



THE 2019 MOBILE NETWORK TEST IN SWEDEN



For the third time, P3 and connect have conducted a mobile network test in Sweden. In each year, the Swedish operators presented a very high level of performance and reliability –

and still managed to continually improve their results. So, expectations for this year's benchmark are high: How did the Swedish mobile networks perform this time?



RESULTS IN A NUTSHELL

The P3 connect Mobile Benchmark in Sweden has traditionally shown strong results. This trend continues in 2019, with all operators improving over their scores from the previous test – in the cases of Telia, Tele2 and Tre with considerable score increases. Telia wins for the third time in a row, achieving the grade “outstanding” with the highest score in Sweden so far.

Being highly objective and defining the de-facto industry standard, P3’s network benchmarks are widely accepted. The carefully designed methodology of the 2019 benchmark in Sweden 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.

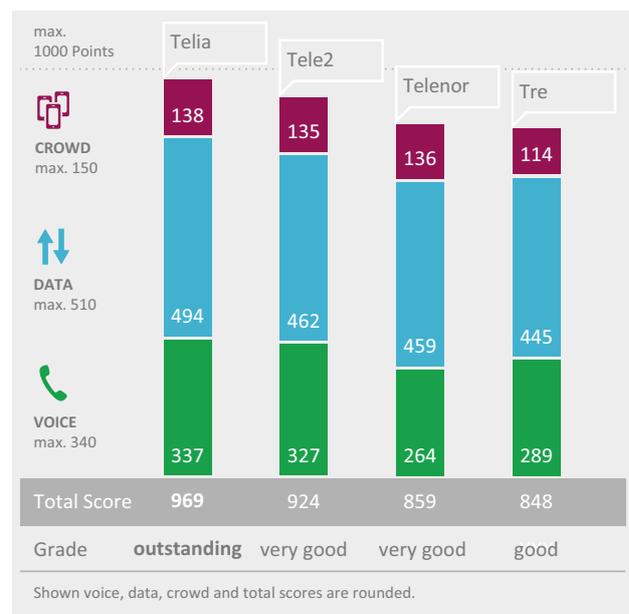
The drive and walktests allow for evaluating the cutting edge of the networks’ capabilities. Crowd-sourcing unveils the service quality, performance and coverage actually experienced by the users. We have thoroughly weighted these categories in order to give a realistic and authoritative assessment of the rated networks’ true potential and performance.

TELIA TAKES THE OVERALL WIN, TELE2 AND TELENOR SHOW VERY GOOD RESULTS. TRE CLEARLY IMPROVES ITS SCORE.

For the third time in a row, Telia is the clear winner of the P3 connect Mobile Benchmark in Sweden, maintaining the lead in voice and data services as well as in the newly added crowd score. Continuously improving its score over the last years and this time achieving the highest score measured by P3 in Sweden so far, Telia well deserves the rare grade “outstanding”. Tele2 and Telenor achieve “very good”, followed by Tre with the grade “good”. All four Swedish operators have improved over their results from our previous benchmarks, with Tele 2 showing the biggest improvement and Telia as well as Tre also achieving most pronounced score increases. Telenor also gathered more points than in the years before, overall keeping its very good performance. Tele2 takes the second rank in voice and data, whereas Telenor ranks second in the crowdsourcing, one point ahead of Tele2. Tre ranks third in voice and shows a considerable score improvement over the result of our previous benchmark. In the crowdsourced assessment of service degradations, we did not observe any limitations in Tre’s network from June 2018 to February 2019.



Telia is the overall winner of the 2019 P3 connect Mobile Benchmark in Sweden – for the third time in a row and with the highest score measured by P3 in Sweden so far. Tele2, Telenor and Tre achieve score increases as well, with Tele2 and Tre improving considerably over our previous test.



Overall Results		Telia	Tele2	Telenor	Tre
Voice, Data and Crowd					
Voice	max. 340 Points	337	327	264	289
Cities (Drivetest)		153	99%	96%	68%
Cities (Walktest)		51	98%	96%	93%
Towns (Drivetest)		68	100%	97%	92%
Roads (Drivetest)		68	99%	96%	76%
Data	max. 510 Points	494	462	459	445
Cities (Drivetest)		230	98%	91%	91%
Cities (Walktest)		76	98%	90%	88%
Towns (Drivetest)		102	95%	90%	89%
Roads (Drivetest)		102	95%	91%	87%
Crowdsourced Quality	max. 150 Points	138	135	136	114
Crowd		150	92%	90%	91%
Connect Rating	max. 1000 Points	969	924	859	848

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



THE SWEDISH OPERATORS

The Swedish mobile networks are characterised by many cooperations. Many of Sweden's 3G and 4G networks are actually operated by joint network companies – providing particularly strong performance and good coverage.



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, the company is the largest Nordic and Baltic mobile operator both in revenues and customer base. Most of its shares are owned by diverse shareholders.

In addition to its own brand, Telia operates a budget mobile service under the name "Halebop". With approximately six million subscribers, Telia is the largest mobile network provider in Sweden. Telia operates a 2G/3G network on 900 MHz and holds individual licences for 4G on 700, 800, 1800 and 2600 MHz. Above that, Telia and Tele2 operate a shared 3G network on 2100 MHz in the 50/50 owned company Sunab. Today, Telia claims to cover 99.9 per cent of the Swedish population with its 4G service. Its offerings include both VoLTE and 4G+ (LTE carrier aggregation).



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. In late 2018, Tele2 closed a merger with the Swedish broadband and TV provider Com Hem. Tele2 offers a budget mobile service under the name "Comviq". With about 3.8 million mobile subscribers, Tele2 is the second largest Swedish mobile operator. In 2001, Tele2 established a cooperation 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) and uses the 2100 MHz frequency range. A similar joint company, "Net4Mobility", was formed in 2009 by Tele2 and Telenor for the operation of a shared 4G network. Tele2 holds 700, 800, 900, 1800 and 2600 MHz licences. The joint 4G network covers 99.9 per cent of Sweden's population and offers VoLTE as well as carrier aggregation.



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. The MVNOs Lycamobile and Vimla use Telenor's network. With about 2.7 million mobile subscribers, Telenor is the third largest Swedish mobile network operator. Together with Tele2, Telenor holds the joint company Net4Mobility that operates 4G and 2G networks on behalf of both operators. Through this, Telenor holds 800, 900, 1800 and 2600 MHz licences. In addition, Telenor and Tele2 acquired spectrum at 700 MHz which is scheduled to be used for 4G in the second half of 2019. 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 99.8 per cent of the Swedish population. It offers both VoLTE as well as 4G+ (LTE carrier aggregation).



