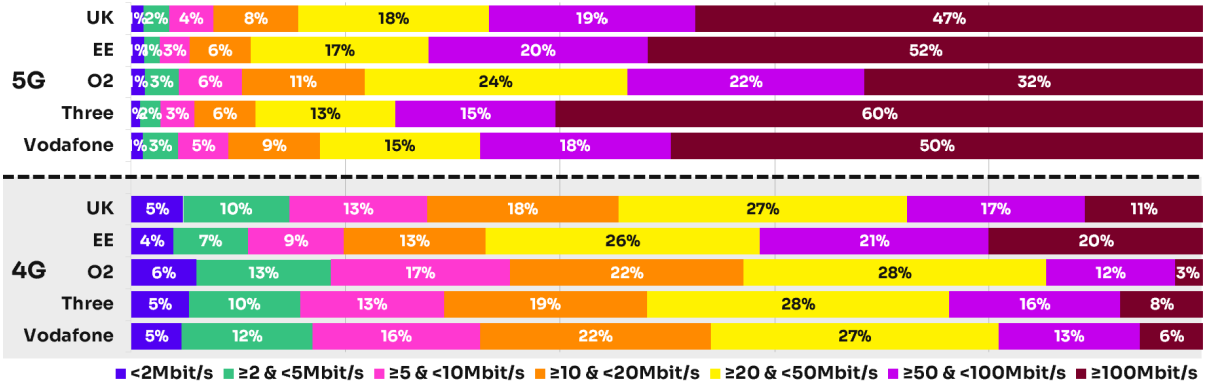
Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: There were insufficient 3G tests in Northern Ireland to allow inclusion in the analysis; data only relates to areas where there was cellular network coverage.

While the distribution of EE and Vodafone's 5G download speeds were broadly in line with the UK average, there were more notable differences in O2 and Three's results.

Three had the highest proportion of 5G measurements that were 100 Mbit/s or more (60%), while O2's (32%) was much lower than the 47% UK average. O2 also had the highest proportion of 5G measurements that were under 10 Mbit/s (10%), suggesting that download speeds on its 5G network are lower than those of the other mobile networks.

O2 also had the lowest average speeds over 4G, with just 3% of its 4G measurements being 100 Mbit/s or higher. This was much lower than the 11% UK average and the 20% recorded by EE (the highest proportion among the mobile providers). Conversely, O2 had the highest proportion of measurements under 10 Mbit/s (at 35%, eight percentage points below the UK average).

Figure 20: Distribution of download speeds, by cellular technology and MNO



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Note: Data only relates to areas where there was cellular network coverage.

