

The 2017 P3 connect Mobile Benchmark in Sweden



For the second time, the testing professionals of P3 have conducted a mobile network test in Sweden. About one year ago, the Swedish operators had presented a very high level of performance and reliability.

So, we were curious whether they would hold up to these high expectations and might even surpass the excellent results of the previous benchmark. More than 14 million customers of the four Swedish operators await the results.



The 2017 P3 connect Mobile Benchmark in Sweden once again proves the strength of the Swedish mobile networks. Three out of four contenders were able to improve, two of them switch their ranking positions.

Results in a nutshell

P3's network benchmarks are widely accepted for setting industry standards as well as being highly objective. The carefully designed methodology scheduled two drivetest cars to visit 21 large cities and 33 smaller towns in Sweden as well as the connecting roads. The areas in which we tested accounted for more than 4 million people, or about 42 per cent of the Swedish population.

Another example for P3's great attention to detail is the use of up-to-date LTE "Cat 9" as well as VoLTE-capable smartphones for the tests. They 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. Also, we constantly readjust the thresholds of our evaluation to represent the latest technological advancements.

With 121 mobile subscriptions per 100 inhabitants, Sweden has a flourishing mobile communications market. And the excellent results from of our first mobile network benchmark in Sweden, conducted in 2016, have set high expectations. Still, three out of the four Swedish contenders were able to improve on their 2016 results.

Telia overall winner, Tele2 equally strong in voice

For the second time, the overall winner is Telia, which manages to score best in the data disciplines and shares the best voice results with Tele2 also impressing. Having ranked third in the previous year, Tele2 shows the biggest improvement both in points and performance.

Telenor slips down to the third rank because it delivers about the same performance as in the previous year. So, due to tighter thresholds, they lose points, but still achieve the grade "very good".

The smallest Swedish operator Tre still comes in last, but again achieves the grade „good“ and has clearly improved on 2016's results.



Shown voice, data and total scores are rounded.

Overall Results Voice and Data			Telia	Tele2	Telenor	Tre
VOICE	max. 400 Points		350	350	320	319
Cities	Drivetest	240	89%	87%	80%	80%
Towns	Drivetest	80	88%	88%	81%	81%
Roads	Drivetest	80	84%	87%	80%	77%
DATA	max. 600 Points		574	528	532	494
Cities	Drivetest	360	97%	88%	88%	84%
Towns	Drivetest	120	93%	87%	88%	80%
Roads	Drivetest	120	94%	90%	90%	80%
TOTAL	max. 1000 Points		924	878	852	813

Mobile networks are particularly strong in Sweden. Still, the Swedish mobile sector is characterised by many cooperations. Some of Sweden's 3G and 4G networks are actually operated by joint network companies.

Sweden's operators



Formerly owned by the Swedish government, Telia AB merged with the Finnish operator Sonera in 2002. After the merger, the Swedish state owned 46 per cent of the new TeliaSonera and Finland a little over 19 per cent. Since then, both states have reduced their ownership in the company. Today, most of Telia's shares are owned by diverse shareholders and the company is the largest Nordic and Baltic mobile operator both in revenues and customer base.

With approximately six million subscribers, Telia is also the largest mobile network provider in Sweden. Its mobile subscriber base equals a market share of about 42 per cent.

As Telia was not successful at the 3G spectrum auction, it cooperates with Tele2 for its 3G services. For 4G, Telia holds licences for 800, 900, 1800 and 2600 MHz individually as well as a 2100 MHz licence together with Tele2. Today, Telia claims to cover 99.9 per cent of the Swedish population with its 4G service.



Telenor is a Norwegian multinational telecommunications company and one of the largest mobile network providers in the world with operations in Scandinavia, Eastern Europe and Asia. Its Swedish operation is the result of Telenor's purchase of Vodafone Sweden in 2005. With about 2.5 million mobile subscribers and a market share of 18 per cent, Telenor is the third largest Swedish mobile network operator.

Together with Tele2, Telenor holds the joint company Net4-Mobility that operates 4G and 2G networks on behalf of both operators. Through this, Telenor holds 800, 900, 1800 and 2600 MHz licences. Also, Telenor has a network sharing agreement with Hutchison (Tre) for 3G in the 2100 MHz band, but the licences are held by Telenor and Tre individually.

The joint 4G coverage with Tele2 reaches about 99.5 per cent of the Swedish population and 90 per cent geographic coverage. Most of the 4G cells support LTE-Advanced with up to 300 Mbit/s.

TELE2

Sweden's first commercial internet provider Swipnet started in 1991 and was renamed Tele2 in 1993. In 1997, the company merged with the internet and cable operators Comviq and Kabelvision. In 2016, Tele2 also acquired the formerly Danish broadband operator TDC.

Today, Tele2 is active in many Nordic and Baltic countries. With about 3.7 million mobile subscribers, which equals a market share of 26 per cent, Tele2 is the second largest Swedish mobile operator.