Tre or Three is the brand name under which the multinational telecommunications company Hutchison started operating 3G (and later also 4G) mobile networks in many countries such as Australia, Austria, Denmark, Ireland, Italy, Sweden, the UK and others. Tre Denmark and Tre 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 the cities Stockholm, Göteborg, Malmö, Lund and Karlskrona. In addition to its own brand, the network of Tre Sweden also supports the MVNO Hallon. With approximately 2.2 million subscribers, 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 99 per cent of the Swedish population. Its 4G/4G+ network supports both VoLTE as well as LTE carrier aggregation.

In the two preceding network tests, all Swedish mobile operators showed a high level of performance. So, we were particularly interested if they would be able to improve once again.

A CLOSE LOOK AT THE SWEDISH 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 more than 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 bench-

marks in the UK and Australia, expanding them to the Netherlands, Spain and Sweden in 2016 while also examining many other mobile networks all over the world including those in the USA and Singapore.

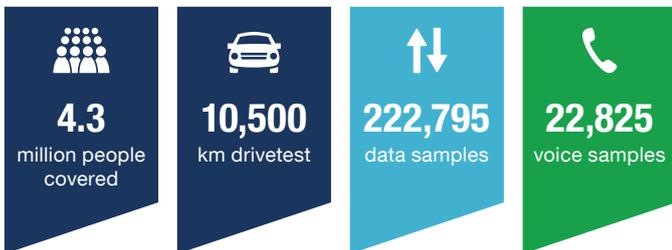
The 2019 P3 connect Mobile Benchmark in Sweden consists of drivetests and walktests conducted from February 21 to March 23, 2019. Two drive test cars together covered about 10,500 kilometres, visiting 20 cities and 27 towns. Additionally, a walktest team visited eight cities. The test areas account for approximately 4.3 million people, or about 43.9 per cent of Sweden's total population.



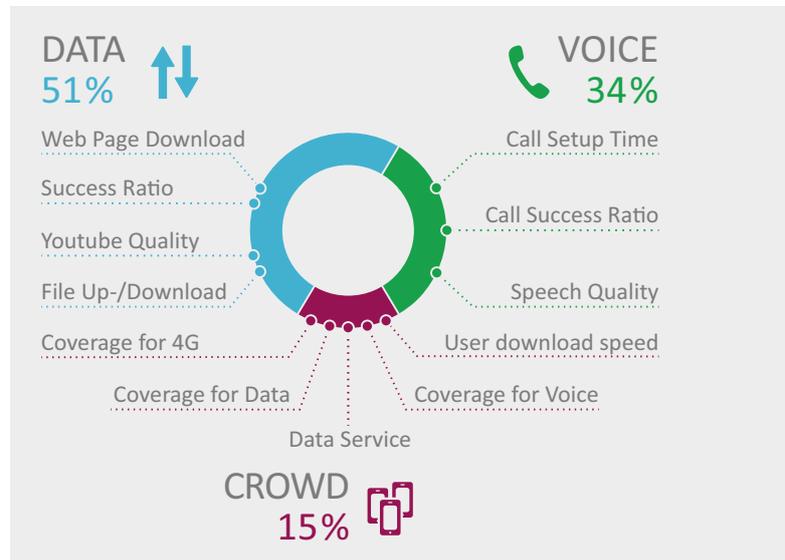
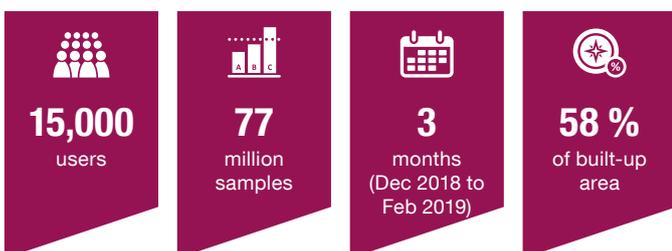
“Telia is the overall winner of this year’s P3 connect Mobile Benchmark Sweden with the highest score ever measured in Sweden, reaching the grade outstanding for the very first time. Also, what is great news for the customers of the other Swedish mobile operators: Each of them managed to improve their scores on an already high level of performance – Tele2 and Tre even considerably.”

Hakan Ekmen
CEO of P3 communications

DRIVETEST AND WALKTEST FACTS



CROWDSOURCING FACTS



VOICE

Even with the increasing importance of data, voice customers still expect reliable connections when actually placing or taking phone calls. How do the Swedish mobile networks manage to fulfil these expectations?

All four operators in Sweden support Voice over LTE (VoLTE) – to a different degree especially in less densely populated parts of the country. Particularly, Tre showed a lack of VoLTE support in the northern part of Sweden. 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 or 2G in order to conduct 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 S9 smartphone per operator. The smartphones 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.

TELIA LEADS IN VOICE. TELE2 ALSO ACHIEVES A VERY GOOD RESULT. TRE RANKS THIRD. TELENOR COMES IN LAST DUE TO SOME CALL SETUP LIMITATIONS.



TELIA STONG IN VOICE IN BIG CITIES

In the voice drivetests conducted in 20 Swedish cities, Telia achieves the highest score, with Tele 2 following closely. Both offer call setup ratios close to 100 per cent. Above that, Telia stands out with a higher speech quality than the other contenders by using predominantly the high-quality EVS (Enhanced Voice Services) codec. Tre ranks third with proper results in all KPIs. Telenor shows comparably long call setup times and a high share of call setup failures.



