RootMetrics®

Substantiation of the UK's Best 4G and 5G Network in the United Kingdom – H2 2021

SUBSTANTIATION OF CLAIMS **Last Reviewed: 10/01/2022**

Claims:

The UK's Best Network for 4G and 5G

Summary

EE's claims, noted above, are based on RootMetrics' extensive testing which assesses calls, texts, data, speed, accessibility and reliability using the latest devices and a geographically representative methodology. The above claims are based on network testing that takes account of all aspects of network performance.

RootMetrics Awards

RootMetrics, an independent mobile analytics firm, publishes a series of reports, titled the UK RootScore® Report (the "RootScore Report"). The RootScore Report ranks the UK's four major mobile network operators ("MNOs") on a number of performance metrics, including "Network Reliability", "Network Speed", "Data Performance", "Network Accessibility," "Call Performance" and "Text Performance". The report also ranks MNOs on "Overall Performance".

For their ongoing testing, RootMetrics benchmarks smartphones against one another on each of the four national networks to determine which device will provide the best overall network experience for a consumer and uses the device type throughout a testing half. As of 2020, all devices used have been capable of accessing the 5G networks of the national mobile network operators.

The results of these awards show that EE was ranked first and therefore is the winner in the overall (best) network performance category for RootMetrics H2 2021 testing.

Why are these results robust?

RootMetrics uses scientific methodologies to design tests, measure activities, and collect data about mobile network performance that are representative of a consumer's mobile experience within a given market. RootMetrics then employs statistical techniques to verify and validate the results. This approach ensures all operators are measured on a level playing field, removes unintentional bias, and allows RootMetrics to provide actual, in-the-field data that confirms or challenges performance numbers that are otherwise only theoretical or based on ideal conditions. Weighting and stratification methods ensure that test data correctly represents the overall national population distribution.

We measure network reliability, accessibility, and speed performance across the activities that consumers use their smartphones for on a daily basis, like browsing webpages, using apps, making calls, and sending texts. Our methodology is designed to ensure that our tests measure performance across a wide range of real-world situations that consumers experience while using their smartphones on a daily basis. For example: we collect samples during periods of high and low congestion; we measure performance across variations in speed, from standing still to driving on the highway; and we perform tests whether coverage is poor or excellent or somewhere in between. We test each network head-to-head in these situations to make comparisons easy and assure all networks are measured on a level playing field.

Methodological Facts from RootMetrics' UK tests conducted between July and December 2021:

- 650,000 tests performed
- 25,000 miles driven

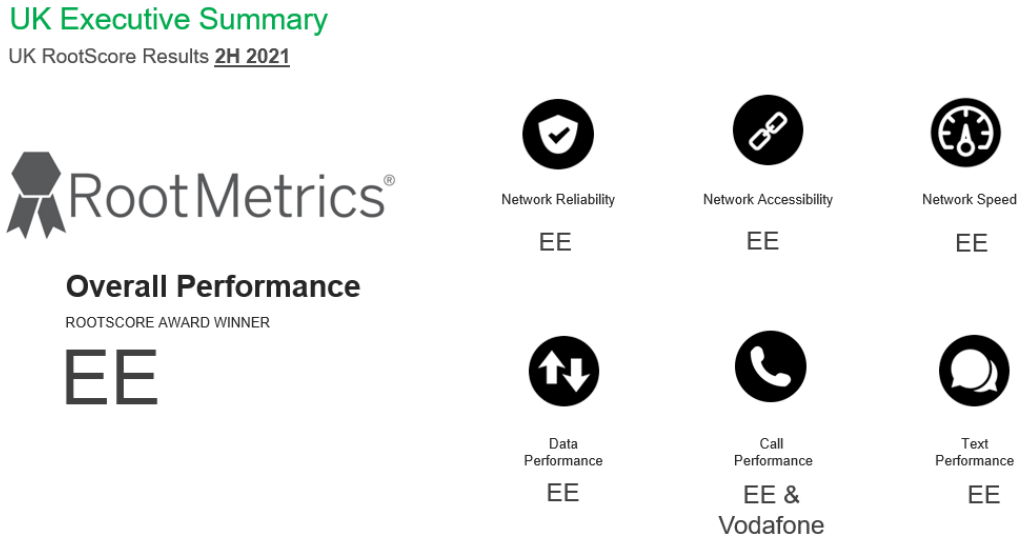
- 4 nations visited
- 16 of the largest metropolitan areas (Eurostat 'Large Urban Zones' [LUZs]) included

The UK's Best Network for 4G and 5G H2 2021

As can be seen in the summary below, EE won outright or shared the award in all categories of RootMetrics H2 2021 UK testing. With this strong performance across subcategories, EE was also the winner of the Overall (Best) Network performance award. Please see the appendix for a breakdown of competitor performance against EE in each category.