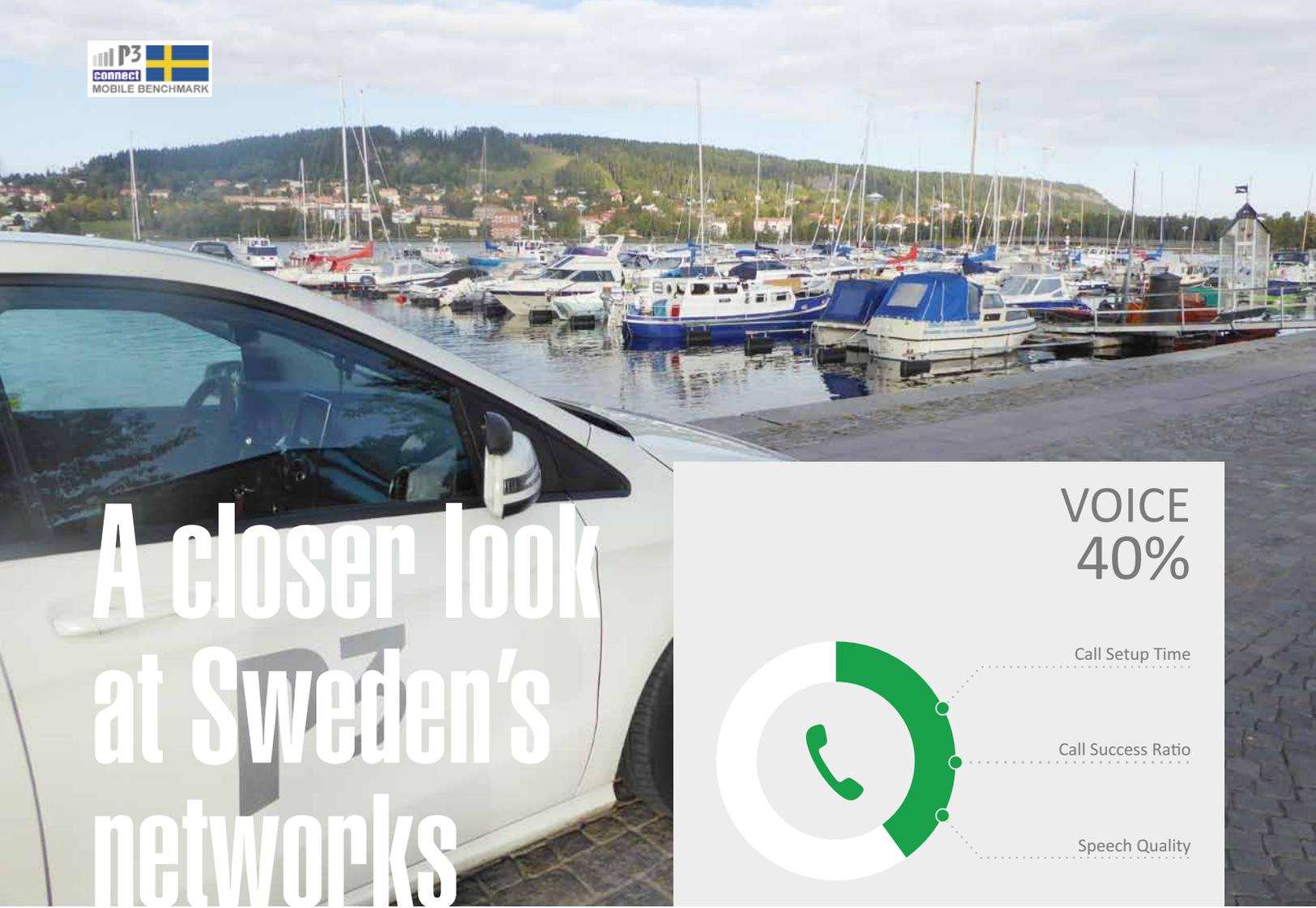
In 2001, Tele2 was one of the winners of the 3G spectrum auction, and established a co-operation with Telia who had not received a 3G licence. Their shared 3G network is owned and operated by the joint company Sunab (Svenska UMTS-nät AB). A similar joint company, "Net4Mobility", was formed in 2009 by Tele2 and Telenor for the operation of a shared 4G network and for amending their existing 2G networks. Tele2 holds 800, 900, 1800 and 2600 MHz licences together with Telenor, and a 2100 MHz licence together with Telia. The joint 4G network covers 99.9 per cent of Sweden's population.



Tre or Three is the brand name under which the multinational telecommunications company Hutchison operates 3G-based mobile networks in many countries such as Australia, Austria, Denmark, Ireland, Italy, Sweden, the UK and others. 3 Denmark and 3 Sweden have a joint network covering most of the two countries with no roaming fees to their customers in both countries. In Sweden, Tre's mobile network is shared with Telenor except for cities like Stockholm, Gothenburg, Malmo, Lund and some others.

With approximately two million subscribers, which equals 14 per cent of the Swedish population, Tre is number four regarding customer numbers in the Swedish mobile network market.

Tre does not operate a 2G network, but offers 3G on 900 and 2100 MHz and 4G on 800 and 2600 MHz. Today, Tre Sweden covers about 98.5 per cent of the Swedish population. Its LTE coverage is somewhat over 80 per cent of the population, but has been growing rapidly in recent years.



A closer look at Sweden's networks

After the excellent results observed in Sweden in 2016, P3 and connect were particularly interested whether the four Swedish mobile operators would be able to improve even on these high standards.

P3 communications GmbH, based in Aachen, Germany, is a world leader in mobile network testing. It is part of the P3 group, with over 3000 employees worldwide and a turnover of more than €300 million. P3 is partnering with the international telecommunications magazine connect, which has more than 20 years of editorial experience 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 mobile network benchmark test in Germany for 15 years, extending it to Austria and Switzerland in 2009.

Since 2014, P3 has also been conducting network benchmarks in Australia and the UK, followed by benchmarks in the Netherlands and Spain since 2015. In 2016, Sweden joined the list of examined countries.

In 2016 alone, P3 compiled more than 60,000 measurement hours in 65 countries across five continents, with its test vehicles covering almost one million kilometres. As the de-facto industry standard, the P3 benchmarking methodology focuses on customer-perceived network quality – examining both voice telephony as well as data connectivity. P3's network benchmarks are widely accepted as an objective authority.

Even more excellence in 2017

As already described on page 3, Sweden's mobile network market presents a unique combination of cooperation and competition at the same time. In our first test of Sweden's networks, conducted in 2016, all operators showed excellent results. So, in 2017 we have been pleasantly surprised that they have held up to these expectations. Three out of four contenders were even able to improve their scores.