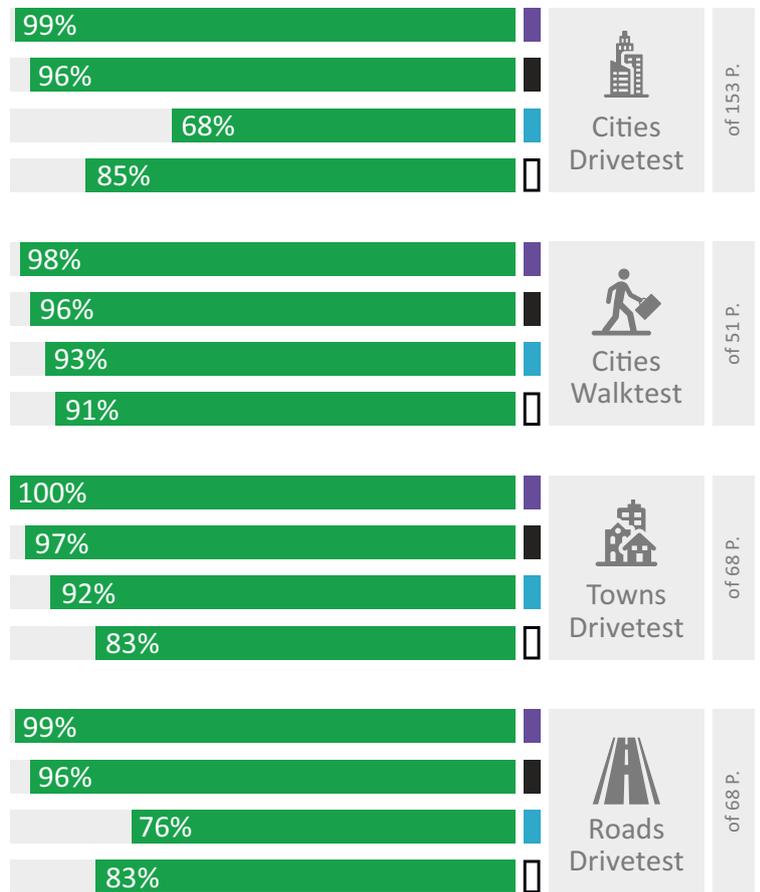
TELIA TAKES A NARROW LEAD IN VOICE WALKTESTS IN BIG CITIES

In the walktests which took place in eight Swedish cities, the four operators rank closer together. Telia still takes the lead, but the other candidates are following at close distance. In this scenario, Telia and Tele 2 achieve an impressive success ratio of 100 per cent. Telenor shows no particular call setup limitations. Again, Telia provides the highest speech quality due to a wide use of the EVS codec.

VOICE

340 of 1000 Points

- Telia
- Tele2
- Telenor
- Tre





TELIA & TELE 2

TELIA LEADS VOICE DRIVETESTS IN TOWNS, TELE 2 ALSO STRONG

In the voice results of the drivetests conducted in 27 Swedish towns, Telia and also Tele2 show an impressive call success ratio of 100 per cent. As in the categories before, Telia achieves the best score by providing a higher speech quality. In towns, Telenor also provides a high call reliability and ranks third considering all KPIs. Tre follows at some distance, but still provides reasonable voice results in this category.



TELIA & TELE 2

GOOD VOICE RESULTS ON ROADS. TELIA LEADS, TELE 2 FOLLOWS CLOSELY

When it comes to conducting voice calls on the roads, Telia and Tele2 are again in the lead. Once again, Telia provides a better, EVS-based, speech quality. Tre and Telenor rank at some distance compared to the leading two contenders. In terms of call success ratios and speech quality, Tre and Telenor are on a similar level, but slightly longer call setup times make Telenor rank last in this category. As both Telenor and Tre have implemented a lower share of VoLTE up to now, a higher amount of calls with circuit-switched fallback (CSFB, also see page 5) may explain their longer call setup times.

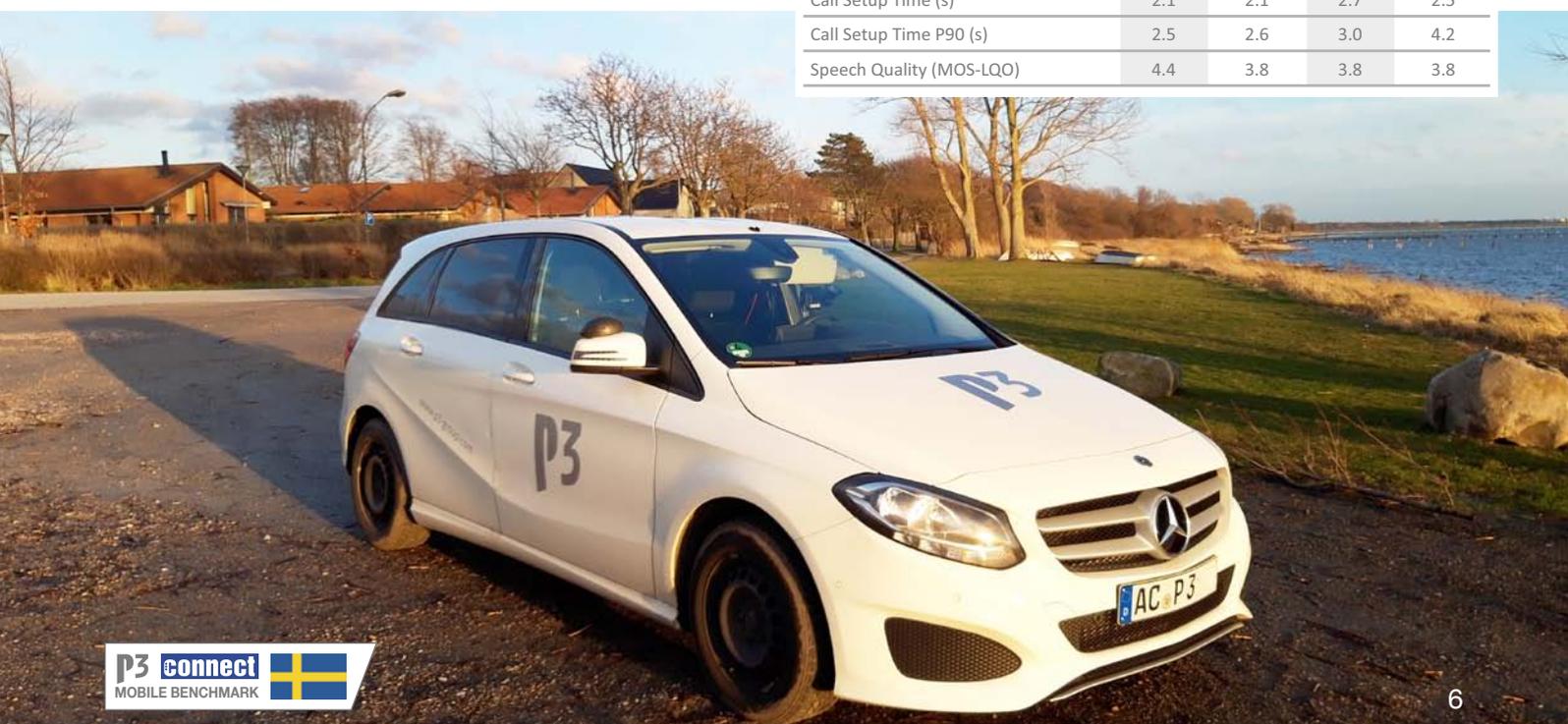


VOICE RESULTS AT A GLANCE

Telia takes the win in the voice discipline due to an especially high speech quality, achieved by its wide use of the high-quality EVS codec. Tele2 achieves a very good second rank in voice, providing high call success rates in all scenarios. Tre ranks third, achieving proper results in all categories. Telenor comes in last, due to some call setup limitations particularly in the city drivetests and on the roads.

