

The great 2019 Mobile Network Test



In its 25th year, the connect mobile network test is still considered the highest benchmark, offering maximum objectivity as well as a distinct customer orientation. We have further refined our methodology in order to provide an even broader picture of the performance of the tested mobile networks.

A quarter of a century! The renowned mobile network test conducted by connect and P3 communications has already arrived in its 25th year. The Aachen-based company which specialises in network testing teamed up once again with the experienced editorial staff of connect. In a combined effort we make sure that the results are determined according to realistic and statistically reliable methods. In our close cooperation, we go to great lengths in order to investigate the performance and reliability of mobile networks. The figures below impressively prove our efforts.

The reward of this effort is not only that the tested operators assign a much higher significance to our results than to those of less sophisticated network examinations. But also that connect readers can definitely rely on our findings when they chose a mobile network operator.

Further refined methodology

However, we did not rest on our laurels but continuously worked on further refining our methodology. Our aim is to present the most accurate

picture of the actual quality of mobile networks.

Last year, we started to amend the results of our elaborate drivetests and walktests with the additional findings of crowdsourcing analyses. Now, we have further strengthened this approach by considering not only the networks' stability, but also their coverage as well as the data rates actually received by their users. This is the only way to get the complete picture: The drivetests and walktests provide information about the maximum performance of a network; crowdsourcing reveals which share of this performance actually arrives at the average user. Those who limit their evaluations to just one of these two aspects, can only depict part of the complex reality.

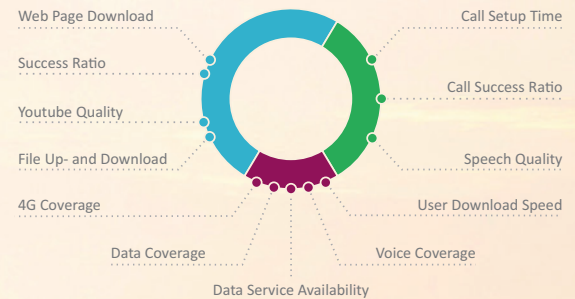
Regarding the mobile network test for Switzerland, we have to inform you that, due to the extensive testing efforts, it was not possible to conduct the testing campaign in Switzerland simultaneously to Germany and Austria this time. But we will catch up and present the results from this traditionally strong alpine country in the 3/2019 edition of connect.

HANNES RUEGHEIMER



DATA 51%

VOICE 34%



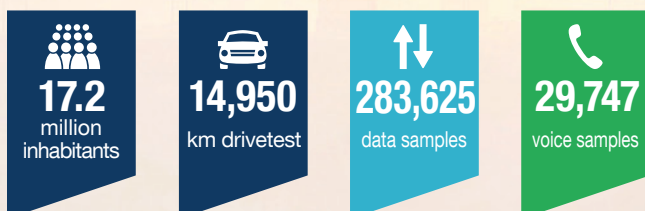
CROWD 15%



A 360 degree view at network quality

The crowdsourcing results, which have been added to our evaluation, have a share of 15 per cent in the overall grades. As in the years before, we have then splitted the remaining points in a proportion of 40 to 60 among the disciplines voice and data.

DRIVETESTS AND WALKTESTS



CROWDSOURCING



Indicated are the combined values for Germany and Austria. See the separate values per country under „Methodology“ on page 68.

Germany

Voice

Although smartphones offer many means of communication, voice telephony is still important. Which operators offer stable and high-quality connections?



In Germany, Voice over LTE (or short VoLTE) is already an established standard. Smartphones equipped for this standard transport voice calls in 4G networks via LTE data packets and do not have to switch back to 3G or 2G for telephony. This enables considerably shorter call setup times and usually also more solid connections. As all three German mobile networks not only support VoLTE but also the higher bandwidth EVS (Enhanced Voice Services) codes, our measurement values overall show a high speech quality.

Telekom leads the field with mostly very good results. This operator offers the shortest call setup times in larger cities, small towns and also on the connecting roads. In the drive-test scenarios the company also achieve the highest success

rates and a narrow lead concerning speech quality. In the walktests which we conducted in ten German cities, Vodafone scores a little better due to slightly higher success rates. Speech quality is on a very high level in this scenario for all three candidates.

O2 shows weaknesses in smaller towns and on the roads

In smaller towns, O2 distinctly falls back behind Telekom and Vodafone. Compared to the large cities, the call setup times increase in the Telefónica network, while success ratios and measured speech quality drop.

On the highways and roads the phone works best in the Telekom network. Here, Vodafone and especially O2 show some room for improvement concerning all measured parameters.

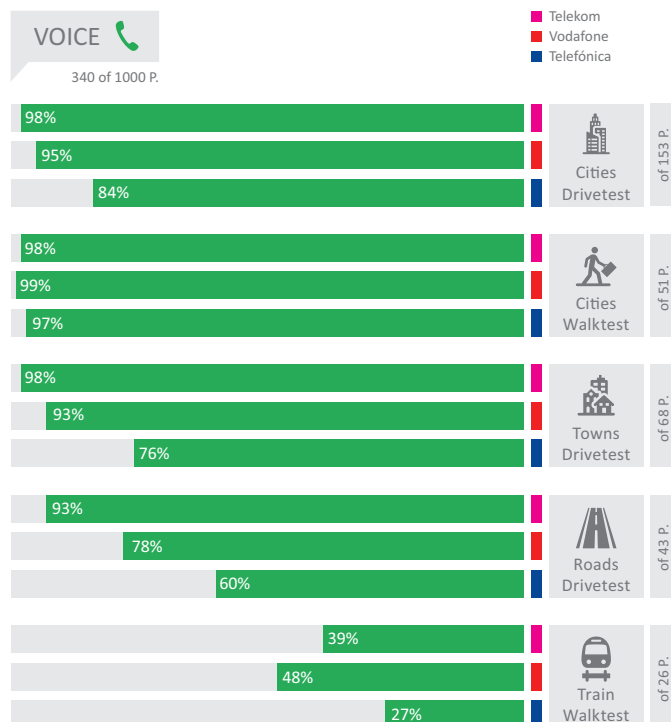
Still unsatisfactory: Voice calls in German railways

When it comes to placing and taking phone calls while travelling on German railways, the results of all three operators are still not particularly good. What makes this especially sad: Compared to the previous year, almost nothing has changed when looking at the measured values. The slightly improved

speech quality can probably be explained with the factors VoLTE and EVS as mentioned before.

Vodafone scores slightly better in this discipline than the two other networks. However, looking at only 48 per cent degree of fulfilment related to the total of points achievable in this category, this is no true comfort.

OPERATOR	Telekom	Vodafone	Telefónica
VOICE (Cities; Drivetest)			
Call Success Ratio (%)	99.6	99.1	97.3
Call Setup Time $\bar{\sigma}$ (s) / P90 (s)	1.8/ 2.1	1.7/ 2.3	2.6/ 3.0
Speech Quality (MOS-LQO)	4.4	4.3	4.2
VOICE (Cities; Walktest)			
Call Success Ratio (%)	99.7	99.8	99.5
Call Setup Time $\bar{\sigma}$ (s) / P90 (s)	1.8/2.1	1.8/2.4	2.3/2.6
Speech Quality (MOS-LQO)	4.4	4.4	4.4
VOICE (Towns; Drivetest)			
Call Success Ratio (%)	99.6	98.8	96.6
Call Setup Time $\bar{\sigma}$ (s) / P90 (s)	1.8/ 2.2	2.0/ 2.6	3.1/ 5.4
Speech Quality (MOS-LQO)	4.3	4.2	4.1
VOICE (Roads; Drivetest)			
Call Success Ratio (%)	98.1	94.3	90.4
Call Setup Time $\bar{\sigma}$ (s) / P90 (s)	2.0/ 2.2	2.2/ 3.3	3.1/ 5.3
Speech Quality (MOS-LQO)	4.3	4.1	3.9
VOICE (Train; Walktest)			
Call Success Ratio (%)	83.9	86.1	73.4
Call Setup Time $\bar{\sigma}$ (s) / P90 (s)	2.4/ 4.4	2.4/ 3.8	3.6/ 6.0
Speech Quality (MOS-LQO)	3.9	3.9	3.6



Data

Web surfing, messaging, uploading, downloading or streaming – who delivers the best mobile internet performance?

