The 2017 Mobile Network Test in the United Kingdom

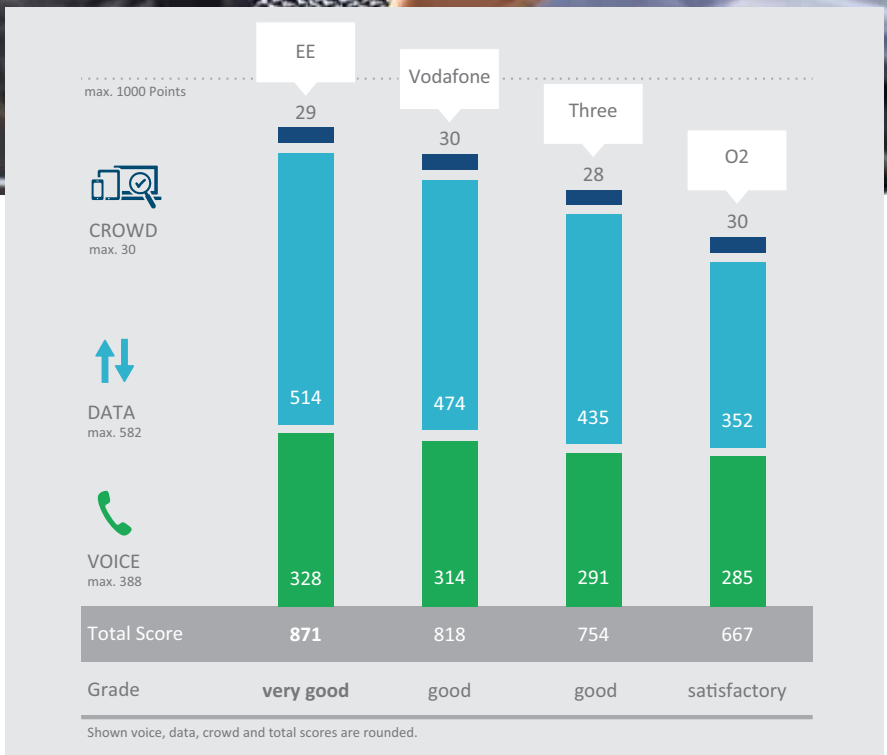
The fourth sucessive year, the consulting, engineering and testing company P3 communications GmbH and connect magazine have examined UK's mobile networks'. How would the ongoing improvements of the LTE network and the rollout of enhancements like Voice over LTE affect the ranking of the four mobile operators in the UK? Or simply put: Which operator offers the best network for mobile voice and data?

The 2017 P3 connect Mobile Benchmark in the United Kingdom has a clear winner with a very good EE, and a good Vodafone on rank two. In contrast, Three and O2 have lost some ground compared to our previous year's benchmark.

Results in a nutshell

Due to the carefully designed methodology, including drivetests and walktests, P3's network benchmarks are highly objective, and have been widely accepted as authoritative. In this year, the drive tests covered 20 of the largest cities in the UK with more than 100,000 inhabitants. Additionally, we conducted walktests in 11 cities, eight of which have also been included in the drivetests. The cars also visited smaller towns and drove on trunk roads and motorways. The areas in which we tested caters for more than 17 million people, or roughly 27% of the UK population.

P3's rigorous and meticulous measurement included the use of up-to-date LTE Cat 9 as well as VoLTE-capable smartphones for the tests. We also constantly readjust the thresholds of our evaluation. With steps like these, we reflect the latest technical developments in the mobile networks and once more emphasise the scope of our benchmarking: How do the mobile networks perform at the edge of what is technically feasible – and to what extent do customers benefit from these capabilities? In order to provide valid answers to these questions, we have also used the most comprehensive mobile plans available from each operator.



Top ranking EE and second-placed Vodafone

The overall winner of this year's UK benchmark is EE with the grade "very good" and a clear lead in voice and data as well as a high degree of operational excellence. Vodafone ranks second at some distance in voice and data and the overall grade "good" (but a full 30 points in our new crowdsourcing assessment – see page 10).

Compared to the previous year, both top-ranking contenders show distinct score improvements, with EE achieving the most distinct gain. Three comes in third, showing a definite gap over Vodafone's voice and data as well as to the operational excellence results but still achieving the grade "good". As in 2016, O2 ranks last with the grade "satisfactory". In terms of points, both Three and O2 have lost some ground compared to the previous year.

Overall Results Voice and Data		EE	Vodafone	Three	O2
Voice	max. 388	328	314	291	285
Cities (Drivetest)	174.6	84%	85%	73%	78%
Cities (Walktest)	58.2	96%	95%	78%	85%
Towns (Drivetest)	77.6	84%	76%	80%	72%
Roads (Drivetest)	77.6	78%	66%	71%	56%
Data	max. 582	514	474	435	352
Cities (Drivetest)	261.9	89%	86%	76%	62%
Cities (Walktest)	87.3	85%	82%	63%	41%
Towns (Drivetest)	116.4	87%	75%	80%	66%
Roads (Drivetest)	116.4	90%	78%	75%	67%
Crowd	max. 30	29	30	28	30
2017-07	10.0	100%	100%	100%	100%
2017-08	10.0	90%	100%	100%	100%
2017-09	10.0	100%	100%	83%	100%
Connect Rating	max. 1000	871	818	754	667

Of the four mobile networks competing in the UK, EE and O2 are the largest players in terms of subscribers, followed closely by Vodafone, with the smaller Three attacking with agressive tariffs.

The UK operators

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. The operator claims that its 4G coverage today reaches about 99 per cent of the UK population. The geographic 4G coverage currently is approximately 85 per cent, with an ambition to hit 95 per cent by 2020. 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 which also reach a population coverage in the 98 to 99 per cent range.

EE operates a growing number of "LTE Advanced" network cells that support Category 9 (Cat 9) and thus faster speeds of up to 450 Mbps. Also, EE offers Voice over LTE (VoLTE) in parts 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 September 2017, O2 claimed to cover over 97 per cent of the UK population with its 4G service, striving to meet a regulatory requirement of covering 98 per cent of the indoor population by the end of 2017.

O2 operates its 4G network mainly on 800 MHz with limited additional 1800 MHz coverage in London. Additionally, O2 provides 2G on 900 and 1800 MHz and 3G on 900 and 2100 MHz. Like the other UK operators, O2 has started to roll out Voice over LTE (VoLTE) in parts 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 18 million 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 currently operates 4G/LTE at 800 and 2600 MHz and has started to refarm also some of its 3G spectrum at 2100 MHz to 4G. 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+", currently offering up to 450 Mbps – 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 9.2 million customers Three is the smallest mobile network operator in the UK but claims to carry over 40% 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 98 per cent of the UK's population with 3G and about 91 per cent of the poplulation with 4G. Ultimately, Three is aiming at 98 per cent UK population coverage with its 4G network. Three has also started to deploy Voice over LTE (VoLTE) in parts of its growing 4G network.

A close look at the UK networks

All UK operators are working hard to expand their LTE networks' coverage and performance. Recently, they also introduced VoLTE. How will these investments affect the results of our network test?

