TUTELA

United Kingdom

State of Mobile Networks

Annual Report

SEPTEMBER 2019

www.tutela.com

After years of anticipation, 2019 was the year that 5G finally went live in the UK. All four network operators have deployed 5G in some fashion, bringing the tantalizing prospect of gigabit cellular networks much closer to reality.

But for the vast majority of consumers, 4G networks handle their daily internet browsing, video streaming, and voice calling -- and all 4G networks aren't built equal. To evaluate the performance of EE, Three, Vodafone, and O2, Tutela has evaluated 223,349,898,716 measurements collected from iOS and Android smartphones in the UK, taken from February 1st to July 31st 2019. The results include over 30 million throughput tests and over 520 million latency tests, taken from over 1.9 million unique devices, over both 3G and 4G networks.

Key findings

- EE came in first place in both Excellent and Core Consistent Quality, with 82.6% of tests from its subscribers meeting the requirements for the most demanding mobile use-cases. That was a significant outperformance of Vodafone, which was in second place for Excellent Consistent Quality, at 76.5%.

- All four networks were relatively close for Core Consistent Quality. Just 3.3% separated first-place EE from fourth-place 3, showing that, when they have signal, UK subscribers almost always have a network sufficient for use-cases like streaming standard-definition video.

- The gap between operators is much more pronounced when looking at median download throughput: EE's 21.2 Mbps result is more than double that of O2 and 3, and nearly 8 Mbps faster than second-placed Vodafone.

- The four operators take significantly different approaches to how they provide coverage: EE and 3 use mid-band and high-band spectrum for the vast majority of their data traffic, while Vodafone and O2 use the low-band 800 MHz spectrum much more heavily. Low-band spectrum travels further and penetrates buildings better than mid-band or high-band, but there is less capacity available, which explains some of the speed and coverage differences between the networks.

Results overview

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Mobile experience results
UK, September 2019

	EE	Three	O₂	vodafone
Excellent Consistent Quality	⭐ Winner			
Core Consistent Quality	⭐ Winner			
Download throughput	⭐ Winner			
Upload throughput	⭐ Winner			
Latency	⭐ Winner			

Results from 219,916,172,439 measurements taken in Common Coverage Areas between February 1st to July 31st 2019.

"EE delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Best Mobile
Network
Experience

SEPTEMBER 2019

Based on the highest Excellent Consistent Quality in Common Coverage Areas.
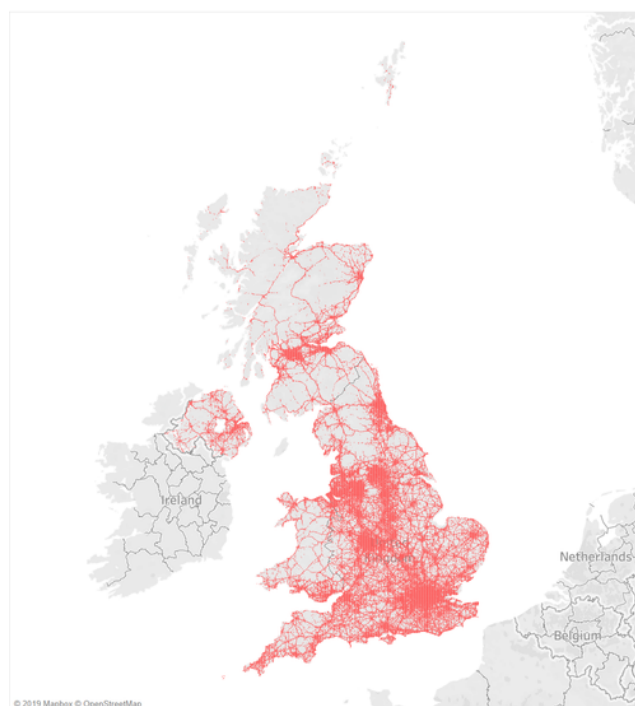
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Understanding this report

Tutela uses two key methodological components to best compare user experience across operators: Consistent Quality and Common Coverage Areas. Consistent Quality is a set of metrics that Tutela has developed to objectively evaluate when networks are (and are not) enabling users to do almost everything that they want to do on their smartphones.

The methodology is covered in detail at the end of this report and on our website, but simply put, there are two sets of thresholds, Excellent and Core. A connection that hits the Excellent threshold is sufficient for use-cases like 1080p video streaming or multiplayer gaming, while a Core connection will stream standard-definition video or handle things like web browsing or uploading photos to social media. The percentages you see in this report represent the percentage of tests on a given operator that were above the Excellent or Core thresholds. These were most recently re-assessed and updated September 1st, 2019.

Common Coverage Areas are parts of the country where the majority of operators offer service. In this report, we present results nationally and from Common Coverage Areas, which helps present both a full national picture, as well as highlighting network conditions wherever operators are directly in competition.