VOICE
40%



Call Setup Time

Call Success Ratio

Speech Quality

DATA
60%

Web Page Download

Success Ratio

Youtube Quality

File Up- and Download



Hakan Ekmen,
Managing Director of
P3 communications
GmbH.

“All operators took the challenge of the P3 connect Mobile Benchmark, and three operators were able to improve their overall score compared to last year. 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.”



While data communications are ever more prevalent, customers still expect excellent voice quality. How do the Swedish mobile networks perform in this discipline?

Voice

P3's two measurement cars drove about 10,000 kilometers in total, covering 21 larger Swedish cities and 33 smaller towns as well as over the connecting roads. Each car carried eight Samsung S7 smartphones which permanently called each other. Our testing equipment registered success ratios, setup times and speech quality.

An important change compared to the test in the previous year is that Telia, Tele2 and Tre have started their deployments of Voice over LTE (VoLTE). So, a number of our test calls in these networks were already set up in this potentially superior technology.

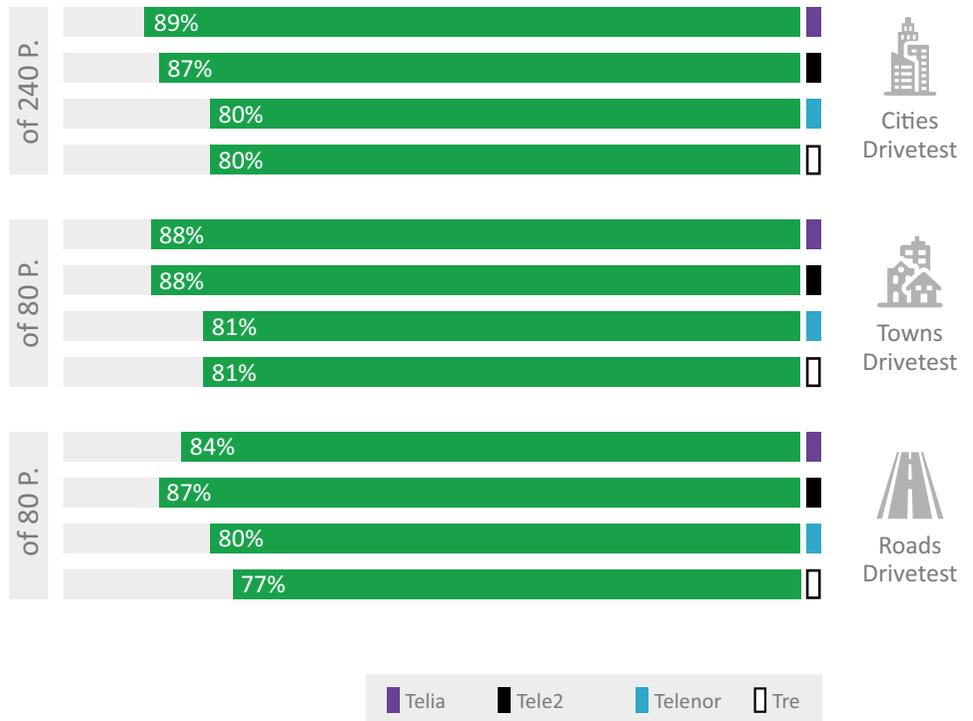
Tele2 and Telia on a par in voice results

In the voice discipline, overall test winner Telia and pursuer Tele2 lead the field and achieved the same number of points. Both Telia and Tele2 score high in large cities, while Tele2 is particularly strong in smaller towns and on the connecting roads. Compared to the previous test, Tele2 managed to improve considerably in the voice category, which might be explained by its recent introduction of VoLTE.

Telenor shows high success ratios in all tested areas, but loses points due to noticeably long call setup times. This sets back this operator so distinctly that Telenor only reaches the third rank in the overall score. Tre still ranks last in the voice category, but shows clear improvements – especially when bearing in mind that we have raised some of the thresholds of our voice scoring compared to the previous test.

400 of 1000 Points

VOICE 



VOICE RESULTS AT A GLANCE

Telia and Tele2 share the win in the voice category. In this discipline, Tele2 improved clearly in comparison to the previous year. Telenor still achieves good results, but loses points due to long call setup times. Tre shows slight improvements over the voice results of the previous year.

Voice - Drivetest	Telia	Tele2	Telenor	Tre
Cities				
Call Success Ratio (%)	99.5	99.4	99.2	98.3
Call Setup Time (s)	4.7	4.9	7.4	5.5
Speech Quality (MOS-LQO)	3.6	3.5	3.5	3.5
Towns				
Call Success Ratio (%)	99.2	99.4	99.3	98.4
Call Setup Time (s)	4.6	4.6	7.1	5.6
Speech Quality (MOS-LQO)	3.5	3.5	3.5	3.5
Roads				
Call Success Ratio (%)	98.1	99.1	98.9	97.1
Call Setup Time (s)	5.0	5.1	7.4	6.2
Speech Quality (MOS-LQO)	3.5	3.5	3.4	3.5

Data

The volume of mobile data downloads and uploads is constantly growing. While 4G/LTE currently is the best technology to cope with these increasing demands and Swedish 4G networks realise a wide coverage of the population, bandwidth is still a limiting factor for all mobile operators. The current Swedish plans to rededicate the 700 MHz frequency band, formerly used for TV broadcasting, to mobile communications speak for themselves.

So, all operators face challenges to provide sufficient data rates to their customers. Furthermore, a good mobile internet experience demands quick loading times. This includes the download of different types of web-pages, downloads and uploads of large files as well as the increasingly important reception of video streams from services like Youtube.

In order to check the reliability and performance of data connectivity in the Swedish networks, one Samsung Galaxy S7 per operator was installed in one of our test cars while one Sony Xperia XZ per operator was installed in the second car. This distribution was chosen in order to represent the varying performance of different smartphone models in different networks.