The parameters for data connectivity determined by the measurement cars and the walktest teams are still the most prestigious category of our network test and thus contribute the highest number of possible points to the overall score. Als already in voice, Telekom scores best also in this discipline.

A detailed look at the single sub-categories reveals pleasant improvements in the O2 network, particularly in the walktests conducted in larger cities. The operator puts a special focus on these areas while merging the formerly separate networks of O2 and E-Plus. Thus, in this category Telefónica almost ranks the same as Vodafone.

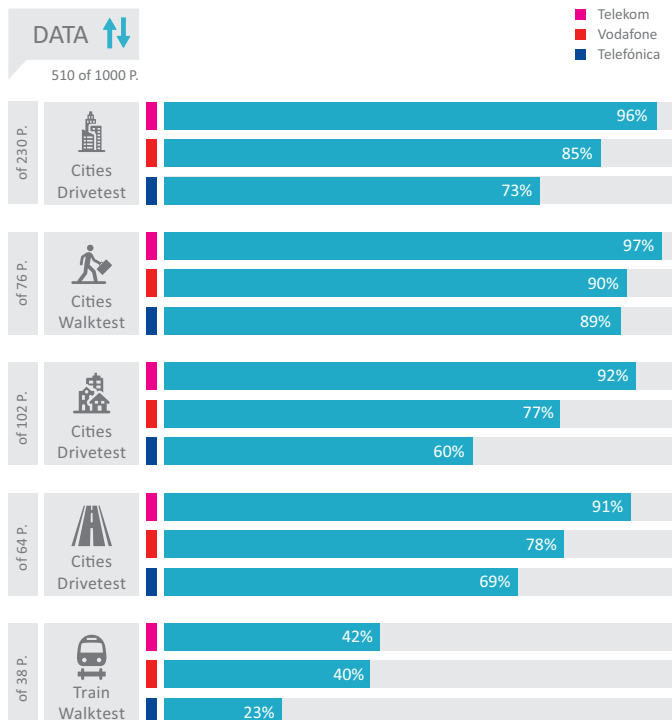
However, in the other disciplines of our test, the ranking is distinct: Telekom leads, Vodafone follows at a clear

distance and O2 brings up the rear.

Telekom ahead in almost all data disciplines

Whether we look at web browsing, file uploads and downloads or Youtube playback – the Bonn-based operator achieves the strongest results in every single sub-category. In most cases, Vodafone follows and achieves a good second position. And O2 ranks third. One of the rare exceptions are the success ratios of file uploads during the walktests in large cities.

The results from the smaller towns that we have considered in our test, constantly rank behind those from the large cities. But while Telekom still scores very well and Vodafone at least well in this category, we see a considerable drop in the performance of the O2 network. >>



OPERATOR	Telekom	Vodafone	Telefónica
DATA (Cities; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.9/100.0	99.2/99.1	98.2/98.0
Static: Avg. Session Time (s)	1.0	1.3	1.6
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	353/761	346/705	380/591
File-Download (3MB)			
Success Ratio/∅ Session Time (%/s)	100.0/1.0	99.4/2.6	99.0/4.5
90%/10% faster than (kbit/s)	16940/75472	5221/63492	2189/50633
File-Upload (1MB)			
Success Ratio/∅ Session Time (%/s)	99.9/0.7	99.9/1.0	99.3/1.4
90%/10% faster than (kbit/s)	10805/29028	4442/27119	2710/21108
File-Download (7 seconds)			
Success Ratio (%)	99.9	99.0	98.4
∅ Throughput (kbit/s)	73179	46699	30448
90%/10% faster than (kbit/s)	22923/136522	5751/103849	2560/73774
File-Upload (7 seconds)			
Success Ratio (%)	99.7	99.8	98.8
∅ Throughput (kbit/s)	37227	22294	17863
90%/10% faster than (kbit/s)	12905/58433	4959/50026	3291/38709
Youtube Videos			
Success Ratio/Start Time (%/s)	99.9/1.2	97.0/1.5	93.0/1.9
Playouts without Interruptions (%)	99.9	98.6	97.6
∅ Video Resolution (p)	1077	1051	1000
Youtube Live			
Success Ratio/Start Time (%/s)	99.2/1.8	96.5/2.3	91.2/2.3
Playouts without Interruptions (%)	98.9	97.9	96.0
∅ Video Resolution (p)	1081	1048	962
DATA (Cities; Walktest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.8/99.9	99.5/99.3	99.6/99.3
Static: Avg. Session Time (s)	1.0	1.2	1.2
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	353/766	329/747	361/661
File-Download (3MB)			
Success Ratio/∅ Session Time (%/s)	99.9/0.9	99.9/1.6	99.9/1.8
90%/10% faster than (kbit/s)	20309/77872	9570/68788	8003/57873
File-Upload (1MB)			
Success Ratio/∅ Session Time (%/s)	99.9/0.7	99.9/0.8	99.7/1.0
90%/10% faster than (kbit/s)	11461/29091	6016/28986	5814/25765
File-Download (7 seconds)			
Success Ratio (%)	99.9	99.7	100.0
∅ Throughput (kbit/s)	78191	67401	43000
90%/10% faster than (kbit/s)	27548/140761	12924/126943	9696/87325
File-Upload (7 seconds)			
Success Ratio (%)	99.9	99.1	99.9
∅ Throughput (kbit/s)	37066	32447	28522
90%/10% faster than (kbit/s)	14231/57366	7891/54890	6638/51332
Youtube Videos			
Success Ratio/Start Time (%/s)	99.6/1.2	98.4/1.3	97.8/1.4
Playouts without Interruptions (%)	100.0	99.0	99.3
∅ Video Resolution (p)	1076	1055	1059
Youtube Live			
Success Ratio/Start Time (%/s)	99.7/1.7	98.8/2.2	97.6/2.1
Playouts without Interruptions (%)	99.1	98.0	98.8
∅ Video Resolution (p)	1086	1046	1052
DATA (Towns; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.8/99.9	99.5/98.9	97.1/96.6
Static: Avg. Session Time (s)	1.1	1.5	1.8
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	373/738	363/625	404/548
File-Download (3MB)			
Success Ratio/∅ Session Time (%/s)	100.0/1.4	99.6/3.5	97.2/5.7
90%/10% faster than (kbit/s)	9338/72289	3246/45846	1789/37211
File-Upload (1MB)			
Success Ratio/∅ Session Time (%/s)	99.8/0.9	99.4/1.5	97.1/2.3
90%/10% faster than (kbit/s)	6033/26693	3042/19507	1480/17109
File-Download (7 seconds)			
Success Ratio (%)	100.0	98.8	97.4
∅ Throughput (kbit/s)	59472	24718	18788
90%/10% faster than (kbit/s)	10444/111083	3153/59534	2056/43612
File-Upload (7 seconds)			
Success Ratio (%)	99.4	99.6	95.3
∅ Throughput (kbit/s)	30904	15897	12196
90%/10% faster than (kbit/s)	6731/57300	3213/26323	1523/24444
Youtube Videos			
Success Ratio/Start Time (%/s)	99.2/1.3	95.1/1.9	91.5/2.2
Playouts without Interruptions (%)	99.2	96.3	95.2
∅ Video Resolution (p)	1072	1026	967
Youtube Live			
Success Ratio/Start Time (%/s)	99.2/1.8	94.7/2.7	89.0/2.5
Playouts without Interruptions (%)	98.8	94.8	96.9
∅ Video Resolution (p)	1070	980	903

Connecting Roads

Connected navigation, streaming apps residing in the infotainment systems of modern cars as well as applications like parking space finders or fuel information – they all base on reliable connectivity on the road. Performance in the car is in the focus of our drivetests anyway. What is particularly interesting in this context are the highways and rural roads that our measurement vehicles passed while travelling between the larger cities and smaller towns considered in our test route.