TUTELA   Common Coverage Areas (3G & 4G)

© 2019 Mapbox © OpenStreetMap

TUTELA   Measurement Locations

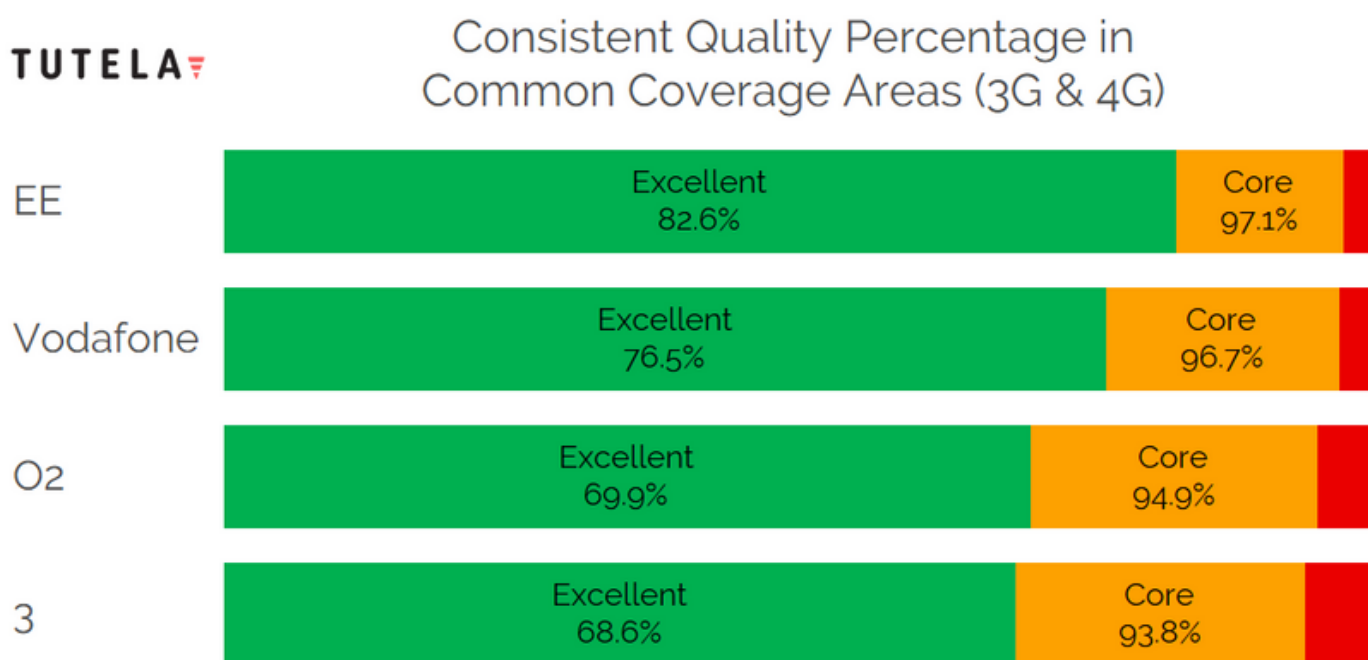© 2019 Mapbox © OpenStreetMap

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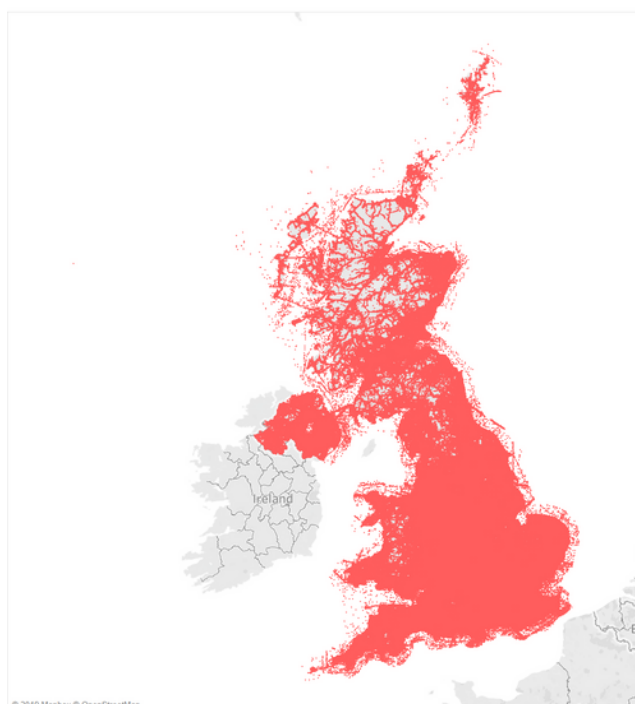
Consistent Quality

Back in October 2012, EE was the first network to launch a 4G network in the UK(1). Seven years later, EE's network is still in first place, both in the underlying network performance metrics, and in both Excellent and Core Consistent Quality. 82.6% of tests recorded from EE's customers met or exceeded the demanding Excellent Consistent Quality thresholds in Common Coverage Areas. At a national level, there's very little difference -- EE's network consistently outperforms second-place Vodafone by over six percent.

Looking at Core Consistent Quality, the gap between operators is much smaller. Although EE still comes out on top, at 97.1% the gap to next-closest Vodafone is just 0.4% -- and customers on 3 still see 93.8% of their tests pass the Core Consistent Quality thresholds.

