

Switzerland

In Helvetia, traditionally, the air is getting particularly thin up there. Which Swiss operators makes it to the winner's podium this time?

► Here comes another long-time tradition: When we compare the performances in Germany, Austria and Switzerland, the Swiss operators demonstrate where the forefront can be found. While our evaluation scheme delivers a wide dispersion of results in other countries, the Swiss contenders regularly achieve the grade "outstanding" – which connect issues only rarely.

Still, this fierce combat on the highest level is exciting again and again: Which Swiss network manages to collect the total win? How distinct is the lead over the best operators in Germany and Austria? And how does the smallest Swiss operator Salt fare in comparison to its bigger competitors

Swisscom and Sunrise? Let's have a closer look.

Voice connections

After recently also Salt introduced the modern telephony mode VoLTE (Voice over LTE) in its network, conducting voice calls over data packets and without the „circuit-switched fallback“ to 3G or 2G connections is now standard in all three Swiss networks. And it pays off: The smallest operator Salt now comes much closer to its two strong competitors when we look at the call



setup times or voice quality – even if it does not absolutely reach their very high levels. Especially in smaller towns, the gap is still a little more distinct. But also there as well as on the Swiss roads, Salt managed to improve its performance over the previous year.

Also noteworthy are the high success ratios achieved by Sunrise and Swisscom in cities and towns as well as on the connecting roads. In the Sunrise network, literally a 100 percent of the test calls conducted during the walktests in cities and towns succeeded.

Swisscom accomplishes the same in the larger cities and only narrowly misses the 100 percent mark in the smaller towns. Possibly record-breaking as well are Sunrise's call setup times ranging clearly below one second in all tested scenarios – including Swiss trains.

Data connections

What was already apparent in the voice discipline, becomes clear again in the data category: Swisscom and Sunrise have a neck-and-neck race on the highest level, Salt follows at a relatively close distance.



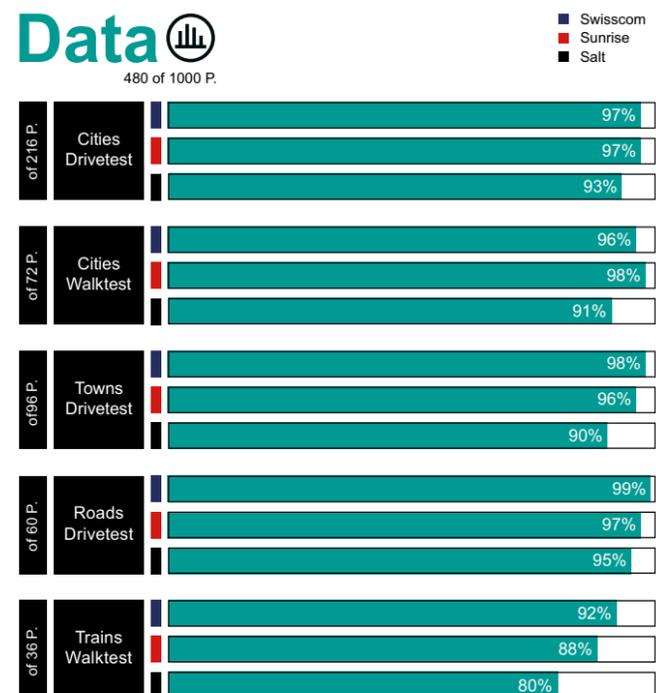
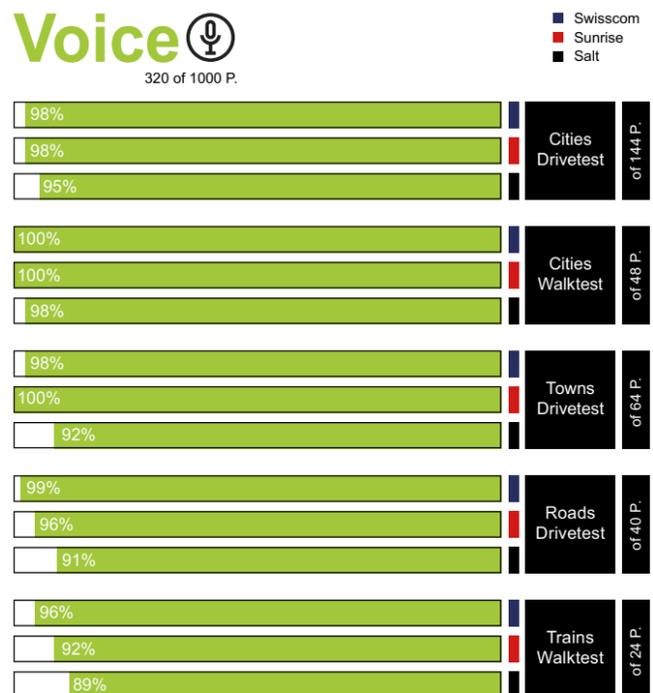
Almost complete LTE coverage at all locations visited by unlaut's teams and a high share of data connections with 4CA („4 carrier aggregation“ – the combination of four LTE carrier frequencies on suitable devices) in the larger cities – this is what characterizes the measurement

results of Swisscom and Sunrise. In bigger cities and smaller towns as well as on the connecting roads, the two Swiss operators with the largest customer numbers achieve top success rates for all data tests. But also the smaller contender Salt does not have to hide its results.

The tight distance at which the battle for the top position is fought at becomes apparent when we take a closer look at the test results in the individual categories: In the drivetests conducted in larger cities, Sunrise and Swisscom practically share the same high rank. In the big-city walktests

Swisscom takes a narrow lead, while in the drivetests in smaller towns an on the connecting roads, it is Swisscom's turn to achieve the top score. Again, also Salt shows convincing results in the data measurements conducted on the roads. All in all, Swiss drivers get on very well with all three operators.