Voice

	Telia	Tele2	Telenor	Tre
Cities (Drivetest)				
Call Success Ratio (%)	99.8	99.8	96.7	99.0
Call Setup Time (s)	2.2	2.1	3.6	2.8
Call Setup Time P90 (s)	2.6	2.6	10.6	7.0
Speech Quality (MOS-LQO)	4.3	3.7	3.7	3.8
Towns (Drivetest)				
Call Success Ratio (%)	100.0	100.0	99.8	98.6
Call Setup Time (s)	2.2	2.1	3.2	3.1
Call Setup Time P90 (s)	2.6	2.6	5.3	6.8
Speech Quality (MOS-LQO)	4.3	3.7	3.7	3.8
Roads (Drivetest)				
Call Success Ratio (%)	99.7	99.7	97.3	98.0
Call Setup Time (s)	2.3	2.1	3.4	3.4
Call Setup Time P90 (s)	2.7	2.7	10.0	7.1
Speech Quality (MOS-LQO)	4.3	3.7	3.7	3.7
Cities (Walktest)				
Call Success Ratio (%)	99.7	99.7	99.1	99.1
Call Setup Time (s)	2.1	2.1	2.7	2.5
Call Setup Time P90 (s)	2.5	2.6	3.0	4.2
Speech Quality (MOS-LQO)	4.4	3.8	3.8	3.8



↑↓ DATA

The volume of transmitted data is growing rapidly, which emphasises the importance of data connectivity. Which Swedish operator manages best to keep up with the increasing demand?

Data connectivity is the most prestigious discipline in our benchmark and also in the operators' marketing. All four Swedish networks claim to cover a large part of the population with LTE services – the claimed percentages all range in the high nineties. And all four operators continue to spend large sums on upgrading and expanding their networks to meet the growing demand – including the installation of early 5G network cells. Today, all four Swedish operators have equipped their 4G networks to offer the combination of LTE carriers in different frequency bands. This “carrier aggregation” is the technical basis for the so-called “4G+” services which theoretically support data rates of up to 1 Gbps.

In order to assess the performance and reliability of data connections, each of our two drivetest cars and also the walktest team carried one Samsung Galaxy S9 per operator. Supporting the so-called LTE category 18, these smartphones were able to benefit from carrier aggregation with download speeds up to 1.2 Gbps.

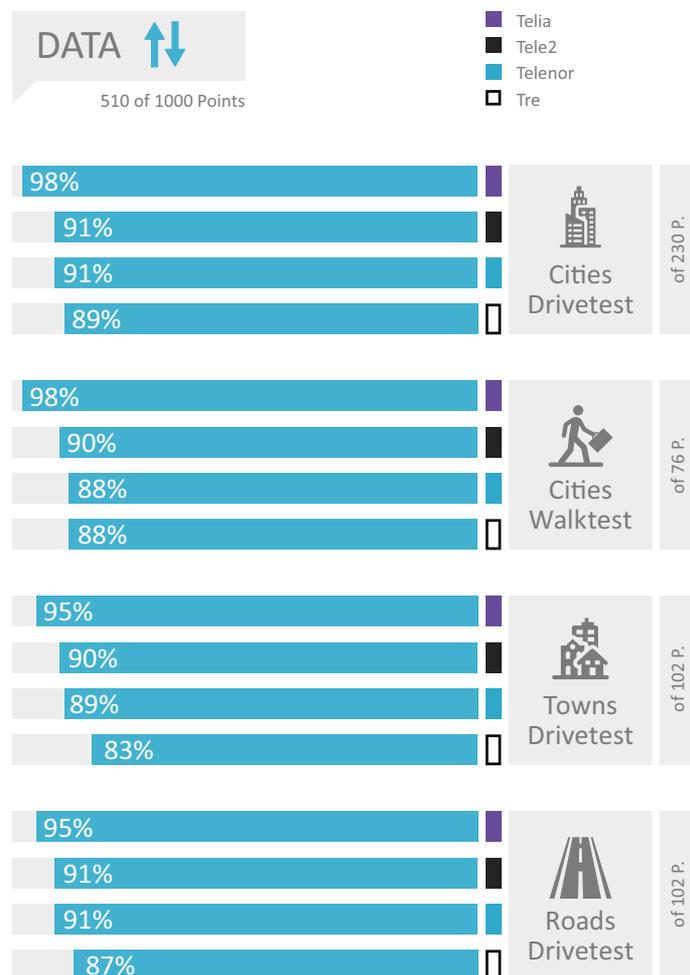
P3'S SCORING REWARDS HIGH PERFORMANCE AS WELL AS THE NETWORKS' AVAILABILITY AND STABILITY

The smartphones constantly performed a suite of tests covering the 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.

For downloads and uploads we 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. At the same time, P3 assesses the networks' availability and stability by examining the success ratios for each of the mentioned use 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 ALSO LEADS IN THE DATA CATEGORY. TELE2 AND TELENOR FOLLOW AT A DISTANCE, RANKING CLOSELY TOGETHER. TRE RANKS LAST, BUT STILL OFFERS A VIABLE DATA PERFORMANCE.





TELIA

TELIA TAKES THE LEAD IN DATA DRIVETESTS CONDUCTED IN CITIES

As in the voice discipline, Telia also takes a clear lead in the big city data drivetests with high success rates and an impressive average throughput of more than 110 Mbps in file downloads. A possible explanation is that Telia shows the highest share of 3CA (aggregation of three carrier frequencies) in the cities. Tele2, Telenor and Tre rank closely together, but at a distance to the leading Telia. All operators achieve high success ratios in the data drivetests conducted in cities, providing very good data reliability to their customers. In the Youtube category, Tre shows a particular good performance, ranking closely behind Telia.