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Consistent Quality Percentage in Common Coverage Areas (3G & 4G)

	Excellent	Core
EE	82.6%	97.1%
Vodafone	76.5%	96.7%
O2	69.9%	94.9%
3	68.6%	93.8%

(1) Engagdet, EE switches on 4G in 11 UK cities, offers fiber broadband to 11 million sites and opens 700 stores https://www.engadget.com/2012/10/30/ee-4g-launches-in-11-UK-cities/
Retrieved 27 August 2019

Consistent Quality

In practical terms, these high Core Consistent Quality results mean that the vast majority of the time, UK mobile customers have access to a network connection that's sufficient for simple use-cases. Telecoms regulator Ofcom has prioritized this type of consistent access to a baseline service (its metric of data coverage is designed to simulate a 2 Mbps download throughput(2)); with the national average for access to this kind of connection above 95%, it seems as though operators are paying attention to hitting Ofcom's target.

(2) Ofcom, Coverage obligations in the 700 MHz and 3.6-3.8 GHz spectrum award
https://www.ofcom.org.uk/__data/assets/pdf_file/0022/135157/Consultation-Coverage-obligations-in-the-700-MHz-and-3.6-3.8-GHz-spectrum-award-Ofcoms-approach-to-verifying-compliance.pdf
Retrieved 27 August 2019

Key performance indicators

Excellent Consistent Quality

Download throughput > 5 Mbps
Upload throughput > 1.5 Mbps
Latency < 50 ms
Jitter < 30 ms
Packet loss < 1%

Core Consistent Quality

Download throughput > 1.5 Mbps
Upload throughput > 0.5 Mbps
Latency < 100 ms
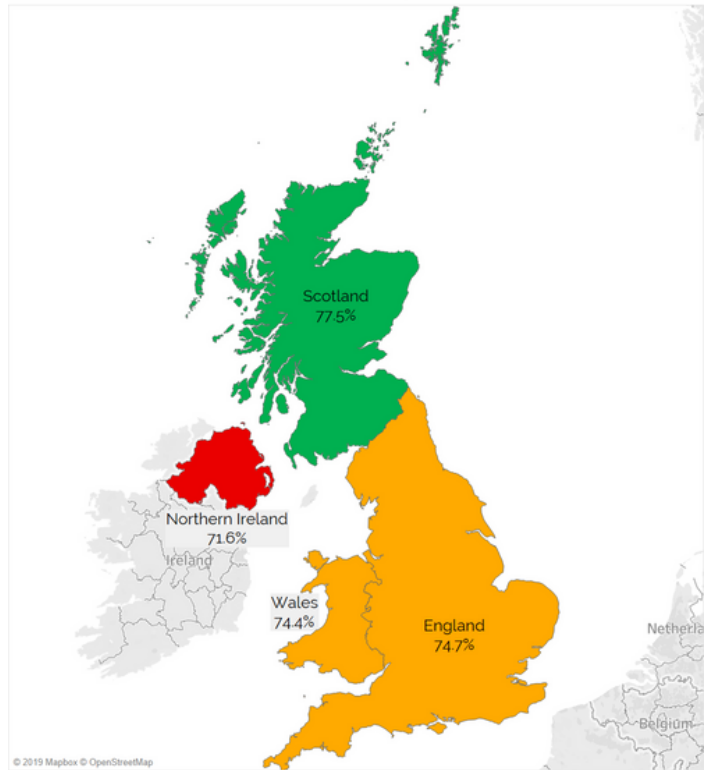Jitter < 50 ms
Packet loss < 5%

Across the four nations that make up the United Kingdom, Scotland's network quality stands out. It leads England significantly for Excellent Consistent Quality, with 77.5% of connections sufficient for the most demanding use-cases like streaming 1080p HD video. England and Wales offer similar network quality, with 74.7% of records hitting the more stringent thresholds. Northern Ireland's Excellent Consistent Quality was 71.6%, putting it in last place, significantly behind Scotland.

For Core Consistent Quality, the results were much closer: England, Wales, and Northern Ireland all had 95% of tests above the thresholds, while Scotland still led the pack with 96.6%. This suggests that the difference in networks between the countries is mostly limited to top-end performance, with networks across all of the UK delivering similar core results.

"Scotland leads England for Excellent Consistent Quality, with 77.5% of connections sufficient for the most demanding use-cases"

TUTELA   Excellent Consistent Quality Percentage in Common Coverage Areas (3G & 4G)

Scotland 77.5%

Northern Ireland 71.6%
Ireland

Wales 74.4%

England 74.7%

Netherla

Belgium

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TUTELA   Core Consistent Quality Percentage in Common Coverage Areas (3G & 4G)