Distinct ranking on the roads

In this discipline, the well-known picture from the earlier cate-

gories repeats itself: Telekom takes the lead, Vodafone follows second (but falls back surprisingly in comparison to the previous year, and O2 remains on the third rank. However, it is at least good news for Telefónica customers that their operator has managed to improve a little in this category compared to last year's result. This may be an indication for the advanced merger of the two networks.

However, for drivers who are looking out for the best success ratios possible and the highest mobile data rates, there is currently almost no way around Deutsche Telekom.

Modern cars demand online connectivity. Which of the German mobile networks live up to the constantly rising requirements?

OPERATOR	Telekom	Vodafone	Telefónica
DATA (Roads; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.2/99.5	96.7/96.5	95.4/94.7
Static: Avg. Session Time (s)	1.2	1.5	1.7
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	387/697	382/641	426/577
File-Download (3MB)			
Success Ratio/∅ Session Time (%/s)	99.7/2.1	96.7/3.4	95.2/4.4
90%/10% faster than (kbit/s)	5685/60256	3136/43376	2761/40262
File-Upload (1MB)			
Success Ratio/∅ Session Time (%/s)	99.6/1.2	97.9/1.5	93.8/2.2
90%/10% faster than (kbit/s)	3945/24338	2733/19212	1521/18307
File-Download (7 seconds)			
Success Ratio (%)	99.5	97.5	95.6
∅ Throughput (kbit/s)	43355	26491	21265
90%/10% faster than (kbit/s)	5885/102610	3126/62961	2745/49798
File-Upload (7 seconds)			
Success Ratio (%)	98.8	95.8	93.9
∅ Throughput (kbit/s)	22454	15524	12750
90%/10% faster than (kbit/s)	4820/47751	2837/25951	1683/25783
Youtube Videos			
Success Ratio/Start Time (%/s)	97.0/1.6	93.3/1.9	91.4/2.0
Playouts without Interruptions (%)	98.3	97.5	97.1
∅ Video Resolution (p)	1057	1021	960
Youtube Live			
Success Ratio/Start Time (%/s)	98.4/2.1	92.1/2.7	90.0/2.6
Playouts without Interruptions (%)	95.9	95.6	96.8
∅ Video Resolution (p)	1060	1004	913

Data on Railways

Hoping for better results regarding the mobile internet connectivity on German trains after the weak results of all three operators in the voice category, leads to another disappointment. In this discipline, the level of the measurement values practically remains unchanged after a full year.

In German trains, even the strongest contender is not good

Compared to the previous year, Telekom shows a small performance improvement. With this, it can overtake the Vodafone network which led by a narrow margin in this category last year. However, a 42 per cent degree

of fulfilment this is hardly a reason to celebrate.

Anybody who wants to work on their notebook, tablet or smartphone while travelling on a German train and has to access web sites or transmit data, will have to put up with rather poor success ratios of 80 to 90 per cent. Watching Youtube videos during the train ride can be even more frustrating – here, the success ratios are at even lower values of 67 to 76 per cent.

So, the conclusion of this not too glorious discipline in our 2019 network test can only be: When it comes to using the internet on trains in Germany, a lot still need to be done.

Working on your notebook, tablet or smartphone – or just watching a Youtube video. How well does this actually work today? Our test results are disillusioning.

OPERATOR	Telekom	Vodafone	Telefónica
DATA (Train; Walktest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	86.6/87.2	86.5/87.4	79.9/75.3
Static: Avg. Session Time (s)	2.5	2.6	2.5
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	599/453	553/433	623/401
File-Download (3MB)			
Success Ratio/∅ Session Time (%/s)	92.0/11.3	90.2/11.1	82.9/10.6
90%/10% faster than (kbit/s)	778/28989	818/26171	958/19245
File-Upload (1MB)			
Success Ratio/∅ Session Time (%/s)	87.9/2.9	91.7/3.3	80.9/3.6
90%/10% faster than (kbit/s)	1182/17949	992/15523	795/12504
File-Download (7 seconds)			
Success Ratio (%)	89.2	88.9	79.7
∅ Throughput (kbit/s)	13646	10112	8244
90%/10% faster than (kbit/s)	875/36785	974/26592	981/19941
File-Upload (7 seconds)			
Success Ratio (%)	91.1	88.6	79.7
∅ Throughput (kbit/s)	11616	9009	7849
90%/10% faster than (kbit/s)	1162/27012	1670/16869	879/16911
Youtube Videos			
Success Ratio/Start Time (%/s)	73.0/2.7	73.4/2.8	68.0/2.9
Playouts without Interruptions (%)	91.7	91.6	88.5
∅ Video Resolution (p)	870	794	822
Youtube Live			
Success Ratio/Start Time (%/s)	71.4/2.9	75.8/3.5	67.3/3.9
Playouts without Interruptions (%)	88.0	91.4	83.2
∅ Video Resolution (p)	791	696	672

Crowd

In this year, the results of crowd-sourcing analyses are part of the total score for the first time.

In our new crowdsourcing discipline, Telekom also takes the lead. As could be expected, when considering voice coverage, all three candidates score well. But when looking at the data coverage and its quality in the assessed area, some weaknesses at O2 become obvious. The are even more distinct when specifically examining the 4G coverage and its quality. But also Vodafone could score better in this category.

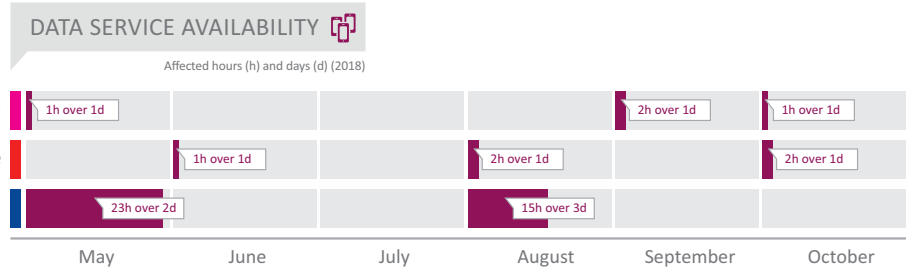
Long outage at O2

The data rates identified in the crowdsourcing shows the almost well-known ranking: Telekom leads, Vodafone follows,

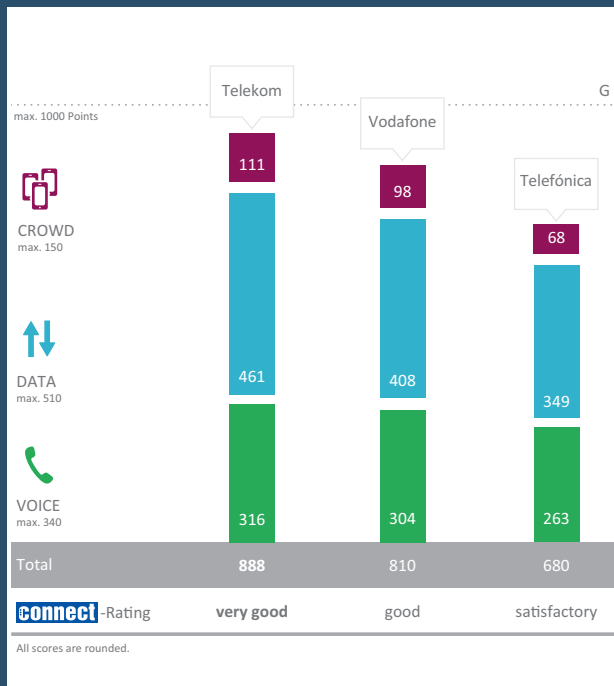
O2 brings up the rear. However, in the fastest "evaluation areas", O2 actually manages to overtake Vodafone by a narrow margin.