TELIA

TELIA ALSO SHOWS BEST PERFORMANCE IN CITY WALKTESTS

The results of the data walktests that were conducted in eight large Swedish cities, are very similar to those of the city drivetests for data services. Once more, Telia takes the lead with high success ratios but overall somewhat lower data rates than those observed in the drivetests. Tele2, Telenor and Tre also achieve very good scores, performing on a similar level. High success ratios in this category mean a good reliability for the use of data services by pedestrians.

Data in Cities (Drivetest)

	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.8/100.0	99.7/100.0	99.7/99.2	99.4/99.7
Static: Avg. Session Time (s)	0.9	1.2	1.3	1.2
Live: Reaction Time (ms)	315	334	304	334
Live: Initial DL Speed 1st second (kB/s)	1588	1360	1349	1175
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/0.9	100.0/1.7	99.4/1.7	99.7/1.4
90%/10% faster than (Mbit/s)	20.1/82.8	7.9/59.6	8.4/61.2	9.5/67.2
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/0.6	100.0/0.9	99.9/1.0	99.7/1.4
90%/10% faster than (Mbit/s)	12.2/28.5	5.4/25.6	5.0/25.2	2.8/18.3
File Download (7 Seconds)				
Success Ratio (%)	100.0	99.9	99.7	99.9
Avg. Throughput (Mbit/s)	114.4	54.9	61.1	59.2
90%/10% faster than (Mbit/s)	38.7/199.5	8.2/127.6	10.6/132.0	12.3/119.4
File Upload (7 Seconds)				
Success Ratio (%)	99.9	99.9	99.9	99.6
Avg. Throughput (Mbit/s)	36.8	23.4	23.7	12.7
90%/10% faster than (Mbit/s)	14.8/53.7	5.5/44.5	5.3/45.0	2.9/23.8
Youtube Video				
Success Ratio/Start Time (%/s)	100.0/1.0	99.0/1.6	99.3/1.3	99.6/1.3
Playouts without Interruptions (%)	99.8	99.3	99.1	99.7
Avg. Video Resolution (p)	1078	1073	1072	1019
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	99.6/1.4	99.4/2.0	99.2/1.8	99.9/1.6
Playouts without Interruptions (%)	99.8	98.9	99.0	99.0
Avg. Video Resolution (p)	1076	1072	1070	1017

Data in Cities (Walktest)

	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.6/99.8	99.7/99.8	99.6/98.5	99.3/99.5
Static: Avg. Session Time (s)	1.0	1.2	1.3	1.2
Live: Reaction Time (ms)	319	337	306	323
Live: Initial DL Speed 1st second (kB/s)	1668	1471	1395	1197
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/0.9	99.8/1.6	98.6/1.8	99.7/1.5
90%/10% faster than (Mbit/s)	24.4/77.4	8.0/60.8	7.9/66.8	10.4/60.8
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.8/0.6	99.8/1.1	99.2/1.1	99.4/1.4
90%/10% faster than (Mbit/s)	11.0/28.0	4.3/26.2	4.5/25.8	3.3/16.9
File Download (7 Seconds)				
Success Ratio (%)	100.0	99.6	99.8	99.7
Avg. Throughput (Mbit/s)	114.3	61.1	66.7	55.0
90%/10% faster than (Mbit/s)	40.2/194.7	8.3/137.5	9.6/144.9	11.9/106.6
File Upload (7 Seconds)				
Success Ratio (%)	100.0	100.0	99.6	99.1
Avg. Throughput (Mbit/s)	36.8	23.9	23.8	11.7
90%/10% faster than (Mbit/s)	12.9/55.6	4.8/46.9	4.6/45.5	3.7/20.8
Youtube Video				
Success Ratio/Start Time (%/s)	99.7/1.0	98.6/1.5	98.8/1.2	99.8/1.3
Playouts without Interruptions (%)	100.0	99.2	99.4	99.7
Avg. Video Resolution (p)	1080	1075	1072	1062
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	99.0/1.4	99.0/1.9	98.6/1.7	99.7/1.6
Playouts without Interruptions (%)	100.0	99.7	97.6	98.6
Avg. Video Resolution (p)	1079	979	1071	1059





TELIA

TELIA ALSO LEADS IN THE DATA DRIVETESTS CONDUCTED IN TOWNS

In the 27 smaller Swedish towns visited by our drivetest cars, the ranking is similar to the results achieved in the bigger cities. Telia takes the lead here as well, with Tele2 and Telenor following at some distance, but almost on a par. These two operators, who share their 4G infrastructure, show a wide bandwidth utilization via carrier aggregation in the towns (and also on the roads). Tre scores last in this category, showing some room for improvement concerning service reliability and also in the data rates, particularly in the upload tests.



ALL SWEDISH NETWORKS

TELIA ALSO RANKS FIRST ON THE ROADS, WHILE ALL FOUR OPERATORS OFFER VIABLE AUTOMOTIVE CONNECTIVITY

When it comes to using data services while driving on the connecting roads in Sweden, Telia once more achieves the highest score showing high success ratios and overall the fastest throughputs. Tele2, Telenor and also Tre follow at a not too far distance, offering good reliability as well as viable data rates. So, all in all, Swedish customers can rely on stable and fast data connections for the increasingly important automotive connectivity.



DATA RESULTS AT A GLANCE

As in the voice category, Telia also ranks best overall in the data category. Generally, all Swedish operators offer a very good data reliability across all tested scenarios including the demanding rural roads. Tele2 and Telenor follow at some distance, but rank closely together. In towns and on roads, they provide good data rates due to the increasing share of LTE carrier aggregation. Particularly in the bigger cities, Tre shows high performance levels, falling a little behind in the smaller towns and on the roads.

Data in Towns (Drivetest)

	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.7/100.0	99.9/100.0	99.8/99.1	98.8/98.8
Static: Avg. Session Time (s)	1.0	1.2	1.3	1.4
Live: Reaction Time (ms)	334	342	316	389
Live: Initial DL Speed 1st second (kB/s)	1390	1326	1316	987
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/1.2	100.0/1.8	99.4/2.0	100.0/2.2
90%/10% faster than (Mbit/s)	11.3/71.6	6.6/59.3	6.0/61.2	6.0/59.2
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/0.8	100.0/1.0	99.8/0.9	98.8/2.0
90%/10% faster than (Mbit/s)	7.9/25.5	4.8/24.3	5.4/22.6	1.9/15.7
File Download (7 Seconds)				
Success Ratio (%)	100.0	100.0	100.0	99.8
Avg. Throughput (Mbit/s)	70.5	50.4	54.0	46.9
90%/10% faster than (Mbit/s)	20.5/134.7	7.9/108.8	6.7/123.5	7.3/104.5
File Upload (7 Seconds)				
Success Ratio (%)	100.0	100.0	100.0	98.3
Avg. Throughput (Mbit/s)	28.1	20.6	20.3	10.8
90%/10% faster than (Mbit/s)	8.5/48.9	5.4/40.3	5.4/41.4	2.2/20.9
Youtube Video				
Success Ratio/Start Time (%/s)	100.0/1.1	98.7/1.6	98.5/1.3	99.0/1.5
Playouts without Interruptions (%)	99.8	98.2	98.7	99.4
Avg. Video Resolution (p)	1075	1072	1075	947
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	100.0/1.5	99.6/2.1	98.3/1.7	98.4/1.7
Playouts without Interruptions (%)	98.4	99.2	97.0	96.7
Avg. Video Resolution (p)	1069	1065	1058	950

