



THE 2021 MOBILE NETWORK TEST IN THE NETHERLANDS



For the sixth time, the benchmarking expert umlaut and connect magazine have conducted their authoritative benchmark of the mobile networks in the Netherlands. Once again, we seized the opportunity to further enhance the underlying methodology.

In a marketplace characterised by very strong performances, the competition takes place on a high level. With the arrival of 5G and their ongoing expansion of 4G networks, how do the three Dutch operators perform this time?



KEY FINDINGS

For the fifth time in a row, T-Mobile wins the umlaut connect Mobile Benchmark in the Netherlands and also achieves the highest score determined by umlaut worldwide in 2020. With the grade “outstanding”, the same as the test winner, KPN ranks second and achieves connect’s 5G Innovation Award. Vodafone ranks third with the grade “very good”.

umlaut’s network benchmarks are widely accepted as the de-facto industry standard and for being highly objective. The carefully designed methodology of our 2021 benchmark in the Netherlands reflects umlaut’s holistic approach to network benchmarking. Its benchmarks combine drivetests and walktests to execute detailed voice and data measurements under controlled circumstances with a sophisticated crowdsourcing approach. This provides profound insights into the overall coverage of voice and data (with focus on 4G and 5G) services, real-world User Download Speeds and the Quality of Broadband Service. The drivetests and walktests allow for evaluating the maximum of the networks’ capabilities. Crowdsourcing reveals the service quality and performance actually experienced by real users. We have thoroughly weighted these components in order to give a realistic and authoritative assessment of the rated networks’ true potential and performance.

Even in the time of the Corona pandemic, our analyses showed that the networks remained stable, though with somewhat altered customer usage patterns. When conducting this year’s benchmark, we have of course carefully adapted the logistics to ensure maximum safety for our team members.

T-MOBILE IS THE OVERALL WINNER, KPN FOLLOWS AT A DISTANCE OF EIGHT POINTS, BOTH ARE “OUTSTANDING”

T-Mobile managed to continue its winning streak, scoring best in the umlaut connect Mobile Benchmark in the Netherlands for the fifth time in a row and also achieving the highest score determined by umlaut worldwide in 2020. The win is achieved by a lead over KPN in the Crowdsourcing category, also T-Mobile scores best among all three competitors in the Voice category. KPN achieves the best results in the Data category and the second best in Voice, but falls a little behind in the Crowdsourcing score. Vodafone ranks third both in Voice and Data, but achieved the strongest Crowdsourcing results, scoring one point more than the overall winner T-Mobile.

In comparison to the results of the 2019 umlaut connect Mobile Benchmark in the Netherlands, which was published in spring 2019, all three operators have lost some points. This is not uncommon especially in countries with a very high performance level, as we continually raise the thresholds of our scoring in order to keep track with the technological advancement. Also, the Crowdsourcing methodology was significantly updated, which makes the results in this discipline not 1:1 comparable to those of our previous benchmark.



T-Mobile is the overall winner, with KPN following at a distance of eight points. T-Mobile leads in Voice, KPN in Data. Both operators achieve the grade “outstanding”. Vodafone follows on third place, scoring 9 points behind KPN and closely leading the field in the crowdsourcing category.



Overall Results		T-Mobile	KPN	Vodafone
Voice	max. 320 P.	317	314	312
Cities (Drivetest)	144	99%	98%	98%
Cities (Walktest)	48	100%	99%	98%
Towns (Drivetest)	64	99%	99%	99%
Roads (Drivetest)	40	97%	97%	95%
Railways (Walktest)	24	97%	94%	95%
Data	max. 480 P.	458	461	445
Cities (Drivetest)	216	96%	97%	93%
Cities (Walktest)	72	96%	97%	95%
Towns (Drivetest)	96	96%	96%	92%
Roads (Drivetest)	60	97%	97%	94%
Railways (Walktest)	36	88%	91%	87%
Crowdsourced Quality	max. 200P.	187	179	188
Crowd	200	94%	89%	94%
Connect Rating	max. 1000 P.	962	954	945

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

THE DUTCH OPERATORS

Traditionally, the mobile operators in the Netherlands compete on the highest performance level. The most recent mergers and acquisitions resulted in a noticeable change of market shares. According to the customer numbers published by the operators, T-Mobile is now the largest Dutch mobile operator, sending KPN and Vodafone to second and third place in terms of customer base.



