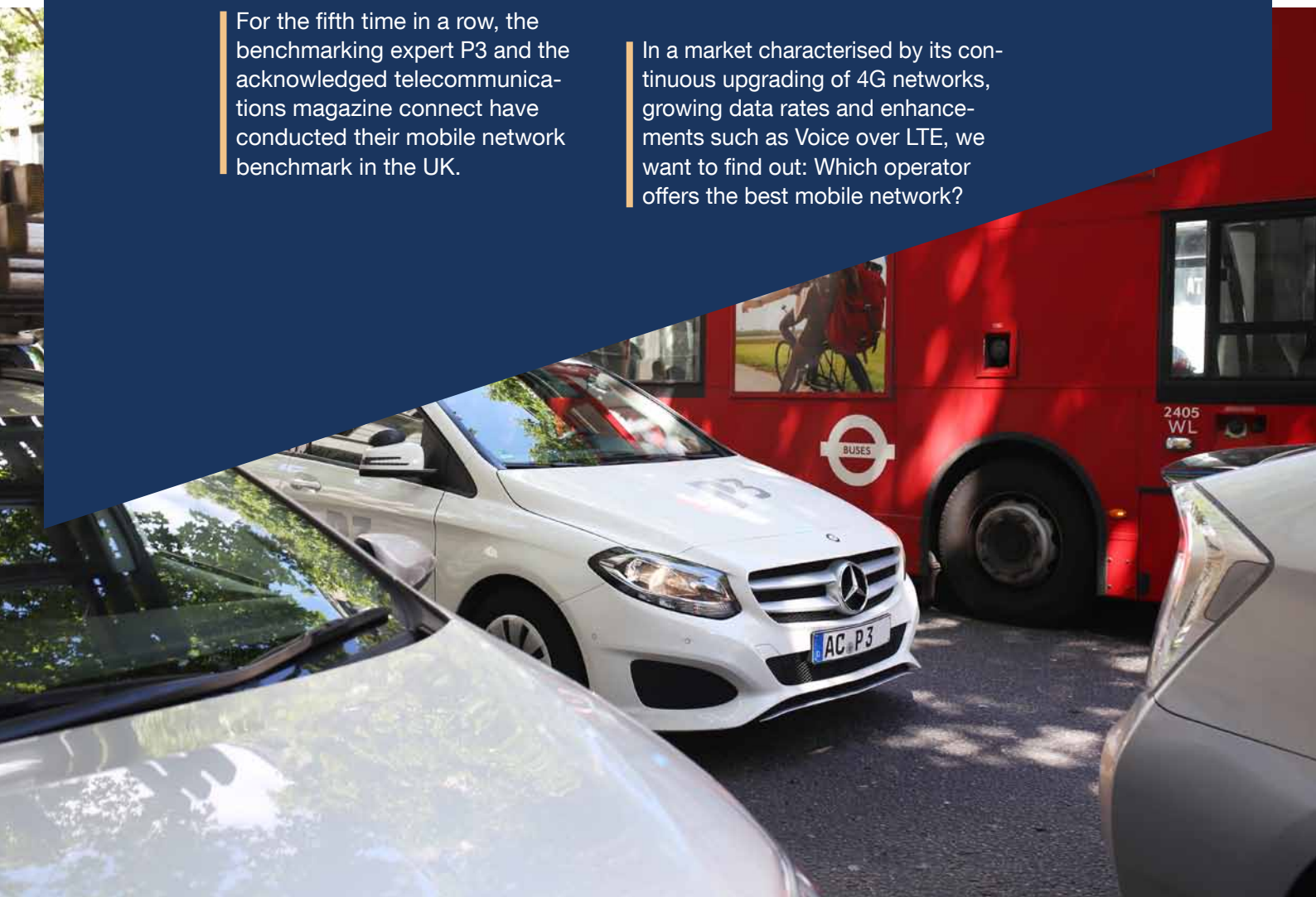
P3 connect MOBILE BENCHMARK

THE 2018 MOBILE NETWORK TEST IN THE UNITED KINGDOM

For the fifth time in a row, the benchmarking expert P3 and the acknowledged telecommunications magazine connect have conducted their mobile network benchmark in the UK.

In a market characterised by its continuous upgrading of 4G networks, growing data rates and enhancements such as Voice over LTE, we want to find out: Which operator offers the best mobile network?



RESULTS IN A NUTSHELL

The overall ranking of this year's P3 connect Mobile Benchmark in the UK looks familiar. But in the detailed categories, the operators show varying results – improving in some areas, but losing ground in others.

> EE is the winner with strong results in all disciplines and scenarios. Vodafone achieves a good second rank. Three is strong in towns, but overall only performs satisfactory. O2 scores last and achieves the grade "satisfactory" the same as Three.

P3's network benchmarks are widely accepted as being highly objective and defining the de-facto industry standard The carefully designed methodology of the 2018 benchmark in the UK combines drivetests and walktests for executing detailed voice and data measurements under controlled circumstances with a sophisticated crowdsourcing approach. This provides profound insights into the overall coverage of voice, data and 4G services, real-world User Download Speeds and Data Service Availability. For the first time in the UK, this year we have extended our walktest to also cover railway connections.

P3's holistic approach to network benchmarking includes both drivetest and walktest measurements as well as crowdsourcing. The drive and walktests allow for evaluating the cutting edge of the networks' capabilities. Crowdsourcing unveils the service quality, performance and coverage actually experienced by the users. We have thoroughly weighted these components in order to give a realistic and authoritative assessment of the rated networks' true potential and performance.

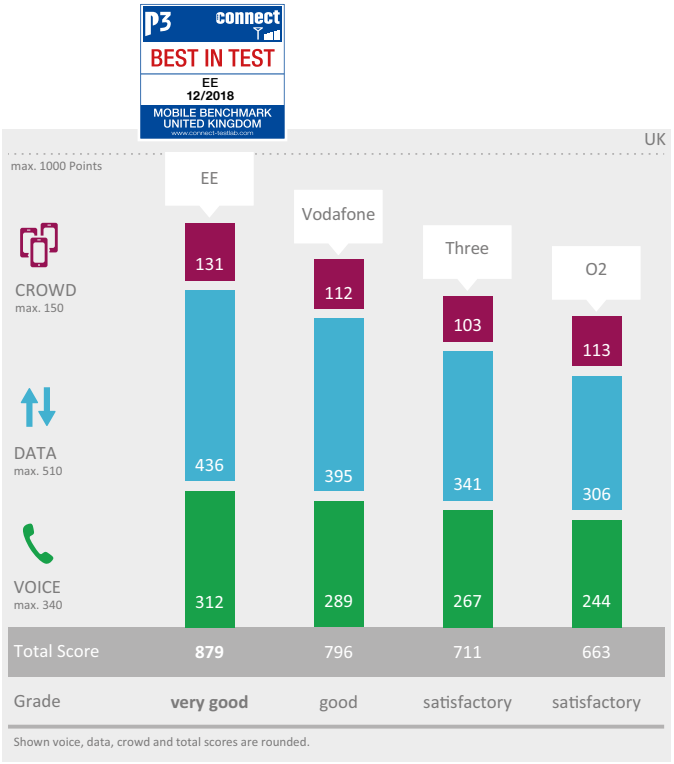
EE TAKES THE OVERALL LEAD, VODAFONE ALSO STRONG IN CITIES AND ON THE ROADS. THREE OFFERS BEST DATA PERFORMANCE IN TOWNS, O2 RANKS SECOND IN CROWD SCORE

In the voice category, EE is clearly leading, showing strong results in all tested scenarios and delivering excellent speech quality due to its use of the modern EVS (Enhanced Voice Services) codec. Vodafone offers excellent success ratios for voice calls in the city walktests together with EE. Three ranks third and O2 last, with both offering good voice results in the towns.

In the data tests, EE shows the best results as well. This is applicable for the city drivetests, on the roads and – at a lower level – on railways. In the city walktests, EE and Vodafone are on a par, with the other two lagging behind. Three shows the best data performance in towns.

In the crowd score, EE takes the lead in all categories, particulary in the crowdsourced quality. It did not suffer any service degradations from May to October 2018. O2 ranks second in the crowdsourcing and Vodafone third, only one point behind O2. Three follows at some distance on the last rank in the crowd discipline but proves to be also very reliable with only hour of service degradation in the observation period.

All UK operators show considerable room for improvements on the railways.



Shown voice, data, crowd and total scores are rounded.

Overall Results Voice, Data and Crowd		EE	Vodafone	Three	O2
Voice	max. 340	312	289	267	244
Cities (Drivetest)	153	95%	89%	82%	75%
Cities (Walktest)	51	100%	96%	89%	75%
Towns (Drivetest)	68	93%	86%	85%	79%
Roads (Drivetest)	43	94%	88%	76%	73%
Trains (Walktest)	26	48%	29%	27%	24%
Data	max. 510	436	395	341	306
Cities (Drivetest)	230	89%	80%	63%	64%
Cities (Walktest)	76	85%	85%	57%	43%
Towns (Drivetest)	102	82%	77%	84%	64%
Roads (Drivetest)	64	94%	85%	81%	79%
Trains (Walktest)	38	61%	37%	42%	28%
Crowdsourced Quality	max. 150	131	112	103	113
Crowd	150	87%	75%	69%	75%
Connect Rating	max. 1000	879	796	711	663

Percentages and points rounded to integer numbers.
For the calculation of points and totals, the accurate, unrounded values were used.