The phones constantly performed a suite of tests covering the use cases mentioned before. For most of these checks, success ratios and average session times were logged. For downloads and uploads we also recorded average throughputs. 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.

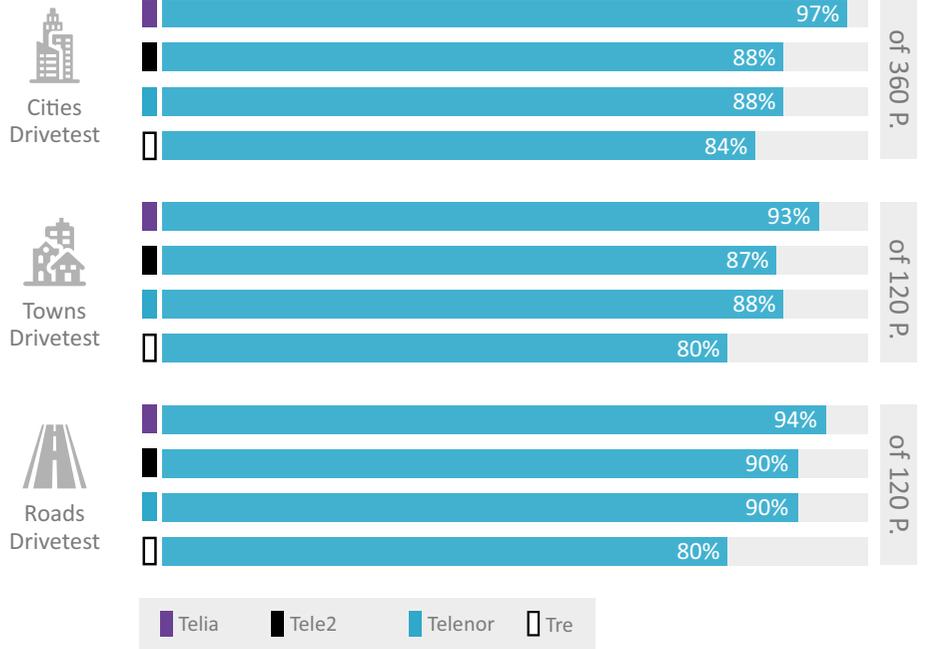
P3's approach for Youtube testing recognizes that this popular video service uses adaptive bit rates. This method strives for a better user experience, subordinating pixel resolution to stable playback. As a consequence, besides success ratios, start times and the absence of interruptions, we have added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

Telia offers best data performance in cities

In the cities, Telia clearly leads the field, while Tele2 and Telenor offer comparable performance, and Tre is following at a short distance. All four operators achieve high success ratios at web page downloads, with only Tre leaving some room for improvement when it comes to downloading live web pages. >>



With data volumes growing exponentially and tight limitations on available bandwidth, all operators face challenges in providing a satisfying user-experience. Which Swedish contender manages to best meet the growing demand?



Data in Cities - Drivetest

	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.9/100.0	99.7/99.8	99.6/99.8	99.1/99.7
Static: Avg. Session Time (s/s)	1.0	1.4	1.3	1.5
Live: Reaction Time (ms)	394	446	417	813
Live: Initial DL Speed 1st second (kB/s)	660	579	594	567
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/0.9	99.9/2.3	99.9/2.0	99.9/3.4
90%/10% faster than (kbit/s)	18222/67989	4417/53074	6745/52402	4989/36697
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.9/0.7	99.7/1.5	99.8/1.4	99.4/1.9
90%/10% faster than (kbit/s)	8604/27778	2737/20997	3048/21680	2738/14045
File Download (7 Seconds)				
Success Ratio (%)	100.0	100.0	100.0	99.5
Avg. Throughput (kbit/s)	85726	38607	41753	31063
90%/10% faster than (kbit/s)	22776/166969	7146/87172	6867/93887	9512/66203
File Upload (7 Seconds)				
Success Ratio (%)	99.9	99.6	99.5	99.4
Avg. Throughput (kbit/s)	30076	16298	17503	10938
90%/10% faster than (kbit/s)	10243/44103	3464/33922	3481/35055	2910/18756
Youtube Video				
Success Ratio/Start Time (%/s)	99.8/1.9	98.2/2.3	98.4/2.2	99.5/2.7
Playouts without Interruptions (%)	99.8	98.8	98.7	99.3
Average Video Resolution (p)	1078	1070	1070	1070