In 2000, Deutsche Telekom bought a minority of the Dutch mobile network operator Ben, which was later extended to a 100 per cent acquisition. In 2003, Ben was renamed T-Mobile Netherlands, with the brand “Ben” becoming a “no-frills” offer within its portfolio. In 2007, T-Mobile NL additionally acquired Orange. At the end of 2018, the company completed its acquisition of the smallest Dutch mobile operator, Tele2. By now, also the technical infrastructure of the formerly separate carriers has been merged, with Telekom holding 75 per cent and Tele2 holding 25 per cent of the assets. At the end of its fiscal year 2019, T-Mobile Netherlands reported a revenue of 1.9 billion Euros and 5.6 million mobile subscribers. In late 2020, the company continued its series of acquisitions by absorbing the former MVNO Simpel, increasing its mobile customers to 6.7 million, making T-Mobile the largest Dutch mobile operator. T-Mobile’s network offers 2G mostly at 900 MHz, 3G at 2100 MHz and 4G/LTE at 800, 900, 1800, 2100 and 2600 MHz. Its 4G network supports both VoLTE as well as “4G+” (carrier aggregation) up to 1 Gbps. T-Mobile launched 5G soon after the end of the spectrum auction in July 2020. At the end of October 2020, T-Mobile claimed that 90 per cent of the Dutch population lived within its 5G coverage area.



The Koninklijke PTT Nederland N.V. emerged from the privatisation of the formerly state-owned PTT in 1998. For its fiscal year 2019, the company reported a total revenue of 5.5 billion Euros as well as 6.5 million mobile customers. In addition, KPN reports 3.3 million fixed broadband and 2.2 million interactive TV customers. The company focuses on marketing its KPN brand, however with Simyo, Telfort and Ortel it also has offerings in the “no-frills” segment. KPN operates 2G/GSM at 900, 3G/UMTS at 900 and 2100 MHz and 4G/LTE at 800, 1400, 1800, 2100 and 2600 MHz. 3G is scheduled to be phased out by the end of 2021. 4G is operated with VoLTE as a standard as well as with “carrier aggregation”, which enables theoretical download speeds of up to 1 Gbps. KPN launched 5G at the end of July 2020, starting in most of the so-called Randstad area (Amsterdam, Rotterdam, The Hague and Utrecht) as well as Eindhoven, reaching about half of the Dutch population. The operator strives to reach nationwide 5G coverage in 2021.



The Dutch subsidiary of the international Vodafone Group acquired the operator Libertel in 2003, forming Vodafone Netherlands. In 2016, it merged with the cable and fibre operator Ziggo. Today, 50 per cent of the joint company VodafoneZiggo is owned by the Vodafone Group and another 50 per cent by Liberty Global. Currently, VodafoneZiggo is the smallest mobile operator in the Netherlands, reporting about 5.1 million mobile customers. The company also specifies 3.9 million fixed (broadband, video and telephony) subscribers. For its financial year 2019, VodafoneZiggo announced a turnover of 3.9 bn Euros, of which 1.4 bn were gained in its mobile business. The company operates 2G networks at 900 and 1800 MHz, 3G at 2100 MHz and 4G/LTE at 800, 1800, 2100 and 2600 MHz. It was the first Dutch operator to phase out 3G in order to devote its spectrum to 4G and 5G. VoLTE is supported all over its 4G network, and with “4G+” the operator offers carrier aggregation up to 1 Gbps. Already at the end of April 2020, VodafoneZiggo was the first carrier to offer 5G all over the Netherlands, starting on already available frequencies and later extending the service to spectrum acquired in the frequency auction which had ended in July 2020. In late 2020, VodafoneZiggo claimed to already reach 80 per cent of the Dutch population, aiming at reaching national coverage soon.

The network benchmarks conducted by umlaut and connect are widely accepted as a completely objective authority. Shortly before the beginning of 2021, we present the umlaut connect Mobile Benchmark in the Netherlands for the sixth time, with a further enhanced methodology.

A CLOSE LOOK AT THE DUTCH NETWORKS

umlaut, based in Aachen, Germany, is a world leader in mobile network testing. The company was formerly known as P3 and changed its name in fall 2019 in the course of restructuring and refocusing its activities. umlaut has over 4,500 employees, distributed over about 50 locations all over the world, and a turnover of more than 400 million Euros.

umlaut is partnering with the international telecommunications magazine connect, which has more than 25 years of editorial expertise and is one of the leading test authorities in Europe for telecommunications products and services. Together, umlaut and connect have been conducting the most important network benchmark test in Germany

for more than 15 years, extending it to other European countries since 2009. As the de-facto industry standard, umlaut's benchmarking methodology focuses on customer-perceived network quality.