Scotland 96.6%

Northern Ireland 95.5%
Ireland

Wales 95.3%

England 95.6%

Netherla

Belgium

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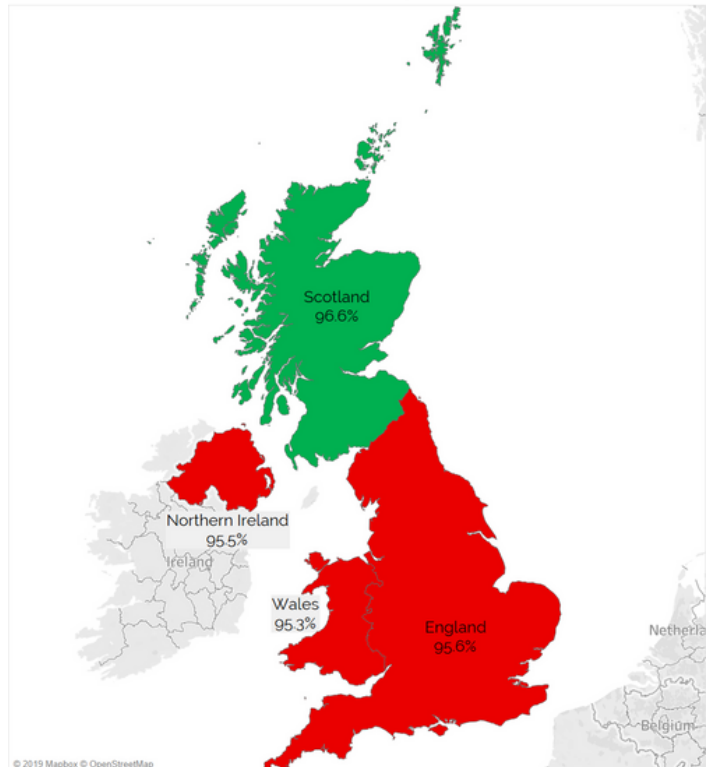
Looking at results taken across the entirety of the UK, rather than in Common Coverage Areas, the Consistent Quality percentages drop slightly for two of the operators - EE and Vodafone, which is to be expected. Results taken outside of Common Coverage Areas are predominantly in rural areas, where providing coverage is more challenging. The nationwide results incorporate tests taken anywhere in the UK, and as such performance is likely to drop across the board. However, the decrease in overall Excellent Consistent Quality percentages is extremely limited; EE and Vodafone saw their results drop by just 0.1%, while there was no change for O2 or 3. O2, for example, relies heavily on low-band spectrum, which provides better range and building penetration than mid-band or high-band spectrum, which goes some way to explain the lack of difference between nationwide and Common Coverage Area results.

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Consistent Quality Percentage
Nationwide (3G & 4G)

Operator	Excellent	Core
EE	Excellent 82.5%	Core 97.1%
Vodafone	Excellent 76.4%	Core 96.7%
O2	Excellent 69.9%	Core 94.9%
3	Excellent 68.6%	Core 93.8%
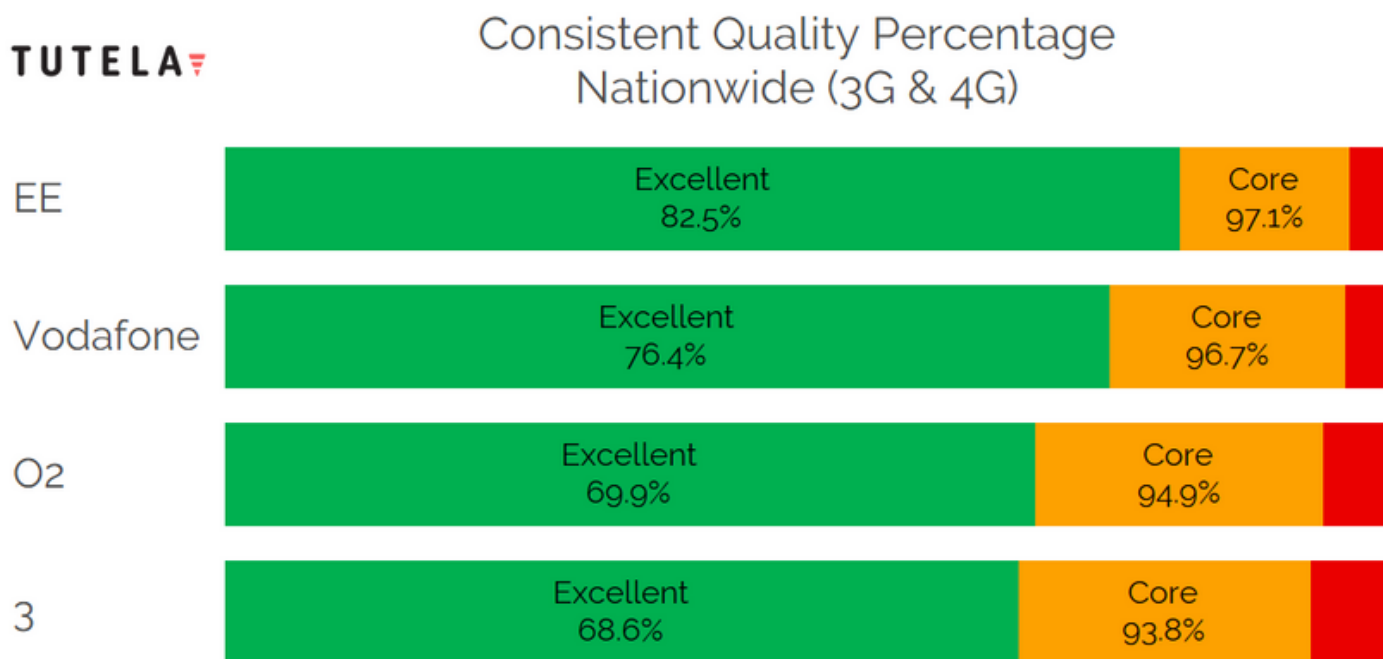
Download throughput

Whilst EE has an edge in Excellent Consistent Quality compared to other operators, its average download throughput performance stands out. EE's median download throughput in Common Coverage Areas was 21.2 Mbps, nearly 8 Mbps faster than second-place Vodafone, and over 10 Mbps faster than O2 and 3.