Operator	Swisscom	Sunrise	Salt
Voice Cities (Drivetest)			
Call Success Ratio (%)	99.7	99.6	99.3
Call Setup Time Ø (s) / P90 (s)	1.1/1.3	0.7/0.7	1.7/1.9
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.2	4.5/4.3	4.4/4.0
MultiRAB Connectivity (%)	99.9	99.9	99.9
Voice Cities (Walktest)			
Call Success Ratio (%)	100.0	100.0	99.8
Call Setup Time Ø (s) / P90 (s)	1.1/1.3	0.7/0.7	1.6/1.8
Speech Quality Ø / P10 (MOS-LQO)	4.6/4.5	4.7/4.6	4.5/4.2
MultiRAB Connectivity (%)	100.0	100.0	99.8
Voice Towns (Drivetest)			
Call Success Ratio (%)	99.6	100.0	98.8
Call Setup Time Ø (s) / P90 (s)	1.1/1.3	0.7/0.8	1.9/3.0
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.2	4.5/4.3	4.4/3.7
MultiRAB Connectivity (%)	100.0	100.0	100.0
Voice Roads (Drivetest)			
Call Success Ratio (%)	99.6	98.9	97.6
Call Setup Time Ø (s) / P90 (s)	1.1/1.4	0.7/0.7	1.9/2.6
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.2	4.5/4.2	4.4/3.8
MultiRAB Connectivity (%)	100.0	99.9	99.6
Voice Trains (Walktest)			
Call Success Ratio (%)	98.8	97.7	96.9
Call Setup Time Ø (s) / P90 (s)	1.2/1.5	0.7/0.8	1.8/2.0
Speech Quality Ø / P10 (MOS-LQO)	4.4/3.8	4.4/3.8	4.4/3.7
MultiRAB Connectivity (%)	100.0	100.0	100.0



Operator	Swisscom	Sunrise	Salt
Data (Roads; Drivetest)			
Web Page Download			
Success Ratio (%)	100.0	99.6	99.5
Total Session Time (s)	0.7	0.7	0.7
File Download (5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.9	99.8/1.2	99.4/1.6
90%/10% faster than (Mbps)	30.3/125.0	20.9/114.3	15.3/109.2
File Upload (2.5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/1.0	99.8/1.2	99.8/1.5
90%/10% faster than (Mbps)	14.6/47.4	10.4/43.7	9.8/39.6
File Download (7 seconds)			
Success Ratio (%)	100.0	99.8	99.6
Ø Throughput (Mbps)	123.0	84.6	72.2
90%/10% faster than (Mbps)	33.6/215.1	22.7/159.6	17.7/139.3
File Upload (7 seconds)			
Success Ratio (%)	100.0	99.6	99.6
Ø Throughput (Mbps)	44.4	32.6	35.0
90%/10% faster than (Mbps)	20.1/62.1	9.0/55.4	11.6/57.7
Youtube Videos			
Success Ratio/Start Time (%/s)	100.0/0.8	99.2/0.9	97.8/0.9
Ø Video Resolution (p)	921	919	918
Youtube Live			
Success Ratio/Start Time (%/s)	99.6/1.1	98.4/1.2	97.2/1.3
Ø Video Resolution (p)	1036	1034	1027



Operator	Swisscom	Sunrise	Salt
Data (Trains; Walktest)			
Web Page Download			
Success Ratio (%)	99.2	98.7	97.0
Total Session Time (s)	1.0	1.1	1.1
File Download (5MB)			
Success Ratio/Ø Session Time (%/s)	99.3/3.3	99.3/3.9	98.3/4.4
90%/10% faster than (Mbps)	6.2/81.8	5.5/62.9	4.9/62.0
File Upload (2.5MB)			
Success Ratio/Ø Session Time (%/s)	99.7/1.7	100.0/2.2	98.0/2.2
90%/10% faster than (Mbps)	5.9/36.9	4.9/32.1	6.5/32.6
File Download (7 seconds)			
Success Ratio (%)	99.7	98.0	96.9
Ø Throughput (Mbps)	45.6	38.9	28.7
90%/10% faster than (Mbps)	7.1/94.0	8.0/77.8	4.0/59.2
File Upload (7 seconds)			
Success Ratio (%)	99.0	98.3	96.9
Ø Throughput (Mbps)	25.5	22.6	23.2
90%/10% faster than (Mbps)	6.9/44.4	5.0/40.4	7.0/39.6
Youtube Videos			
Success Ratio/Start Time (%/s)	97.4/1.3	95.7/1.5	90.1/1.3
Ø Video Resolution (p)	912	910	900
Youtube Live			
Success Ratio/Start Time (%/s)	96.6/1.4	95.3/1.5	93.1/1.4
Ø Video Resolution (p)	1020	1030	1026

Top mobile connectivity in Swiss trains

With only minor limitations, this also applies to Swiss railways. Here the helvetic operators show their neighbours (Austria to some extent, but first of all Germany), how the provision of mobile communications in trains should really look like. In the telephony category, the best contender Swisscom convinces with gathering 96 percent of the available points. The weakest candidate, Salt, still achieves 89 percent. When it comes to data connections, the overall level is even higher. When we look at success ratios between 90 percent and 99 percent for

accessing websites or receiving video streams, it would seem almost silly to mention a “potential for improvement” in the light of the results from Austria and Germany.

Still, we do not want to miss the opportunity to mention that on the overall utterly high level, in a direct comparison between the competitors, Swisscom is slightly ahead. Sunrise scores in the middle field, and Salt last. But even this third-ranking operator achieves results which would easily suffice for a category win in other countries. Sorry, but we simply could not help mentioning this fact once again ...