These awards represent experiences on available network technologies. In the case of EE, 98.9% of tests from the UK RootScore Report were conducted on 4G and 5G networks. Additionally, in some urban areas 100% of tests were conducted on these network types. With the level of 4G and 5G availability demonstrated by all operators, RootMetrics considers these awards to be a comparison of each operator's combined 4G and 5G network. Therefore, the best overall performance award is bestowed upon EE based on their combination of 4G and 5G network performance.

Network Operator	EE	Virgin Media O2	Three	Vodafone
Percentage of tests conducted on 4G or 5G networks	98.9%	93.7%	86.5%	92.0%



Best 4G Network

4G H2 2021 Speed Performance:

1. H2 2021 4G Median Download Speeds (Mbps) – Overall Results

As seen in the table below, H2 2021 testing concluded that EE had the fastest Overall Median Download Speed across the UK when comparing against competitor MNOs (Vodafone, Virgin Media O2 and Three). The closest competitor was Vodafone who recorded 16.7 Mbps vs EE's 40.7 Mbps.

Network Operator	EE	Virgin Media O2	Three	Vodafone
Speed (Median)	40.7	9.8	15.5	16.7

2. H2 2021 4G 5th Percentile Download Speeds (Mbps) – Overall Results

As seen in the table below, H2 2021 testing concluded that EE had the fastest overall 5th Percentile Download Speeds (Mbps) across the UK compared to competitor MNOs (Vodafone, Virgin Media O2 and Three) The closest competitor was Vodafone at 1.3 Mbps vs EE's 2.2 Mbps.

Network Operator	EE	Virgin Media O2	Three	Vodafone
Speed (5th Percentile)	2.2	0.7	0.5	1.3

3. H2 2021 4G 95th Percentile Download Speeds (Mbps) – Overall Results

As seen in the table below, H2 2021 testing concluded that EE had the fastest overall 95th Percentile Download Speeds (Mbps) across the UK compared to competitor MNOs (Vodafone, Virgin Media O2 and Three). The closest competitor was Vodafone at 102.9 Mbps vs EE's 159.2 Mbps.

Network Operator	EE	Virgin Media O2	Three	Vodafone
Speed (95th Percentile)	159.2	62.6	67.7	102.9

4G Coverage

- EE has 99% population coverage across the UK.
- Based on RootMetrics testing, EE has 93.1% 4G geographic coverage across the UK compared to Vodafone 4G 89.5%, Virgin Media O2 4G 89.0% and Three 4G 67.3%

4G H2 2021 Reliability

Two key metrics that support the Reliability award from RootMetrics are access success and task success, providing a summary of a device's ability to access the network and complete a task on the network.

In the case of 4G access success, EE recorded success in accessing the network in 98.4% of tests, Vodafone in 98.3%, Virgin Media O2 in 97.4%, and Three in 96.4%.

For 4G task success, EE and Vodafone recorded success in completing tasks on the network in 98.6% of tests, Virgin Media O2 in 97.6%, and Three in 96.8%.

4G H2 2021 Call and Text

During RootMetrics 2021 H2 testing, nearly all of EE's call and text tests were conducted on 4G. EE and Vodafone delivered statistically indistinguishable performance in our call testing. EE outperformed all other carriers in text testing.

Network Operator	EE	Virgin Media O2	Three	Vodafone
Percentage of call tests on 4G	96.6%	96.6%	88.1%	96.5%
Percentage of text tests on 4G	99.3%	95.6%	87.1%	94.6%

4G H2 2021 Performance Summary

Considering EE's 4G speed superiority at the 5th percentile, median, and 95th percentile, combined with EE's excellent 4G reliability, the strength of its 4G call performance, and the superiority of its text performance, EE provided the best combination of 4G network performance in H2 2021.

Best 5G Network from RootMetrics

Ranking methodology

The RootMetrics 5G scoring framework is designed to measure progress towards the 5G standards outlined in IMT-2020, focusing on metrics that are most important to consumer experience and use case application.