In the analysis of network availability which is based on six months of measurements (May to October 2018), Telefónica attracts negative attention with two service degradations each spanning many hours in May and August.

	Telekom	Vodafone	Telefónica
Voice Coverage			
Quality of Coverage (%)	97.9	97.7	97.7
Test Area Coverage (%)	99.6	99.6	99.5
Data Coverage			
Quality of Coverage (%)	89.9	85.4	77.8
Test Area Coverage (%)	97.1	95.3	88.1
4G Coverage			
Quality of Coverage (%)	75.4	58.9	47.8
Test Area Coverage (%)	95.2	90.6	70.3
User Data Speed			
10% EA faster than (kbit/s)	40965	35944	36541
10% Users faster than (kbit/s)	14354	14623	13070
Avg. Users Best Throughput (kbit/s)	5123	5054	4418
Data Service Availability			
Number of degraded days (d)	3	3	5
Number of degraded hours (h)	4	5	38



Single review



For the eighth time in a row, the Bonn-based operator wins connect's mobile network test in Germany. Compared to the previous year, Telekom was able to slightly improve its performance – this is also true when segregating the newly added crowd points. The very good overall result would arithmetically equal a school grade of 1.3 (of 6 levels, with 1.0 being the best grade).



When directly comparing the degrees of fulfilment in the separat test categories with those of the previous year, the Dusseldorf operator falls back slightly. But as we have further enhanced our test methods year over year, the overall performance probably remained constant. The achieved second rank and the overall grade "good" would arithmetically equal a school grade of 1.8.



In comparison to the previous year, O2 managed to improve considerably – both in the voice and data disciplines. The advancements in larger cities stand out particularly. The results in smaller towns, on the connecting roads and on railways (where all German operators perform poorly) remain weak points. O2 improves its results, now reaching the grade "satisfactory", which equals a school grade of 3.1. >>

Austria

Each year, the operators in the Alpine republic give each other a neck-and-neck race. This year sees a change in the top rank – after a competition on a overall high level.

Since we had expanded our great network test to also include Austria and Switzerland in 2009, Austrian operators are constantly the best comparing all three regions. They frequently battle for the overall lead on a very high level.

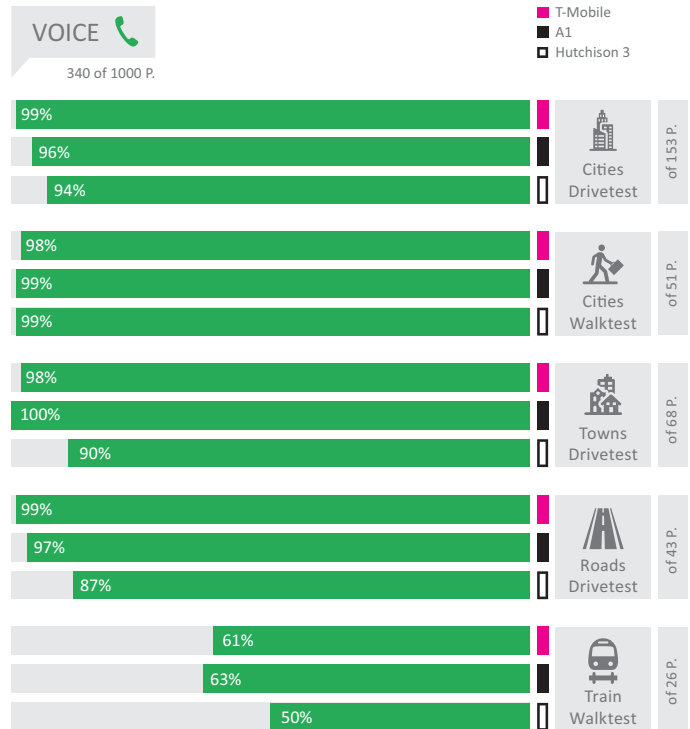
Good news for Austrian mobile customers: They can choose between three strong operators – at considerably lower tariffs as in the neighbouring Germany. Only high roaming fees in the non EU neighbour country Switzerland regularly annoy Austrian smartphone users.

It may be a small comfort that such extra revenues allow Austrian operators to make continuous upgrades to their infrastructure. Also, especially the winner of our network test in Austria was able to improve its score compared to last year's its results from the previous year.

Voice connections

In the summer of 2018, also Hutchison/Three has introduced VoLTE as the last of the Austrian operators. So, now this modern 4G telephony mode is available in all three Austrian networks. In the previous year it was A1 alone offering the VoLTE technology to their customers.

This is clearly reflected in the measurement values – T-Mobile and Three catch up to the high results of A1 concerning call setup times and speech quality. Actually, now T-Mobile connects calls in the shortest time. With the exception of the walktests in large cities, Three scores at a clear distance behind its two stronger competitors. The values



OPERATOR	T-Mobile	A1	Hutchison3
VOICE (Cities; Drivetest)			
Call Success Ratio (%)	99.9	99.4	98.9
Call Setup Time Ø (s) / P90 (s)	1.1/1.2	1.9/2.2	2.8/3.1
Speech Quality (MOS-LQO)	4.4	4.4	4.3
VOICE (Cities; Walktest)			
Call Success Ratio (%)	99.6	99.8	99.8
Call Setup Time Ø (s) / P90 (s)	1.2/1.3	1.8/2.2	2.5/2.8
Speech Quality (MOS-LQO)	4.4	4.4	4.4
VOICE (Towns; Drivetest)			
Call Success Ratio (%)	99.7	100.0	98.2
Call Setup Time Ø (s) / P90 (s)	1.1/1.3	1.9/2.3	2.8/3.1
Speech Quality (MOS-LQO)	4.4	4.4	4.3
VOICE (Roads; Drivetest)			
Call Success Ratio (%)	99.7	99.2	97.8
Call Setup Time Ø (s) / P90 (s)	1.2/1.3	1.9/2.3	3.1/5.1
Speech Quality (MOS-LQO)	4.3	4.3	4.1
VOICE (Train; Walktest)			
Call Success Ratio (%)	89.2	90.0	87.2
Call Setup Time Ø (s) / P90 (s)	1.5/2.2	2.3/3.3	3.1/4.6
Speech Quality (MOS-LQO)	4.1	4.1	3.8

determined in smaller towns and on the connecting roads fall back considerably compared to those in the cities.

Compared to the previous year, T-Mobile improved the most in the voice discipline. But also A1 and Three were able to step it up a notch in this category.

Data connections

The results of the data measurements are also on a pleasantly high level – and also quite close. The results of the drivetests and walktests conducted in large cities account for the very high performance of all three Austrian mobile networks. A little more

surprisingly, this is also true for the smaller towns and the connecting roads.