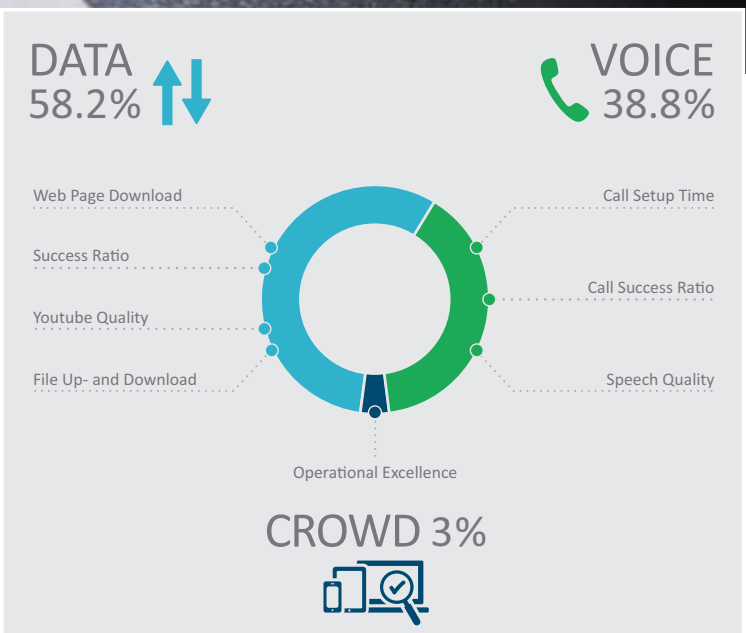
P3 communications GmbH, based in Aachen, Germany, is a world leader in mobile network testing. It is part of the P3 group, with over 3,000 employees worldwide and a turnover of more than €300 million. P3 is partnering with connect, the international telecommunications magazine connect, which has more than 20 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 15 years, extending it to Austria and Switzerland in 2009. Starting in 2014, P3 has also been conducting benchmarks in the UK and Australia, expanding its public mobile network benchmarks to the Netherlands, Spain and Sweden in 2016.

In 2016 alone, P3 compiled more than 60,000 measurement hours in 65 countries across five continents, with its test vehicles covering more than 620,000 miles. As the de-facto industry standard, the P3 benchmarking methodology focuses on customer-perceived network quality – examining voice telephony that makes up 38.8 per cent of the result, data connectivity that contributes 58.2 per cent as well as operational excellence, currently accounting for three per cent of the total result. P3's network benchmarks are widely accepted as a completely objective authority.

EE and Vodafone on top positions with score improvements

After a tie of both contenders in 2016, this year's P3 connect Mobile Benchmark in the UK finds EE to be the clear winner and Vodafone ranking second. Both top-ranking contenders in the UK show distinct score improvements over our 2016 results.



Hakan Ekmen, CEO of P3 communications GmbH.

"All operators took the challenge of the P3 connect Mobile Benchmark and have increased their LTE coverage. In 2018 over the top content services, technologies like carrier aggregation and voice over LTE as well as crowdsourcing-based use cases will become more important. This will make the results even more exciting."

Voice

Voice services may become less important – however, customers expect reliable connections when talking on the phone. How do the UK networks fulfil these expectations?

On their tour through the UK, P3's four test cars visited 20 of the largest UK cities and many smaller towns as well as covering the connecting roads. Additionally, two walktest teams conducted tests in selected cities and towns. For the voice rating, each car and walktest team member carried Samsung Galaxy S7 smartphones that permanently called each other. The connected testing equipment registered success ratios, setup times and speech quality. In order to simulate normal smartphone usage, data transfers took place in the background of the test calls.

EE shows best voice performance, Vodafone almost on par in larger cities

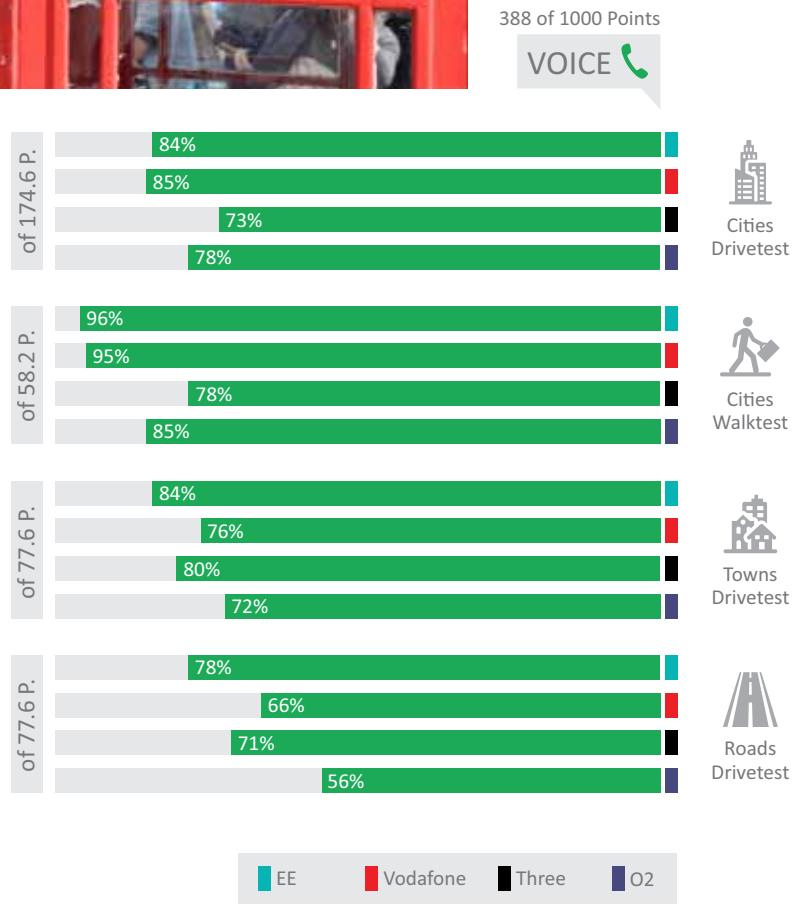
EE and Vodafone share the best test results for voice services in the larger cities. Here, Vodafone scored even slighty higher than EE in the drivetest scenario. And O2 is ahead of Three in the voice tests conducted in larger cities. However, in smaller towns and on the roads, EE takes a clear lead over its competitors.

All UK operators have started to roll out Voice over LTE (VoLTE) in their networks. EE, Vodafone and O2 managed to distinctly reduce call setup times in the cities, which might be one of the effects of VoLTE.

In the Three network, we observed considerably longer call set up times in larger cities – with a gap of more than 1.5 seconds to the other three contenders. O2 is losing ground in terms of voice performance especially in the smaller towns and on the roads.

VOICE RESULTS AT A GLANCE

EE delivers the best voice performance in the UK. In larger cities, Vodafone shows equally good results, but falls somewhat behind in smaller towns and on the roads. O2 is strong in voice in larger cities, but falls back in towns and on the roads. Three scores third in voice, but shows long call set up times.