Data in Towns - Drivetest	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.6/99.9	99.8/99.7	100.0/100.0	98.7/99.8
Static: Avg. Session Time (s/s)	1.1	1.4	1.4	1.8
Live: Reaction Time (ms)	427	461	422	1290
Live: Initial DL Speed 1st second (kB/s)	640	577	591	533
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/1.2	100.0/2.4	100.0/2.2	100.0/4.1
90%/10% faster than (kbit/s)	12191/60560	4896/52794	6113/50420	4518/31721
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.6/1.0	100.0/1.7	100.0/1.6	98.9/3.1
90%/10% faster than (kbit/s)	5664/23215	2335/19070	2778/20408	1644/13841
File Download (7 Seconds)				
Success Ratio (%)	99.8	99.7	99.5	99.8
Avg. Throughput (kbit/s)	53181	37545	41559	23150
90%/10% faster than (kbit/s)	16530/99569	6061/85525	6640/93988	7578/46473
File Upload (7 Seconds)				
Success Ratio (%)	99.6	98.9	99.7	98.9
Avg. Throughput (kbit/s)	23588	13271	14429	10176
90%/10% faster than (kbit/s)	6814/38087	2752/30588	2979/31060	2078/19282
Youtube Video				
Success Ratio/Start Time (%/s)	99.8/2.0	98.4/2.2	98.3/2.2	99.3/3.2
Playouts without Interruptions (%)	99.8	98.9	98.6	99.6
Average Video Resolution (p)	1077	1072	1069	1072
Data on Roads - Drivetest				
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.7/99.9	99.8/99.7	99.5/99.7	98.0/99.0
Static: Avg. Session Time (s/s)	1.2	1.5	1.4	2.0
Live: Reaction Time (ms)	434	460	441	1534
Live: Initial DL Speed 1st second (kB/s)	620	563	582	512
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	99.9/1.8	100.0/2.9	99.8/2.5	99.6/4.7
90%/10% faster than (kbit/s)	7429/58309	3642/44069	4647/43557	4169/31558
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.3/1.5	100.0/2.0	99.2/1.8	98.5/3.9
90%/10% faster than (kbit/s)	2498/22222	2092/15700	2310/17778	1422/14089
File Download (7 Seconds)				
Success Ratio (%)	99.9	99.8	99.7	99.0
Avg. Throughput (kbit/s)	46065	28877	29690	20597
90%/10% faster than (kbit/s)	8082/102794	5708/60189	5948/64684	5528/44101
File Upload (7 Seconds)				
Success Ratio (%)	98.8	99.1	99.0	96.5
Avg. Throughput (kbit/s)	17279	11292	11256	7682
90%/10% faster than (kbit/s)	2831/37031	2965/23721	2031/25506	1532/18022
Youtube Video				
Success Ratio/Start Time (%/s)	99.2/2.2	98.4/2.5	98.5/2.3	97.3/3.6
Playouts without Interruptions (%)	99.5	99.0	98.8	98.8
Average Video Resolution (p)	1072	1058	1068	1061

Also, Telia clearly offers the highest data rates in the cities. Similar to the voice category, Tele2 shows a considerable improvement of the results of the previous year, which can be explained by their deployment of LTE carrier aggregation. Above that, both Telia and Tre achieve high success ratios when accessing Youtube videos, while Telenor and Tele2 fall a little behind in this category.

Telenor ranks second in smaller Swedish towns, Tele2 and Telenor on a par on connecting roads

A similar ranking can be observed also in smaller Swedish towns and on the connecting roads: Telia constantly leads, with Tele2 and Telenor mostly scoring on a par, and Tre following at a distance. Tre's gap to the leading three contenders is even a little wider in the countryside than in the larger cities.

Especially in the smaller towns, we noticed a slight advantage for Telenor over the otherwise almost equally strong Tele2. This is due to slightly faster reaction times and slightly higher data rates. Like in the previous year, Tre ranks last also in the data discipline. But most of its considerable gain in terms of points originates from improvements in data communications.

DATA RESULTS AT A GLANCE

Telia is also the overall winner in the data category due to higher data rates and very good success ratios. Tele2 and Telenor are almost equally strong in all tested areas, with a slight advantage for Telenor in smaller towns. Tre ranks last. In comparison to the previous benchmark, Telia, Tele2 and also Tre could most noticeably improve on their data scores.



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 Sweden's mobile networks from the users' perspective.

Testing Methodology

The P3 connect Mobile Benchmark in Sweden took place from August 19th to September 9th, 2017. All samples were collected between 8am and 10pm. The network tests covered 21 larger cities, of which 7 count more than 100 000 inhabitants. Additionally, our test routes led through 33 smaller towns as well as the connecting roads. This combination of test areas had been carefully selected to provide a significant series of test results covering the Swedish population. The areas chosen for the 2017 test account for more than 4 million people, or 42 per cent of the total Swedish population.

P3 conducted the tests with two drive-test cars, equipped with arrays of Samsung Galaxy S7 Cat 9 smartphones (Voice) as well as a mixed allocation of Samsung Galaxy S7 and Sony Xperia XZ Cat 9 smartphones (Data) for the simultaneous measurement of voice and data services.

Voice testing

Two smartphones per operator in each car were used for the voice tests, setting up test calls from one car to another. The audio quality of the transmitted speech samples was evaluated using the HD-voice capable and ITU standardized so-called POLQA wideband algorithm. All Swedish operators offer 4G capable subscriptions. To take the high share of LTE offerings into account, speech samples

were acquired partly in 4G preferred to 3G preferred mode and partly in 4G preferred to 4G preferred mode. As a consequence, in 4G networks with VoLTE support, the phones would prefer this voice mode. In 4G networks without VoLTE, they would need to switch ("fall back") to 2G or 3G for the voice calls (so called "circuit-switched fall back" or CSFB).

In order to account for 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 40 per cent of the total benchmark results.

Data testing

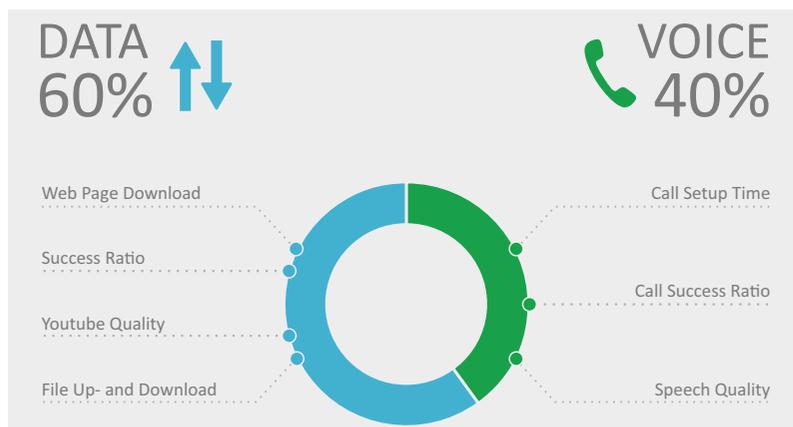
Data performance was measured using four smartphones in each car – one per operator. One car was equipped with four Samsung Galaxy S7 while the other car was carrying four Sony Xperia XZ in order to respect the variable data performance of different smart phones in different networks. In order to further reflect the customer experience, 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. >>



Three boxes were mounted into the back and into the side windows of each measuring car in order to support twelve smartphones per car.