To provide an objective view of 5G performance, RootMetrics reviewed a variety of publications and sources in determining what metrics should be evaluated, as well as what performance thresholds should be considered. In addition to the IMT-2020 5G standards, RootMetrics compared recommended performance thresholds for a 5G use case (cloud gaming) and reviewed consumer survey results to better understand expectations from users. Taken together, this multi-faceted approach helped delineate what KPIs are most important while also providing key benchmarks for network comparisons.

Defining what constitutes a 5G experience and the importance of 5G availability

A consumer's 5G experience is built out of a combination of two broad pillars: 1) the network performance delivered while on 5G and 2) how often those 5G networks are actually available.

Assuring that both elements of this 5G equation are considered is especially critical during this growth phase of 5G rollouts and as networks continue to mature. Performance metrics are important but viewing performance without also factoring in availability can create a skewed picture of the 5G experience. After all, an amazing 5G speed only matters to consumers if they can actually access the network consistently.

To that end, the RootMetrics 5G scoring framework first considers how well each network performs across key 5G KPIs (covering speed, reliability, and latency) and then uses the percentage of tests on 5G (availability) as a multiplier. This approach creates a balance that provides a clearer picture into the consumer's 5G experience. It rewards operators that offer the best combination of

performance plus availability, while mitigating the impact of an operator excelling in *only* performance or *only* availability.

- An operator with fantastic performance but low availability will have its score impacted negatively by low availability (since, again, if a consumer cannot access the network, that performance is moot).
- Conversely, an operator with high availability but low performance will have its score impacted negatively by its weaker speed, reliability, or latency KPIs.
- An operator cannot score highly by focusing on performance across only a small area or on wide availability at the expense of stronger performance.
    - This type of mitigation is especially important as different spectrum bands of 5G become available: some spectrum favours broad coverage and some spectrum leads to faster speeds. A true 5G experience must consider both elements, not one at the expense of the other.
- Consumers are thus able to see which operator provides the best overall combination of performance plus availability.

Selection of performance metrics

Much of the conversation around 5G focuses on the potential for extremely fast speeds. A March 2020 survey[1] supports the idea that download speeds are at the top of consumers' minds when thinking about 5G. For this reason, RootMetrics weights speeds slightly higher than reliability and latency when evaluating networks.

While speed might be the first thing consumers think of when it comes to 5G, use cases including mobile gaming, augmented or virtual reality, and connected vehicles will also rely on 5G's promise of near-perfect reliability and low latencies.

To capture fully these consumer expectations and use case needs, the following metrics are considered when RootMetrics evaluates 5G networks:

- Download Throughput 5th Percentile (Speed)
- Download Throughput Median (Speed)
- Lite Data Secure Access Speed (Latency)
- Lite Data Secure Access Success (Reliability)
- Lite Data Secure Task Success (Reliability)

Each of these categories is then scored based upon the performance thresholds defined below.

Evaluating availability

[1] https://www.ansys.com/-/media/ansys/corporate/resourcelibrary/brochure/ansys-5g-survey-infographic.pdf?la=en&hash=4A18E71A92731D76D4B52763E46CAC0AC5391A93

5G availability is determined based upon the number of tests RootMetrics recorded on 5G compared to other network technologies:

- Percent of tests on 5G (Availability)

As mentioned above, availability functions as a multiplier within the RootMetrics framework. Once the above performance metrics have been evaluated and the corresponding performance score for each category calculated, 5G availability rates are then factored in as a weighting factor as described above.

The equation is simple and straightforward: the performance of an operator is multiplied by the percentage of tests RootMetrics recorded on 5G.

Performance Thresholds

The expectation is that 5G technology will move towards ubiquity over the next couple of years. As networks expand and mature, RootMetrics expects performance to continue to improve. When evaluating 5G performance, RootMetrics has therefore taken into consideration key guidelines from IMT-2020[2], including:

- User experienced data rate of 100 Mbps downlink
- Control plane latency of 20ms or less
- 99.9999% reliability

Thresholds for download throughput metrics in the 5G rating are based on the expectation of eventually achieving 100 Mbps at the 5th percentile for download throughput, and more generally the expectation that 5G speeds will be in the hundreds of Mbps (with peak speeds much higher than that). The 100 Mbps mark matches with 5G-specific applications, such as the minimum throughput needed for entry-level VR experience as shown in the recent Ofcom report[3]. This threshold also maps to what RootMetrics has publicised[4], including information that shows consumers how these 5G speeds will impact typical mobile behaviour.