THE UK OPERATORS

Each of the four mobile networks competing in the UK claims to have growing subscriber numbners. EE and O2 are the largest players, followed by Vodafone, with the smaller Three attacking with aggressive tariffs.

With approximately 30 million customers, EE (formerly Everything Everywhere) is the biggest mobile network operator in the UK. Since January 2016, EE has been part of the British Telecom Group. EE started offering a 4G service in October 2012. Regarding their 4G coverage, EE has chosen to report geographic coverage instead of population coverage from now on. In this context, they refer to the Connected Nations Report by UK's regulator Ofcom and thus quote to currently offer 84 per cent 4G geographic coverage. EE operates its 4G network at 800 MHz, 1800 MHz and 2600 MHz. Additionally, it operates 2G at 1800 MHz and 3G at 2100 MHz. Furthermore, EE operates a growing number of LTE Advanced network cells that support speeds of up to 450 Mbps under the name "4GEE". And EE offers Voice over LTE (VoLTE) in most of its 4G network. All plans come with 4G at no extra cost.

O2 claims to be the second largest mobile network operator in the UK with approximately 25 million customers. Formerly a subsidiary of British Telecom, O2 plc was purchased by the Spanish telecommunications company Telefónica in 2006. Today, the company also owns half of the mobile virtual network operator Tesco Mobile which operates on the O2 network in the UK. O2 started providing its 4G service in August 2013 and has expanded this service across the UK since. In November 2018, O2 claimed to cover approximately 99 per cent of the UK population with its 4G service. O2 operates its 4G network mainly on 800 MHz with limited additional 1800 and 2100 MHz coverage in metropolitan areas. Additionally, O2 provides 2G on 900 and 1800 MHz and 3G on 900 and 2100 MHz. Like the other UK operators, O2 has rolled out Voice over LTE (VoLTE) in most of its 4G network.

Vodafone UK is part of the Vodafone Group which is also headquartered in the UK. The Vodafone Group owns and operates networks in 21 countries. Vodafone UK launched 4G/LTE in 2013. With around 17 million mobile subscribers, Vodafone is the third largest mobile network in the UK after EE and O2. In June 2012, Vodafone and O2 signed a deal to "pool" their network technologies, creating a single national grid of 18,500 transmitter sites. Both networks however announced they would continue to use their own independent spectrum. Vodafone operates 4G/LTE at 800, 1800, 2100 and 2600 MHz and claims to cover 99 per cent of the UK population. Additionally, Vodafone offers 2G at 900 and 1800 MHz plus 3G at 900 and 2100 MHz. With "Carrier Aggregation", Vodafone is upgrading its 4G network to "4G+", offering up to 1 Gbps – as well as Voice over LTE (VoLTE) telephony.

Three UK is a subsidiary of Hutchison Whampoa and launched its mobile service in the UK in 2003. As a relatively young operator Three started as a 3G-only network supplemented by 2G via national roaming. In December 2013, Three began to roll out its 4G/LTE service and expanded it rapidly all over the UK. With about 10.1 million customers Three is the smallest mobile network operator in the UK but claims to carry over 36 per cent of the nation's data traffic. Offering the cheapest price for 4G and unlimited data plans (excluding tethering) may well support this claim. In addition to 1800 MHz, Three offers 4G also at 800 MHz as well as 3G on 2100 MHz. The company currently claims to cover 99 per cent of the UK's population with at least 3G. According to their own account, abut 84 per cent of Three's customer base is using 4G. The operator has also started to deploy Voice over LTE (VoLTE) in most of its 4G network.

With the addition of crowdsourcing, P3 and connect have extended their scope in order to present an even more complete look at network quality and performance.

A CLOSE LOOK AT THE UK NETWORKS

P3, headquartered in Aachen, Germany, is a world leader in mobile network testing. The company has over 3,500 employees worldwide and a turnover of more than 350 million Euros. P3 is partnering with the international telecommunications magazine connect, which has 25 years of editorial expertise and is one of the leading test authorities in Europe for telecommunications products and services. Together, P3 and connect have been conducting the most important network benchmark test in Germany for more than 15 years, extending it to Austria and Switzerland since 2009. Starting in 2014, P3 has also been conducting benchmarks in the UK and Australia, expanding its public mobile network tests to the Netherlands, Spain and Sweden in 2016 as well as examining many other mobile networks all over the world including those in the USA and Singapore.

The 2018 P3 connect Mobile Benchmark in the UK consists of drivetests and walktests conducted from October 30 to December 3, 2018. Four drive test cars together covered about 11,750 kilometres, visiting 22 cities and 35 towns. Additionally, two walktest teams visited ten cities and travelled on trains between them. The test areas account for approximately 16.6 million people, or about 26.2 per cent of the total population of the United Kingdom.

> The UK's networks improved overall on last year. We adapt our testing methodology every year to keep close to technological advances as well as to the actual experience of end-users. This year, we have added the railway measurements into our scope for the P3 connect Mobile Benchmark in the UK and derived some interesting conclusions. For next year, we expect the first developments in 5G to come.
>
> **Hakan Ekmen**
> CEO of P3 communications

DRIVETEST AND WALKTEST FACTS

16.6 million people covered

11,750 km drivetest

259,705 data samples

28,926 voice samples

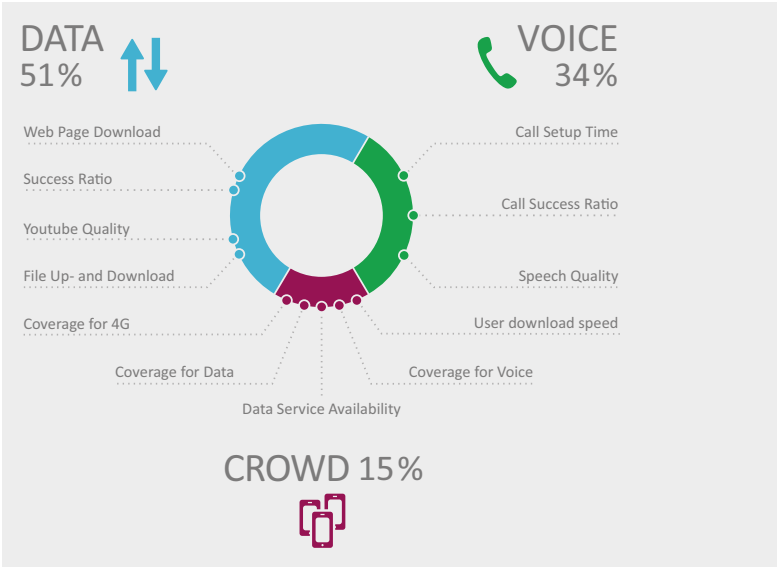
CROWDSOURCING FACTS

268,000 users

2.99 billion samples

3 months (Aug to Oct 2018)

91.0 of built-up area



VOICE

Many customers use voice services less intensely than data. However, when actually taking or placing a phone call, they expect reliable connections. How do the UK networks manage to fullfil these expectations?

EE LEADS IN VOICE, SHOWING VERY GOOD RESULTS IN CITIES, TOWNS AND ON ROADS. IN TRAINS, THE RESULTS ARE IN NEED OF IMPROVEMENT.

All four operators in the UK now support Voice over LTE (VoLTE). VoLTE transmits voice calls as data packets over a 4G connection. This way, the otherwise necessary "circuit-switched fallback", which forces smartphones to switch back to 3G in order to take or place a phone call, can be avoided. Also, VoLTE supports better audio codecs providing operators with the opportunity to deliver higher speech quality to their customers.

For the voice rating, each drivetest car and each walktest team carried one Samsung Galaxy S8 smartphone per operator. The phones in the cars called a counterpart in one of the other cars. The phones carried by the walktest teams called a stationary counterpart. The connected testing equipment registered success ratios, call setup times and speech quality. In order to simulate normal smartphone usage, data transfers took place in the background of the test calls.