Each box housed four smartphones allowing the simultaneous testing of four mobile operators.



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 the tests were conducted with the best-performing mobile plan available from each operator. Data scores account for 60 per cent of the total results.

Routes and samples

The test routes are shown on page 1 of this report. In the 21 big cities and 33 smaller towns indicated, the cars had to follow pre-defined routes. Altogether, the two test cars covered more than 10 000 kilometres, of which approximately 3700 km led through the big cities, while 6300 km were covered in smaller towns and on connecting roads.

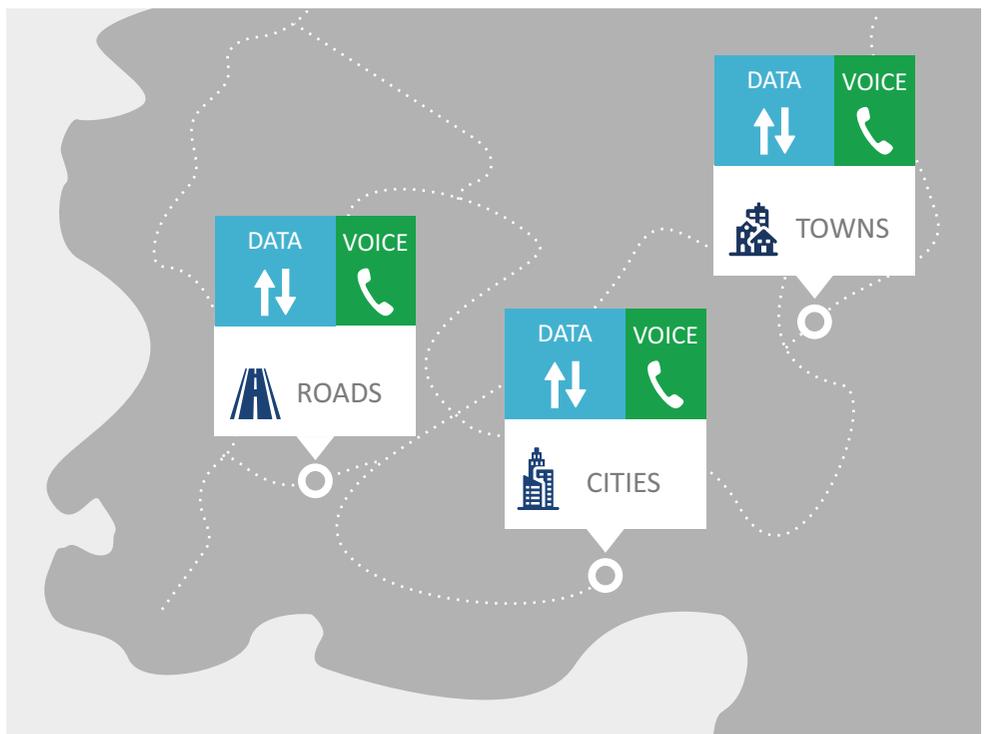
Performance indicators and rating

The score weighting reflects both the geographical distribution of Sweden's population and the ranking of usage scenarios. Therefore, 600 of the total of 1000 maximum points were assigned to the cities – 240 maximum points refer to the voice results and 360 maximum points reflect the data results. For the towns and the roads, a maximum of 200 points each is available. In both categories, the possible maximum is 80 points in the voice, and 120 points in the data category. The tables on page 2 and page 10 of this report show the percentage of maximum points that each operator has achieved in each discipline.



SCORE BREAKDOWN

Cities		600	Towns		200	Roads		200
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Hakan Ekmen, Managing Director of P3 communications GmbH and Bernd Theiss, Head of connect's test lab, inspect the testing equipment.

Conclusion

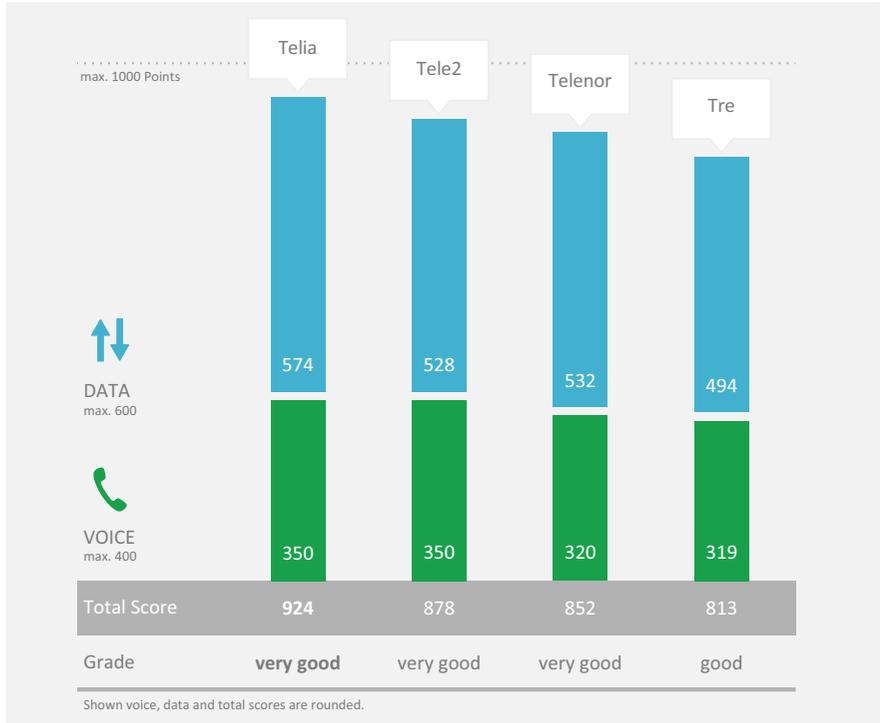
Despite overall strong performance levels, our benchmark of the four Swedish mobile networks still shows a distinct ranking order.