Operator	Swisscom	Sunrise	Salt
Data (Cities; Drivetest)			
Web Page Download			
Success Ratio (%)	99.9	99.8	99.8
Total Session Time (s)	0.7	0.7	0.7
File Download (5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/1.2	100.0/1.1	99.9/2.0
90%/10% faster than (Mbps)	24.2/115.9	22.9/116.6	10.5/98.4
File Upload (2.5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.8	100.0/1.0	99.9/1.1
90%/10% faster than (Mbps)	19.2/47.8	13.1/45.1	13.5/39.6
File Download (7 seconds)			
Success Ratio (%)	99.9	100.0	99.9
Ø Throughput (Mbps)	110.7	101.5	59.9
90%/10% faster than (Mbps)	30.8/208.1	26.0/195.7	13.3/128.9
File Upload (7 seconds)			
Success Ratio (%)	99.9	99.9	99.9
Ø Throughput (Mbps)	48.4	38.2	38.7
90%/10% faster than (Mbps)	21.1/62.4	13.7/58.7	13.3/58.9
Youtube Videos			
Success Ratio/Start Time (%/s)	99.7/0.8	99.6/0.9	99.5/0.9
Ø Video Resolution (p)	920	918	917
Youtube Live			
Success Ratio/Start Time (%/s)	99.0/1.1	99.6/1.1	98.1/1.2
Ø Video Resolution (p)	1033	1032	1032
Data (Cities; Walktest)			
Web Page Download			
Success Ratio (%)	99.7	99.9	99.8
Total Session Time (s)	0.7	0.6	0.8
File Download (5MB)			
Success Ratio/Ø Session Time (%/s)	99.8/1.1	100.0/1.1	99.6/2.1
90%/10% faster than (Mbps)	22.0/133.4	24.8/124.6	11.2/89.5
File Upload (2.5MB)			
Success Ratio/Ø Session Time (%/s)	99.6/0.8	100.0/0.9	99.8/1.2
90%/10% faster than (Mbps)	23.0/47.9	14.0/45.6	14.8/39.7
File Download (7 seconds)			
Success Ratio (%)	99.8	100.0	99.8
Ø Throughput (Mbps)	118.5	106.8	53.2
90%/10% faster than (Mbps)	25.0/240.5	29.6/204.2	12.1/110.7
File Upload (7 seconds)			
Success Ratio (%)	99.6	99.8	99.6
Ø Throughput (Mbps)	49.6	39.4	38.2
90%/10% faster than (Mbps)	26.4/62.5	15.6/58.5	15.5/58.5
Youtube Videos			
Success Ratio/Start Time (%/s)	99.8/0.8	100.0/0.9	98.5/1.0
Ø Video Resolution (p)	920	920	915
Youtube Live			
Success Ratio/Start Time (%/s)	99.2/1.1	100.0/1.1	97.4/1.3
Ø Video Resolution (p)	1038	1039	1037
Data (Towns; Drivetest)			
Web Page Download			
Success Ratio (%)	99.9	99.8	99.5
Total Session Time (s)	0.7	0.7	0.8
File Download (5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.9	100.0/1.1	99.3/1.9
90%/10% faster than (Mbps)	30.3/113.9	23.7/106.8	10.8/95.5
File Upload (2.5MB)			
Success Ratio/Ø Session Time (%/s)	100.0/0.7	100.0/1.2	99.6/1.2
90%/10% faster than (Mbps)	20.0/47.7	11.3/44.3	11.6/39.4
File Download (7 seconds)			
Success Ratio (%)	100.0	100.0	99.8
Ø Throughput (Mbps)	107.1	88.6	57.8
90%/10% faster than (Mbps)	34.0/195.2	27.8/152.1	13.7/119.9
File Upload (7 seconds)			
Success Ratio (%)	100.0	100.0	98.9
Ø Throughput (Mbps)	47.8	35.1	33.8
90%/10% faster than (Mbps)	23.9/62.4	10.6/56.1	9.7/56.0
Youtube Videos			
Success Ratio/Start Time (%/s)	100.0/0.9	99.8/1.0	99.1/1.0
Ø Video Resolution (p)	921	920	912
Youtube Live			
Success Ratio/Start Time (%/s)	99.1/1.1	99.1/1.1	98.6/1.2
Ø Video Resolution (p)	1034	1034	1028

Crowd

In the crowdsourcing, the three Swiss networks show top results again. Still, Swisscom takes a narrow lead once more.

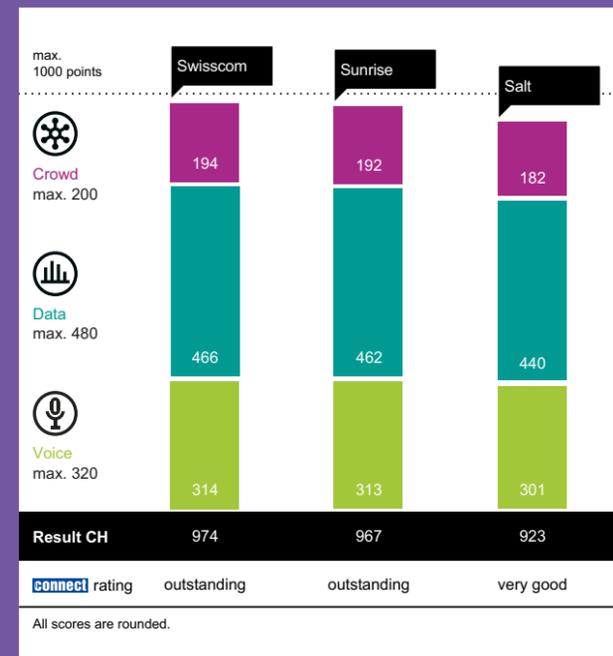
► In the results of our crowdsourcing analysis, Swisscom and Sunrise once again rank at a very close distance. There is a gap of just two points separating Swisscom, which also leads in this category, from its pursuer Sunrise. In contrast, the ten point lag of Salt behind Sunrise is already a bit more pronounced.