EE

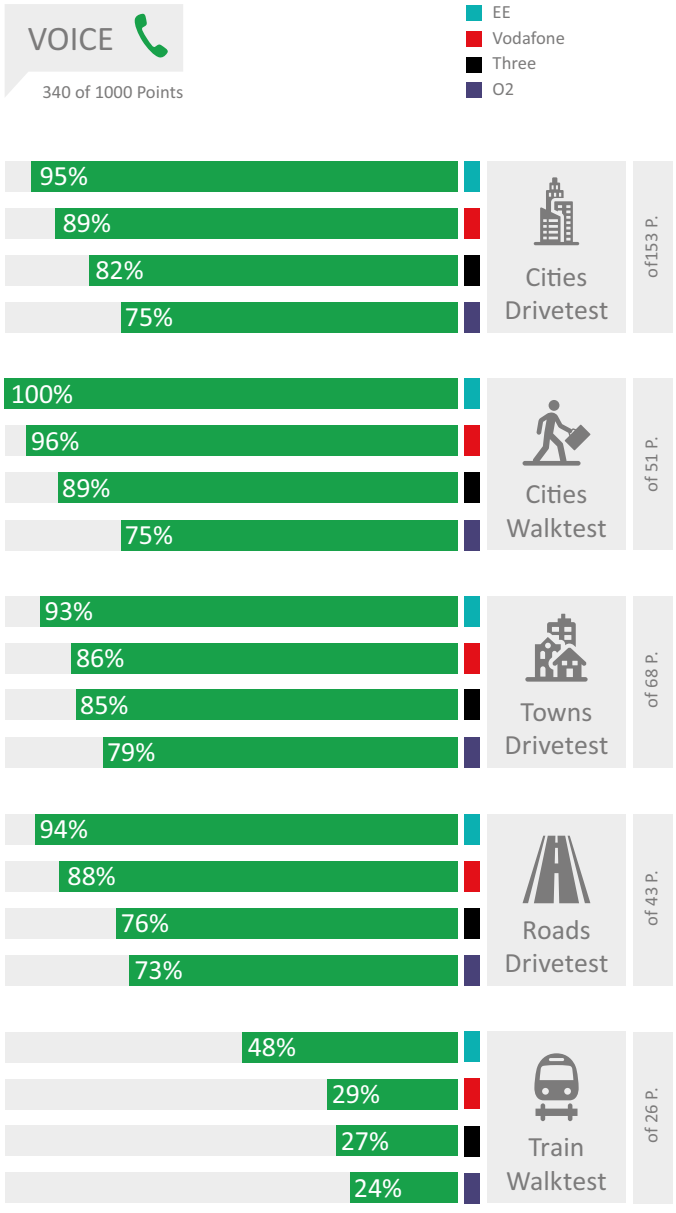
EE LEADS IN THE BIG CITY DRIVETESTS

In the voice drivetests conducted in 22 UK cities, EE achieves the highest score. It offers the highest call success ratios, shortest call setup times and best speech quality. Vodafone ranks second due to slightly lower KPIs in all these categories. Three follows on the third rank, being on par with Vodafone in terms of success ratios and speech quality, but showing longer setup times. O2 ranks last.

EE

EE AHEAD IN BIG CITY WALKTESTS

The walktest teams generally captured a higher performance level for voice in the cities than the drivetest teams – except for O2 which reaches a degree of fullfillment of 75 per cent in both disciplines. EE shows an impressive success ratio of 100 per cent and also very good results for the other KPIs. The ranking is the same as in the drivetests. O2 offers nice speech quality, but lags behind in the other KPIs.



EE

EE HAS ALSO BEST RESULTS IN TOWNS

The results of the drivetests leading through 35 towns accounts for the same ranking as in the cities. EE is leading once again, followed by Vodafone, and Three is close behind. O2 ranks last. Interestingly, Three and O2 achieve slightly better results in the smaller towns than in the big cities. Also, it is pleasing to see that the performance of all four candidates in the towns went up compared to the previous year.

EE

EE STREETS AHEAD ON ROADS

When it comes to conducting voice calls on the roads, EE is again in the lead. Vodafone ranks recond, with Three and O2 following at some distance. Again, compared to last year's results, all four UK operators managed to increase their performance in this discipline. With call success ratios aorund 97 per cent, even the weaker contenders offer an acceptable level of voice service.

EE

EE LEADS IN OVERALL WEAK RESULTS ON BRITISH RAILWAYS

For the first time in the UK, this year's P3 connect Mobile Benchmark also comprises walktests conducted while travelling on British trains. However, their results are quite sobering: Even EE as the strongest candidate only achieves 48 per cent of the possible points in this discipline. Vodafone follows with a meagre 29, Three at 27 and O2 at 24 per cent. The main problem is the very limited call success ratios – our tests results indicate that EE customers only stand a 87 per cent to get through when trying to conduct a phone call while travelling on a British train. This chance drops to 81 per cent in Three's and O2's networks and to even 78 per cent at Vodafone. The latter at least offers better call setup times when such a call attempt actually succeeds.

VOICE RESULTS AT A GLANCE

In the voice category, EE is clearly leading the field. It shows strong results in all aggregations. As EE mainly uses the modern EVS codec, it delivers excellent speech quality. Vodafone follows on the second rank, offering excellent success ratios in the city walktests together with EE. Three ranks third, but is in general on a par with Vodafone in success ratios, lagging behind mainly in call setup times. O2 comes in last, but offers good results especially in smaller towns. The newly added railway measurements reveal big challenges for all operators.

Voice	EE	Vodafone	Three	O2
Cities - Drivetest				
Call Success Ratio (%)	99.1	98.4	98.4	97.5
Call Setup Time (s)	2.3	2.5	3.9	4.5
Call Setup Time P90 (s)	2.5	3.0	6.5	7.7
Speech Quality (MOS-LQO)	4.3	3.8	3.8	3.9
Towns - Drivetest				
Call Success Ratio (%)	98.9	97.9	99.4	98.7
Call Setup Time (s)	2.4	2.6	6.4	6.5
Call Setup Time P90 (s)	2.8	3.1	7.3	8.5
Speech Quality (MOS-LQO)	4.2	3.8	3.7	3.8
Roads - Drivetest				
Call Success Ratio (%)	98.6	97.7	96.6	96.9
Call Setup Time (s)	2.5	2.7	6.0	6.6
Call Setup Time P90 (s)	2.8	3.5	7.3	9.2
Speech Quality (MOS-LQO)	4.2	3.7	3.7	3.7
Cities - Walktest				
Call Success Ratio (%)	100.0	99.7	99.0	96.3
Call Setup Time (s)	2.2	2.5	3.4	3.5
Call Setup Time P90 (s)	2.5	3.2	4.6	4.8
Speech Quality (MOS-LQO)	4.4	3.9	3.8	4.1
Trains - Walktest				
Call Success Ratio (%)	86.9	78.2	80.7	80.7
Call Setup Time (s)	3.0	3.4	4.5	5.4
Call Setup Time P90 (s)	5.3	5.3	5.8	7.7
Speech Quality (MOS-LQO)	4.0	3.6	3.6	3.6

DATA

With the volume of transmitted data permanently growing, data connectivity constantly becomes more important. Which operator in the UK manages best to meet the increasing demand?

EE TAKES THE OVERALL LEAD IN THE DATA DISCIPLINE AS WELL. IN THE CITY WALKTESTS, VODAFONE IS ON A PAR WITH EE. THREE SCORES BEST IN TOWNS.

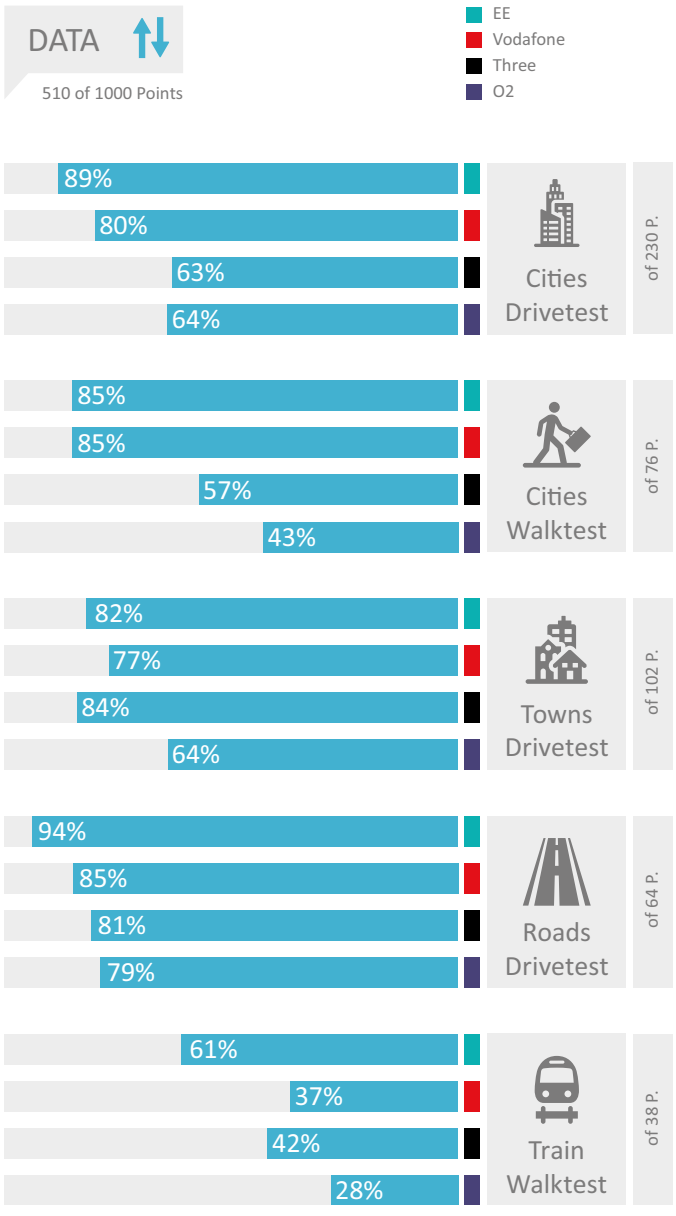
Data connectivity is the most prestigious discipline in our benchmark and also in the operators' marketing. All four UK networks claim to cover a large part of the population with LTE services – the claimed percentages range in the high nineties. Three states a combined 3G/4G data coverage of 99 per cent of the population and specifies that about 84 per cent of its 10.1 million customers are using 4G (also see page 3). All four operators are continuing to spend millions and billions on upgrading and expanding their networks to meet the growing demand.