Apart from EE, the other operators are much more equal in terms of download performance. It's notable that all four operators recorded median download throughput speeds around 10 Mbps, double the requirement for Excellent Consistent Quality.

TUTELA Median Download Speed in Common Coverage Areas

EE	21.2Mbps
Vodafone	13.3Mbps
O2	9.9Mbps
3	9.7Mbps

TUTELA Median Download Speed Nationwide

EE	21.2Mbps
Vodafone	13.3Mbps
O2	9.9Mbps
3	9.7Mbps

Upload throughput

The gap between EE and other operators is less pronounced for upload performance. EE is in first place, with a median upload throughput of 8.3 Mbps. At that speed, the average Instagram picture would upload in less than a quarter of a second(3). All four operators' median upload throughput is well in excess of the 1.5 Mbps required to hit Tutela's Excellent Consistent Quality standard.

EE saw the greatest drop when comparing results from Common Coverage Areas to national-level results -- but that drop was still just 0.1 Mbps. Vodafone, 3 and O2 saw no decrease.

TUTELA Median Upload Speed in Common Coverage Areas

EE	8.3Mbps
Vodafone	6.5Mbps
O2	5.3Mbps
3	4.7Mbps

TUTELA Median Upload Speed Nationwide

EE	8.2Mbps
Vodafone	6.5Mbps
O2	5.3Mbps
3	4.7Mbps

(3) Based on a typical 1080 x 1080 photo upload, approximately 150 KB

Latency

Latency performance was particularly strong across all of the UK, with less than five milliseconds separating first and last place. EE was once again in first place for latency performance, likely helped in no small part by having the highest time on 4G.

The difference in latency performance between 3G and 4G networks is vast, and since EE customers spend more time on 4G than customers of any other network, it's not surprising that EE also has the lowest median latency. Across the board, however, all four operators provided particularly strong latency performance. For some use-cases like web browsing, a user's perception of a "fast" connection is more likely to be driven by low latency than particularly fast download throughput.

All four operators having a median latency below 20 milliseconds means that UK consumers are getting a consistently excellent performance in latency-sensitive applications like multiplayer gaming, real-time video calls -- and yes, web browsing.

TUTELA Median Latency in Common Coverage Areas

EE   13.0ms

O2   16.5ms

Vodafone 16.9ms

3   17.3ms

TUTELA Median Latency Nationwide

EE   13.0ms

O2   16.6ms

Vodafone 16.9ms

3   17.3ms

Data and spectrum usage

The four operators take significantly different approaches to how they provide coverage: EE and 3 use mid-band and high-band spectrum for the vast majority of their data traffic, while Vodafone and O2 use the low-band 800 MHz spectrum much more heavily. Low-band spectrum travels further and penetrates buildings better than mid-band or high-band, but there is less capacity available, which explains some of the speed and coverage differences between the networks.

O2's utilization of 800 MHz in particular stands out. O2 owns 20 MHz of 800 MHz spectrum(4), which carries nearly 76% of O2's 4G data traffic. By comparison, EE owns 90 MHz of 1800 MHz spectrum, which carries 60% of EE's LTE traffic.

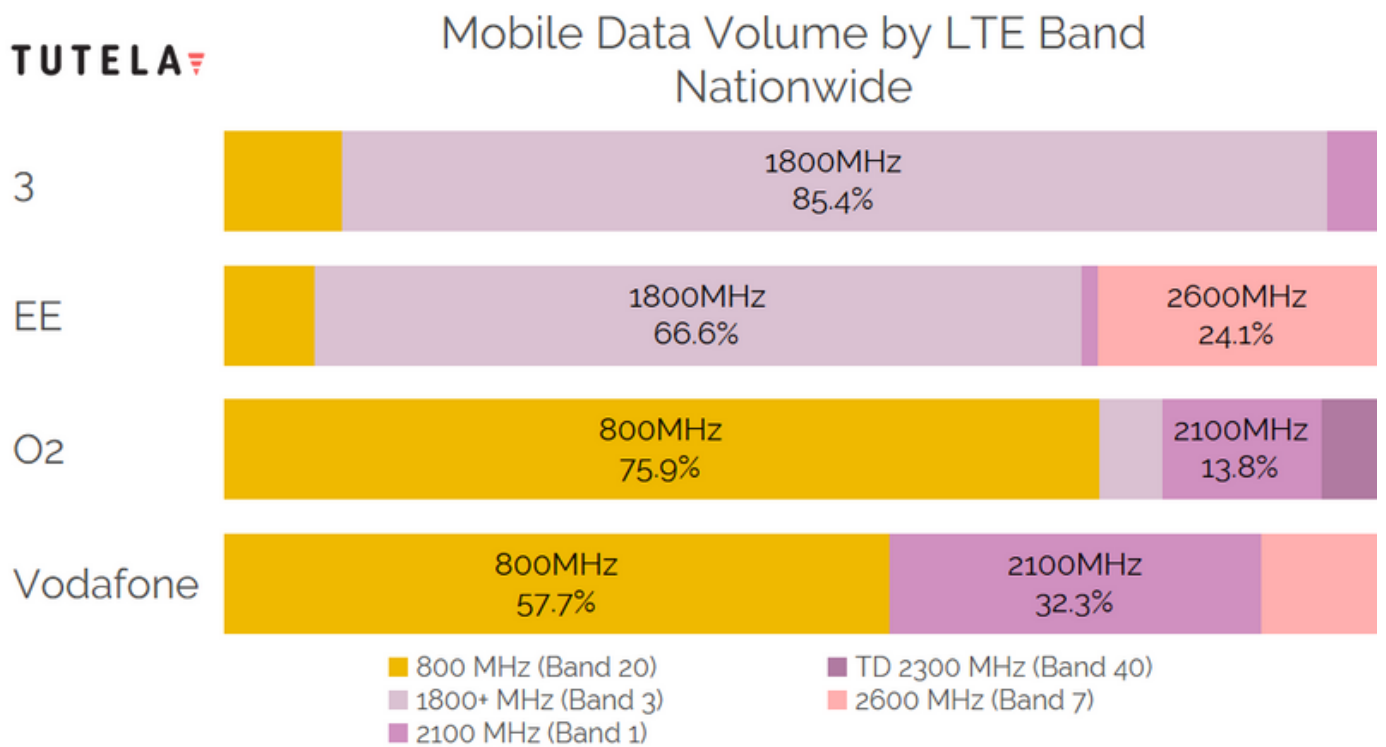(4) SMTA Global Spectrum Allocation Database (July 2019)