The determined coverage rates are very high for Swisscom and Sunrise in urban as well as rural areas. Salt shows convincing coverage results in the rural areas, but lags a little behind its competitors when it comes to 4G and data (3G + 4G) coverage. The data rates of downloads and uploads identified for Swisscom are a little ahead of the competition both in urban and rural areas, and wrap up the operator’s overall win.

Concerning service availability, we can only report that none of the three Swiss networks showed any degradations whatsoever during the half-year observation period.

Operator	Swisscom	Sunrise	Salt
Crowd Country – Operational Excellence			
Number of degraded days (d)	0	0	0
Number of degraded hours (h)	0	0	0
Crowd urban			
Voice Coverage (%)	99.7	99.8	99.8
Data Coverage (%)	99.4	99.7	97.5
4G Coverage (%)	98.0	98.2	94.5
Download data speed (Mbps)	112.0	92.7	74.5
Upload data speed (Mbps)	36.5	26.5	24.5
Crowd non-urban (Benchmark view)			
Voice Coverage (%)	100.0	100.0	100.0
Data Coverage (%)	100.0	100.0	99.9
4G Coverage (%)	100.0	99.9	99.3
Download data speed (Mbps)	60.0	38.4	36.7
Upload data speed (Mbps)	13.5	6.9	5.8
Crowd non-urban (Own network view)			
Voice Coverage (%)	99.9	99.9	100.0
Data Coverage (%)	99.7	99.9	99.9
4G Coverage (%)	99.6	99.8	99.1
Download data speed (Mbps)	52.7	36.5	35.6
Upload data speed (Mbps)	10.1	6.1	5.2

Single Review



Among the two “outstanding” Swiss operators, this year the market leader Swisscom takes the overall win once again – for the second time in a row. In doing so, the operator outperforms its pursuer Sunrise in all three test categories – in some cases with a gap of only one point as in the voice evaluation, yet overall at some distance.



“Outstanding” is also Sunrise’s grade – even if the gap behind the overall winner is not quite as narrow as last year (when it was just one point). Overall, Sunrise stepped it up a notch in the crowd assessment. The drivetest and walktest results range basically at the same level as in the previous year. In the face of our tighter methodology, thus Sunrise has improved at least to some extent.



The third rank in Switzerland would still be the first in Germany. But analogies like this are actually not needed for this operator which is awarded with the overall grade “very good”. More interesting for the company and its customers: Salt achieved the biggest score improvement of all Swiss operators over the previous year. It derives from a clear increase in the voice discipline and also in the crowdsourcing.

SERVICE TEST

SERVICE TEST

Methodology

■ The tests in Germany took place from October 1st to November 1st, 2019, the ones in Austria from October 3rd to 18th, and the ones in Switzerland from October 10th to 30th, 2019. For each country, connect's partner for the network measurements, umlaut, used two vehicles for drivetesting the chosen cities, towns and roads. Each car carried a total of six Samsung Galaxy S9 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 S9 smartphones that were installed in trolleys and backpacks with additional strong batteries. The devices' firmware was each operator's current firmware version. If such software was not available, the



Each drivetest vehicle carried six Samsung Galaxy S9 smartphones.

most current firmware from Samsung was used.

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. In Germany, the measurements included 20 larger cities and 24 smaller towns, while the walktests frequented ten cities. The measurement cars drove a total of approx. 9,780 kilometers. With their drivetests, they covered about 14.4 million inhabitants which equals about 1715 percent of the German population. In Austria, the drivetests covered 11 big cities and 20 smaller towns, the walktest team visited seven cities. Here, the vehicles covered about 6,010 km equalling 3.1 million inhabitants or 35.3 percent of the population. In Switzerland, the drivetests covered 18 big cities and 33 smaller towns, the walktests took place in eight cities. The test route in Switzerland was about 6,590 km long, equalling about 2.2 million inhabitants or approximately 26.1 percent of the population. For the definition of the test routes umlaut generates four independent plans, from which connect then randomly chooses one.

Voice telephony

Voice services were measured with the smartphones performing calls alternating between the measurement cars ("mobile to mobile"). The walktest teams



Professional and critical: Bernd Theiss, head of test and technology at connect (on the left), and Hakan Ekmen, CEO of umlaut (on the right).

called a stationary counterpart for all voice tests. In the assessment of call setup times we also rate the so-called P90 value. Such values specify the threshold in a statistical distribution, below which 90 percent of the gathered values are ranging. For speech quality, we publish the P10 value (10 percent of the values are lower than the specified threshold), because in this case higher values are better. Background data traffic was transmitted by one of the smartphones simultaneously in order to reflect a realistic usage scenario. As a new KPI in 2019, we also evaluate the so-called MultiRAB (Multi Radio Access Bearer) Connectivity. This value denominates whether data connectivity is available during the phone calls. Audio quality was assessed by using the HD-Voice capable POLQA wide band scoring. All devices were configured in "LTE preferred" mode.

Data connectivity

To assess cellular data performance, top websites (according to the Alexa ranking) were dynamically downloaded. Additionally a static website was tested, the industry standard ETSI (European Telecommunications Standards Institute) Kepler refer-

ence page. HTTP downloads and uploads were conducted with 5 MB and 2.5 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. Youtube measurements considered the "adaptive resolution" 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 as well as the videos' average resolution.

Crowdsourcing

The results of the crowdsourcing analysis performed by umlaut contribute 20 percent to the total score. For this purpose, in all three countries samples collected from mid-May until end of October 2019 were evaluated. For Germany, a total of 2.8 billion single measurement values from von 476,000 users was analyzed. This represents about 99.3 percent of the built-up area in urban surroundings and 91.5 percent of the rest of the country's built-up area. For Austria, umlaut considered approx. 902 million values from a total of 99,800 users – represent-



ing a 100 percent of the built-up area in cities and 92.1 percent of the built-up area outside of them. The figures for Switzerland: 41,400 users contributed 200 million samples. This covers a 100 percent of the built-up area in cities, and 88.4 percent outside of them.