However, the four operators pursue different rollout strategies. EE and Vodafone chase each other with continually growing data rates that currently go up to 1 Gbps, based on the so-called carrier aggregation (the combination of multiple carrier frequencies). In contrast, O2 and Three stick around a solid 100 Mbps and mainly focus on enlarging their 4G footprints.

P3'S SCORING REWARDS HIGH PERFORMANCE AS WELL AS THE NETWORKS' AVAILABILITY AND STABILITY

In order to assess the performance and reliability of data connections, each of our four drivetest cars and also the walktest team carried one Samsung Galaxy S8 per operator. Supporting the LTE category 16, these smartphones were able to benefit from carrier aggregation up to 1 Gbps. P3's testing considers such fast throughputs as well as the networks' availability and stability. The benchmarking of web-page downloads as well as file downloads and uploads rewards fast throughputs. At the same time, P3 assesses the networks' availabilty and stability by examining success ratios. In order to assess typical performance as well as peak speeds, we determined the minimum data rates that are availability in 90 per cent of the cases plus the peak data rates that would be surpassed in 10 per cent of the cases.

YouTube playouts concentrate on reliability aspects. As YouTube streams videos at adaptive bitrates, the average value of the received video resolution is another important performance indicator.



EE

EE TAKES THE LEAD IN CITY DRIVETESTS

In the scoring of their performances determined during the drivetests conducted in 22 UK cities, EE takes the lead, followed by a strong performance by Vodafone. These two operators overall deliver quite high success ratios, convincing download speeds and Youtube playback performance. O2 and Three fall behind, with O2 scoring slightly better than Three in this category.

Data in Cities - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	98.9/99.3	97.4/99.2	94.8/96.3	95.5/95.5
Static: Avg. Session Time (s)	1.3	1.4	1.7	1.9
Live: Reaction Time (ms)	324	356	303	331
Live: Initial DL Speed 1st second (kB/s)	717	682	568	524
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.6/1.9	98.2/2.5	97.9/5.1	98.4/5.8
90%/10% faster than (kbit/s)	7992/58680	5233/52863	1905/45802	1764/31088
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.8/0.8	99.0/1.1	98.8/1.4	99.0/1.6
90%/10% faster than (kbit/s)	7588/27682	4673/22466	4013/15009	2861/17312
File Download (7 Seconds)				
Success Ratio (%)	99.4	97.7	96.2	98.2
Avg. Throughput (kbit/s)	49279	43249	22268	19686
90%/10% faster than (kbit/s)	8749/103296	6921/88728	2307/54483	1855/48853
File Upload (7 Seconds)				
Success Ratio (%)	99.7	98.1	98.3	98.2
Avg. Throughput (kbit/s)	30251	21926	18076	12306
90%/10% faster than (kbit/s)	8703/53633	6221/40701	5026/33438	3070/22802
Youtube Video				
Success Ratio/Start Time (%/s)	98.2/1.4	97.2/1.6	89.2/1.9	90.1/2.1
Playouts without Interruptions (%)	99.3	98.9	96.0	95.6
Average Video Resolution (p)	1068	1055	1006	994
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	97.1/1.9	95.4/2.2	86.1/2.3	90.7/2.6
Playouts without Interruptions (%)	98.5	98.0	93.4	93.9
Average Video Resolution (p)	1075	1050	991	946

EE & VODAFONE

EE AND VODAFONE ON A PAR IN BIG CITY WALKTESTS

In the data results of the walktests that were conducted in ten large cities of the UK, EE and Vodafone achieve the same score. Looking closer at the single KPIs, both are on a par in the web tests, EE is a little ahead in the file transfer tests and Vodafone lead regarding Youtube playback. The gap between the leading duo and the other contenders is a little more pronounced, with O2 falling behind distinctly in this category. Among other weak points, O2 shows noticeably low success ratios when it comes to playing back Youtube videos. In terms of using data connectivity while walking in the big cities, there is clearly a two-tier system in the UK.

Data in Cities - Walktest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	98.6/98.4	98.0/99.7	92.5/94.7	90.4/93.7
Static: Avg. Session Time (s)	1.4	1.4	1.8	2.2
Live: Reaction Time (ms)	350	415	304	375
Live: Initial DL Speed 1st second (kB/s)	630	706	531	449
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.9/2.8	99.1/2.1	97.9/6.3	94.8/8.0
90%/10% faster than (kbit/s)	4760/54006	6646/49689	1556/38760	1181/24123
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.9/0.8	99.5/1.2	98.6/1.9	94.3/2.2
90%/10% faster than (kbit/s)	8156/25682	4354/21164	2899/12121	1754/15686
File Download (7 Seconds)				
Success Ratio (%)	99.0	99.7	95.2	95.5
Avg. Throughput (kbit/s)	41801	40184	16730	12940
90%/10% faster than (kbit/s)	5048/89904	8377/82016	1639/38800	1292/29757
File Upload (7 Seconds)				
Success Ratio (%)	99.4	99.2	98.1	92.6
Avg. Throughput (kbit/s)	26832	21273	14260	9834
90%/10% faster than (kbit/s)	9295/45484	5776/39318	3062/26822	1827/20082
Youtube Video				
Success Ratio/Start Time (%/s)	97.5/1.6	98.7/1.5	84.2/1.9	84.5/2.5
Playouts without Interruptions (%)	98.3	99.2	96.3	95.3
Average Video Resolution (p)	1045	1066	960	926
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	97.3/2.0	98.1/2.3	80.6/2.5	87.1/3.0
Playouts without Interruptions (%)	98.3	97.5	92.6	90.8
Average Video Resolution (p)	1035	1061	937	850

THREE IS DATA CHAMPION IN TOWNS

Providing data connectivity in towns seems to be the domain of Three. Here the smallest UK operator even outperforms the strong contenders EE and Vodafone. O2 ranks last, offering the same overall performance as in the larger cities.

EE RANKS FIRST ON THE ROADS, BUT GOOD RESULTS FOR ALL CONTENDERS

The scores achieved by the UK operators on the connecting roads is altogether pleasant. EE leads, but the other three contenders show also good results. More good news: All four operators show better data performances on the roads compared to their results from last year.

EE BEST ON RAILWAYS, BUT OVERALL MUCH ROOM FOR IMPROVEMENT

While there is good news concerning data performance on the roads, the same can unfortunately not be said about the railways. Only EE shows relatively acceptable performance in this discipline. Three ranks second, Vodafone third and O2 last – each at a distinct distance to their competitors.

Data in Trains - Walktest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	91.7/92.0	85.6/89.2	85.6/86.6	80.9/81.0
Static: Avg. Session Time (s)	1.8	2.2	2.6	2.5
Live: Reaction Time (ms)	511	558	456	483
Live: Initial DL Speed 1st second (kB/s)	566	505	460	427
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	94.7/5.1	89.1/5.9	90.3/8.4	86.2/9.9
90%/10% faster than (kbit/s)	1867/45610	1982/34488	1118/32259	900/23641
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	96.4/2.4	84.3/4.2	90.7/4.1	82.4/3.5
90%/10% faster than (kbit/s)	1388/20997	730/13949	820/11995	959/14253
File Download (7 Seconds)				
Success Ratio (%)	93.6	84.8	90.6	84.8
Avg. Throughput (kbit/s)	23970	18012	17449	10865
90%/10% faster than (kbit/s)	2571/55040	2231/45828	1581/48150	1336/26842
File Upload (7 Seconds)				
Success Ratio (%)	90.2	79.5	87.3	79.1
Avg. Throughput (kbit/s)	16382	8390	7764	7486
90%/10% faster than (kbit/s)	1696/35375	1062/19244	857/19229	824/19176
Youtube Video				
Success Ratio/Start Time (%/s)	86.2/2.1	81.6/2.5	82.8/3.2	73.7/2.7
Playouts without Interruptions (%)	96.6	96.2	92.6	93.7
Average Video Resolution (p)	1009	949	820	814
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	83.1/2.9	69.4/2.9	72.8/3.8	70.7/2.8
Playouts without Interruptions (%)	91.4	87.5	83.7	89.0
Average Video Resolution (p)	1010	865	738	689