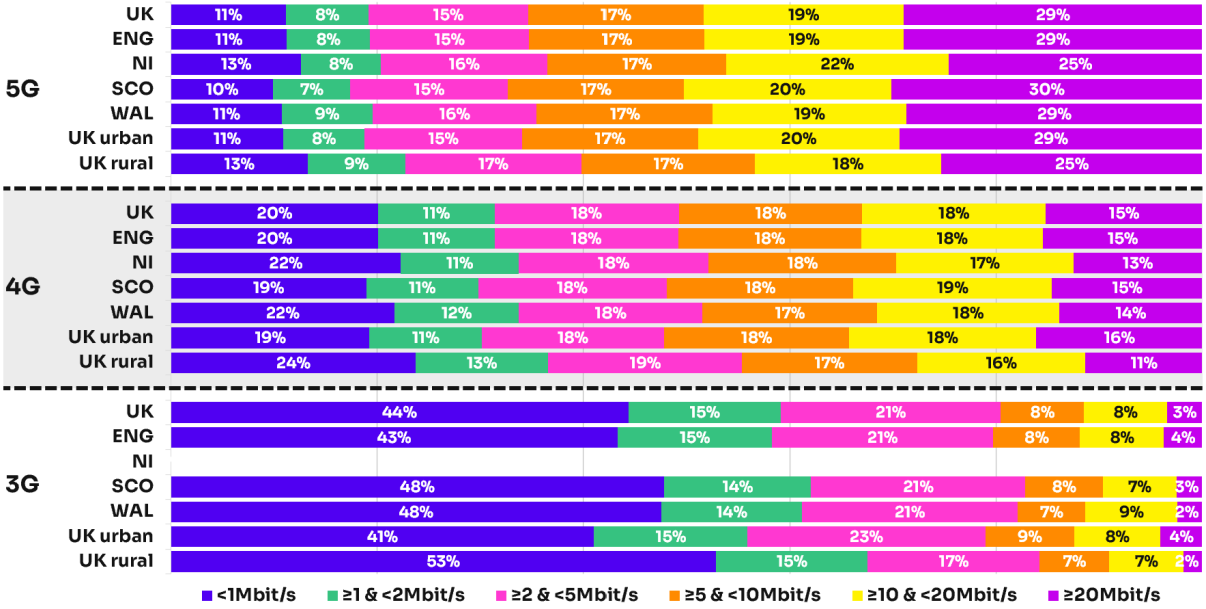
Distribution of upload speeds

Opensignal also uses time-based tests to measure connection upload speeds. Our analysis of these time-based tests shows that the proportion of upload speeds that were 20 Mbit/s or more were higher on 5G networks (29%) than on 4G (15%) and 3G (3%), while there was a higher proportion of upload speeds of less than 1 Mbit/s on 3G networks (44%) than on 4G (20%) and 5G (11%).

Across the UK nations, Northern Ireland had both the lowest proportion of 5G upload speeds at 20 Mbit/s or higher (25%) and the highest proportion of 5G upload tests that were under 1 Mbit/s (13%). Over 4G, Northern Ireland and Wales had significantly lower-than-average proportion of upload speeds of 20 Mbit/s or higher (13% and 14% respectively), and significantly higher-than-average proportion of 4G upload speeds of under 1 Mbit/s (both 22%).

The proportion of speed tests at 20 Mbit/s or more were higher, while the proportion of those under 1 Mbit/s were lower in urban areas than in rural areas across all three cellular technologies.

Figure 21: Distribution of upload speeds, by cellular technology, UK nation, and rurality

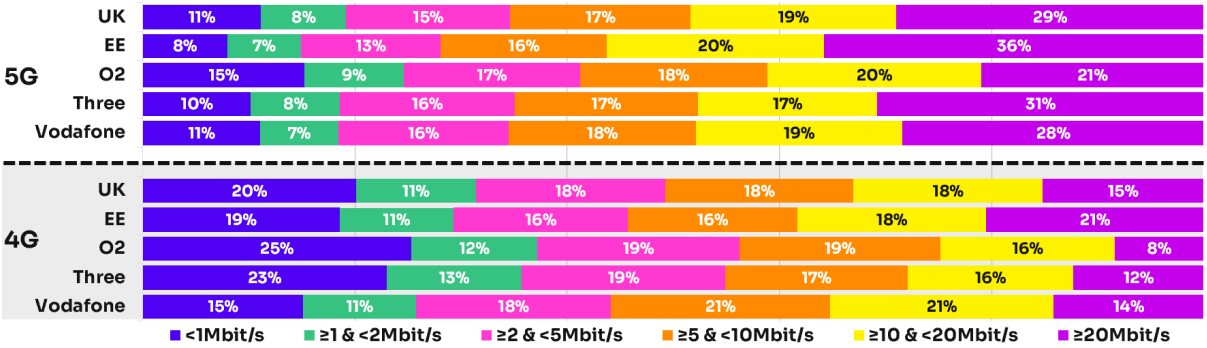


Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Notes: There were insufficient 3G tests in Northern Ireland to allow inclusion in the analysis; data only relates to areas where there was cellular network coverage.

Across the four MNOs, EE had the highest proportion of 5G and 4G speed tests that were 20 Mbit/s or more (36% and 21% respectively), seven percentage points higher over 5G and five percentage point higher over 4G compared to the UK averages. EE also had the lowest proportion of speeds under 1Mbit/s over 5G (8%), while Vodafone customers had the lowest proportion of 4G speeds under 1Mbit/s (15%).