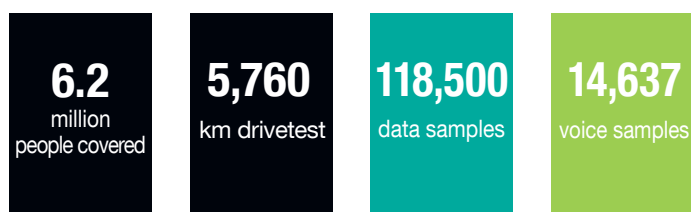
Conducting the 2021 umlaut connect Mobile Benchmark in the Netherlands was certainly challenging in the light of the Corona pandemic. But the drivetest and walktest teams managed to realize all planned measurements in November 2020, covering a total of 5,760 km and approx. 36.3 per cent of the Dutch population. In addition, the score includes the results of extensive crowdsourcing analyses considering 24 weeks from late May to early November, 2020.



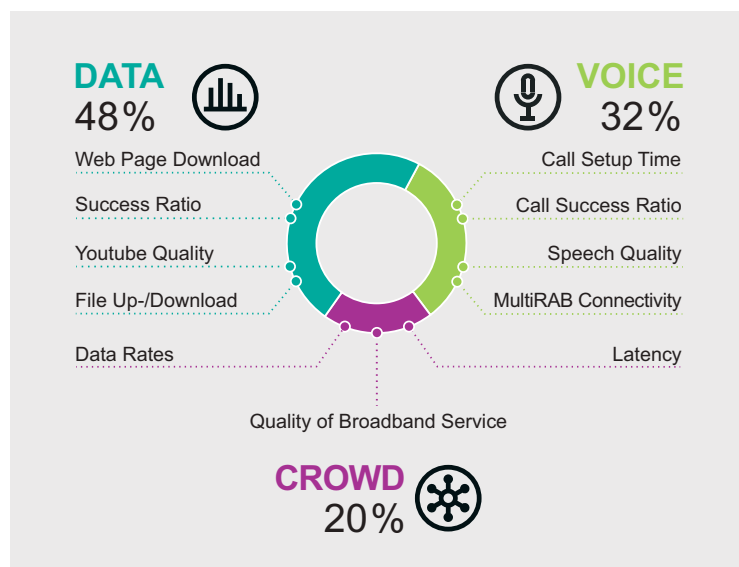
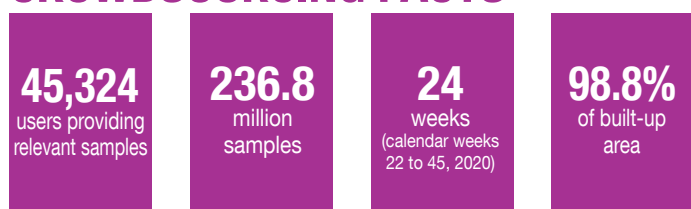
Congratulations to the Netherlands and T-Mobile being "best in test" for the fifth time in a row in our umlaut connect Mobile Benchmark. Again, all operators are showing excellent performances of their networks. On top, we already see a very good 5G coverage and performance in the Netherlands.

Hakan Ekmen, CEO
Telecommunication at umlaut

DRIVETEST AND WALKTEST FACTS



CROWDSOURCING FACTS



VOICE

Although smartphones offer many means of communication, voice telephony is still important. When actually taking or placing a phone call, customers expect reliable connections. How do the Dutch networks fulfil these expectations?

All of the operators in the Netherlands have been supporting Voice over LTE (VoLTE) for years now, making it the standard mode for the transmission of voice calls in all three networks. VoLTE transmits voice calls as data packets over a 4G connection. This way, the otherwise necessary "circuit-switched fallback", which forces smartphones to switch back to 3G or 2G in order to take or place a phone call, can be avoided. Furthermore, VoLTE codecs potentially support a wider audio bandwidth. Another advantage of realising voice connections via LTE is that VoLTE typically reduces call setup times.

For the Voice rating, each drive test car and each walk test team carried one Samsung Galaxy S10 smartphone per operator. The phones in the cars called a counterpart in one of the other cars. The phones carried by the walk test teams in the cities called a stationary smartphone as a counterpart. In order to simulate normal smartphone usage, additional data transfers took place in the background of the test calls. In addition, we also evaluate the so-called Multirab (Multi Radio Access Bearer) connectivity. This value denominates whether data connectivity is available during the phone calls. The Voice scores account for 32 per cent of the total result.

**T-MOBILE
SHOWS THE
BEST VOICE
RESULTS,
KPN RANKS
SECOND, AND
VODAFONE
ZIGGO THIRD
– BUT ALL
OF THEM
QUITE CLOSE
TOGETHER.**

Voice

320 of 1000 Points

T-Mobile
KPN
Vodafone

CITIES DRIVETEST

T-MOBILE

NECK AND NECK RACE IN VOICE DRIVETESTS IN THE CITIES: T-MOBILE AHEAD, KPN AND VODAFONE FOLLOWING AT CLOSE DISTANCE

In the voice measurements conducted during the drivetests in 22 big Dutch cities, all three operators give each other a neck and neck race. T-Mobile leads in this scenario by a very close margin of just one percentage point, offering a call success ratio of 100 per cent and the shortest call setup times. The other two operators follow at close distance with also very good results. All three operators also achieve a very good speech quality, using predominantly the high-quality EVS codec.