Data in Towns - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	97.6/98.6	96.4/98.7	98.5/99.5	95.5/95.5
Static: Avg. Session Time (s)	1.3	1.6	1.4	2.1
Live: Reaction Time (ms)	399	396	295	318
Live: Initial DL Speed 1st second (kB/s)	628	577	630	493
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.5/2.4	98.7/3.6	100.0/2.2	98.1/6.3
90%/10% faster than (kbit/s)	7213/51284	3117/41580	6544/50104	1765/25178
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.3/1.2	99.3/1.3	99.8/1.4	99.3/1.3
90%/10% faster than (kbit/s)	4802/24768	4014/17316	2810/15558	3971/17881
File Download (7 Seconds)				
Success Ratio (%)	99.3	99.7	99.4	98.3
Avg. Throughput (kbit/s)	34793	26452	34281	12982
90%/10% faster than (kbit/s)	7221/70406	3800/66271	8384/65206	2141/29195
File Upload (7 Seconds)				
Success Ratio (%)	98.4	99.3	99.7	99.7
Avg. Throughput (kbit/s)	25384	16123	17280	13042
90%/10% faster than (kbit/s)	6446/47706	4868/29613	3713/34347	3519/25031
Youtube Video				
Success Ratio/Start Time (%/s)	97.0/1.5	96.7/1.9	97.5/1.5	90.6/2.1
Playouts without Interruptions (%)	98.8	96.6	99.3	95.5
Average Video Resolution (p)	1065	1051	1040	1003
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	95.5/2.0	96.8/2.5	95.9/2.0	88.3/2.6
Playouts without Interruptions (%)	97.8	96.7	97.9	92.0
Average Video Resolution (p)	1071	1004	1055	926

Data on Roads - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	98.8/99.5	97.3/98.9	96.9/98.0	96.5/97.1
Static: Avg. Session Time (s)	1.2	1.5	1.7	1.7
Live: Reaction Time (ms)	373	394	318	325
Live: Initial DL Speed 1st second (kB/s)	695	619	582	576
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.5/1.8	99.2/2.9	98.1/3.2	99.1/4.3
90%/10% faster than (kbit/s)	7877/56471	4364/41379	3958/49080	2828/32832
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.3/1.1	98.7/1.5	98.1/2.0	98.7/1.4
90%/10% faster than (kbit/s)	5026/25723	3044/17441	1938/14809	3249/18824
File Download (7 Seconds)				
Success Ratio (%)	99.7	99.1	99.0	98.2
Avg. Throughput (kbit/s)	42207	27266	30723	17329
90%/10% faster than (kbit/s)	10051/81101	5069/57182	5082/66238	2991/38533
File Upload (7 Seconds)				
Success Ratio (%)	99.0	98.0	97.9	98.6
Avg. Throughput (kbit/s)	27097	16624	14306	14856
90%/10% faster than (kbit/s)	6698/49307	4750/27858	1962/33774	3777/25772
Youtube Video				
Success Ratio/Start Time (%/s)	99.1/1.5	97.9/1.8	96.5/2.0	93.2/1.9
Playouts without Interruptions (%)	99.3	98.0	97.5	96.7
Average Video Resolution (p)	1069	1053	974	1026
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	97.4/1.9	94.9/2.4	91.6/2.4	92.9/2.6
Playouts without Interruptions (%)	98.8	97.0	96.3	93.7
Average Video Resolution (p)	1084	1030	968	1004

DATA RESULTS AT A GLANCE

EE shows the best data performance and reliability in the city drivetests, on the roads and – at a lower level – on railways. In the city walktests, EE and Vodafone are on a par, with the other two operators distinctly lagging behind. Three offered the best data performance in towns. Alongside the other operators, O2 achieves relatively good results on the roads. All UK operators show considerable room for improvements on the railways.

CROWD

In this year, the results of crowd sourcing analyses are part of the total score for the first time. 268,000 users in the UK have contributed to the data gathering that took place from August to October, 2018.

EE TAKES THE LEAD IN CROWD-SOURCED QUALITY AND OVERALL IN ALL CROWDSOURCED CATEGORIES.

While the drivetests and walktests determine the peak performance of the examined networks, crowd-sourcing can add important dimensions such as time, geography or variety in devices and tariff plans – if done in the right way.

For the collection of crowd data, P3 has integrated a background diagnosis processes into more than 800 diverse Android apps. If one of these applications is installed on the end-user's phone and the user authorizes the background analysis, data collection takes place 24/7, 365 days a year. Reports are generated for every quarter of an hour and sent daily to P3's cloud servers. Such reports generate just a small number of bytes per message and do not include any personal user data. A more detailed description of our crowdsourcing methodology can be found on page 15 of this report.

Based on the total population count of 66 million people, one of 246 inhabitants of the United Kingdom has contributed to the gathering of 2.99 billion single samples of crowd data. The considered test area represents 99 per cent of the built-up area of the UK.

EE

EE LEADS THE FIELD REGARDING CROWDSOURCED COVERAGE

All UK operators show a good score level for their voice and data coverage. In the Quality of Voice Coverage, EE, Vodafone and O2 are more or less on a par, In the Quality of Data Coverage (which considers 3G plus 4G), Three takes a narrow lead. The Quality of 4G Coverage leaves some room for improvement. In particular, Three falls behind competition regarding 4G coverage for both footprint (Test Area Coverage) as well as the likelihood of being able to actually use 4G service (4G Quality of Coverage). Looking at all three coverage KPIs combined, EE leads the field.

Crowd Overall	EE	Vodafone	Three	O2
Voice Coverage				
Quality of Coverage (%)	97.8	97.8	95.7	97.6
Test Area Coverage (%)	99.7	99.3	98.5	99.5
Data Coverage				
Quality of Coverage (%)	97.0	96.0	97.2	95.6
Test Area Coverage (%)	99.6	98.1	98.5	98.5
4G Coverage				
Quality of Coverage (%)	89.3	73.3	61.1	75.3
Test Area Coverage (%)	99.1	93.7	87.5	96.2
User Download Speed				
10% EA faster than (kbit/s)	66893	42441	47919	41802
10% Users faster than (kbit/s)	18765	15332	15879	12216
Avg. Users Best Throughput (kbit/s)	6492	5361	5692	4362
Data Service Availability				
Degraded days (d)	0	3	1	3
Degraded hours (h)	0	3	1	4

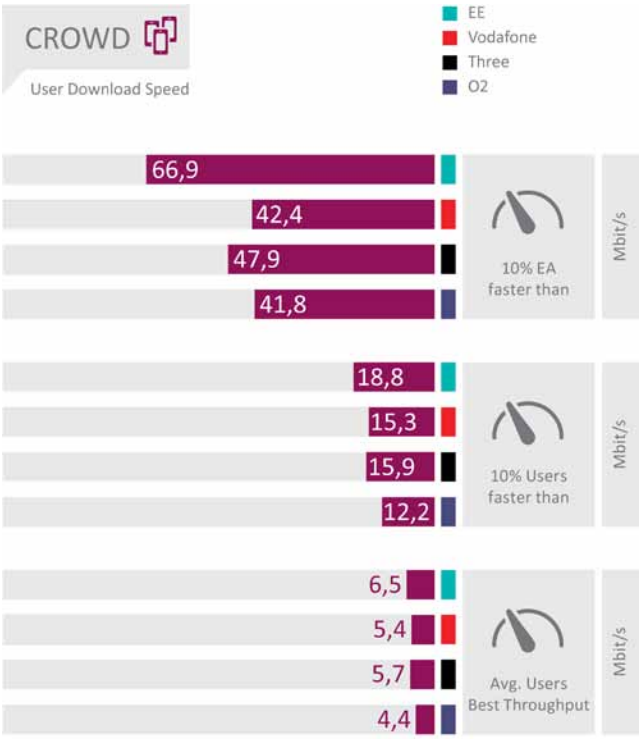
ASSESSING COVERAGE BASED ON CROWD KPIS

Our coverage metrics correnspond to the results of our drivetests and walktests. However, it is no surprise that the crowdsourced KPIs for voice, data and 4G coverage deviate to a certain extent from the population coverage values stated by most operators: P3's gathering of crowd data reflects where people actually are and move as opposed to their places of residence and working. Furthermore, our crowdsourcing also comprises indoor or other disadvantageous reception situations, while operators commonly base their claims on outdoor reception only.

EE

EE SHOWS FASTEST DOWNLOAD SPEEDS IN TOP 10 PER CENT OF EVALUATION AREAS

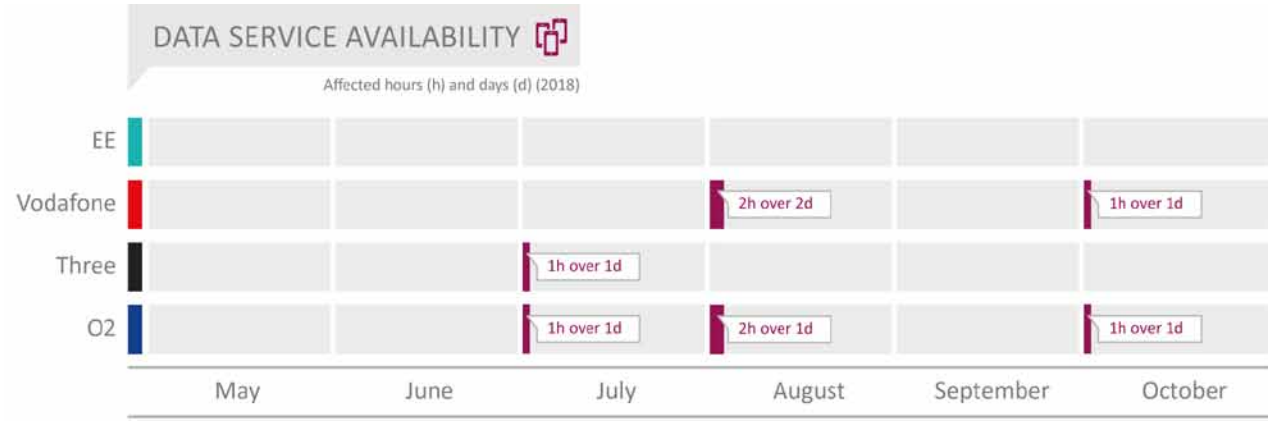
In the assessment of download speeds available to the users, EE shows the best results for the top 10 per cent of Evaluation Areas. In this category as well as in the assessment of average download speeds, Three scores ahead of Vodafone and O2. Generally, it must be taken into consideration that a part of the actual user base probably experiences data speed limitations caused by their mobile tariffs.