O2 had the lowest proportion of 5G and 4G speed tests at 20Mbit/s or higher, at 21% and 8% respectively (eight pp lower than the UK average over 5G and seven pp under the UK average over 4G). O2 also had the highest proportion of speeds under 1Mbit/s over both cellular technologies, at 15% on 5G and 25% on 4G networks (four pp above the UK average over 5G and five pp higher than the UK average over 4G).

Figure 22: Distribution of upload speeds, by cellular technology and MNO



Source: Ofcom, using crowdsourced data provided by Opensignal; October 2023 to March 2024 data.
Note: Data only relates to areas where there was cellular network coverage.

A1 Technical methodology

Ofcom uses measurements collected from mobile users to measure the mobile network performance and the consumer experience of using different mobile services. Opensignal's data collection methodology uses a sample of UK smartphone users who have installed apps that include the Opensignal software development kit (SDK) on their device. The data collection framework and sample are developed and managed by Opensignal Limited ('Opensignal') and data was licensed to Ofcom. Opensignal also managed the collection and aggregation of the crowdsourced data.

Data collection

Individual measurements from smartphones are collected every day, under conditions of normal use. These include measurements in both indoor and outdoor locations.

Opensignal measures the end-to-end consumer network experience and the full path from the user device all the way to the Content Delivery Network (CDN) that host popular apps, services, and websites.

Measurements of network speed are collected based on both user-initiated tests and automated tests. The majority of measurements are generated through automated tests (i.e. no user interaction), executed independently and at random intervals to capture what users are experiencing at a typical moment in time.

A rigorous post-processing system is used that takes the raw measurements and calculates robust and representative metrics. This includes several steps to quality-assure the measurements.

For example, if a user failed to download any content, this measurement is eliminated and treated as a "failed test" rather than being included in the average speed calculation.

Table A1: Data collection processes and actions

Process	Action taken
Initial filtering	Certain entries are automatically filtered out (e.g. when a phone is in a call), which are known to produce non-typical results.
Operator name mapping	To ensure that the results only reflect the experience of customers who bought the operator's own branded service, Opensignal removes results from mobile virtual network operator (MVNO) subscribers and subscribers who are roaming from results for mobile network operators (MNOs). These subscribers may be subject to different Quality of Service (QoS) restrictions than an operator's own customers and so their experience may be different.
Selection of network type	Opensignal consolidates data into technology types — e.g. when considering 3G connections, Opensignal includes the various 3GPP releases that include HSDPA, HSUPA and UMTS R99 into one group.

The metrics analysed by Ofcom are:

- Share of cellular network connections
- Data connection success rate
- Response time (latency)
- Time to download a 2MB/5MB/10MB file
- Time to upload a 1MB file
- Distribution of download speeds
- Distribution of upload speeds

Metrics

Share of cellular network connections

Share of cellular network connections measures the frequency of individuals being connected to different cellular technologies. The share of cellular network connections metric is calculated across all cellular network generations.

Table A2: Identification of cellular network generations

Category	Description
2G	Records when the user was connected to 2G (Network Type is one of “GPRS”, “EDGE”, “GSM”).
3G	Records when the user was connected to 3G (Network Type is one of “UMTS”, “WCDMA”, “HSDPA”, “HSUPA “, “HSPA”.
4G	Records when the user was connected to LTE (Network Type is “LTE”) i.e. 4G.
5G	Records when an NR connection has been allocated to the device (NR State=3 in non-standalone access) or when there is a standalone access 5G connection.

Data connection success rate

The data connection success rate metric provides a view on the success of an Opensignal server response test to connect to the internet using a 3G, 4G and 5G cellular data network connectivity when a mobile phone screen is on to mirror consumer behaviour. The Opensignal server response test is also used to measure the latency, and its methodology is recorded below.

Response time (latency)

Response time, often referred to as latency, is the delay between a consumer making a request to their mobile network for information and the network providing this information to the device.

Server response tests are performed against a number of leading content delivery networks (CDNs) that are typically used to host popular apps, websites, and mobile services.

A server response (SR) test is defined as a test which determines the latency, jitter and packet loss of the current connection using UDP. To accurately measure these KPIs, a predetermined number of packets are sent to the test servers, usually 100 packets. Each of these packets contains a 32-byte payload which holds a number indicating the ordering of that packet in the sequence of packets sent out.