Voice - Drivetest	EE	Vodafone	Three	O2
Cities				
Call Success Ratio (%)	98.8	98.8	97.6	98.0
Call Setup Time (s)	4.9	4.7	6.7	5.2
Speech Quality (MOS-LQO)	3.5	3.5	3.6	3.4
Towns				
Call Success Ratio (%)	98.7	97.8	98.6	97.4
Call Setup Time (s)	5.1	5.5	6.4	6.5
Speech Quality (MOS-LQO)	3.5	3.4	3.6	3.4
Roads				
Call Success Ratio (%)	96.6	93.8	95.3	91.7
Call Setup Time (s)	5.2	5.6	6.2	6.5
Speech Quality (MOS-LQO)	3.5	3.3	3.6	3.3

Voice - Walktest	EE	Vodafone	Three	O2
Cities				
Call Success Ratio (%)	99.8	99.4	98.4	98.0
Call Setup Time (s)	2.7	2.6	6.4	3.4
Speech Quality (MOS-LQO)	3.6	3.7	3.6	3.6

Data

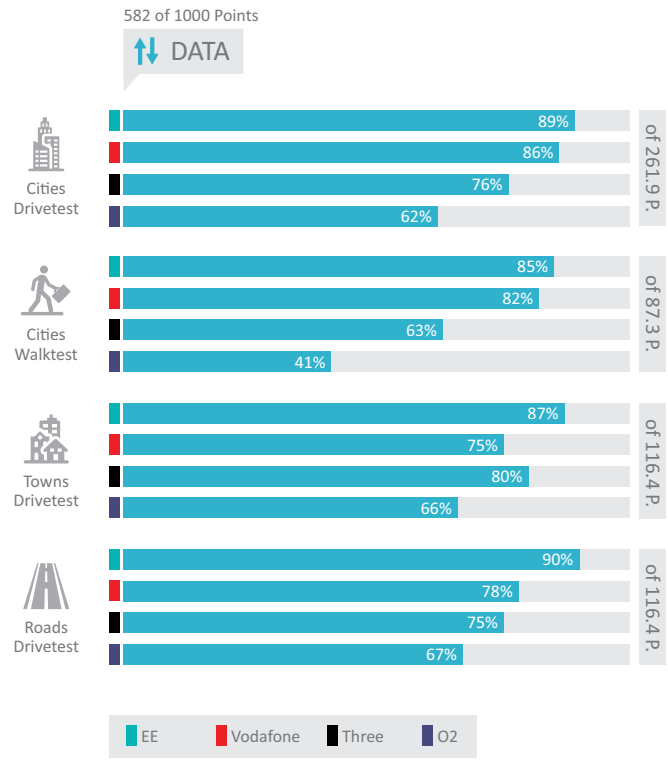
The volume of transmitted data is steadily growing. So, all operators face the challenge to keep data rates and reaction times at a high level. Which UK operator manages to best meet the growing demand?

The volume of mobile data downloads and uploads is growing exponentially. While 4G/LTE currently is the best technology to cope with these increasing demands and all UK 4G networks realise a wide coverage of the population, the four operators pursue different rollout strategies. EE and Vodafone chase each other with continually growing data rates that currently go up to 450 Mbps, based on the so-called carrier aggregation (the combination of multiple carrier frequencies). In contrast, O2 and Three stick with a solid 100 Mbps and mainly focus on enlarging their 4G footprint. P3's testing takes both aspects into account – the benchmarking of web-page downloads as well as file downloads and uploads rewards fast throughputs. At the same time, it 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 available in 90 per cent of the cases plus the peak data rates that would be surpassed in 10 per cent of the cases.

P3's approach for YouTube testing recognises that this popular video service uses adaptive bit rates. This method strives for a better user experience, subordinating pixel resolution to stable playback. As a consequence, besides success ratios, start times and the absence of interruptions, we have added the average video resolution as another important performance indicator.

EE is data leader in larger cities

In the drivetests and walktests that P3 conducted in the large cities of the UK, EE takes a clear lead in the data category. With also strong results in the larger cities, Vodafone closely follows in these areas. >>



Data in Cities - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.1/99.4	98.7/99.3	98.4/98.9	94.8/96.6
Static: Avg. Session Time (s/s)	1.5	1.6	1.7	2.4
Live: Reaction Time (ms)	377	371	358	440
Live: Initial DL Speed 1st second (kB/s)	500	480	490	377
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.9/2.0	99.8/2.5	99.3/3.9	97.9/6.6
90%/10% faster than (kbit/s)	8454/45732	5302/53274	2787/40796	1494/27304
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.4/1.1	99.7/1.3	99.3/1.4	99.1/2.0
90%/10% faster than (kbit/s)	5043/25429	4335/17857	4305/15625	2228/14514
File Download (7 Seconds)				
Success Ratio (%)	99.5	99.0	98.9	98.4
Avg. Throughput (kbit/s)	44166	37949	24561	13748
90%/10% faster than (kbit/s)	10049/86364	5931/81757	2990/56837	1814/31606
File Upload (7 Seconds)				
Success Ratio (%)	99.2	99.3	98.9	98.6
Avg. Throughput (kbit/s)	25068	16747	17588	11359
90%/10% faster than (kbit/s)	6242/41536	4792/29335	4538/29370	3271/19032
Youtube Video				
Success Ratio/Start Time (%/s)	98.6/2.1	98.2/2.3	91.7/2.4	89.4/3.5
Playouts without Interruptions (%)	99.2	98.2	96.1	92.9
Average Video Resolution (p)	1074	1063	1043	1016

Data in Cities - Walktest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.0/99.3	97.6/99.0	98.1/97.1	92.1/91.1
Static: Session Time (s/s)	1.5	1.8	2.1	2.7
Live: Reaction Time (ms)	403	391	367	462
Live: Initial Download speed (Kbyte/s)	457	421	400	312
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.8/2.9	99.8/3.9	96.7/7.5	93.4/11.1
10% faster than (kbit/s)	5220	2776	1184	746
90% faster than (kbit/s)	34159	48159	27422	23189
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.1/1.1	99.8/1.4	98.8/1.6	95.5/2.7
10% faster than (kbit/s)	5988	3570	3660	1381
90% faster than (kbit/s)	23599	19512	14094	11782
File Download (7 Seconds)				
Success Ratio (%)	100.0	98.8	97.2	94.2
Avg. Throughput (kbit/s)	36286	37030	11865	10202
10% faster than (kbit/s)	6560	3680	1175	783
90% faster than (kbit/s)	74054	89508	29830	25827
File Upload (7 Seconds)				
Success Ratio (%)	98.5	99.8	97.5	94.4
Avg. Throughput (kbit/s)	24807	18176	16361	7758
10% faster than (kbit/s)	8328	5270	4372	1615
90% faster than (kbit/s)	41015	35257	27336	15122
Youtube Video				
Success Ratio/Start Time (%/s)	97.2/2.3	97.6/2.6	80.0/2.9	74.3/3.9
Video playouts without interruptions (%)	96.8	97.7	90.0	91.8
Average Video Resolution (p)	1064	1054	999	990

EE especially scores high in the disciplines of web browsing as well as file downloads and file uploads. In the YouTube tests, EE and Vodafone show a strong performance and are clearly ahead of Three and O2. EE showed the best YouTube performance in the drivetest scenarios, while Vodafone shows the strongest Youtube performance in the walktest scenarios.

Three ranking second in smaller towns

In the towns outside metropolitan areas, EE is also leading the field. However, similar to the voice results, Three performs somewhat stronger in smaller towns than the overall second-ranking Vodafone. This is especially due to Three's strong results for file downloads and web browsing in towns. In the Youtube discipline in smaller towns, the results of Three and Vodafone are not far apart.

EE ahead on major roads, Vodafone closely behind

On the connecting roads, EE again takes a clear lead, providing fast data rates and achieving convincing success ratios. Vodafone and Three also show strong results in this category, while O2 lags a little behind. Nonetheless, with the success ratios in all considered categories scoring well over 90 per cent even on the relatively demanding connecting roads, all four mobile network operators provide viable performance even in the more rural areas.