EE

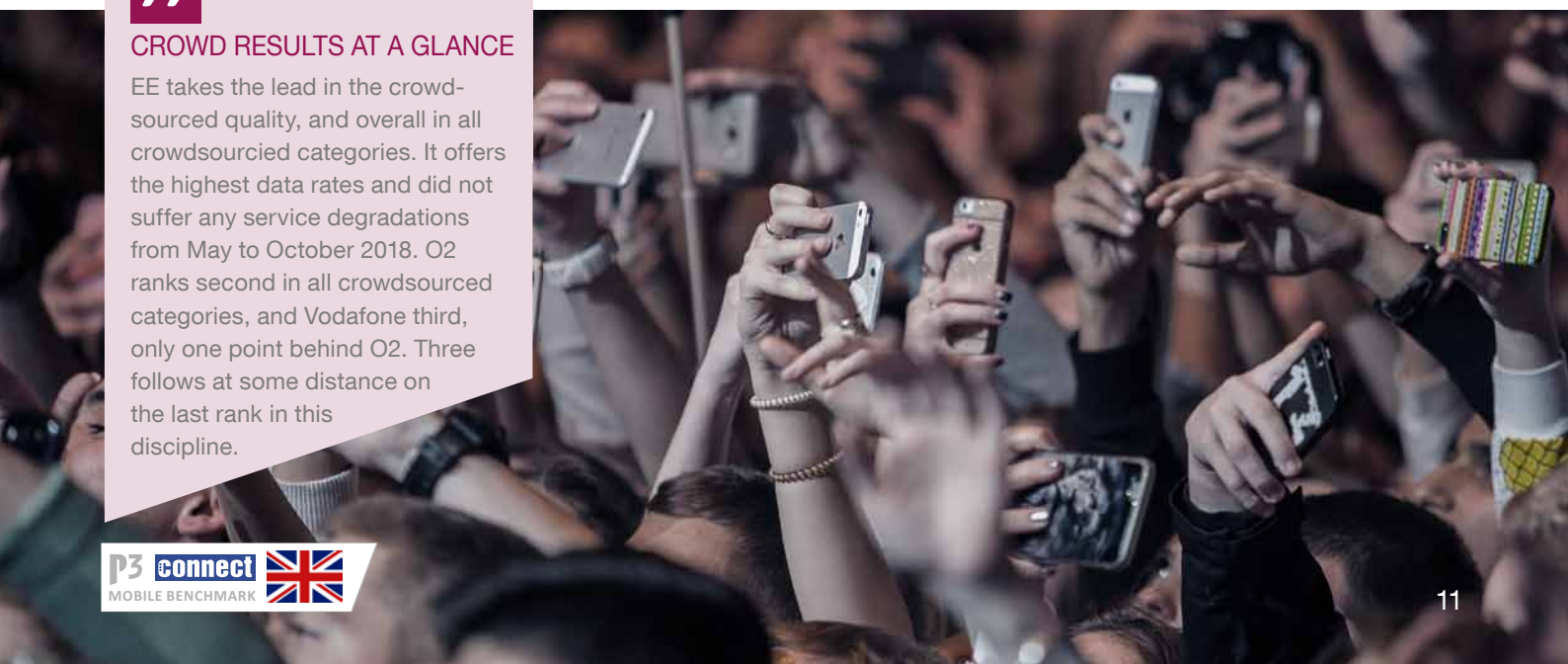
EE DID NOT SHOW ANY SERVICE DEGRADATIONS FROM MAY 2018 TO OCTOBER 2018

Other than the rest of the crowd KPIs, our examination of Data Service Availability covers six months (May to October 2018). EE scores best in this consideration again, showing no service degradations in the observation period. Three ranks second with a one hour outage in July. Vodafone suffered two outages – one in August and one in October. O2 ranks last in this category, because our examination revealed three outages in July, August and October.



CROWD RESULTS AT A GLANCE

EE takes the lead in the crowdsourced quality, and overall in all crowdsourcied categories. It offers the highest data rates and did not suffer any service degradations from May to October 2018. O2 ranks second in all crowdsourced categories, and Vodafone third, only one point behind O2. Three follows at some distance on the last rank in this discipline.



LONDON

Traditionally, P3 and connect take a closer look at the UK's capital to see how the operators cover this lively centre of business, politics and society.

Being by far the most densely populated area in the UK, London is an especially demanding terrain for deploying and maintaining a mobile network. This is why we regularly take a closer look to see how coverage in the capital compares to the rest of the United Kingdom. Therefore we have filtered the results of the voice and data drive and walktests as well as the crowd results obtained in the London area from the nationwide values. As the city scores neither contain the results of the drivetests conducted in the smaller towns or on the connecting roads nor the walktest results from the trains, we have adapted the maximum achievable points accordingly. So while the partial scores for voice, data and crowd can be compared with the nationwide results, this should not be done with the points for the drivetests and walktest.

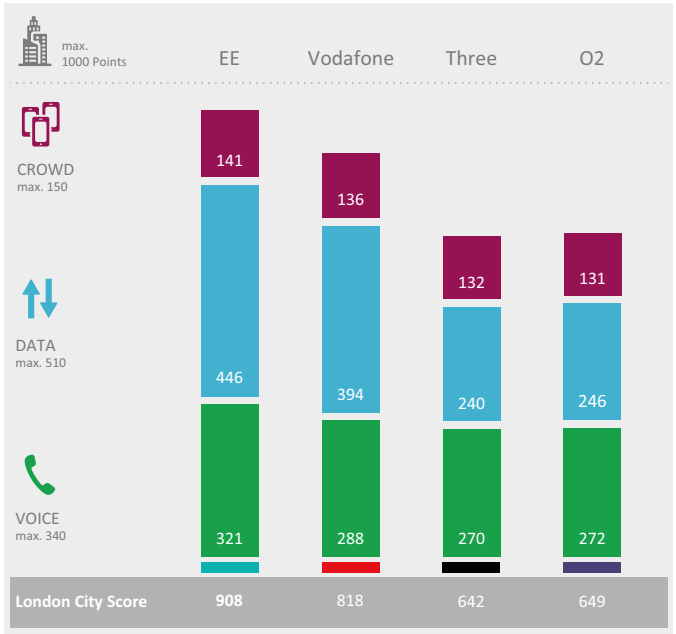
EE LEADS IN LONDON TOO, VODAFONE RANKS SECOND AND SCORES SLIGHTLY BETTER THAN IN THE WHOLE UK

The overall winner in London is EE – much the same as in the nationwide assessment. In the capital, this operator achieves somewhat higher scores than in the overall results. Interestingly, its drivetest results are slightly lower than in the whole country assessement. In the walktests, EE scores slightly better in the capital or, in the case of the voice measurements, it achieves the same score of a full 100 per cent. The crowd results in London are also a little higher than the nationwide score. EE achieves the same 100 per cent score as all over the UK.

Vodafone ranks second in London as well, but achieves better scores in London for the voice drivetest as well as for the data drive and walktest results compared to its nationwide score. Also, its crowd score for London is considerably higher than all over the country. The scores of the voice walktests conducted in London fall a little behind the nationwide average.

O2 OVERTAKES THREE IN LONDON, BOTH ARE CLOSE TOGETHER

In contrast to the nationwide ranking, O2 achieves the third rank in London and overall scores two points ahead of Three. In comparison to the whole UK, O2 in London shows particularly better results in the voice drive and walktests and in the crowd score, but falls behind in the dara drivetests and walktests. Notably, Three's results in London are behind the nationwide average with the only exception of the crowd score.



LONDON RESULTS AT A GLANCE

As in the nationalwide results, EE is also the winner in London. It achieves better or the same results than in the whole UK, particularly in the walktests. The drivetests conducted in London show weaker results – which is also true for Vodafone and Three, as well as O2's data performance. Still, Vodafone reaches a strong second rank in the capital. O2 overtakes Three in London, with both contenders scoring close together.

London Overall Results Voice, Data and Crowd		EE	Vodafone	Three	O2
Voice	max. 340	321	288	270	272
City (Drivetest)	255	93%	84%	80%	76%
City (Walktest)	85	100%	88%	78%	91%
Data	max. 510	446	394	240	246
City (Drivetest)	383	87%	76%	52%	56%
City (Walktest)	128	87%	81%	32%	24%
Crowdsourced Quality	max. 150	141	136	132	131
Crowd	150	94%	91%	88%	87%
Connect Rating	max. 1000	908	818	642	649

Percentages and points rounded to integer numbers.
For the calculation of points and totals, the accurate, unrounded values were used.