The SDK chooses the closest test server based on the geographical distance between the device and the server locations. Each packet is then sent to the test server via UDP which is connectionless. This means that, unlike TCP connections, there is minimal handshaking involved which could produce measurement results that indicate slower-than-actual speeds.

The UDP protocol is also used to simulate latency-sensitive applications, such as video and VoIP calling. The precise time that each packet is sent out is recorded to nanosecond precision and stored for later calculations. The packet spacing is 20ms between packets.

The test server receives the packets sent from the SDK and then immediately echoes them back to the listening device. The precise time that each packet is received back on the device is also recorded along with the specific payload of each packet. As this payload indicates the ordering of the packets returned to the device. The Metro Ethernet Forum (MEF) 10 specification is used to calculate the latency.

Latency is determined as 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.

Time to download a 2MB/5MB/10MB file and upload a 1MB file

The Opensignal SDK performs a collection of active tests, where phones are prompted to download a 2MB, 5MB or 10MB file and upload a 1MB file, and the throughput experienced when downloading / uploading these files is recorded.

The download throughput is measuring the duration it takes to download a 2MB file from a randomly selected CDN test server over a TCP connection. 2MB is selected to simulate downloading photos or short low-resolution video clips in messaging apps or social media usage. The measured download throughput is recorded against the current cellular connection (2G, 3G, 4G and 5G).

Download throughput tests are performed against CDNs commonly used to host popular website and other web applications over HTTPS. This allows test files to be downloaded with a low latency through one of the CDN edge servers located around the world. The payload is requested via URL. The actual end server that delivers the payload is determined by the CDN.

The fixed sized throughput tests do not measure the maximum throughput of the network. There is a technical limitation with the download throughput tests that limit the minimum throughput to 350Kbps. This is the result of the timeout implementation within the Opensignal SDK.

Each CDN service determines the closest edge test server to serve the download test file based on the IP address of the device. The SDK opens a TCP connection (HTTPS GET) to the test server to start downloading the test file.

The current time is then recorded in nanoseconds, as well as a received (Rx) byte count. The received byte count is a numerical count of how many bytes have been delivered over the wireless radio at a given time. This is the last step performed before the actual bytes are streamed from the server, to ensure that the measurements have the highest level of accuracy. Data bytes are streamed-in as 1024-byte blocks until either the file has completed downloading or a timeout or a cancel test event is triggered. The connection is then closed, the current time and the device's current received byte count are recorded.

Download and upload speed

Opensignal's download and upload speed metrics assess the mean speeds experienced on data connections to mobile networks.

Opensignal's speed tests involve downloading or uploading a file for a set period of time in order to test the data performance of a user's mobile network, directly from their handset.

The test is performed over HTTPS connections and multiple threads are used to simulate a typical mobile app data connection. The download and upload servers are the same as those used by popular mobile apps, websites, and mobile services that internet users connect to every day, provided by major content delivery networks (CDNs).

Opensignal collects data primarily via automated tests that run in the background. These tests are run at various points in time to ensure that the metrics are truly reflective of the speed users experience during normal usage of their mobile network.

To calculate the metrics for download and upload throughput speed, Opensignal begins from a dataset of individual test records which contains a series of fields including: the test location, time, type (user-initiated or automated), the network connection type (e.g. Wi-Fi, UMTS, LTE, 5G etc.), the servers that were used, the IP address, various RF parameters and a series of metrics associated with the speed and latency of the data connection that was measured during the test.

A2 Statistical methodology

The 2024 Mobile Matters report analyses findings collected from Opensignal's crowdsourced data sample between 1 October 2023 and 31 March 2024.

Crowdsourced sample records were included in the analysis if they met the following criteria:

a) the mobile network was either EE, O2, Three or Vodafone.
b) the location was in the UK and the UK nation was either England, Northern Ireland, Scotland, or Wales.
c) the cellular technology was known – either 2G, 3G, 4G or 5G.

Records that did not meet the above criteria were excluded from the analysis.

Ofcom has only analysed the performance recorded on Android smartphones (i.e. tests run on Apple iOS devices and devices where the operating system was not identified have been excluded from our analysis). Non-user-initiated tests were not included in the analysis.