The lower threshold used for the 5th percentile metric was determined by reviewing recommendations associated with mobile cloud gaming as a representative 5G use case. Research across Xbox[5], Google Stadia[6], and others suggests that a minimum speed of 10 Mbps is required to assure a smooth consumer experience for SD gaming. To provide opportunity for further differentiation of networks, a second threshold of 30 Mbps was established and represents a minimum speed needed to support more intensive performance needs for multi-player and/or HD games.

[2] https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Documents/060R1e.pdf and https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Documents/S01-1_Requirements%20for%20IMT-2020_Rev.pdf
[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0011/211115/report-emerging-technologies.pdf
[4] https://www.rootmetrics.com/en-US/content/speeds-in-the-real-world-infographic
[5] https://support.xbox.com/en-US/help/games-apps/cloud-gaming/about-cloud-gaming#about-cellular-gameplay
[6] https://support.google.com/stadia/answer/9607891?hl=en

Thresholds for the latency measure of lite data secure access speed, are targeted towards the sub 20 ms goal outlined in IMT-2020 with the interim step at a half a star tied to current expectations for latency for smooth performance on mobile gaming platforms. Here too RootMetrics reviewed typical use case latency requirements. Current recommendations from Xbox, for instance, suggest a latency of less than 60 ms is required for smooth game play experience. In short, both independent recommendations—the ideal sub 20 ms from IMT-2020 and the more achievable 60 ms threshold from gaming recommendations—are captured within the RootMetrics star rating framework.

The reliability expectations in IMT-2020 are near perfect at 99.9999%. To account for the early stage of 5G and in acknowledgement that few consumers will have practical impacts from a slightly lower reliability in current use cases the threshold for the reliability metrics was set at 99.5% - still an impressive value when compared to network performance as a whole.

National aggregation

As of the second half of 2021, 5G rollout in the UK has been primarily concentrated in the metro areas. Due to the relative lack of 5G seen in national drive route testing, the national rollup calculation for 5G metrics includes only testing from RootMetrics' Metro testing across UK's top 16 metros. All 5G data tests from across the 16 metros are used to calculate the national level metrics. There is no weight applied in this aggregation.

Rating Framework and quick metric summary

As shown below, EE delivered the best 5G performance in UK testing for H2 2021.

Availability: 5G availability is the gateway for consumers to access enhanced mobile network experience promised by this new technology and acts as a multiplier of the other performance metrics within the RootMetrics framework.

5th percentile: 5th Percentile speeds experienced on 5G provide a measure of minimum performance required to provide access great media content quickly or great gaming experiences on the go.

Median download throughput: Median download speeds > 100Mbps provide consumers faster access to higher quality media on the go, enable enterprise organisations to work from anywhere, and deliver enhanced mobile broadband to consumers in the home who may not have access to fixed broadband.

LDRS and latency: Improved latency enables quicker responses and lag-free applications and sets the stage for future 5G use cases such as autonomous cars and more.

Reliability: A consistent user experience requires high access reliability to connect to the service and task reliability to receive the necessary data to operate the service.

	5th Percentile Download Speed (Mbps)	Median Download Speed (Mbps)	Latency (ms)
EE	**30.86**	**146.68**	116
Virgin Media O2	15.43	123.43	47.5
Three	10.31	115.19	**41**
Vodafone	15.80	116.72	47

	LDRS Access Success	LDRS Task Success	Percentage of Tests on 5G
EE	99.79%	99.87%	**41.0%**
Virgin Media O2	99.78%	99.91%	28.9%
Three	99.60%	99.33%	35.2%
Vodafone	99.86%	99.80%	30.5%

UK's Best 5G Network

Operator	Availability Multiplier	Performance Score	5G Score
EE	**41.0%**	84.29	**34.53**
O2	28.9%	**87.29**	25.22
Three	35.2%	81.66	28.77
Vodafone	30.5%	86.82	26.52

Appendix

RootMetrics H2 2021 Test Results

Here, you can see the RootMetrics' H2 2021 results for each of the individual mobile network awards. EE won or shared the top spot in all seven award categories.