Data in Towns - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.1/99.0	97.6/97.8	99.2/99.2	94.3/97.3
Static: Avg. Session Time (s/s)	1.5	1.7	1.8	2.3
Live: Reaction Time (ms)	407	388	546	454
Live: Initial DL Speed 1st second (kB/s)	508	450	506	397
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.3/1.6	98.2/3.4	100.0/2.4	98.6/5.4
90%/10% faster than (kbit/s)	10005/53004	3541/34212	5210/43088	2150/33755
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.7/1.6	98.1/1.7	98.6/2.4	97.9/2.5
90%/10% faster than (kbit/s)	2514/22663	2867/15038	1389/15299	1571/14270
File Download (7 Seconds)				
Success Ratio (%)	99.5	97.4	99.8	99.1
Avg. Throughput (kbit/s)	39721	19284	33988	16777
90%/10% faster than (kbit/s)	11150/75259	4152/41297	7116/64148	2388/39267
File Upload (7 Seconds)				
Success Ratio (%)	99.0	97.7	98.4	97.6
Avg. Throughput (kbit/s)	20456	13275	14326	10368
90%/10% faster than (kbit/s)	2888/38937	3592/20986	1863/29613	2124/19321
Youtube Video				
Success Ratio/Start Time (%/s)	98.9/2.2	95.8/2.7	95.8/2.2	93.5/3.3
Playouts without Interruptions (%)	99.3	97.4	98.5	96.1
Average Video Resolution (p)	1074	1054	1060	1032

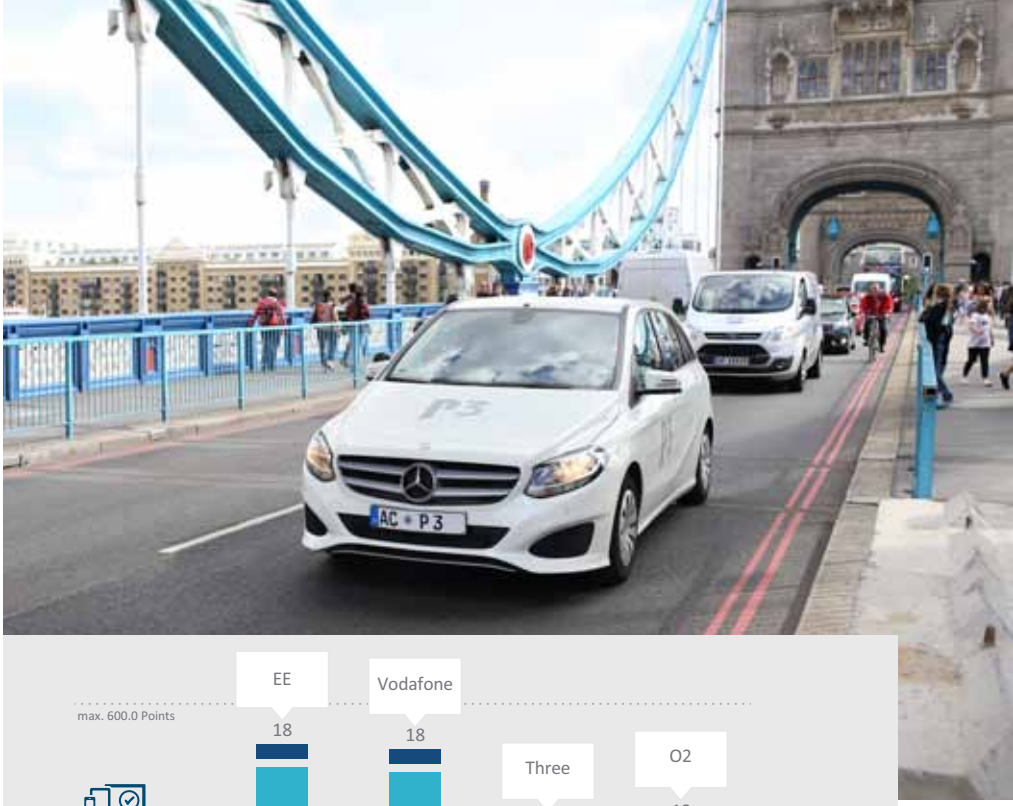
DATA RESULTS AT A GLANCE

Again, EE is the overall winner in the data categories. Vodafone follows at a close distance, with a strong performance especially in the walktest scenarios. Three ranks third in the total data category, but is able to score ahead of the overall second-ranking Vodafone in smaller towns. O2 ranks last in all data test scenarios. But all four UK networks achieve relatively high success ratios even in demanding areas like the smaller towns and connecting roads.

Data on Roads - Drivetest	EE	Vodafone	Three	O2
Web-Page Download (Live/Static)				
Success Ratio (%/%)	98.1/99.0	95.7/95.9	96.3/96.1	89.1/92.6
Static: Avg. Session Time (s/s)	1.5	1.7	2.2	2.5
Live: Reaction Time (ms)	434	420	830	559
Live: Initial DL Speed 1st second (kB/s)	498	455	458	400
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	98.7/1.7	96.4/3.0	99.0/3.6	95.3/5.3
90%/10% faster than (kbit/s)	9796/54176	4481/39467	3637/41082	2359/34360
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	98.1/1.6	96.7/1.9	96.0/3.1	95.4/2.8
90%/10% faster than (kbit/s)	2520/22663	2433/15232	1226/15189	1319/14771
File Download (7 Seconds)				
Success Ratio (%)	99.2	97.3	98.4	96.3
Avg. Throughput (kbit/s)	39478	24122	27022	17243
90%/10% faster than (kbit/s)	11287/71339	4943/48910	4386/63080	2971/38715
File Upload (7 Seconds)				
Success Ratio (%)	97.6	94.8	95.4	95.2
Avg. Throughput (kbit/s)	19871	13564	11467	11347
90%/10% faster than (kbit/s)	2498/37311	3107/21804	1208/28965	2402/20120
Youtube Video				
Success Ratio/Start Time (%/s)	97.2/2.2	93.6/2.4	92.3/2.8	94.4/3.4
Playouts without Interruptions (%)	98.9	97.9	96.3	96.8
Average Video Resolution (p)	1076	1063	1037	1052

London

Traditionally, P3 and connect take a closer look at the capital to see how the operators cover this busy metropolis.



Being a major business hub and 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 country.

As the tests in London cannot obtain the points that could be gathered in smaller towns or on connecting roads, the achievable maximum is 600 points. We have adapted the achievable crowd score points accordingly which results in a possible maximum of 18 points.

Vodafone one point ahead in voice

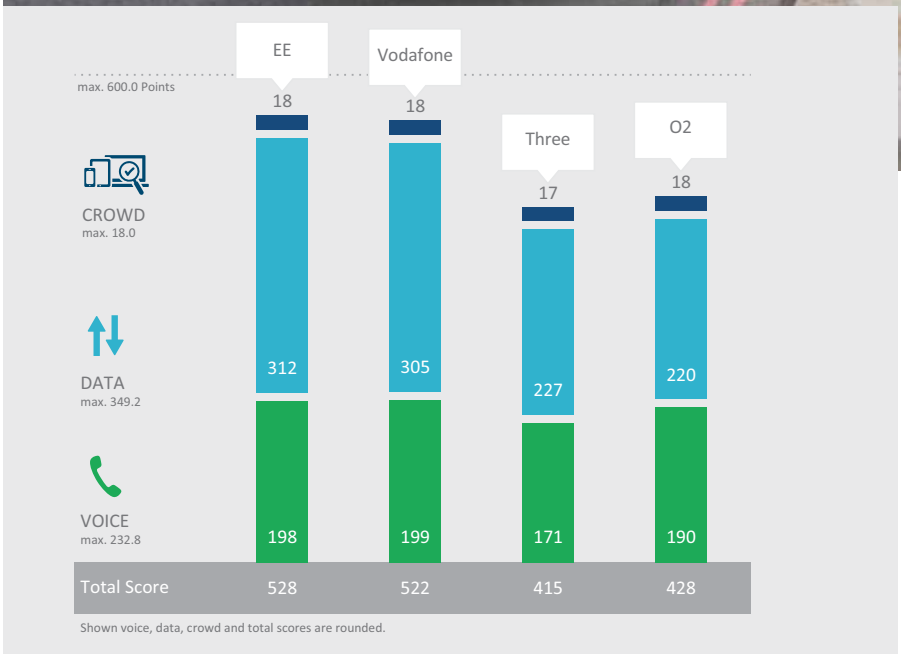
In the drivetests and walktests measuring voice services in London, Vodafone takes a narrow lead over EE. But clearly ahead in the data discipline, EE defends the overall first rank also here.