Both Ofcom and Opensignal have ensured that the sample sizes are sufficient to ensure the robustness of the findings shown in the report and that the sample distribution broadly matches both the population distribution of the United Kingdom and the relative operator shares.

Metrics and analysis methodology

For the 2024 Mobile Matters report the following metrics were analysed:

- Share of cellular network connections (%).
- Average proportion of successful data connections (%).
- Average (median) response time (ms).
- Average (median) time to download a 2MB/5MB/10MB file (seconds).
- Average (median) time to upload a 1MB file (seconds).
- Distribution of download speeds (%).
- Distribution of upload speeds (%).

Share of cellular network connections

This measure assesses how cellular network connections are distributed across each cellular technology (2G, 3G, 4G or 5G). Our analysis looked at how the proportion of these connections on each technology differed by nation, rurality, and mobile network operator (MNO). Two-tailed tests of proportion were performed to look for statistically significant differences which are shown in the report. With such a large number of tests, very small differences between the proportions can be statistically significant. However, there may be no practical difference for the consumer in their mobile phone experience.

Data connection success rate

To assess the data connection success rate, we looked at the total number of server response tests performed and calculated the percentage of these tests that were successful. The proportion of successful tests was then compared by nation, rurality, MNO, and cellular technology (3G, 4G or 5G). We used records where the mobile screen was on during this test, so we can assess the percentage of cases when the user was able to connect to data services when the device was in active use.

When there is such a large number of readings, even very small differences between averages or proportions can be statistically significant. However, this may not equate to a noticeable or practical difference for the consumer in their experience of using their phone.

The proportion of successful tests with upper and lower 95% confidence intervals was calculated for each subgroup, and comparisons were made using two-tailed statistical tests. Analysis was carried out comparing 3G, 4G and 5G cellular technologies, nation, rurality, and MNO (only 4G and 5G performance was analysed at MNO level), and to look for any statistically significant differences in the performance of data services.

Response time (latency)

Response time, or latency, which is the delay in milliseconds between a consumer making a request to their mobile network for information, was compared by cellular technology and MNO. A two-tailed test of median response times was carried out on all sub-group comparisons.

Time to download files

The Opensignal dataset performs a collection of active tests, where phones are prompted to download a file of size 2MB, 5MB or 10MB, and the throughput experienced when downloading this file is recorded. We applied a conversion to this measure by multiplying the file size by 8 (to convert from MB to Mbit) and divided this figure by the recorded throughput to produce a measure showing the time taken for the user to download a 2MB, 5MB or 10MB file, respectively. The median time taken to download files of each size was calculated for each subgroup. Two-tailed tests of median download times were carried out on all sub-group comparisons. Performance was compared by cellular technology, nation, rurality, and MNO.

Time to upload files

The Opensignal dataset also contains active upload tests, where the throughput experienced when prompted to upload a 1MB file is recorded. We applied the same conversion as above to produce a measure assessing the time taken to upload a 1MB file. The median time taken to upload a 1MB file was calculated for each subgroup. Two-tailed tests of median download times were carried out on all sub-group comparisons. Performance was compared by cellular technology, nation, rurality, and MNO.

Distribution of download and upload speeds

To assess the distribution of download and upload speeds, we used the Opensignal speed test which downloads or uploads data for a set period of time. Over a set period of time, the download/upload speed received is recorded every 30ms, and this collection of measurements is trimmed[8] and averaged to give a single value. The distribution of these speed tests is then calculated based on different speed bands[9] and compared by cellular technology, nation, rurality, and MNO.

[8] Top and bottom 10% of the tests were discarded.

[9] For download speed: < 2 Mbps, ≥ 2 and < 5 Mbps, ≥ 5 and < 10 Mbps, ≥ 10 and < 20 Mbps, ≥ 20 and < 50 Mbps, ≥ 50 and < 100 Mbps and > 100 Mbps, for upload speed: < 1 Mbps, ≥ 1 and < 2 Mbps, ≥ 2 and < 5 Mbps, ≥ 5 and < 10 Mbps, ≥ 10 and < 20 Mbps, ≥ 20.