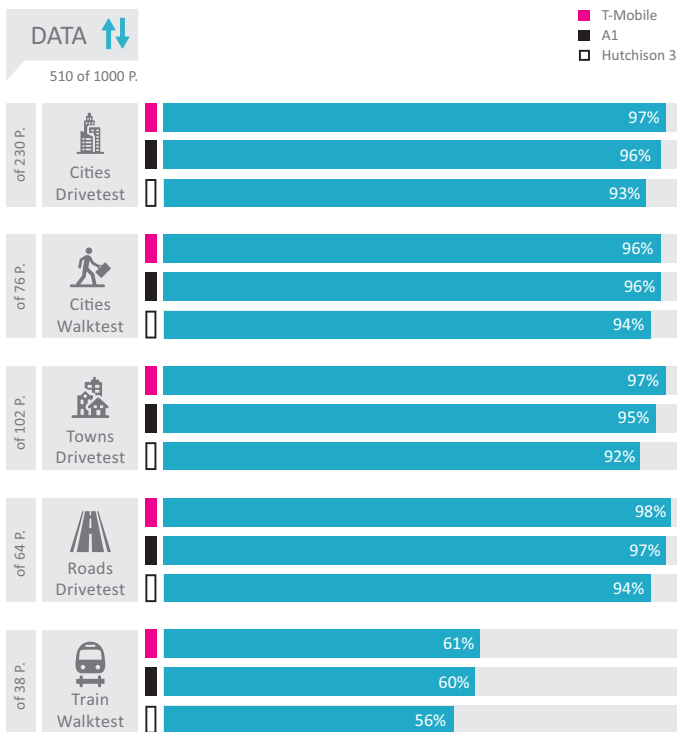
The success rates of web page downloads are on a high level for all contenders. A1 and T-Mobile score almost the same here, while Three slightly falls behind in this category.

Looking at the data rates of file downloads, A1 takes the lead several times, frequently followed by Three. In contrast, T-Mobile counters with slightly faster file uploads. When playing back Youtube videos, all three are on a similarly high level.

All in all, the scores achieved in all the examined regions indicate the same ranking: T-Mobile takes



OPERATOR	T-Mobile	A1	Hutchison3
DATA (Cities; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.8/100.0	99.9/100.0	99.2/99.7
Static: Avg. Session Time (s)	0.9	0.9	1.0
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	256/553	276/568	330/533
File-Download (3MB)			
Success Ratio/Ø Session Time (%/s)	99.9/0.8	99.9/0.8	99.5/0.9
90%/10% faster than (kbit/s)	20848/77670	21373/91255	18097/78380
File-Upload (1MB)			
Success Ratio/Ø Session Time (%/s)	99.9/0.5	99.9/0.6	99.5/0.6
90%/10% faster than (kbit/s)	14733/31621	13285/31250	11923/23529
File-Download (7 seconds)			
Success Ratio (%)	100.0	98.6	99.7
Ø Throughput (kbit/s)	77723	81701	69467
90%/10% faster than (kbit/s)	26660/136405	25041/154445	20270/132837
File-Upload (7 seconds)			
Success Ratio (%)	100.0	99.9	99.3
Ø Throughput (kbit/s)	44029	41263	30917
90%/10% faster than (kbit/s)	19604/60874	18908/55234	16070/41652



Youtube Videos			
Success Ratio/Start Time (%/s)	99.9/1.1	99.9/1.1	99.4/1.3
Playouts without Interruptions (%)	99.9	100.0	100.0
Ø Video Resolution (p)	1078	1077	1077
Youtube Live			
Success Ratio/Start Time (%/s)	100.0/1.7	99.6/1.9	100.0/2.5
Playouts without Interruptions (%)	99.3	99.7	99.9
Ø Video Resolution (p)	1084	1085	1087
DATA (Cities; Walktest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.6/99.8	99.8/99.8	99.6/99.4
Static: Avg. Session Time (s)	0.9	0.9	1.0
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	270/542	316/562	344/535
File-Download (3MB)			
Success Ratio/Ø Session Time (%/s)	99.8/0.7	99.8/0.7	99.7/0.9
90%/10% faster than (kbit/s)	24699/82759	25894/91603	21243/87591
File-Upload (1MB)			
Success Ratio/Ø Session Time (%/s)	99.5/0.6	99.5/0.6	99.1/0.7
90%/10% faster than (kbit/s)	13640/31746	12153/30418	11158/23739
File-Download (7 seconds)			
Success Ratio (%)	99.8	98.5	99.8
Ø Throughput (kbit/s)	85206	86348	74323
90%/10% faster than (kbit/s)	30105/145888	28070/158781	22352/136173
File-Upload (7 seconds)			
Success Ratio (%)	99.5	99.7	99.2
Ø Throughput (kbit/s)	41116	38999	30498
90%/10% faster than (kbit/s)	17147/60817	17009/54059	12324/41744
Youtube Videos			
Success Ratio/Start Time (%/s)	99.8/1.1	100.0/1.1	99.8/1.3
Playouts without Interruptions (%)	100.0	100.0	100.0
Ø Video Resolution (p)	1071	1076	1076
Youtube Live			
Success Ratio/Start Time (%/s)	100.0/1.7	99.6/1.8	99.3/2.4
Playouts without Interruptions (%)	100.0	99.6	100.0
Ø Video Resolution (p)	1076	1080	1086
DATA (Towns; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.9/100.0	99.9/100.0	99.0/99.4
Static: Avg. Session Time (s)	0.9	1.1	1.0
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	283/538	336/538	362/529
File-Download (3MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.8	100.0/0.9	99.4/0.8
90%/10% faster than (kbit/s)	21378/73440	18605/82759	18729/81081
File-Upload (1MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.5	100.0/0.7	98.9/0.6
90%/10% faster than (kbit/s)	15936/29851	10426/27884	10905/23296
File-Download (7 seconds)			
Success Ratio (%)	100.0	99.4	100.0
Ø Throughput (kbit/s)	76796	78183	74518
90%/10% faster than (kbit/s)	31628/121260	19755/150419	21570/140275
File-Upload (7 seconds)			
Success Ratio (%)	99.7	99.7	98.9
Ø Throughput (kbit/s)	42630	32174	28335
90%/10% faster than (kbit/s)	19112/60493	13781/48131	13144/40629
Youtube Videos			
Success Ratio/Start Time (%/s)	99.7/1.1	100.0/1.2	99.5/1.3
Playouts without Interruptions (%)	100.0	100.0	100.0
Ø Video Resolution (p)	1078	1080	1080
Youtube Live			
Success Ratio/Start Time (%/s)	100.0/1.7	100.0/1.9	100.0/2.4
Playouts without Interruptions (%)	100.0	100.0	100.0
Ø Video Resolution (p)	1086	1080	1088

OPERATOR	T-Mobile	A1	Hutchison3
DATA (Roads; Drivetest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.9/99.6	99.8/99.8	99.0/99.0
Static: Avg. Session Time (s)	1.0	1.0	1.1
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	282/528	309/557	354/520
File-Download (3MB)			
Success Ratio/Ø Session Time (%/s)	99.8/1.0	99.8/0.9	99.4/1.0
90%/10% faster than (kbit/s)	15189/71280	20114/89686	13505/82845
File-Upload (1MB)			
Success Ratio/Ø Session Time (%/s)	99.8/0.8	99.0/0.9	98.0/1.0
90%/10% faster than (kbit/s)	8078/29304	8156/28965	7061/22792
File-Download (7 seconds)			
Success Ratio (%)	99.6	98.1	99.6
Ø Throughput (kbit/s)	68177	86723	81172
90%/10% faster than (kbit/s)	16976/129556	23588/159193	21923/153513
File-Upload (7 seconds)			
Success Ratio (%)	99.8	99.4	98.2
Ø Throughput (kbit/s)	34706	34059	26901
90%/10% faster than (kbit/s)	11001/59317	13058/50337	9332/40162
Youtube Videos			
Success Ratio/Start Time (%/s)	99.8/1.1	99.8/1.2	99.4/1.4
Playouts without Interruptions (%)	100.0	100.0	100.0
Ø Video Resolution (p)	1077	1073	1041
Youtube Live			
Success Ratio/Start Time (%/s)	99.6/1.9	99.2/1.9	99.2/2.5
Playouts without Interruptions (%)	99.6	99.6	99.6
Ø Video Resolution (p)	1077	1082	1041

NETWORK TEST

the lead, A1 Telekom follows on the second rank, and Hutchison/Three on the third.