For a wireless network, the amount of deployed spectrum has a close correlation with the number of users that the network can handle, as well as the peak download speeds. That goes some way to explaining why O2's median download throughput falls behind some of the other operators. It also explains why 3 -- which, similar to EE, uses 1800 MHz for the vast majority of its network traffic -- has such different results. to EE. While EE has 90 MHz of 1800 MHz

spectrum available for its network, 3 has just 30 MHz available.

However, O2's nationwide usage of 800 MHz spectrum also has an advantage: since low-band radio waves travel further and penetrate buildings better than higher-band alternatives, O2's network saw no change in performance between nationwide samples or those taken in common coverage areas.

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Mobile Data Volume by LTE Band Nationwide

3	1800MHz 85.4%	
EE	1800MHz 66.6%	2600MHz 24.1%
O2	800MHz 75.9%	2100MHz 13.8%
Vodafone	800MHz 57.7%	2100MHz 32.3%

- 800 MHz (Band 20)
- 1800+ MHz (Band 3)
- 2100 MHz (Band 1)
- TD 2300 MHz (Band 40)
- 2600 MHz (Band 7)

O2 and Vodafone share some cell towers and antennas nationwide, and as a result the similar percentage of time spent on 4G and 3G for their customers is expected. EE's long-term focus on 4G and refarming 3G spectrum(5) has clearly paid off, as customers spend just 13.7% on 3G. 3 is the clear outlier: customers spend not quite 75% of their time on 4G. 3 owns less spectrum compared to the other operators, and in the past focused on deployed advanced 3G technologies such as DC-HSPDA, rather than 4G. However, 3 owns significantly more spectrum in the 3.5 GHz band, which it plans to use for 5G, so expect the current situation to change in the future.

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Percent of Time by Mobile Connection Type Nationwide

	4G	3G
EE	4G 86.3%	3G 13.7%
O2	4G 82.5%	3G 17.5%
Vodafone	4G 82.1%	3G 17.9%
3	4G 74.1%	3G 25.9%
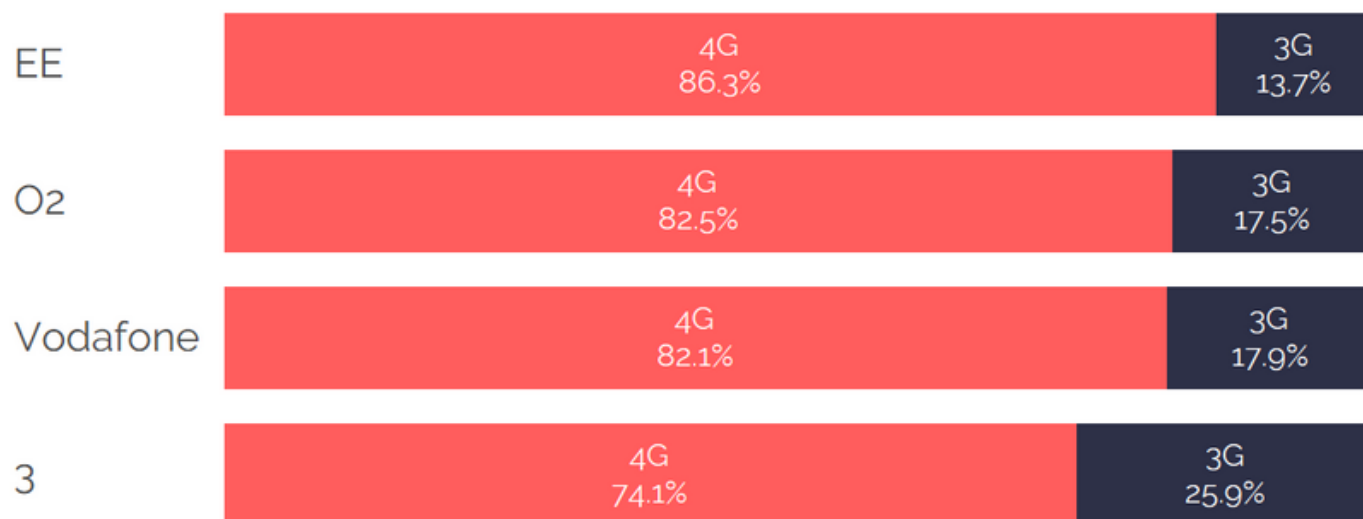
(5) ISPreview, EE Refarm UK 3G Spectrum Bands into Ultrafast 4G Mobile Broadband
https://www.ispreview.co.uk/index.php/2018/09/ee-refarms-uk-3g-spectrum-into-ultrafast-4g-mobile-broadband-bands.html
Retrieved 27 August 2019