Data on Roads (Drivetest)

	Telia	Tele2	Telenor	Tre
Web-Page Download (Live/Static)				
Success Ratio (%/%)	99.5/99.7	99.8/99.7	99.6/99.4	98.9/99.4
Static: Avg. Session Time (s)	1.1	1.3	1.3	1.5
Live: Reaction Time (ms)	322	333	316	395
Live: Initial DL Speed 1st second (kB/s)	1333	1203	1189	965
File Download (3 MB)				
Success Ratio/Avg. Session Time (%/s)	100.0/1.8	99.8/2.6	99.8/2.6	99.6/2.6
90%/10% faster than (Mbit/s)	6.6/72.1	4.3/54.1	4.2/56.3	5.3/55.8
File Upload (1 MB)				
Success Ratio/Avg. Session Time (%/s)	99.8/1.2	99.8/1.1	99.5/1.2	98.4/2.3
90%/10% faster than (Mbit/s)	4.0/25.8	4.2/23.0	4.1/21.9	1.6/17.0
File Download (7 Seconds)				
Success Ratio (%)	99.9	99.6	99.5	99.6
Avg. Throughput (Mbit/s)	68.5	37.7	41.6	39.4
90%/10% faster than (Mbit/s)	10.2/149.5	3.7/90.0	4.4/110.0	7.1/97.0
File Upload (7 Seconds)				
Success Ratio (%)	98.8	99.5	99.4	96.4
Avg. Throughput (Mbit/s)	23.1	17.7	17.7	10.2
90%/10% faster than (Mbit/s)	4.2/47.6	4.0/37.8	4.0/34.4	1.7/21.6
Youtube Video				
Success Ratio/Start Time (%/s)	99.4/1.3	96.8/1.7	96.8/1.5	98.3/1.5
Playouts without Interruptions (%)	99.4	98.1	98.4	99.7
Avg. Video Resolution (p)	1058	1059	1057	906
Youtube live Smartphone				
Success Ratio/Start Time (%/s)	99.2/1.7	97.6/2.2	97.2/1.8	97.7/1.8
Playouts without Interruptions (%)	99.0	96.9	97.3	96.6
Avg. Video Resolution (p)	1057	1047	1039	905



CROWD

In this year, the results of crowd sourcing analyses are part of the total score for the first time. 15,000 users in Sweden have contributed to the data gathering that took place from December 2018 to February 2019.

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 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 authorises 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 13.

Based on the population count of approximately 10 million people, one of 667 inhabitants of Sweden has contributed to the gathering of 77 million samples of crowd data. The considered test area represents 58 per cent of the built-up area of the country.



ALL OPERATORS SCORE HIGH IN VOICE AND DATA COVERAGE, SOME ROOM FOR IMPROVEMENT AT 4G

All Swedish operators achieve high scores for their voice and data coverage. In the Quality of Voice Coverage, all four networks are more or less on a par. In the Quality of Data Coverage (which considers 3G plus 4G), Tre achieves a particularly high score, while the other three fall a little behind. In contrast, Tele2 and Telenor offer the best Quality of 4G Coverage (the likelihood of being able to actually use 4G services) ahead of Telia. Here, Tre considerably loses ground against its competition. But also for Telia, Tele2 and Telenor, this KPI leaves some room for improvement.

TELIA SCORES BEST IN THE CROWD-SOURCED CATEGORIES, FOLLOWED CLOSELY BY TELENOR AND TELE2. TRE COMES IN LAST.

Crowd

	Telia	Tele2	Telenor	Tre
Voice Coverage				
Quality of Coverage (%)	99.9	99.8	99.8	99.8
Test Area Coverage (%)	100.0	100.0	100.0	99.6
Data Coverage				
Quality of Coverage (%)	99.2	99.1	99.2	99.9
Test Area Coverage (%)	100.0	99.9	99.7	99.6
4G Coverage				
Quality of Coverage (%)	88.0	92.6	91.7	81.6
Test Area Coverage (%)	98.9	98.7	97.6	78.5
User Download Speed				
10% EA faster than (Mbit/s)	59.9	59.4	50.6	39.3
10% Users faster than (Mbit/s)	24.5	21.7	23.0	21.2
Avg. Users Best Throughput (Mbit/s)	9.0	8.5	8.7	8.2
Data Service Availability				
Degraded days (d)	1	3	1	0
Degraded hours (h)	1	17	3	0

ASSESSING COVERAGE BASED ON CROWD KPIS

Our coverage metrics correspond 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.



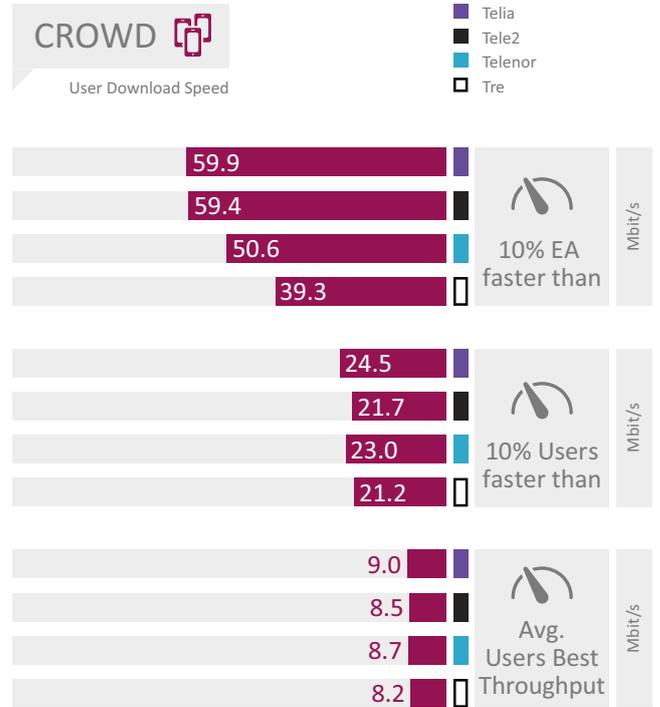
TELIA AND TELE2 SHOW FASTEST DATA RATES IN TOP 10 PER CENT OF EVALUATION AREAS

In the assessment of download speeds available to the users, Telia and Tele2 show the best results for the top 10 per cent of Evaluation Areas. In this category, Telenor ranks third and Tre last. In the consideration of the download speeds achieved by the top 10 per cent of users, Telenor takes the second rank behind Telia. In terms of average data rates, all four operators rank closely together.