O2 ahead of Three in London

Also, in the total results for London, O2 overtakes Three with a noticeable advance of 13 points. This advance is mostly obtained in the voice discipline. Regarding data performance, Three is still ahead of O2. In the proportionally matched crowd score, only Three loses one of the possible maximum of 18 points.

LONDON RESULTS AT A GLANCE

The overall winner in the capital is EE, with Vodafone taking a lead in the voice discipline. In London, O2 is somewhat ahead of Three due to stronger voice results. However when taking the data category into consideration, Three's score remains ahead of O2.



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

London Overall Results Voice and Data		EE	Vodafone	Three	O2
Voice	max. 232.8	198	199	171	190
Cities (Drivetest)	174.6	82 %	81 %	73 %	79 %
Cities (Walktest)	58.2	96 %	97 %	77 %	90 %
Data	max. 349.2	312	305	227	220
Cities (Drivetest)	261.9	91 %	88 %	71 %	68 %
Cities (Walktest)	87.3	86 %	86 %	46 %	49 %
Crowd	max. 18	18	18	17	18
2017-07	6.0	100 %	100 %	100 %	100 %
2017-08	6.0	100 %	100 %	100 %	100 %
2017-09	6.0	100 %	100 %	83 %	100 %
Connect Rating	600.0	528	522	415	428

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

Case Study: 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 perfomed additional analyses for the six largest UK cities behind London behind London, as well as Belfast to account for the capital of Northern Ireland.

As interesting as the focus on the densely populated London area may be, for obvious reasons 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 an attempt to also provide some insights for these points of view, we have additionally analysed the performances of the four operators in seven large UK cities – specifically Belfast, Birmingham, Bristol, Glasgow, Liverpool, Manchester and Sheffield. We would like to present the results as a case study. The values represented in the chart below are part of the overall UK score but do not earn individual grades. They may, however, help local customers to better chose their ideal network. We have not included the crowd score in this assesment, as the crowdsourced data in the single cities would not measure up to the required statistical relevance.

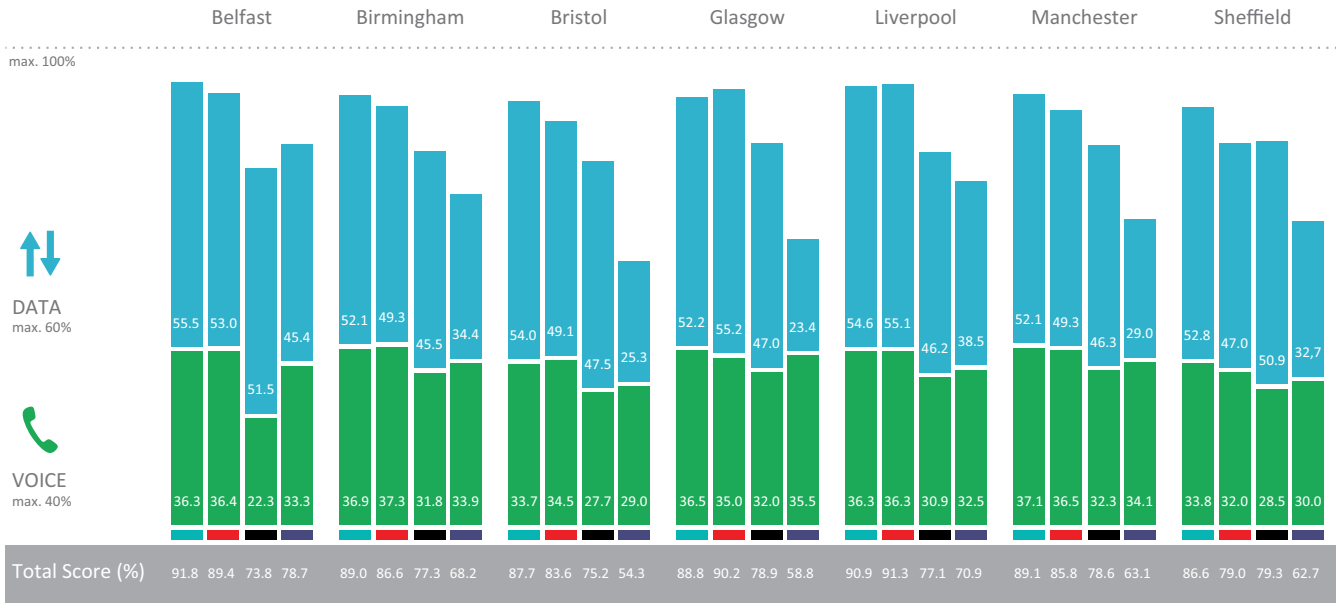
EE still mostly leading, Vodafone overtaking in Glasgow and Liverpool

In the cities of Birmingham, Bristol and Manchester, the overall picture is not much different to the nationwide results. Here, EE takes the lead, and the subsequent ranking is identical to our total score for the UK. In Belfast, EE also leads before Vodafone. However, here O2 scores stronger than Three and reaches the third rank thanks to strong voice results. And in Sheffield, Three overtakes Vodafone by the fraction of a per cent and thus ranks second.

In Glasgow and Liverpool, Vodafone manages to take the lead over EE. In Liverpool, the gap is quite narrow, while it is a little more pronounced in Glasgow. In both cities, Vodafone takes the win due to strong data results. Looking only at the voice discipline, EE still is ahead in Glasgow (with a strong O2 as a third top voice candidate) and scores on par with Vodafone in Liverpool.

Three very strong in data in some cities

Looking for local champions, we can see that Three scored remarkably well in the data discipline in Belfast, Bristol, Glasgow and Sheffield. In Sheffield, Three manages to score slightly ahead of Vodafone, ranking second in the overall evaluation. But even in those cities where the competitors show remarkable strength in specific categories, EE still scores very high and – aside from the exceptions mentioned above – can defend its overall top position.