Compared to last year's results, T-Mobile managed to slightly improve, A1 is overall on the same level than in the previous year, while Three fell a little behind.

Mobile communications on Austrian railways

Especially in comparison to its large neighbour in the north, the Austrian operators offer respectable performance also on the railways. However, when looking at the results of the previous year, only T-Mobile succeeds in improving its score in the railway category of this test – thanks to better voice results. Regarding telephony in railways, A1 and Three fall a little behind. Here, the market leader A1 still

achieves the highest score, ahead of its two competitors.

When accessing the internet while travelling on trains, the penalty is even bigger. In this discipline, only T-Mobile is able to defend the results from last year, while A1 and Three clearly fall back.

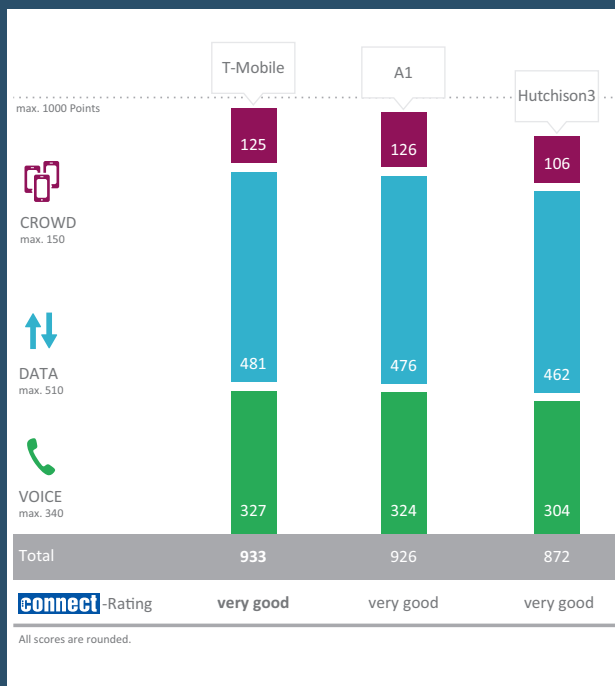
A possible explanation: The Austrian Railways have strongly improved their WiFi offering in the trains. This is clearly benefiting travellers, but leads to a higher strain on the mobile networks which serve as the backbone. Additionally, some effects can be attributed to the stricter test requirements of this year.

So, all in all, the Austrian operators show some room for improvement on the railways. However, compared to Germany, Austrian train customers have every reason to be happy.



OPERATOR	T-Mobile	A1	Hutchison3
DATA (Train; Walktest)			
Web-Page Download (Live/Static)			
Success Ratio (%/%)	91.2/91.1	92.2/91.8	89.4/92.4
Static: Avg. Session Time (s)	1.5	1.4	1.7
Live: React. Time (ms) /Vol. in 1.sec (kB/s)	339/451	379/491	461/459
File-Download (3MB)			
Success Ratio/Ø Session Time (%/s)	93.7/3.0	92.7/2.9	91.6/2.6
90%/10% faster than (kbit/s)	3487/49251	4491/71901	6018/51881
File-Upload (1MB)			
Success Ratio/Ø Session Time (%/s)	88.5/2.3	88.1/2.8	84.4/2.9
90%/10% faster than (kbit/s)	1188/20101	991/18433	1285/14956
File-Download (7 seconds)			
Success Ratio (%)	92.8	90.4	91.9
Ø Throughput (kbit/s)	34918	43298	37299
90%/10% faster than (kbit/s)	4052/90904	6588/99553	5330/81781
File-Upload (7 seconds)			
Success Ratio (%)	89.4	87.4	86.4
Ø Throughput (kbit/s)	13340	12746	10502
90%/10% faster than (kbit/s)	1782/28607	738/30121	1408/19901
Youtube Videos			
Success Ratio/Start Time (%/s)	90.0/1.9	88.3/1.4	88.9/1.8
Playouts without Interruptions (%)	99.6	99.5	99.5
Ø Video Resolution (p)	992	1016	1002
Youtube Live			
Success Ratio/Start Time (%/s)	88.0/2.5	90.8/2.5	88.9/3.1
Playouts without Interruptions (%)	97.1	96.3	96.2
Ø Video Resolution (p)	1007	966	968

Single review



This year, the winner in Austria is T-Mobile. It is particularly noteworthy that this operator managed to fight its way to the top rank in this year, starting from the third rank in the previous year. This pull-up succeeds especially due to clearly improved results in the voice discipline. Arithmetically, its very good result would equal a school grade of 1.2.



With a difference of seven points to this year's winner in Austria, A1 Telekom reaches the second rank only at a narrow distance. In the crowd assessment, A1 even takes the lead, the voice and data results both only score narrowly behind the winner. In smaller towns, this operator even closely leads before T-Mobile and a little more distinct before Three. Its "very good" grade equals a school grade of 1.2.



Compared to the previous year's results, Three shows a slight improvement in the voice and a slight degradation in the data discipline. The overall result is approximately on the same level as the one from last year. In the new crowd score, Three loses a couple of points – particularly due to the determined 4G coverage. Still, its overall result is "very good" with a school grade equivalent of 1.4

Crowd

Aside from some smaller differences, the crowdsourcing results confirm those of our drivetests and walktests.

The results of our crowdsourcing analyses indicate a small lead for A1, but T-Mobile also does well in the category.

The determined coverage is high for both operators just mentioned, as expected. However, Hutchison/Three falls distinctly behind in the coverage with all data services as well as in 4G/LTE.

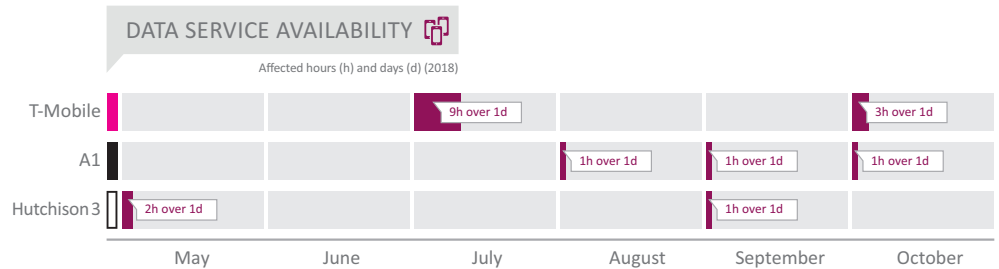
On the other hand, Three leads when it comes to the data speeds identified for each evaluation area and for each participating user, followed by A1 and, at some distance, T-Mobile. All in all, these values are on a high level.

T-Mobile misses an overall win in the crowd assessment

especially due to the evaluation of data service availability. For this examination, we have considered the six month period from May to October 2018, divergent from the observation period of the drive and walktests ranging from August to October.