The data base for these analysis 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 and upload data rates can be achieved – provided that the user has before agreed to this completely anonymous data collection. These values are gathered every 15 minutes and transmitted once a day to umlaut'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, umlaut 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, each tile must deliver a minimum number of users and measurement data. In our 2019 benchmark framework, we differentiate between a „Benchmark View" and an „Own Network View": For the Benchmark View, only those evaluation areas are considered for which we have

determined valid results for all operators who are considered in the benchmark. In the Own Network View an evaluation area will also be considered if there is none of the competitors present. Above that, we now distinguish urban and non-urban areas in our crowd evaluations – respecting that the coverage with mobile services is usually higher in urban than in rural areas.

Data Throughputs

For each "evaluation area" umlaut determines the maximum download and upload speeds reached by each participating user with 15 minutes time slices. Then, the maximum value of these slices with a 4 week grid is calculated, and of these eventually the P90 value (as explained earlier).

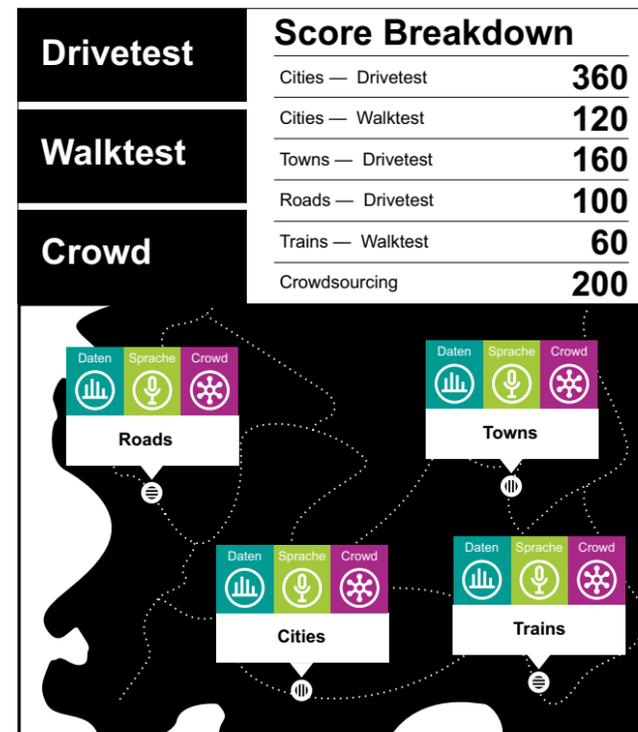
Network stability

Another aspect determined in the crowdsourcing are degra-



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

dations or anomalies in the (data) network connectivity. A sophisticated algorithm distinguishes simple loss of network coverage (such as in elevators, car parks or buildings with poor indoor reception) from actual degradations. Incidents that occur at night between 10 pm and 8 am are not considered. Points will be deducted for the number of days and the number of hours with recognized service degradations. A even more detailed description of our methods and the results for other countries can be found online at www.connect-testlab.com. >>



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.

Fairness and Transparency

The process of our mobile network test starts long before the actual execution of the measurements. In doing so, the longtime experience of connect and umlaut helps us to adequately look into even last-minute allegations.

■ To ensure fair and transparent testing, in recent years certain routines proved to be helpful. This includes connect and umlaut informing the operators at an early stage about the basic parameters of our tests.

Among other details, this so-called framework consists of the smartphones used for testing and the firmware installed on them, the KPIs gathered during the measurements and being considered in the evaluation, the basic scoring scheme and the exact timing. connect and umlaut defined these frame conditions for this year's mobile network test early in 2019 and subsequently informed the CTOs of the

operators about them. We are then open for feedback and suggestions, but critically check every single one and also have to reject many of them.

But the competitors also eye each other suspiciously. Thus, shortly before our editorial deadline, one operator confronted us with the allegation that a competitor had provided us with SIM cards which would assign their users a larger share of bandwidth than the most powerful tariff of the operator in question would normally allow for. We investigated this accusation – but controlling the terms and conditions of the affected tariff at first re-

mained inconclusive. However, the comparison of the borrowed test SIMs with a regularly bought one, which is part of our standard testing procedure, revealed that both SIMs operated identically – even in situations with heavy network utilisation. This implied the conclusion that there was no attempt of fraud, but that the suspect had not clearly communicated the respective contract conditions.

The fact that such discussions and disputes are fought very intensively and also until the last second, is once again proof that the operators take our methodology and also our results very seriously.

Conclusion

Hannes Rügheimer,
connect author



The fact that the rankings in all three tested countries did not change compared to the previous year, proves again the very high level that the competition of the operators takes place on.

Because in order to make sure that our network test stays the de-facto industry standard also in its 26th year, we regularly update or testing and evaluation methods to the advancing technological development. Part of this is that umlaut and connect raise our thresholds and requirements from year to year. If under these conditions really all operators manage to improve over their results from the previous year, as is was the case this time, we are particularly happy. For this proves that our demanding network test ultimately helps to improve the networks – to the

advantage of all customers.

In Germany, a strong Telekom gains the overall victory for the ninth time in a row. The Bonn company even managed to once again improve its scores in the voice discipline and in the crowdsourcing. Also Vodafone which ranks second improved its results. But definitely the greatest leap forward in Germany is achieved by Telefónica/O2. Overall good measurement results but also good marks in the crowdsourcing show that the Munich-based operator made notable headway in the last year in integrating the formerly separate networks of E-Plus and O2.

But the performance level which overall ranks below those from the two neighbouring countries and particularly the poor results of our measurement in the

trains make quite clear that there is still much to do for the German operators.