UK'S LARGEST CITIES





For the inhabitants of other large cities in the UK, it is interesting to see how the different operators perform in their areas. Therefore, we performed additional analyses for nine large cities all over the United Kingdom.

As interesting as the focus on the densely populated London area is, the inhabitants of other large UK cities and the capitals of the other countries besides England have their own perspective on network performance and availability.
In order to also provide valuable insights for their inhabitants, we have additionally analysed the performances of the four operators in nine large UK cities – specifically Belfast, Birmingham, Bristol, Cardiff, Edinburgh, Glasgow, Liverpool, Manchester and Sheffield.

SAME RANKING AS NATIONWIDE IN BELFAST, LIVERPOOL AND SHEFFIELD: EE LEADS, VODAFONE SECOND

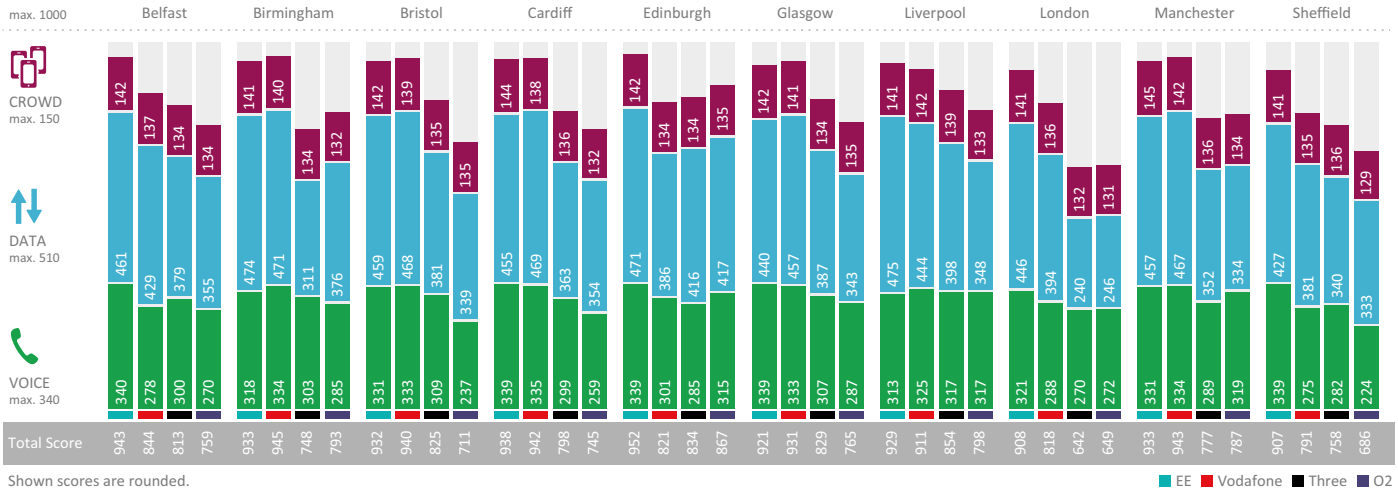
The same ranking as in the nationwide assesment can be seen in Belfast, Liverpool and Sheffield. Here, EE is the clear leader, followed by Vodafone. Three ranks third, and O2 last. While in Belfast and Sheffield this ranking is quite distinct, all four contenders score quite close together in Liverpool. Here, even Three and O2 show comparably strong results.

VODAFONE OVERTAKES EE IN BIRMINGHAM, BRISTOL, CARDIFF, GLASGOW AND MANCHESTER

In Birmingham, Bristol, Cardiff and Manchester, the fight for the top rank is close, but Vodafone manages to overtake a still strong EE in these cities by a close margin. In Birmingham, Vodafone is stronger in voice than EE, in Cardiff and Glasgow stronger in data. In Bristol and Manchester, Vodafone outranks the nationwide winner in both disciplines. Their crowd scores are in most cases close together.
In Birmingham and Manchester, O2 shows stronger results than Three. In Bristol, Cardiff and Glasgow it is just the other way round.

EE LEADS IN EDINBURGH, BUT O2 RANKS SECOND, THREE THIRD AND VODAFONE LAST

In Edinburgh, it is no surprise that EE ranked first, but the order of the other contenders is interesting. In the capital of Scotland, O2 shows a particularly strong performance and ranks second due to especially good data results. The crowd scores confirm the leading position of EE, the other three operators rank close together in this perspective. Three even manages to overtake Vodafone which can be explained by Vodafone's eye-catchingly weak data results in this city.



TESTING METHODOLOGY

The methodology of the P3 connect Mobile Benchmark is the result of more than 15 years of testing mobile networks. Today, network tests are conducted in more than 80 countries. Our methodology was carefully designed to evaluate and objectively compare the performance and service quality of mobile networks from the users' perspective.

The P3 connect Mobile Benchmark in the UK comprises of the results of extensive voice and data drivetests and walktests as well as a sophisticated crowdsourcing approach.

DRIVETESTS AND WALKTESTS

The drivetests and walktests in the UK took place from October 30 to December 3, 2018 All samples were collected during the day, between 8.00 a.m. and 10.00 p.m. The network tests covered inner-city, outer metropolitan and suburban areas. Measurements were also taken in smaller towns and on the connecting highways. The four measurement cars together covered about 3,750 kilometres in the cities, about 1,700 km in towns and about 6,300 km on the roads – resulting in a total of 11,750 kilometres.

The combination of test areas has been selected to provide representative test results across the UK population. The areas selected for the 2018 test account for approximately 16.6 million people, or roughly 26.2 per cent of the total population of the UK.

The drivetests covered 22 cities and 35 towns. Additionally, two teams conducted walktests in 10 cities and also on railway journeys between them. The routes are shown on page 1, all visited cities and towns are listed in the box on the right.

The four drive-test cars as well as the battery-powered backpacks of the walktest teams were equipped with arrays of Samsung Galaxy S8 smartphones for the simultaneous measurement of voice and data services.

VOICE TESTING

One smartphone per operator in each car was used for the voice tests, setting up test calls from one car to another. The walktest team also carried one smartphone per operator for the voice tests. In this case, the smartphones called a stationary counterpart.

The audio quality of the calls was evaluated using the HD-voice capable and ITU standardised POLQA wideband algorithm.

All smartphones used for the voice tests were set to VoLTE preferred mode. In networks or areas where this modern 4G-based voice technology was not available, they would perform a fallback to 3G or 2G.

As a new KPI in 2018, we assess the so-called P90 value for call setup times. P90 values specify the threshold in a statistical distribution, below which 90 per cent of the gathered values are ranging.

In order to account for typical smartphone use during the voice tests, background data traffic was generated through random injection of small amounts of HTTP traffic. The voice scores account for 34 per cent of the total results.

DATA TESTING

Data performance was measured by using three more Galaxy S8 in each car or per walktest team – one per operator. Their radio access technology was set to LTE preferred mode.

For the web tests, they accessed web pages according to the widely recognised Alexa ranking In addition, the static Kepler test web page as specified by ETSI (European Telecommunications Standards Institute) was used. In order to test the data service performance, files of 3 MB and 1 MB for download and upload were transferred from or to a test server located on the Internet. In addition, the peak data performance was tested in ▸

VISITED CITIES AND TOWNS

Cities: Belfast (W), Birmingham (W), Bristol (W), Cambridge, Cardiff (W), Derby, Dundee, Edinburgh, Glasgow (W), Huddersfield, Liverpool (W), Greater London (W), Manchester (W), Newcastle upon Tyne, Newport, Northampton, Norwich, Oxford, Sheffield (W), Slough, Southampton, Swansea; (W) designates walktest cities, also a walktest has been conducted in Nottingham

Towns: Ayr, Berwick-upon-Tweed, Bolsover, Brentwood, Brighouse, Bromsgrove, Carlisle, Chester-le-Street, Clevedon, Craigavon, Crewe, Cumbernauld, Derry (Londonderry), Dorchester (West Dorset), Dumfries, Huntingdon, Knutsford, Lancaster, Leyland, Morley, Morpeth, Newmarket, Newton Aycliffe, Newton Mearns, Omagh, Perth, Ripley, Rosyth, Stirling, Taunton, Tewkesbury, Thetford, Wellingborough, Wetherby, Wymondham (South Norfolk)

One Samsung Galaxy S8 per operator took the voice measurements and one additional S8 per operator was used for the data tests. All test phones were operated and supervised by P3's unique control system.

uplink and downlink directions by assessing the amount of data that was transferred within a seven seconds time period.

The evaluation of YouTube playback takes into account that YouTube dynamically adapts the video resolution to the available bandwidth. So, in addition to success ratios, start times and playouts without interruptions, the measurements also determined average video resolution.

All the tests were conducted with the best-performing mobile plan available from each operator. Data scores account for 51 per cent of the total results.

CROWDSOURCING

Additionally, P3 conducted crowd-based analyses of the UK networks which contribute 15 per cent to the end result. They are based on data that were gathered in August, September and October, 2018.