The overall result is quite clear: Telia successfully defends the first rank in Sweden and was even able to improve both in the voice and the data categories over the results of our previous benchmark. In the voice category, Telia shares the top position with Tele2, which is an indicator of the huge efforts that this operator took in order to improve on its position in the overall ranking. These steps include the successful deployment of both VoLTE and carrier aggregation. The still considerable point gap between the two highest ranks, however, can be explained with Tele2 ranking only third in the data category.

Telenor is the only contender in this benchmark not being able to improve on its results of the previous test. A closer examination shows that its performance is almost identical to the results of our 2016 benchmark in Sweden. But as we have raised some thresholds in our scoring scheme and the competitors can already benefit from improved technologies like VoLTE, just staying at the same level actually means a loss of points. In the voice category, the smallest Swedish operator Tre is even threatening to surpass Telenor, who is only one point ahead in this category.

Swedish networks among the best in Europe

While still holding the fourth rank, Tre could improve its performance over its 2016 results. This is especially true in the data category. Also, one should bear in mind that with 813 points and the overall grade "good", even this smallest Swedish operator would achieve a top position in other markets with a weaker mobile environment.



Overall Results Voice and Data			Telia	Tele2	Telenor	Tre
VOICE max. 400 Points			350	350	320	319
Cities	Drivetest	240	89%	87%	80%	80%
Towns	Drivetest	80	88%	88%	81%	81%
Roads	Drivetest	80	84%	87%	80%	77%
DATA max. 600 Points			574	528	532	494
Cities	Drivetest	360	97%	88%	88%	84%
Towns	Drivetest	120	93%	87%	88%	80%
Roads	Drivetest	120	94%	90%	90%	80%
TOTAL max. 1000 Points			924	878	852	813



The Swedish market leader wins this benchmark with a clear lead in the data category and the overall grade "very good". In the voice discipline, test winner Telia shares the first rank with Tele2. Compared to the results of our 2016 mobile benchmark in Sweden, Telia improves both in the voice and data categories.

Obvious efforts to improve its technology and performance result in a very good second rank for Tele2. Thanks to the introduction of VoLTE, this operator even shares the first position with the overall winner Telia in the voice discipline. Also, Tele2 achieves the biggest score improvement in comparison to our previous year's test.

Having ranked second in our 2016 benchmark, this year, Telenor falls to a third rank but still receives the grade "very good". Its overall results are on the same level as in the previous year. But rising thresholds as well as powerful competitors prevented a better placement this time. Accept the challenge, Telenor, and pursue a higher rank next year!

As in our previous benchmark, Sweden's smallest operator Tre scores last in this benchmark. However, Tre could clearly improve over its results from our 2016 mobile network test and absolutely deserves the grade "good". After vast improvements in data, maybe a similar boost in the voice category might lead to an even higher rank.



Operational Excellence

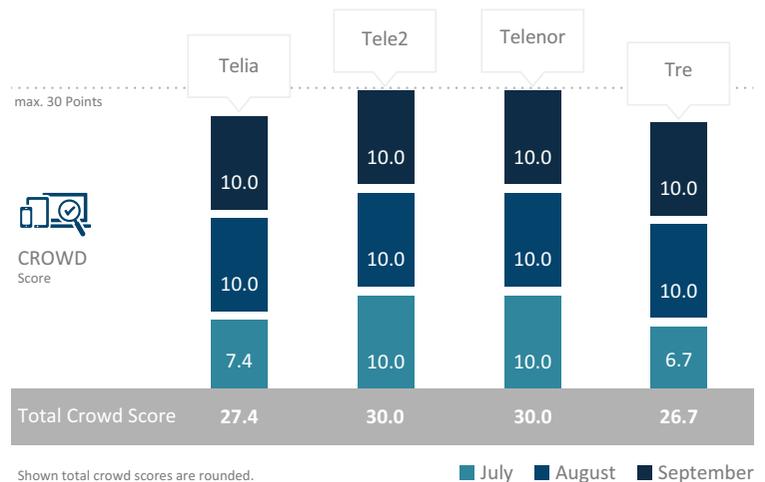
In the near future, we plan to complement our measurements with an additional assessment of service availability. For Sweden this year, we present this crowdsourced approach as a case study – it will become part of the overall scoring next year.

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 described on the previous pages. We are convinced that crowdsourcing can significantly enhance the aspects of benchmarking in the future. Drivetesting has advantages as a very controlled environment. Crowdsourcing accelerates when looking for time periods or geography beyond the driven route.

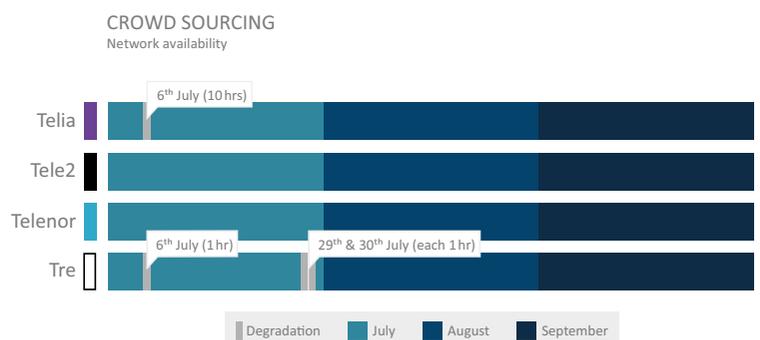
However, when it comes to diagnose the sheer availability of the respective mobile networks, a crowdsourcing approach can provide additional insights. Therefore, P3 has developed an app-based crowdsourcing mechanism in order to assess how a large number of mobile customers experience the availability of their mobile network. We call this aspect “operational excellence”.