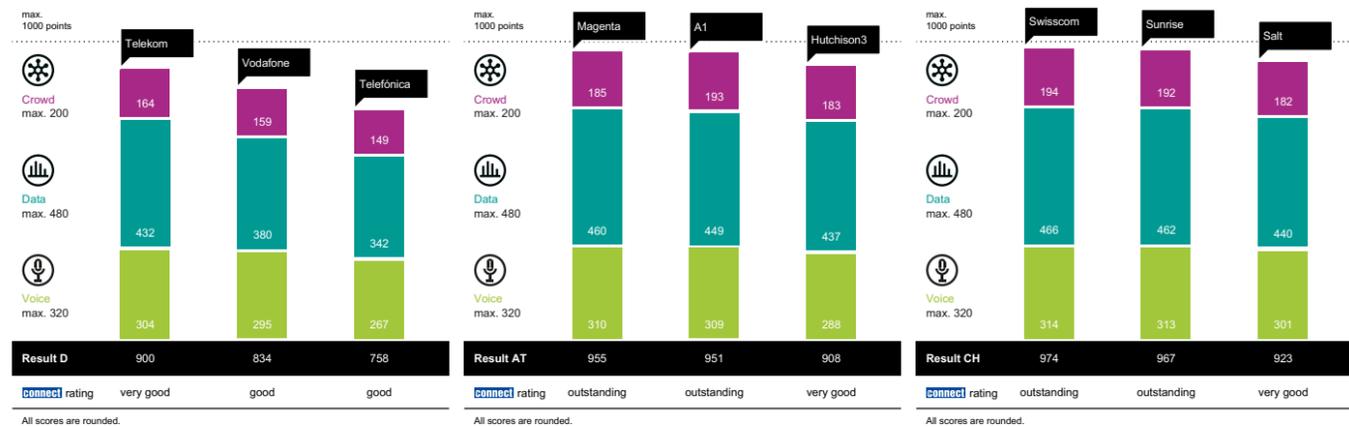
In Austria, Magenta (the former T-Mobile Austria) takes the overall win again this year – and gains the top grade “outstanding” for the first time. The effects of the very close run at the top are well felt by A1 Telekom – which also receives the grade “outstanding” but ranks second at a distance of only four points to the test winner. The smallest network operator in the Alp republic, Hutchison's brand Three, achieves the overall grade “very good” which still designates the most distinct improvement over the previous year among the Austrian providers.

On a still somewhat higher level the neck-and-neck race in Switzerland is fought. But there,

the result shows a somewhat larger distance. Swisscom defends its top position and gains the overall grade “outstanding”. Sunrise scores seven points behind but is also rated to be



“outstanding”. Salt, the smallest operator in Switzerland, achieves the grade “very good” – but can be pleased about achieving the highest growth in points over the previous year.



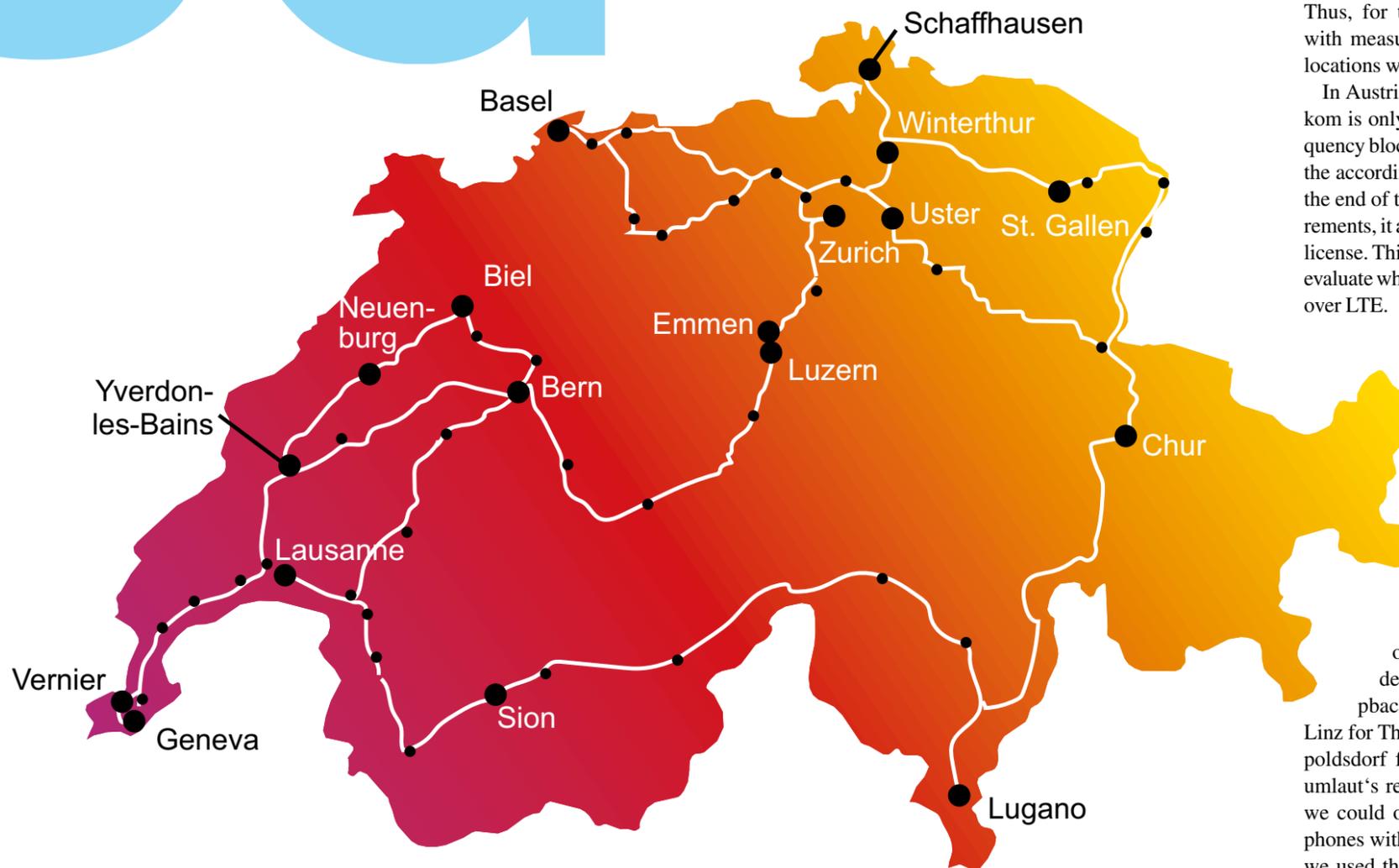
			GERMANY			AUSTRIA			SWITZERLAND		
Overall Results Voice, Data & Crowd			Telekom	Vodafone	Telefónica	Magenta	A1	Hutchison3	Swisscom	Sunrise	Salt
Voice	max. 320 points		304	295	267	310	309	288	314	313	301
Cities	Drivetest	144	95%	93%	89%	99%	99%	95%	98%	98%	95%
Cities	Walktest	48	97%	96%	94%	97%	98%	96%	100%	100%	98%
Towns	Drivetest	64	97%	92%	82%	95%	98%	90%	98%	100%	92%
Roads	Drivetest	40	98%	92%	73%	98%	96%	91%	99%	96%	91%
Trains	Walktest	24	80%	80%	50%	86%	77%	50%	96%	92%	89%
Data	max. 480 points		432	380	342	460	449	437	466	462	440
Cities	Drivetest	216	94%	82%	77%	98%	96%	95%	97%	97%	93%
Cities	Walktest	72	93%	88%	81%	95%	95%	88%	96%	98%	91%
Towns	Drivetest	96	90%	75%	64%	97%	94%	94%	98%	96%	90%
Roads	Drivetest	60	92%	82%	69%	97%	97%	95%	99%	97%	95%
Trains	Walktest	36	60%	48%	39%	80%	68%	59%	92%	88%	80%
Crowd	max. 200 points		164	159	149	185	193	183	194	192	182
Country	60	97%	90%	93%	88%	100%	97%	100%	100%	100%	
Urban	84	71%	71%	69%	95%	94%	93%	94%	95%	84%	
Non-urban (Benchmark View)	44	84%	81%	62%	93%	96%	85%	99%	95%	93%	
Non-urban (Own Network View)	12	81%	79%	59%	90%	93%	83%	96%	94%	92%	
Total	max. 1000 points		900	834	758	955	951	908	974	967	923
connect rating			very good	good	good	outstanding	outstanding	very good	outstanding	outstanding	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.