Methodology

Tutela is an independent crowdsourced data company with a global panel of over 300 million smartphone users. We gather information on mobile infrastructure and test wireless experience, helping organisations in the mobile industry to understand and improve the world's networks.

Tutela collects data and runs network tests via software embedded in a diverse range of over 3,000 consumer applications, which enable the measurement of real-world quality of experience for mobile users, 24/7. For this report, we gathered 223,349,898,716 measurements, including over 30 million speed tests and 523 million latency measurements, from more than 1.9 million devices (iOS and Android smartphones) between February 1st and July 31st 2019.

Tutela measures network quality based on the real-world performance of actual network subscribers, inclusive of occasions when a network or tariff may be throttled or congested. Results in this report are based on a testing configuration designed to represent the typical (rather than maximum) performance that users experience. We use a 2 MB file to perform our download testing and a 1 MB file to perform our upload testing. Latency performance in this report reflects one-way UDP latency. Tests are conducted against the same content delivery networks that power many of the world's most popular consumer applications, and as such reflect the end-to-end performance of the network.

Consistent Quality

Download speed is most often used as a proxy for network quality, but while download throughput is important, it's just one of several crucial requirements for a "good" connection.

As operators have upgraded 3G networks to LTE-Advanced technology, theoretical (and even real-world) peak throughput speeds have increased to where they vastly outstrip the maximum needed for any current use-case. Real-world speeds above 100 Mbps are now common in parts of the world, and with a 4K video stream -- which itself is rarely something smartphone users need -- using a fifth of that, average download speed has lost some of its relevance as the dominant statistic used to measure the quality of wireless networks.

At its most basic, a good connection is one that doesn't get in the way of users doing what they want to do. In the real world, smartphone users aren't running speed tests all day -- they're browsing the web, using apps, voice calling their friends, streaming Netflix and YouTube, or making video calls.

Consistent Quality

To more objectively evaluate when networks are (and are not) enabling users to do those things, Tutela has developed a standard called consistent quality. Simply put, it's two sets of thresholds, called Excellent and Core. If a connection hits the Excellent standard, it's sufficient for the most demanding mobile use-cases, like HD group video calling or 1080p video streaming. A Core connection is good enough for SD video streaming, web browsing, emails, and VOIP calling, but users are more likely to experience delays or buffering when trying to use more demanding apps. Tutela bases the threshold values on the minimum performance requirements published by popular apps. We most recently updated our Consistent Quality thresholds on September 1st, 2019.

Tutela's consistent quality metric, as used in our reports, simply measures the percentage of time that users can hit the thresholds. The higher the number, the more often users have a Core or Excellent quality connection.

Excellent Quality

KPI	Download throughput	Upload throughput	Latency	Jitter	Packet loss
Minimum acceptable value	5 Mbps	1.5 Mbps	50 ms	30 ms	1%

Core Quality

| KPI	Download throughput	Upload throughput	Latency	Jitter	Packet loss
Minimum acceptable value	1.5 Mbps	500 Kbps	100 ms	50 ms	5%

Discover Tutela Explorer

Tutela Explorer is a powerful cloud-based solution for real-time analysis of crowdsourced data. Using the platform, mobile operators can:

- Create coverage and quality maps
- Benchmark network quality and coverage across all operators
- Drill down to any KPI at city, street or even building level
- Analyse spectrum utilisation, performance and more