In the future, we envision this consideration to become part of the overall scoring of our mobile network tests. But as we have been conducting this method in Sweden only for a couple of months and have not yet reached statistically firm numbers of users for all tested networks within the months considered, we have decided to present the results as a case study this year. >>



OPERATIONAL EXCELLENCE AT A GLANCE

Considering July, August and September of 2017, we could only observe degradations in the networks of Telia and Tre in July (see chart below). The glitches in network availability sum up to a total of ten hours in the Telia network and three separate one-hour periods in the network of Tre. According to our planned crowdsourcing methodology and evaluation (see page 12), this would have resulted in a loss of three points each (rounded) for both candidates, while Tele2 and Telenor would have remained unaffected.



So, the resulting observations are not yet included in the score of our network test. Nonetheless, in next year's P3 connect Mobile Benchmark in Sweden, we expect our crowdsourcing results to become a part of the overall test score. The P3 and connect Mobile Benchmark will then be the only mobile network test which combines both aspects (drive testing and crowdsourcing) and thus provides the most comprehensive view on network performance.

Crowdsourcing shows reliable Swedish networks

For this case study, we have taken a closer look at the data network availability in Sweden for the months preceding and including our measurement tours – specifically July, August and September 2017. The underlying methodology is described in detail in the box on the right-hand side of this page.

An in-depth analysis of our crowdsourcing data shows that the Swedish networks are all in all very stable and reliable. The only degradations that we could observe, took place in July. Overall test winner Telia suffered an observable service degradation on the evening of July 5th as well as the morning and afternoon of July 6th. In total, this sums up to ten hours of limited availability. For Tre, we observed a one-hour degradation on July 6th, and additional one-hour glitches on the evening of July 29th as well as on the afternoon of July 30th. Interestingly, despite their distinct sharing of network resources, Tele2 and Telenor did not show any observable degradations in the period under consideration.

While these reductions of service availability were certainly annoying to the customers of the affected networks, they would have had only a limited impact to the overall results even if we already had included them into our scoring. As Telia leads this benchmark with a clear distance to its pursuer Tele2, it would have lost some point but still have turned out as the overall winner of the benchmark.

Based on the present data, Tele2 and Telenor would not have been affected at all, as we did not observe any degradations in their networks during the considered period. Tre might have lost some points, but would still have reached the grade "good".

Although an inclusion of the crowdsourcing results would not have had the capacity to change the actual ranking in Sweden, this might look very different in countries or test results with closer distances between the candidates. So, we are already looking forward to see how this additional factor will affect future mobile network benchmarks.

Crowdsourcing Methodology

The mechanisms of our crowdsourcing analyses carefully distinguish actual service degradations from simple losses of network coverage. Also, the planned scoring model considers large-scale network availability as well as a fine-grained measurement of operational excellence.

For the crowdsourcing of operational excellence, 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.

Additionally, interested parties can deliberately take part in the data gathering with the specific "U get" app (see below).

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 pre-defined 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 percent of valid assessment hours (again per month and per operator). As these requirements were only partly met for the period of this report, we publish the Swedish crowdsourcing as a case study.

Sophisticated scoring model

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 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 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.

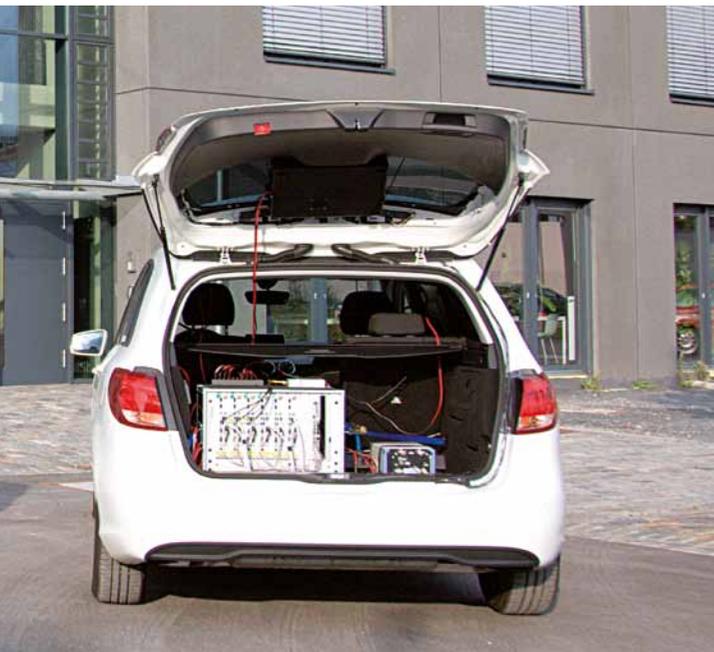
PARTICIPATE IN OUR CROWDSOURCING

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.**



Reactions

We asked the four Swedish mobile operators to comment on the results of the 2017 P3 connect mobile benchmark in Sweden. Here are their responses.



TELE2



“Tele2 Sweden has an area coverage of 90 per cent and population coverage of 99,9 per cent. We are extremely proud of what our network enables for our customers every day. The result of the P3 measurement is a clear proof that our investments contribute to a more digital Sweden. However, we are not yet satisfied. Hence, we will continue to invest with the same strength in existing and future networks.”

Samuel Skott
Chief Executive Officer Tele2 Sweden



“We are very proud of being the winner of the best network among the Swedish mobile operators for the second year in a row. Compared to last year results, which already was at a high level, we actually managed to improve the results even more in the 2017 benchmark.

To have a network among the best operators internationally according to P3 is very exciting and rewarding.”

Mats Lundbäck
Chief Technology Officer Telia Sweden



Telenor and Tre were not available for comments about the 2017 results.