EARLY MEASUREMENTS

Many operators talk loudly about their 5G network upgrades. Still, the new standard is not yet completely ready for our network test. However, umlaut conducted measurements for connect which reveal what the fifth generation of mobile communications can already offer today.



getting a first impression about what 5G is able to offer under the conditions of our network testing. But as the many tens of thousands of network cells in Germany only include a few hundred which are already supporting 5G, umlaut's drivetest cars would have only gathered a very small share of 5G measurements. Thus, for the moment we settled with measurements at a few fixed locations which already offer 5G.

In Austria, the operator A1 Telekom is only allowed to use the frequency blocks which it purchased in the according auction starting from the end of this year. For our measurements, it activated a site with a test license. This allowed us to precisely evaluate which advantages 5G offers over LTE.

The Measurements

So, Austria only allowed for a limited view, as 5G was not yet commercially available in all networks. As the result of consultations with the operators, we had to consider further peculiarities on top of visiting the pre-determined locations in Alpbach for A1 Telekom, in Linz for Three and in Klausen Leopoldsdorf for Magenta. Instead of umlaut's regular benchmark setup, we could only use specific smartphones with speedtest apps. For A1 we used the Samsung S10 5G, for Magenta the Huawei Mate 20X 5G and for Three the ZTE Axon 10 Pro 5G as their preferred devices. In the measurements, 5G convinced with download data rates between 500 and 1100 Mbps. On average, this is five times faster than the smartphones which we used for comparative 4G measurements – and also particularly faster than what can be commonly expected in the fixed-line network.

Switzerland	Sunrise		Swisscom	
Number of Measurements				
5G	778		69	
Mixed	372		965	
4G	15028		14970	
Percentage 5G only	4,80%		0,43%	
Percentage including 5G	7,10%		6,50%	
	5G	4G	5G	4G
Download				
Reliability	100,0%	99,9%	100,0%	100,0%
Average Throughput (Mbps)	405	86	219	107
90%/10% faster than (Mbps)	226/571	23,2/166	144/253	27,5/204
Session Time (s)	0,4	1,1	0,5	0,9
Upload				
Reliability	98,4%	99,8%	100,0%	99,8%
Average Throughput (Mbps)	51,3	33,6	30,6	46,3
90%/10% faster than (Mbps)	22,6/83,1	8,6/56,8	11,5/61,9	21,0/61,5
Session Time (s)	0,7	1,2	1,5	0,7
Website Access				
First 500 kilobits (s)	0,53	0,67	0,51	0,63

Even considering that the resources of an LTE network are distributed over more users, this is a significant speed advantage for 5G.

In Germany, the network test experts of umlaut could already dig a little deeper. With a measurement car retrofitted with Samsung S10 5G, a drivetest team visited three suggested municipalities per operator. For Telekom they were located in Berlin, Cologne and Darmstadt, while Vodafone recommended places in Ratingen, Düsseldorf and Offenbach/Main. Telefónica is obviously dedicated to optimize its LTE network and did not yet take part in the 5G comparison.

In the average of all throughput measurements, 5G showed more than three times the speed of LTE – again a remarkable performance boost. However, the advance shrank when we compared the maximum throughput rates. Here, the newest generation of mobile communications reached 695 Mbps – which is not quite as far ahead of LTE. The latter partially owes its good result of 401 Mbps to the very effective so-called carrier aggregation – the bundling of more than one frequency bands. This works well especially in not too crowded network cells.