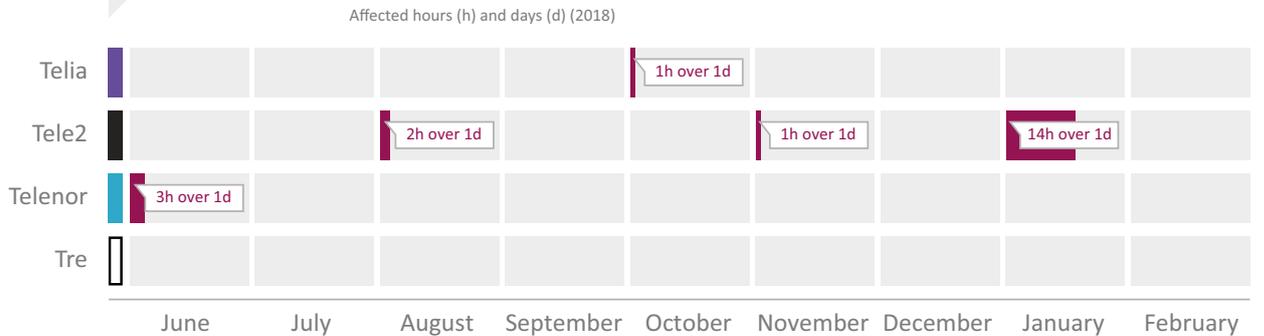


TRE SHOWS NO SERVICE DEGRADATIONS IN NINE MONTH PERIOD, TELIA AND TELENOR CLOSELY BEHIND. ELEVATED LEVEL AT TELE2.

Other than the rest of the crowd KPIs, our examination of Data Service Availability covers nine months (June 2018 to February 2019). Tre scores best in this consideration, showing no service degradation at all in the observed period. For Telia, we observed only one event – taking up to one hour in October. And Telenor showed one degradation of up to three hours in June. For Tele 2 we registered a total of three events, of which the one in January 2019 lasted up to 14 hours.



DATA SERVICE AVAILABILITY



CROWD RESULTS AT A GLANCE

Telia, Telenor and Tele2 achieve high crowd scores. While all four operators show a good voice and data coverage, Tre loses some ground due to a limited Quality of 4G Coverage. In terms of download speeds, Telia, Tele2 and Telenor rank closely together, while Tre falls a little behind. In contrast, Tre did not show any service degradations from June 2018 to February 2019, whereas Tele2 suffered from a bigger outage in January 2019.



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 Sweden 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 Sweden took place from February 21 to March 23, 2019.

All samples were collected during the day, between 8.00 am and 10.00 pm. The network tests covered inner-city, outer metropolitan and suburban areas.

Measurements were also taken in smaller towns and on the connecting highways. The two measurement cars together covered about 3,320 kilometres in the cities, about 680 km in towns and about 6,500 km on the roads – resulting in a total of 10,500 kilometres.

The combination of test areas has been selected to provide representative test results across the Swedish population. The areas selected for the 2019 test account for

approximately 4.3 million people, or roughly 43.9 per cent of the total population of Sweden.

The drivetests covered 20 cities and 27 towns. Additionally, one team conducted walktests in eight cities. The exact routes are shown on page 1 of this report, all visited cities and towns are listed in the box on the right.

The two drive-test cars as well as the battery-powered backpacks of the walktest teams were equipped with arrays of Samsung Galaxy S9 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

VISITED CITIES AND TOWNS

Cities: Boras, Gavle, Goteborg (W), Helsingborg, Jonkoping (W), Karlskrona, Karlstad, Linkoping (W), Lund, Malmo (W), Norrkoping, Orebro (W), Ostersond, Sodertalje, Stockholm (W), Sundsvall, Trollhattan, Umea, Uppsala (W), Vasteras (W). (W) designates walktest cities.

Towns: Åmål, Arboga, Bjärred, Blomstermåla (incl. Ålem), Frillesås (incl. Löftaskog), Härnösand, Hörby, Hudiksvall (incl. Malnbaden), Karlshamn (incl. Torarp), Kristinehamn, Kumla (incl. Hällabrottet), Kungsör, Mellbystrand (incl. Skummeslövsstrand), Mjölby, Oskarshamn (incl. Mysingsö, Saltvik), Rydebäck, Skara, Söderhamn, Söderköping, Sölvesborg (incl. Valjeviken), Strängnäs, Tierp, Torshälla (incl. Torshälla huvud, Ångsholmen), Ulricehamn, Vänersborg, Vårgårda, Västervik (incl. Jenny).

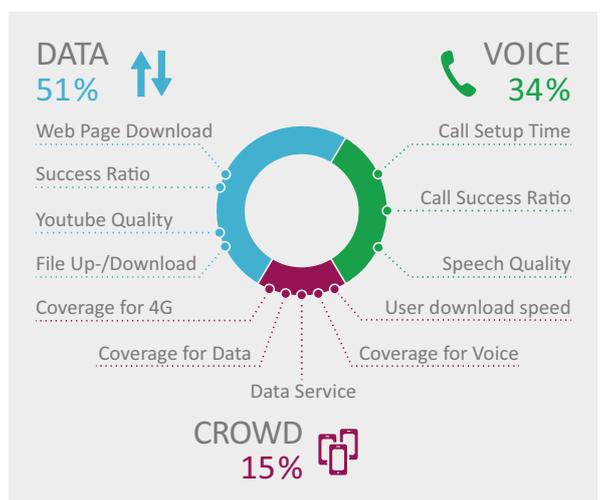
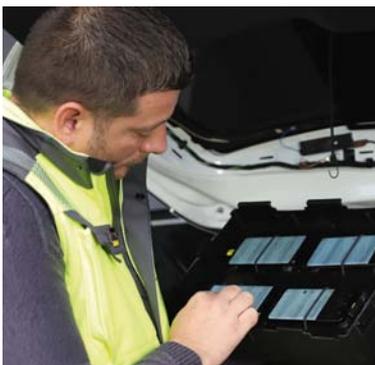
capable and ITU standardised POLQA wideband algorithm.