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

Operational Excellence

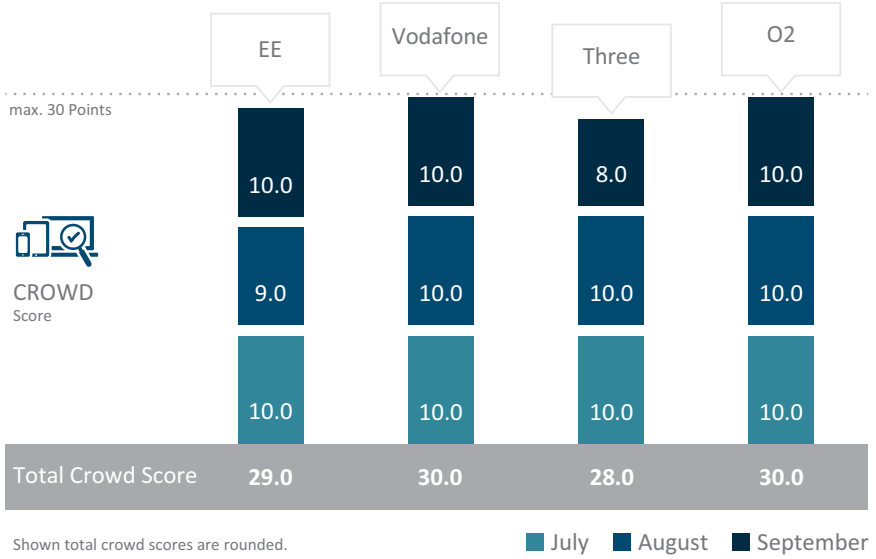
Beginning with this year's P3 connect Mobile Benchmark in the UK, we start to complement our measurements with an additional, crowdsourced assessment of service availability. In this discipline of our 2017 benchmark, Vodafone and O2 are ahead, achieving the full score of 30 points.

An additional important aspect of mobile service quality – above performance and measured values – is the actual availability of the mobile networks to the customers. Obviously, even the best performing network is only of limited benefit to its users, if it is frequently impaired by outages or disruptions.

Therefore, P3 has been looking into additional methods for the quantitative determination of network availability, collecting data via crowdsourcing. This method must however not be confused with the drivetests and walktests described on the previous pages. We are convinced that crowdsourcing can significantly enhance the aspects of benchmarking: Drivetesting and walktesting has obvoius advantages as a very controlled environment, while crowdsourcing accelerates when looking for longer time periods or geography beyond defined test routes. So, when it comes to diagnosing the sheer availability of the respective mobile networks, a crowdsourcing approach can provide additional insights. Therefore, P3 has developed an app-based crowdsourcing mechanism in order to assess how a large number of mobile customers experience the availability of their mobile network. We call this aspect "operational excellence".

The UK mobile network test at hand is the first occasion where we expand our scoring scheme with the results of this crowdsourced investigation. As we have considered the results from July, August and September 2017 and each month is represented by a maximum of ten achievable points, this time the so called "crowdscore" contributes up to 30 points to the total result. >>

CROWD
3%



Shown total crowd scores are rounded.

The detailed methodology of our analysis and the calculation of the resulting points is described on page 13 of this report. As a consequence of this addition, the P3 connect Mobile Benchmark is the only mobile network test which combines both aspects (drivetesting and walktesting as well as crowdsourcing) and thus provides the most comprehensive view on network performance.

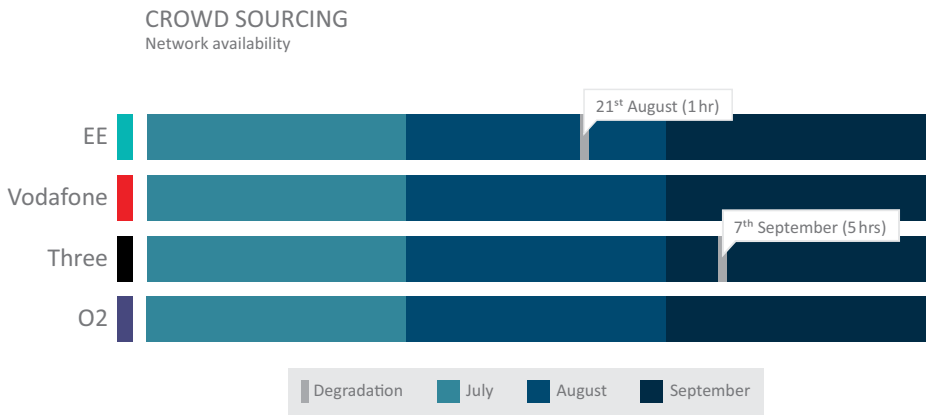
Crowdsourcing shows mostly stable UK networks

The in-depth analysis of our crowdsourcing data gathered in the three months preceding and including our measurement campaign in the UK, shows that the UK networks are all in all very stable and reliable. For Vodafone and O2 we did not observe any degradations in the observation period.

In the relevant months, EE only suffered a one hour service degradation in the afternoon of August 21st. According to our scoring principle, this one-hour degrations costs one point – so EE scored a total of 29 out of 30 possible crowd score points.

In the Three network, we determined an incident that happened during the afternoon and evening of September 7th (exactly from 5pm to 9pm), adding up to a total service degradation of five hours on this day. According to our crowd scoring scheme, this costs one point for the affected day plus another point for the time period of up to six hours. So, Three achieves a crowd score of 28 out of 30.

While these reductions of service availability were certainly annoying to the customers of the affected networks, they only have a limited impact to the overall results and did not have the capacity to change the actual ranking in the UK. However, for next year, we plan to consider a larger number of months and consequently to increase the share that our crowd score has in the total result.



The collection of crowdsourced data is based on app like "U get" (see below) and others, that constantly perform and report anomysed service availability measurements in the background.

OPERATIONAL EXCELLENCE AT A GLANCE

Considering July, August and September of 2017, we could only determine a one-hour degradation in the EE network and a five-hour incident in the Three network. For the networks of Vodafone and O2, we did not observe any relevant incidents. As we considered a three month period this time, which contributes 30 to the total maximum of 1000 achievable points, EE scores 29 out of 30 points and Three reaches 28 out of 30. Vodafone and O2 receive the full amount of 30 crowd score points.

PARTICIPATE IN OUR CROWDSOURCING

Everybody interested in being a part of our "operational excellence" global 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 **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 the mobile customer experience.**

The methodology of the P3 connect Mobile Benchmark is the result of P3's many years of experience. It was carefully designed to evaluate and objectively compare the performance and service quality of the UK's mobile networks from the users' perspective.

Testing Methodology

The P3 connect Mobile Benchmark took place throughout September 2017. All samples were collected during the day, between 8am and 10pm. The network tests covered 20 large cities with more than 100,000 inhabitants. Measurements were also taken in smaller towns as well as on trunk roads and motorways. The combination of test areas had been selected to provide a significant series of test results covering the UK population in England, Scotland, Wales and Northern Ireland. The areas chosen for the 2017 test account for more than 17 million people, or approximately 27% of the total population of the UK.

P3 conducted the tests with four drivetest cars, equipped with arrays of Samsung Galaxy S7 Cat 9 smartphones as well as a mixed allocation of Samsung Galaxy S7 and Sony Xperia XZ Cat 9 smartphones for simultaneous measurement of voice and data services. Additionally, two teams conducted the walktests, also measuring voice and data performance.