An interesting observation is that the new mobile communication standard lags a little behind LTE when it comes to uploads. One of the reasons is that in the current implementation, non-standalone 5G always requires a 4G connection which controls the 5G data transfers. Currently, according to a Telekom specialist, only the downloads actually make use of 5G. Uploads are still executed via 4G, but with additional protocol overhead. When 5G will also support uploads – and even more with „stand-alone 5G“ which does not require a 4G link any more, the speeds of data uploads are definitely bound to change.

In Switzerland which currently precedes Europe in terms of mobile communications, we went all the way. Simultaneously to our network test, we sent an additional drivetest car carrying Samsung Galaxy S10 5G on the way. It drove the same

Germany*	5G	4G
Download		
Average Throughput (Mbps)	516	164
Maximum Throughput (Mbps)	695	401
Upload		
Average Throughput (Mbps)	49,2	58
Maximum Throughput (Mbps)	61,2	86,8

*Telekom and Vodafone, average results from locations suggested by the operators

Wherever we look, we see 5G in the starting blocks. Our longtime network testing partner umlaut and we are also ready to evaluate the 5G network extensions with according measurements. The devices needed for this are available – as well as the necessary knowledge. However, 5G implementations stand only at their very begin-

ning in Austria and Germany, whereas in Switzerland one operator – Sunrise – has already started a large-scale 5G rollout.

But the implementation of the still young mobile communications standard is accompanied by dependencies and problems. It is not a given that the young networks' functions are fully compatible with all new smartphones. And not every

tuning approach in the networks is met by a mobile phone available on the market which supports this exact feature. Therefore, the early rollouts can not yet be fully evaluated. Consequently, we have excluded it from the setup of this year's network test.

But as Vodafone and Telekom assiduously build 5G network cells and gather their first experiences with them, we were also keen on

Generational Conflict

Each time a new mobile communications standard is introduced, this is also a wake-up call for the opponents of this technology. This is true again for the fifth generation, which stirs up the debate due to its new properties – a debate which was believed to be already resolved.

■ Among the arguments which opponents of mobile communication invoke against 5G, are the growing numbers of radio cells, the use of higher frequencies and the so called „beam forming“ – which means directing the radio signals straight onto the users.

However, critics often ignore that radio exposure is actually reduced with a growing number of network cells. The reason is that the intensity of a radio signal rapidly decreases with growing distances. In order to compensate for this, the transmitter has to tune up its power the farther it is positioned from the receiver.

In order to save battery power and energy in the base station, the transmitter and the smartphone both reduce their transmission power for each connection as far as possible. The closer they are together, the less power they use for the transmis-

sion. Therefore, a tighter network of base stations actually leads to lower radio exposures – both for the user caused by his smartphone as well as for bystanders caused by the radio cells.

The higher frequencies of millimeter waves are currently beside the point, because the first 5G implementations start in the sub 6 GHz spectrum, in Germany at around 3.6 GHz. These frequencies are part of the well-tried range between 2.6 GHz for LTE and 5 GHz for WiFi. Concerning millimeter waves, research was intensified. But it is evident already that higher frequencies penetrate human tissue less deeply. Thus, for example the human brain is better shielded against millimeter waves.

It is understandable that beamforming – the focusing of signals to the recipient – can be viewed as a threat. But here



again the output level is reduced so largely that only the necessary minimum reaches the receiver. The maximum radio exposition of a single user stays about the same. And bystanders are exposed at a much lower level reaching down to practically nothing, when they are situated outside the directed beam.

Even after almost 20 years in which more than 50 percent of the population in Europa have used mobile phones, the accurately recorded official cancer registers show no evidence of rising cancer figures due to mobile communications. This should give even the critics something to think about.

routes as our official network test cars. In doing so, the distance between the 5G and the 4G measurement cars was always wide enough to make sure that one car would not affect the transmissions of the other. Thus, the measurements in the 5G model country were executed according to connect's network test standards. In this context, Swisscom claims to have commercially launched 5G in eight cities on April 17th, 2019. Sunrise specified that it already reached 152 cities with 5G by March 30th, 2019.

Of all the measurements, in the Sunrise network already 4.8 percent were completely conducted in the 5G network. For Swisscom the number was substantially lower with a share of 0.43 percent. When taking into account those measurements that contain a partial share of 5G, the percentages came closer together with 7.1% over 6.5%. The lead of Sunrise is all the more surprising as

this operator focuses its 5G implementation to smaller cities and even villages as a fixed-line substitution – while the network test has a larger share in the more densely populated urban areas in order to represent a sufficient share of the total population. In any case, the determined data rates are remarkable, particularly regarding the expectable minimum download speeds (90 percent faster than). In this KPI, Sunrise shows a speed increase by a factor of 10. And even in the slowest it is still 10 percent faster than the maximum speed of many DSL lines in Germany. The minimum speed in the Swisscom network is also faster by a factor of 5, although it already marks the top at 4G within the test area of Germany, Austria and Switzerland. Sunrise also shows an increase in the upload data rates with a minimally reduced 5G reliability in comparison to LTE. In the Swisscom network, we observe the same slowdown as in Germany.

This is only an intermediate result of the 5G implementations in Switzerland which were recently somewhat slowed down due to the flare-up of protests by opponents of mobile communication (see box above). But now it gains momentum again, especially as Swisscom plans to re-allocate parts of the LTE spectrum for 5G on demand via Dynamic Spectrum Sharing (DSS) by the end of the year. Provided that DSS capable phones are soon available, this way a 5G coverage of all of Switzerland could become possible quickly. Sunrise also observes this technology, but currently upgrades its network the conventional way. At the time of writing, it was claimed to cover 331 municipalities – and counting.

And this is good, as unlaut and connect plan to re-visit Switzerland soon again in order to measure a complete 5G network. As for Germany, we are keenly observing the development. **Hakan Ekmen, Bernd Theiss**