A total of nine hours of recognized degradations in July and three in October cost T-Mobile valuable points. >>

Crowd	T-Mobile	A1	Hutchison3
Voice Coverage			
Quality of Coverage (%)	99.0	99.2	97.6
Test Area Coverage (%)	99.3	99.8	99.3
Data Coverage			
Quality of Coverage (%)	98.3	94.6	86.0
Test Area Coverage (%)	98.9	98.2	92.4
4G Coverage			
Quality of Coverage (%)	84.4	81.2	68.8
Test Area Coverage (%)	95.6	96.0	88.2
User Data Speed			
10% EA faster than (kbit/s)	55594	76892	78408
10% Users faster than (kbit/s)	22450	23375	25645
Avg. Users Best Throughput (kbit/s)	7456	7861	8410
Data Service Availability			
Number of degraded days (d)	2	3	2
Number of degraded hours (h)	12	3	3



Methodology

The tests in Germany took place from October 13 to November 12, 2018 – the ones in Austria from October 20 to November 9.

For each country, connect's partner for the network measurements, P3, used two vehicles for drivetesting the chosen cities, towns and roads. Each car carried a total of six Samsung Galaxy S8 smartphones. One per operator was used for the voice tests and another one for the data measurements.

In addition to the drivetest, in each country a walktest team took measurements by foot. For this effort, the teams visited so-called "areas of interest" with a strong visitor frequency like train stations, airport terminals, coffee shops, museums and also local public transport. Travelling from city to city allowed the assessment of cellular network quality within long distance trains.

The walktest teams also utilised Samsung Galaxy S8 smartphones that were installed in trolleys and back packs with additional strong batteries.

The devices' firmware was each operator's current firmware version. If such software



Each drivetest vehicle carried six Samsung Galaxy S8 smartphones.

was not available, the most current firmware from the smartphone manufacturer was used.

Voice telephony

Voice services were measured with the smartphones performing calls alternating between the measurement cars ("mobile to mobile"). The walktest teams called a stationary counterpart for all voice tests.

Background data traffic was transmitted by one of the smartphones simultaneously to each call in order to reflect a realistic usage scenario. Audio quality was assessed by using the HD-Voice capable POLQA (Perceptual Objective Listening Quality Assessment) wide band scoring.

All devices were configured in "LTE preferred" mode. Thus, they could benefit from the more modern "Voice over LTE" (VoLTE) wherever this was available.

Data connectivity

To assess cellular data performance, a sequence of tests was executed. As a dynamic web browsing test, each country's top websites (according to the Alexa ranking) were downloaded in the so-called live web browsing test. Additionally a static website was tested, the industry standard ETSI (European Telecommunications Standards Institute) Kepler reference page.

HTTP downloads and uploads were conducted with 3 MB and 1 MB files, simulating small file transfers. The networks' peak performance was tested with a seven second download and upload of a single, very large file. The Youtube measurements performed on the smartphones considered the "adaptive reso-



Professional and critical: Bernd Theiss, head of test and technology at connect (on the left), and Hakan Ekmen, managing director of P3 communications (on the right).

lution" feature of this video platform. In order to offer a persistent video experience, Youtube adapts the video streams' resolution dynamically to the bandwidth that is currently available. Our scoring therefore considers the success ratio, the time until the playback starts, the percentage of video playouts that take place without interruptions as well as the videos' average resolution or line number count respectively.

Logistics

All drivetests and walktests were done between 8 am and 10 pm. During the drivetests, two cars were present in the same cities, but on different routes to avoid any interference of one car's measurement by the other car's.

On the connecting roads, both vehicles drove a given route, but followed each other at a small temporal and spatial distance. At each location, the test smartphones had to share the networks' bandwidth with normal customers. This represents the usual competition for the limited resource of the networks' available radio frequencies.

In Germany, the measurements included 19 larger cities

and 68 smaller towns, while the walktests frequented ten cities. The measurement cars drove a total of approx. 9,750 kilometers. With their drivetests, they covered about 14.1 million inhabitants which equals about 17.15 per cent of the German population. All in all, a total of 17,570 voice samples und 169,785 data samples was collected.

In Austria, the drivetests covered 11 big cities and 20 smaller towns, the walktest team visited seven cities. Here, the vehicles covered about 3.1 million inhabitants or 35.3 per cent of the population. In the course of the measurements, a total of 12,177 voice and 113,840 data samples was collected.

The definition of the test routes follows a well-defined process: P3 generates four independent and representative city and route plans. The connect editors then randomly choose one of these four alternatives.

Crowdsourcing

The results of the crowdsourcing analyses performed by P3 contribute 15 per cent of the total score. For this purpose, a total of 1.48 billion single measurement values from von 227,000



Boxes mounted to the rear and side windows of the cars contain the smartphones used for testing.

mobile communications users from August until October 2018 was evaluated. For Austria, approx. 710 million values from 76,000 users. For Germany, this comprises 88.5 per cent of the total built-up area, in Austria 89.7 per cent.

The data base for these analyses is obtained by more than 800 popular apps. They log in the background whether there is a network connections, which mobile network technologies are available and what download data rates can be achieved – provided that the user has before agreed to this completely anonymous data collection.

These measurement values are gathered every 15 minutes and transmitted once a day to P3's servers. The reports only comprise of a small number of bytes so that they do not put a substantial strain to the users' data volumes. Readers who wish

to actively support our network test can do this by installing and using the connect app (see box below). However, it is only one of many apps containing the described background functionality.

Network coverage

In order to determine the coverage with 4G, "data" (3G and 4G) as well as telephony, P3 applies a grid of 2 by 2 km tiles to the test area. These "evaluation areas" are then sub-divided into 16 smaller tiles. In order to ensure the statistical relevance of the results, P3 demands a minimum number of users and measurement data per tile. These depend on the number of operators in a country and the total number of their customers. If one contender does not meet these requirements in a certain tile, this tile will not be considered for any of the operators for the sake of fairness.

Even if the smartphone displays the availability of voice and data services in an evaluation area, this does not automatically mean that these services can actually be used. Therefore, P3 additionally determines the "quality of coverage". It indicated, how often users could have actually used the required network service.

Data speed

P3 also investigates the highest download speed that was reached by each participating users per evaluation area during the examined period. For these values, the average is calculated. Additionally, we specify the "P90 values" – the threshold within a statistical distribution under which 90 per cent of the measurement values range. This indicates the network performance over all evaluation areas and also all users under favourable conditions.

Service availability

Another aspect determined in the crowdsourcing are outages of degradations of the (data) network connectivity. A sophisticated algorithm distinguishes simple loss of network coverage (such as in elevators, car parks or indoors) from actual degradations. Incidents that occur at night between 0 am and 6 am are not considered. In contrast to the other crowd results, the service availability considers a six month period – here from May to October 2018.

Points will be deducted for the number of days and the number of hours with service degradations. A even more detailed description of our methods and the results for other countries can be found at www.connect-testlab.com >>

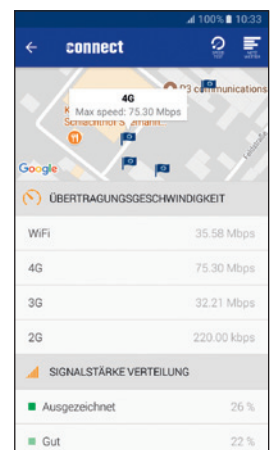
DRIVETEST		SCORE BREAKDOWN	
Cities - Drivetest		383	
Cities - Walktest		127	
Towns - Drivetest		170	
Roads - Drivetest		107	
Trains - Walktest		64	
Crowdsourcing		150	



Participate in our crowdsourcing

The **connect app** not only allows you to take part in our crowdsourcing. Above that, you receive latest telecommunications news and you can also check the speed of your network with an informative speed test. The Android version additionally reveals interesting details like data consumption and usage time per app.