Voice testing

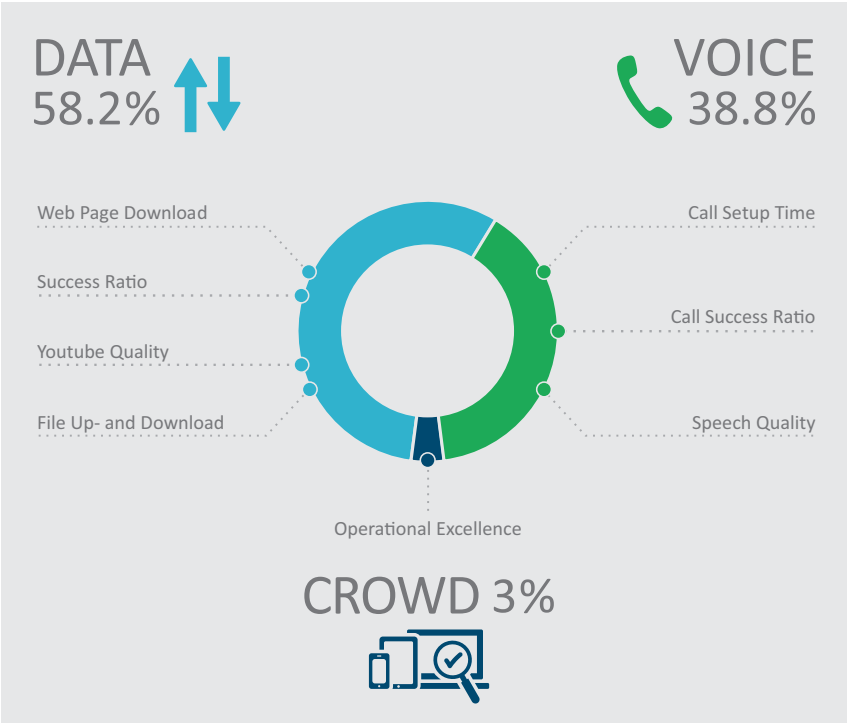
Two smartphones per operator in each car plus four smartphones per operator in the walktests were used for voice evaluation. They were setting up test calls between each other – from car to car and from each walking staff member to a stationary counterpart. The audio quality was evaluated based on the HD-voice capable and ITU standardised so-called POLQA wideband algorithm. All UK operators offer 4G capable subscriptions. All of the smartphones in the voice tests were set to 4G preferred mode. This reflects the common behaviour of customers. When a 4G connection, but no VoLTE was available, this would force the smartphones to switch ("fall back") to 2G or 3G for the voice calls (so called "circuit-switched fall back" or CSFB). In 4G networks with VoLTE support, the phones would prefer this voice mode. In order to further reflect typical smartphone use scenarios during the voice tests, background data traffic was generated in a controlled way through random injection of small amounts of HTTP traffic. The voice test scores account for 38.8% of the total benchmark results.

Data testing

Data performance was measured using one smartphone per operator per car. Two of the drivetest cars were equipped with four Samsung Galaxy S7 each while the other two were carrying four Sony Xperia XZ each. This setup was chosen in order to respect the variable data performance of different smartphones in different networks. For the data walktests, each of the two teams carried one Galaxy S7 per operator. In total, the drivetest cars carried 16 devices for the data tests and the walktest teams carried eight devices. For all data test devices, the radio access technology was set to LTE preferred mode.

The web tests accessed web pages according to the widely recognized 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 3MB and 1MB for download and upload respectively were transferred from or to a test server located on the Internet. In addition, the peak data performance was tested in uplink and downlink directions by assessing the amount of data that was transferred within a 7 seconds time period. Another discipline was the playback of YouTube videos. It took 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, YouTube measurements also determined the average video resolution.

All tests were conducted with the best-performing mobile plan available from each operator and in a full drive and walktest mode. Data scores account for 58.2 per cent of the total results. >>



Each car carried four phones for the data tests and eight phones for the voice tests. They were housed in three special boxes, containing four smartphones each.

Routes and samples

The test routes are shown on page 1 of this report. In the big cities and smaller towns indicated, the cars had to follow predefined routes. Altogether, the four test cars covered more than 4700 miles, of which approximately 2750 miles led through the big cities, while 1950 miles were covered in smaller towns and on connecting roads.

Performance indicators and rating

The score weighting reflects both the geographical distribution of the UK population and the ranking of usage scenarios. Therefore, 582 of the total of 1000 maximum points were assigned to the cities – 233 maximum points refer to the voice results and 349 maximum points reflect the data results. For the towns and the roads, a maximum of 194 points each is available. In both categories, the possible maximum is 78 points in the voice, and 116 points in the data category. The table on page 2 of this report shows the per centage of maximum points that each operator has achieved in each discipline.

Crowdsourcing operational excellence

The remaining 30 points are awarded for operational excellence. For this survey, P3 uses a crowdsourcing method. To acquire these data, P3 considers connectivity reports that are gathered by background diagnosis processes included in a number of popular smartphone apps. While the customer uses one of these apps, a diagnosis report is generated daily and is evaluated per hour. As such reports only contain information about the current network availability, it generates just a small number of bytes per message and does not include any personal user data.

In order to differentiate network glitches from normal variations in network coverage, we apply a precise definition of "service degradation": A degradation is an event where data connectivity is impacted by a number of cases that significantly exceeds the expectation level.

To judge whether an hour of interest is an hour with degraded service, the algorithm looks at a sliding window of 168 hours before the hour of interest. This ensures that we only consider actual network service degradations in contrast to a simple loss of network coverage of the respective smartphone due to prolonged indoor stays or similar reasons.

In order to ensure the statistical relevance of this approach, a valid assessment month must fulfil clearly designated prerequisites: A valid assessment hour consists of a predefined number of samples per hour and per operator. The exact number depends on factors like market size and number of operators. A valid assessment month must be comprised of at least 90 per cent of valid assessment hours (again per month and per operator).

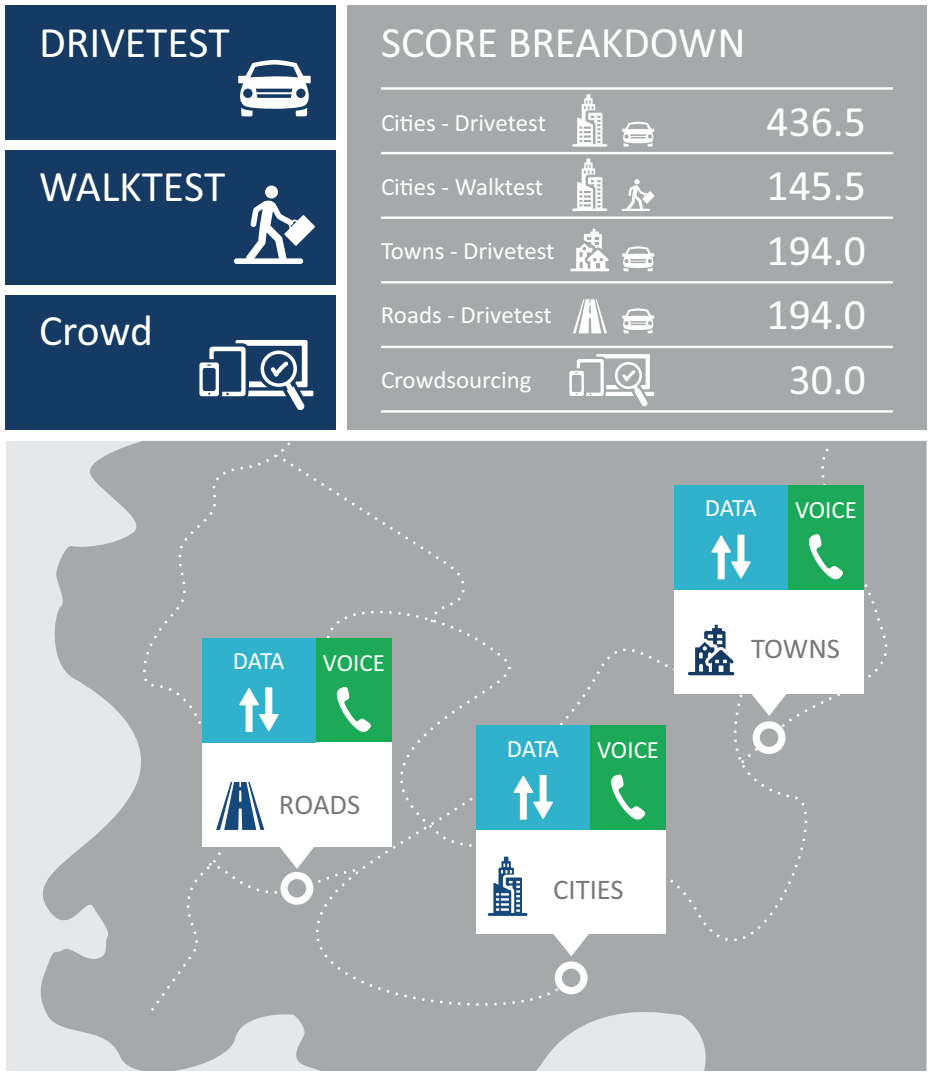
Sophisticated scoring model for operational excellence