Visit www.tutela.com/explorer to learn more

Learn more
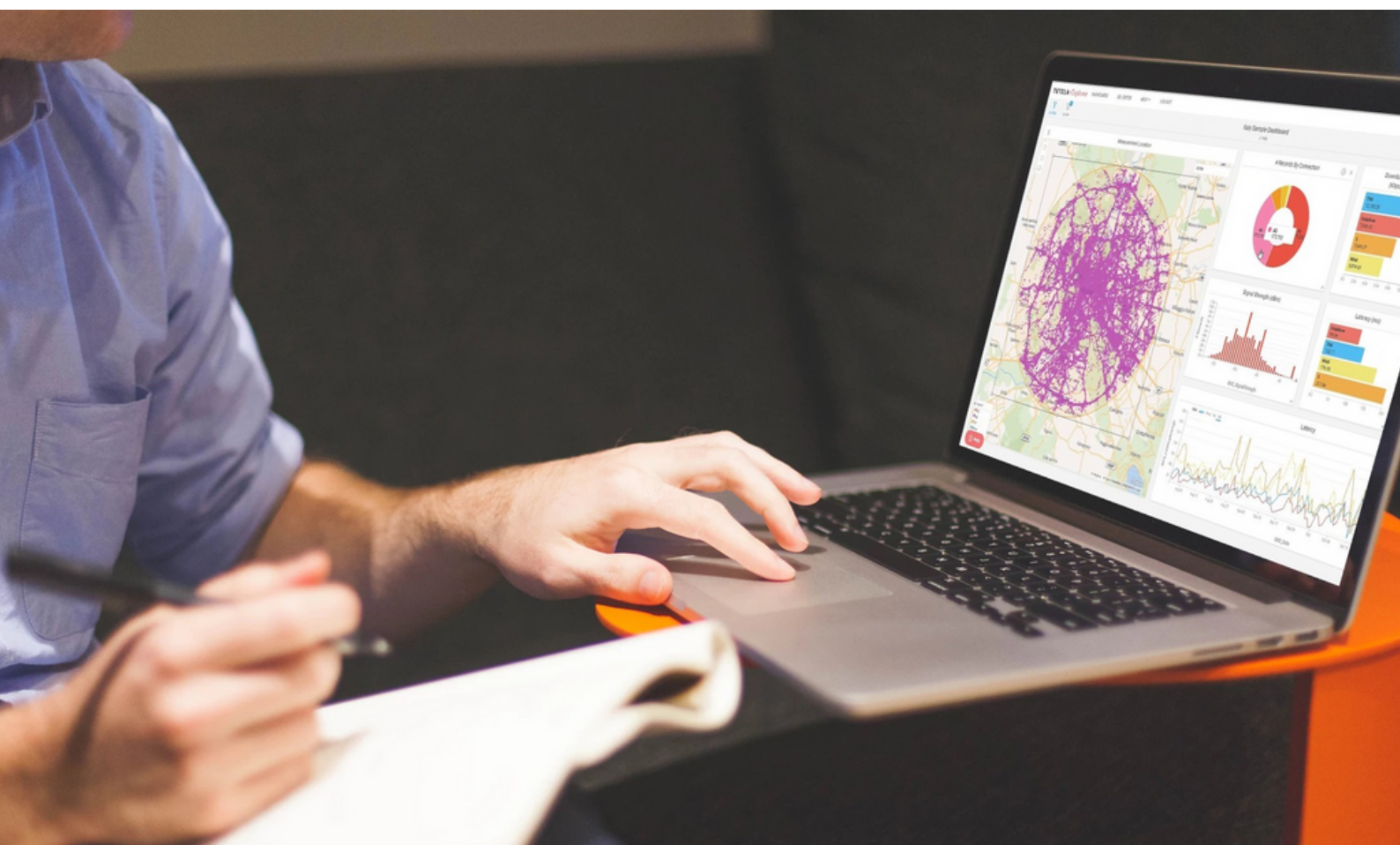
Appendix

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Error Margins

		Download Median	Upload Median	Latency Median	Excellent CQ	Core CQ
Common Coverage Areas	EE	±0.04Mbps	±0.02Mbps	±0.0ms	±0.1%	±0.0%
	O2	±0.02Mbps	±0.01Mbps	±0.4ms	±0.1%	±0.0%
	Vodafone	±0.04Mbps	±0.02Mbps	±0.0ms	±0.1%	±0.0%
	3	±0.02Mbps	±0.01Mbps	±0.3ms	±0.1%	±0.0%
National	EE	±0.04Mbps	±0.02Mbps	±0.0ms	±0.1%	±0.0%
	O2	±0.02Mbps	±0.01Mbps	±0.4ms	±0.1%	±0.0%
	Vodafone	±0.03Mbps	±0.02Mbps	±0.0ms	±0.1%	±0.0%
	3	±0.02Mbps	±0.01Mbps	±0.3ms	±0.1%	±0.0%

		Download Median	Excellent CQ	Core CQ
Common Coverage Areas	Scotland	±0.1Mbps	±0.1%	±0.0%
	Wales	±0.1Mbps	±0.2%	±0.0%
	England	±0.0Mbps	±0.0%	±0.0%
	Northern Ireland	±0.1Mbps	±0.3%	±0.0%

About Tutela

Tutela Technologies, Ltd., is an independent crowdsourced data company with a global panel of over 300 million smartphone users. It gathers information on mobile infrastructure and tests wireless experience, helping organizations in the mobile industry to understand and improve the world's networks. Data and insights provided by Tutela are trusted by the engineering teams at mobile network operators and network equipment manufacturers around the world and used to compare operators as well as inform decisions in network and infrastructure planning and optimisation. The organization is headquartered in Victoria, British Columbia.

Tutela does not collect any sensitive personal data and is compliant with international privacy regulations including GDPR.

For further information about the methodology, data and tools used to create this report, please contact analysis@tutela.com or visit www.tutela.com.

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