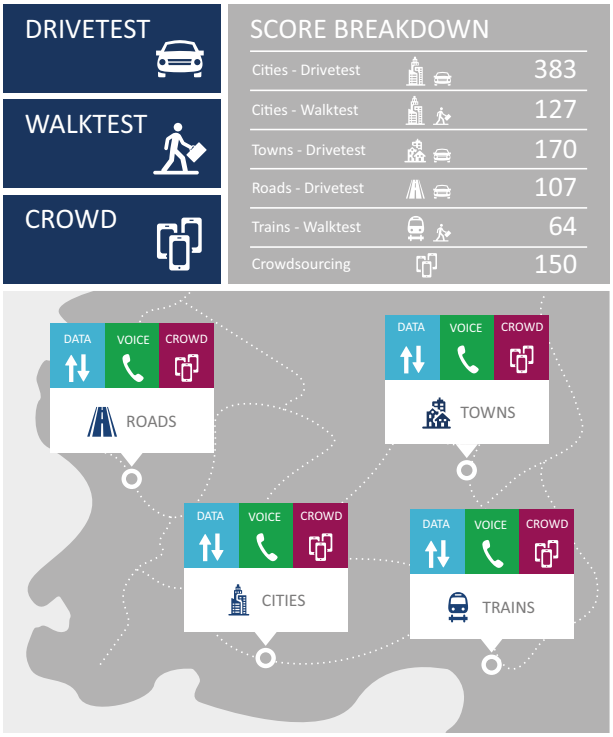
For the collection of crowd data, P3 has integrated a background diagnosis processes into 800+ diverse Android apps. If one of these applications is installed on the end-user's phone and the user authorizes the background analysis, data collection takes place 24/7, 365 days a year. Reports are generated for every quarter of an hour and sent daily to P3's cloud servers.

Such reports contain just a small number of bytes per message and do not include any personal user data. Interested parties can deliberately take part in the data gathering with the specific "U get" app (see box below on the right).

NETWORK COVERAGE

For the assessment of network coverage, P3 lays a grid of 2 by 2 kilometres over the whole test area. The "evaluation areas" generated this way are then sub-divided into 16 smaller tiles. To ensure statistical relevance, P3 requires a certain number of users and measurement values per operator for each tile and each evaluation area. If these thresholds are not met by one of the operators, this part of the map will not be considered in the assessment for the sake of fairness.

"Quality of Coverage" reveals whether voice and data services actually work in an evaluation area. P3 does this because not in each area that allegedly provides network reception, mobile services can actually be used. We specify these values for the coverage of voice services (3G and 4G combined), data (3G and 4G combined) and 4G only.



DATA THROUGHPUTS

Additionally, P3 investigates the data rates that were actually available to each user. For this purpose, we determine the best obtained data rate for each user during the evaluation period and then calculate their average value. In addition, we determine the so-called P90 values for the top throughput of each evaluation area as well as of each user's best throughput. P90 values specify the threshold in a statistical distribution, below which 90 per cent of the gathered values are ranging and depict how fast the network is under favorable conditions.

DATA SERVICE AVAILABILITY

Formerly called "operational excellence", this parameter indicates the number of outages or service degradations – events where data connectivity is impacted by a number of cases that significantly exceeds the expectation level. To judge this, the algorithm looks at a sliding window around the hour of interest. This ensures that we only consider actual degradations as opposed to a simple loss of network coverage due to prolonged indoor stays or similar reasons.

In order to ensure statistical relevance, each operator must have sufficient statistics for trend and noise analyses per each evaluated hour. The exact number depends on the market size and number of operators. A valid assessment month must comprise of at least 90 per cent of valid assessment hours. Deviating from the other crowd score elements, Data Service Availability is rated based on a six-month observation period – in this case from May to Oct 2018.

PARTICIPATE IN OUR CROWDSOURCING

Everybody interested in being a part of our global crowdsourcing panel and obtaining insights into the reliability of the mobile network that her or his smartphone is logged into, can most easily participate by installing and using the "U get" app. This app exclusively concentrates on network analyses and is available under **http://uget-app.com** or via the adjoint QR code.

"U get" checks and visualises the current mobile network performance and contributes the results to our crowdsourcing platform. Join the global community of users who understand their personal wireless performance, while contributing to the world's most comprehensive picture of mobile customer experience.

CONCLUSION

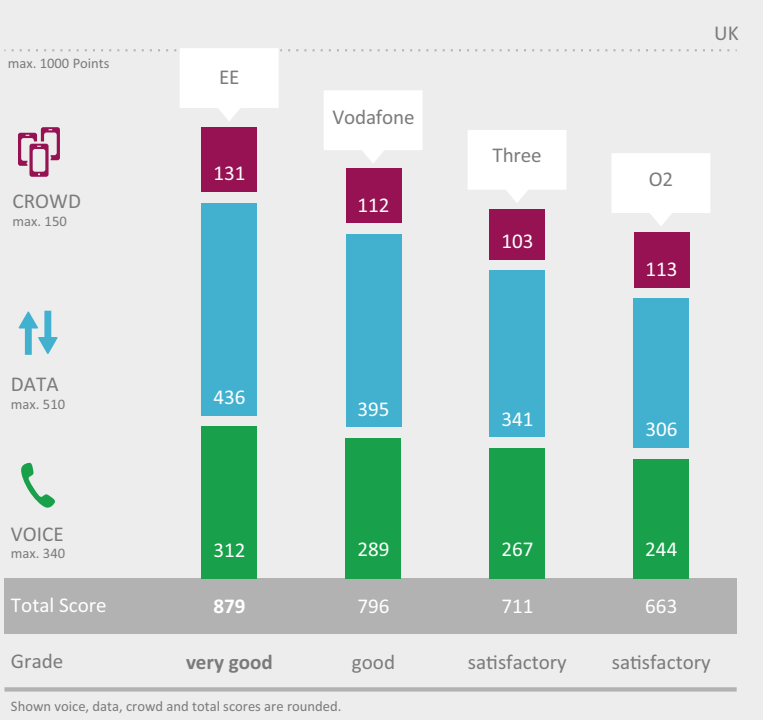
EE is the winner whilst Vodafone achieved a strong second place rank. Three shows some specific strengths but fell behind in the overall scoring, which is similar for Vodafone. O2 performed similarly to last year.

EEs confirms its top rank from previous years and wins the P3 connect Mobile Benchmark in the UK for the fifth time in a row (in 2016, EE and Vodafone won together). Compared to last year's results, EE improves significantly in the voice discipline, but achieves a slightly decreased data score. In the now extended crowd analyses, EE is also the winner.

Vodafone achieves a good second rank, showing especially good results in the big cities and on the roads. In comparison to the previous year, Vodafone managed to improve in the voice results, but lost some ground in the data scores. The same is also true for Three, which fell back to the grade "satisfactory". A remarkable strength of this smallest operator in the UK is that it achieved the best data score in towns. Like all UK operators, Three was also able to increase its performance on the roads for both voice and data.

O2 ranks last. Showing more or less the same performance than last year costs some points, because the requirements of our testing methodology increase year over year. In the crowdsourced assessment, O2 achieved the second-best results, one point ahead of Vodafone.

However, our newly added railway measurements reveal big challenges for all UK operators.



Shown voice, data, crowd and total scores are rounded.

Overall Results Voice, Data and Crowd		EE	Vodafone	Three	O2
Voice	max. 340	312	289	267	244
Cities (Drivetest)	153	95%	89%	82%	75%
Cities (Walktest)	51	100%	96%	89%	75%
Towns (Drivetest)	68	93%	86%	85%	79%
Roads (Drivetest)	43	94%	88%	76%	73%
Trains (Walktest)	26	48%	29%	27%	24%
Data	max. 510	436	395	341	306
Cities (Drivetest)	230	89%	80%	63%	64%
Cities (Walktest)	76	85%	85%	57%	43%
Towns (Drivetest)	102	82%	77%	84%	64%
Roads (Drivetest)	64	94%	85%	81%	79%
Trains (Walktest)	38	61%	37%	42%	28%
Crowdsourced Quality	max. 150	131	112	103	113
Crowd	150	87%	75%	69%	75%
Connect Rating	max. 1000	879	796	711	663

Percentages and points rounded to integer numbers.
For the calculation of points and totals, the accurate, unrounded values were used.

P3 connect BEST IN TEST EE 12/2018 MOBILE BENCHMARK UNITED KINGDOM

1

The overall winner of the 2018 P3 connect Mobile Benchmark in the UK is EE. This operator clearly leads in all tested disciplines including the now extended crowd score and also leads the field in most of the single categories of our assessment. EE's strong voice results are based on its use of the modern EVS codec.

2

Vodafone achieves an overall good second rank. This operator scores particularly strong in the big cities and on the connecting roads. In the data walktests in big cities, Vodafone is on a par with EE. In the crowd analyses, Vodafone achieves an overall good result, scoring one point behind O2.

3

The smallest UK operator ranks third overall, but scores best in the data drivetests in smaller towns. Like all UK operators, Three increases its performance on the roads. Also, it shows a good Data Service availability with just one hour of degradation in the observation period. A decrease in its data scores may be a result of owning the least amount of spectrum in the UK.

4

The third largest operator in the UK all in all scores the same performance as last year – which due to our increasing requirements leads to a net loss in points. However, in our extended crowd score, O2 ranks second. Like Three, O2 offers good voice results particularly in smaller towns. As its competitors, O2 also improved on the roads.