Only if you agree, the app will also perform completely anonymous connection tests in the background. The required data is less than 2 MB per month.



Connectivity at a glance: The "history" shows when and with which technology and speed you were online.

You will find the according downloads in the app stores of Google or Apple with the adjacent QR codes.



Android version



iOS version

FAIRNESS AND TRANSPARENCY

connect and P3 ensure maximum fairness and transparency. However, some involved parties tried with equally complex as well as unsuccessful trickery to improve their results in our test – which is of obvious importance for them.

Part of our standard to ensure fully fair and transparent testing is to inform the operators early about the basic parameters. This so-called framework consists of the smartphones used for testing, the considered KPIs, the basic scoring scheme as well as of the exact timing. connect and P3 defined these frame conditions early in 2018 and subsequently informed the CTOs of the operators about them.

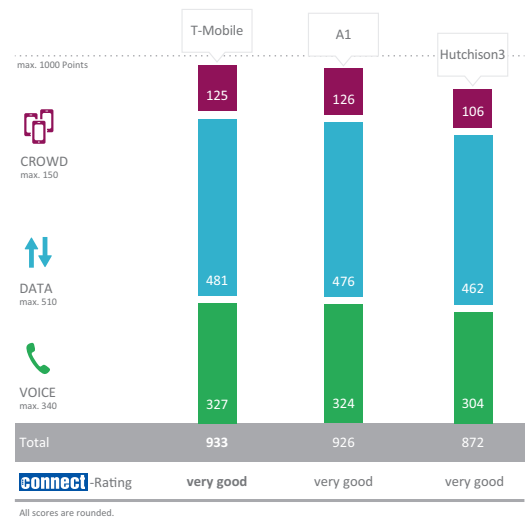
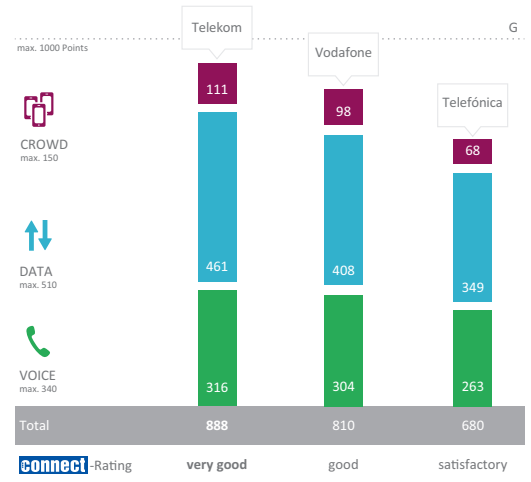
We are open for feedback and suggestions, critically checking every single one. If we regard them as being justified, we then adapt the procedures for all candidates. However, once again we had to decline some suggestions, as we concluded that some operators just wanted to enforce measurement methods which would be advantageous to their own networks only.

However, the often intense discussions prove that all involved operators take our methodology as well as our results very seriously.

Still, the high relevance of connect's mobile network test to the operators sometimes takes on strange forms. connect readers called our attention to the fact that during the testing one of

the operators installed mobile base stations close to a part of the autobahn that was likely to be part of our drivetest route. As investigations by connect concluded, this may be a common procedure before the planned buildup of new network cells at the location in question. Additionally, intense examinations conducted by P3 also showed that even an installation of all available mobile base stations would not noticeably affect the result of an operator.

In one country which was not participating in the network test at hand, we also noticed an attempt to polish the crowdsourcing results up by the means of manipulated smartphones. They conspicuously travelled throughout the whole country. However, as the conspicuous results were easily recognisable, P3 managed to filter them from the data pool. It is unclear whether an operator, a supplier or a competitor of connect is behind these manipulations and whether they intended to boost the results of the affected network or to discredit the same network or connect – especially as it is not possible to identify the originator due to the anonymous data collection.



P3's proprietary control electronics manages the smartphones during the drivetests and collects all logged data.

GERMANY

AUSTRIA

Overall Results Voice and Data			Telekom	Vodafone	Telefónica	T-Mobile	A1	Hutchison3
VOICE	max. 340 Points		316	304	263	327	324	304
Cities	Drivetest	153	98%	95%	84%	99%	96%	94%
Cities	Walktest	51	98%	99%	97%	98%	99%	99%
Towns	Drivetest	68	98%	93%	76%	98%	100%	90%
Roads	Drivetest	42	93%	78%	60%	99%	97%	87%
Train	Walktest	26	39%	48%	27%	61%	63%	50%
DATA	max. 510 Points		461	408	349	481	476	462
Cities	Drivetest	230	96%	85%	73%	97%	96%	93%
Cities	Walktest	76	97%	90%	89%	96%	96%	94%
Towns	Drivetest	102	92%	77%	60%	97%	95%	92%
Roads	Drivetest	64	91%	78%	69%	98%	97%	94%
Train	Walktest	38	42%	40%	23%	61%	60%	56%
CROWD	max. 150 Points		111	98	68	125	126	106
Crowd Total	150		74%	65%	45%	84%	84%	71%
Total	max. 1000 Points		888	810	680	933	926	872
connect -RATING			very good	good	satisfactory	very good	very good	very good

All values have been rounded to integer numbers. The internal calculation of points and percentages was based on three decimal places. Intermediate results therefore can slightly deviate from the specified values.





CONCLUSION

Hannes Ruegheimer,
connect author

Our network test has been the de-facto industry standard for many years, thanks to its elaborate methodology and continuous adaptation to technological innovations. As announced last year, we have made it even more comprehensive by now amending the new dimension of crowdsourcing.

In Germany, a strong Telekom achieved the overall victory for the eighth time in a row. The Bonners were even able to top their previous performance once again. In our new crowd discipline, Telekom also takes the lead. Vodafone's overall performance remains more or less constant – resulting in the second rank and the grade good for the Düsseldorf based operator. The crowd score achieved by Vodafone ranks in the middle field as well.

Although O2 remains on the third rank at some distance to the other contenders, the Munich company managed to increase their performance clearly compared to the previous year. Especially in larger cities, the efforts taken for the integration and expansion of the formerly separate E-Plus and O2 networks pay off. However, in smaller towns and on the connecting roads, there remains work to be done.

The results of our tests on German railways are nothing but sad. No progress at all can be seen in comparison to previous years. Poor performance results both for telephony and data communications clearly demand for finally facilitating some improvements in this field to all three German mobile operators.



In Austria, the performance level of the mobile network is altogether higher than in Germany. All three Austrian operators achieve the grade "very good". This time, T-Mobile manages to battle its way to the top from the third rank in the previous year. This operator owes its success to distinct improvements particularly in the data discipline.

Market leader A1 Telekom ranks second at a close call. In the new crowd score, A1 even leads the field. This operator is especially strong in smaller cities, where it takes the lead at a narrow distance over T-Mobile and a more distinct one over Three.

Hutchison/Three's result is about the same as last year. A direct com-

parison reveals a slight improvement in the voice and a slight degradation in the data discipline. Furthermore, the crowd score indicates some weaknesses in 4G coverage. But all in all, Three also achieves the overall grade "very good".

On the Austrian railways, T-Mobile was able to improve its voice results in comparison to last year. The other contenders drop back a little compared to their previous results. In the data discipline, all three have lost some points. Presumably the considerably improved WiFi offering of the Austrian Railways ÖBB puts more stress on the mobile networks. However, in comparison to Germany, the results still demonstrate a clear lead.