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 so-called circuit-switched fallback (CSFB) 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. ▶

One Samsung Galaxy S9 per operator took the voice measurements and one additional S9 per operator was used for the data tests. All test phones were operated and supervised by P3's unique control system.



DATA TESTING

Data performance was measured by using three more Galaxy S9 per car or 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 uplink and downlink directions by assessing the amount of data that was transferred within a seven seconds time period. This KPI targets to show the network capability, i.e. the maximum achievable data throughput, similar to what speed test apps would show.

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, we also determined average video resolution. All tests were conducted with the best-performing mobile plan of each operator. Data scores account for 51 per cent of the total results.

CROWDSOURCING

Additionally, P3 conducted crowd-based analyses of the Swedish networks which contribute 15 per cent to the end result. They are based on data that were gathered in December 2018 as well as in January and February 2019. For the collection of crowd data, P3 has integrated 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.

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 distri-

DRIVETEST		SCORE BREAKDOWN	
		Cities - Drivetest	383
WALKTEST		Cities - Walktest	127
		Towns - Drivetest	170
CROWD		Roads - Drivetest	170
		Crowdsourcing	150



bution, below which 90 per cent of the gathered values are ranging and depict how fast the network is under favourable 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 market size and the 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 nine-month observation period – in this case from June 2018 to February 2019.

CONCLUSION

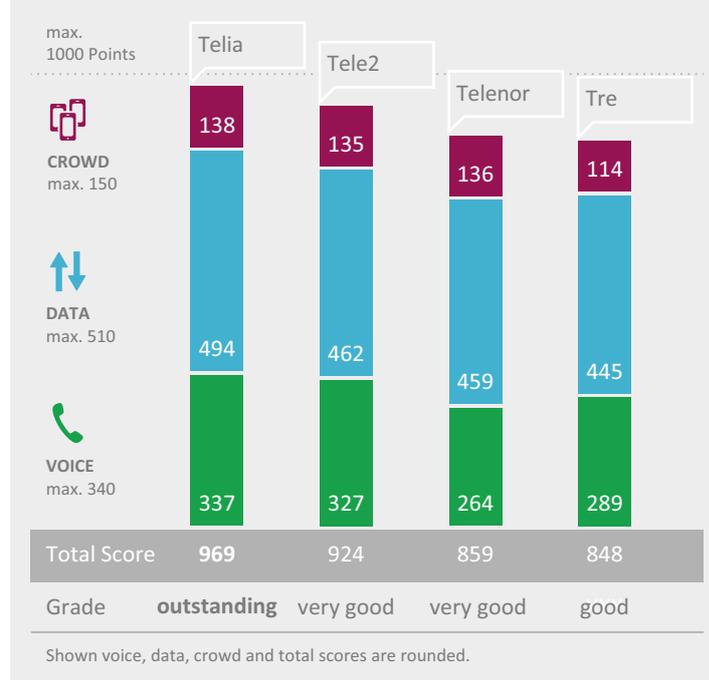
Telia is the overall winner – for the third time in a row and with the rare grade “outstanding”. Tele2, Telenor and Tre achieve score increases as well, with Tele2 and Tre improving considerably.

Telia wins the P3 connect Mobile Benchmark in Sweden for the third time in a row. The largest Swedish operator achieves the highest score that P3 has determined in Sweden so far – well deserving the grade “outstanding”. In comparison to our previous benchmark in Sweden, Telia shows a significant improvement in the voice rating and a slight increase in the data score.

Tele2 ranks second, showing the biggest score improvement over our previous test. Most of its score increase is won in the voice discipline, but Tele2 also improved in the data measurements. Our crowdsourced assessment of service degradations registered a significant event in Tele2’s network in January 2019.

Telenor ranks third, showing a similar data performance as the second ranking Tele2, but losing valuable points due to limited results in the voice category. Although also improving over the results of our previous benchmark, Telenor’s score increase is less pronounced than those of the other three.

Tre, the smallest Swedish operator, ranks fourth but with overall good results. Compared to our previous test, Tre achieved a considerable score increase.



Overall Results Voice, Data and Crowd

		Telia	Tele2	Telenor	Tre
Voice	max. 340 Points	337	327	264	289
Cities (Drivetest)	153	99%	96%	68%	85%
Cities (Walktest)	51	98%	96%	93%	91%
Towns (Drivetest)	68	100%	97%	92%	83%
Roads (Drivetest)	68	99%	96%	76%	83%
Data	max. 510 Points	494	462	459	445
Cities (Drivetest)	230	98%	91%	91%	89%
Cities (Walktest)	76	98%	90%	88%	88%
Towns (Drivetest)	102	95%	90%	89%	83%
Roads (Drivetest)	102	95%	91%	91%	87%
Crowdsourced Quality	max. 150 Points	138	135	136	114
Crowd	150	92%	90%	91%	76%
Connect Rating	max. 1000 Points	969	924	859	848

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



1

The clear winner of the 2019 P3 connect Mobile Benchmark in Sweden is Telia – leading the field in the voice, data and crowd categories alike. The overall score achieved by this operator is also the highest one ever determined by P3 in Sweden. For this convincing performance, Telia has well deserved the rare grade “outstanding”.

2

Tele2 achieves a very good rank, showing the second best results in voice and data and also featuring the biggest score improvement compared to its results from our previous benchmark in Sweden. In towns and on the roads, Tele2 shows particularly good voice results, outranking Telenor and Tre in this discipline, as well as a very good data performance.

3

The data performance of Telenor is almost on a par with the second-ranking Tele2. However, in the voice discipline, this operator ranks a little behind the other contenders. In contrast, Telenor achieves a strong second rank in our crowdsourced assessment, only two points behind the winner Telia. All in all, the third largest Swedish operator shows a very good performance.

4

The smallest Swedish operator ranks third in the voice discipline and fourth in the data and crowd scores. Overall, Tre shows a good performance and also achieves a considerable score increase over our previous benchmark in Sweden. Above that, we did not observe any service degradations at all in the Tre network from June 2018 to February 2019.