The relevant KPIs are then based on the number of days when degradations occurred as well as the total count of hours affected by service degradations. In the scoring model that we plan to apply to the gathered crowdsourcing data, 60 per cent of the available points (in this case a maximum of 18) will consider the number of days affected by service degradations – thus representing the larger-scale network availability. An additional 40 per cent of the total score (here 12 points) is derived from the total count of hours affected by degradations, thus representing a finer-grained measurement of operational excellence.

Each considered month is then represented by a maximum of ten achievable points. The maximum of six points (60 per cent) for the number of affected days is diminished by one point for each day affected by a service degradation. One affected day will cost one point and so on until six affected days out of a month will reduce this part of a score to zero.

The remaining four points are awarded based on the total number of hours affected by degradations. Here, we apply increments of six hours: Six hours with degradations will cost one point, twelve hours will cost two points and so on, until a total number of 24 affected hours will lead to zero points in this part of the score.

Hakan Ekmen, CEO, P3 communications GmbH and Bernd Theiss, Head of connect's test lab, inspect the testing equipment.



MOBILE BENCHMARK

Conclusion

EE is the clear winner of this year's mobile benchmark, followed at some distance by a "good" Vodafone and a "good" Three. O2 ranks last.

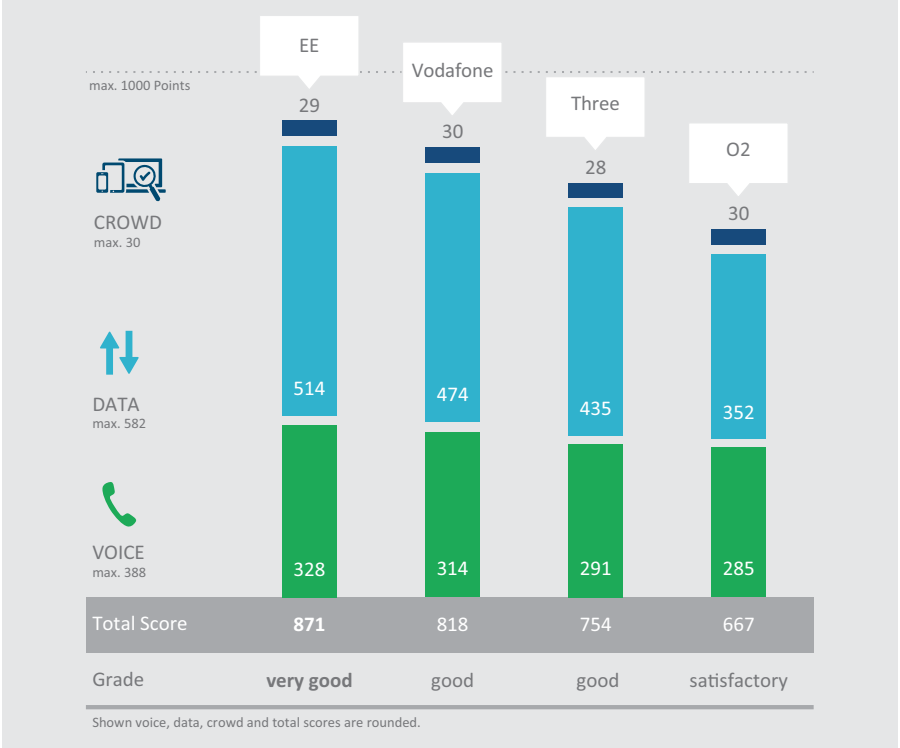
This year, the result is clear: EE is the overall winner of the P3 connect Mobile Benchmark in the UK 2017, taking a lead both in the voice and data categories and also showing a high level of operational excellence. The winner performs especially strong in all data categories as well as in the voice tests conducted in the smaller towns and on the connecting roads. Compared to the previous year, EE also shows the biggest score improvements both in the voice and data categories.

But also Vodafone managed to improve on its 2016 results. In the large cities, Vodafone and EE are on par regarding voice services. When looking at the capital London, Vodafone even takes a lead over EE in the voice category. Nationwide, also in some disciplines like Youtube playback in the walktest scenarios, Vodafone manages to score slightly ahead of EE.

Three and O2 both lose some ground over their 2016 scores. Overall, Three again reaches the third rank. However, particularly in smaller towns, Three achieves somewhat better scores than the overall second-ranking Vodafone. The same is true for the voice tests performed on connecting roads.

As in the previous year, O2 ranks last in the overall results. However, in the voice tests conducted in cities, O2 performs ahead of Three.

Despite these distinct differences, all four UK networks deliver stable performance both in the voice and data disciplines.



Overall Results Voice and Data		EE	Vodafone	Three	O2
Voice	max. 388	328	314	291	285
Cities (Drivetest)	174.6	84 %	85 %	73 %	78 %
Cities (Walktest)	58.2	96 %	95 %	78 %	85 %
Towns (Drivetest)	77.6	84 %	76 %	80 %	72 %
Roads (Drivetest)	77.6	78 %	66 %	71 %	56 %
Data	max. 582	514	474	435	352
Cities (Drivetest)	261.9	89 %	86 %	76 %	62 %
Cities (Walktest)	87.3	85 %	82 %	63 %	41 %
Towns (Drivetest)	116.4	87 %	75 %	80 %	66 %
Roads (Drivetest)	116.4	90 %	78 %	75 %	67 %
Crowd	max. 30	29	30	28	30
2017-07	10.0	100 %	100 %	100 %	100 %
2017-08	10.0	90 %	100 %	100 %	100 %
2017-09	10.0	100 %	100 %	83 %	100 %
Connect Rating	max. 1000	871	818	754	667

1

EE wins this benchmark with excellent voice and data performances, and deserves the overall grade "very good". Scoring 53 points ahead of the second-ranking Vodafone, EE's lead is distinct. The UK's largest operator achieves convincing results in all categories including the newly tested operational excellence.

2

Vodafone clearly improved on its 2016 score, but has to give leeway to the overall winner EE. Especially in the large cities, Vodafone's performance is on par with EE. In London, Vodafone takes a narrow lead over EE in the voice category. This is also true in some nationwide disciplines like YouTube playback in the walktests.

3

Three performs strongly in the voice tests conducted in smaller towns and on connecting roads as well as in the data category in towns. But in comparison to the scores achieved in our 2016 benchmark, this operator loses some ground. However, all in all Three offers reliable connections with a suitable performance.

4

In comparison to our 2016 UK benchmark, O2 falls a little behind. In some categories like the voice tests conducted in the larger cities, O2 still manages to perform ahead of the overall third-ranking competitor Three. Also, O2 collected all available points in our newly introduced operational excellence score.