CITIES WALKTEST

T-MOBILE

T-MOBILE ALSO AHEAD IN WALKTEST VOICE RESULTS WITH KPN AND VODAFONE EACH FOLLOWING AT CLOSE DISTANCE

Basically the same results as in the city drivetests can also be seen in the voice results of the walktests conducted in seven Dutch urban areas. In this scenario, T-Mobile even scores the full amount of possible points, with the two other contenders following at arm's length and a gap of only one percentage point each.



TOWNS DRIVETEST

ALL
OPERATORS

TIE IN VOICE DRIVETESTS CONDUCTED IN TOWNS: ALL THREE DUTCH OPERATORS EQUALLY STRONG IN THIS SCENARIO

In the drivetests conducted in 19 smaller Dutch towns, all three operators scored on par, achieving a fulfilment ratio of 99 per cent. They all delivered a 100 per cent call success ratio and a 100 per cent MultiRAB connectivity in this scenario, as well as very short call setup times and a high level of speech quality. Inhabitants of Dutch towns can be very happy about the quality of mobile telephony available in these places.

ROADS DRIVETEST

T-MOBILE
& KPN

STRONG RESULTS ON DUTCH ROADS, T-MOBILE AND KPN ON PAR, VODAFONE FOLLOWING AT CLOSE DISTANCE

The tendencies seen in the smaller town are also somewhat reflected in the voice measurements performed during the drivetests on 3000 km of connecting roads in the Netherlands. All three operators achieve convincing results in this scenario, with T-Mobile and KPN on par in the sub score determined for this category. Vodafone is also close behind at a gap of only two percentage points. The success ratios of calls are still at 99 per cent or above, also call setup times and speech quality are still very high.

TRAINS WALKTEST

T-MOBILE

T-MOBILE AHEAD IN VOICE TESTS ON TRAINS. VODAFONE ACHIEVES SECOND PLACE IN THIS SCENARIO

Providing voice connectivity for passengers travelling on trains is particularly demanding. Still, even in this scenario, the Dutch operators achieve very high success ratios, short setup times and a very good speech quality. T-Mobile is once again ahead in this category, but here Vodafone rises to second place by offering slightly better call success ratios and MultiRAB connectivity than an also very strong KPN. In comparison to other European countries, including Switzerland which scores also very strong in this area, the Dutch operators perform astonishingly well in the difficult railway scenario.



VOICE RESULTS AT A GLANCE

In the overall assessment, T-Mobile is ahead in the Voice category, followed by the also very strong KPN and Vodafone. VoLTE has been measured for all Dutch operators. All three of them offer excellent call reliability in urban areas and smaller towns. Even on roads and on railways, the call reliability is near to 99 per cent or above. T-Mobile does not show any failed calls in the city drivetests and walktests as well as in towns and also achieves the fastest call setup times in all scenarios.

Operator	T-Mobile	KPN	Vodafone
Voice Cities (Drivetest)			
Call Success Ratio (%)	100.0	99.8	99.8
Call Setup Time Ø (s) / P90 (s)	0.6/0.7	0.8/1.3	1.2/1.3
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.1	4.5/4.0	4.4/3.9
MultiRAB Connectivity (%)	99.8	99.9	99.8
Voice Cities (Walktest)			
Call Success Ratio (%)	100.0	99.9	99.8
Call Setup Time Ø (s) / P90 (s)	0.6/0.7	0.8/0.9	1.3/1.5
Speech Quality Ø / P10 (MOS-LQO)	4.6/4.2	4.6/4.2	4.6/4.1
MultiRAB Connectivity (%)	99.9	99.9	99.9
Voice Towns (Drivetest)			
Call Success Ratio (%)	100.0	100.0	100.0
Call Setup Time Ø (s) / P90 (s)	0.6/0.7	1.0/1.5	1.2/1.4
Speech Quality Ø / P10 (MOS-LQO)	4.6/4.2	4.5/4.0	4.5/3.9
MultiRAB Connectivity (%)	100.0	100.0	100.0
Voice Roads (Drivetest)			
Call Success Ratio (%)	99.4	99.6	99.0
Call Setup Time Ø (s) / P90 (s)	0.7/0.7	1.1/1.6	1.3/1.6
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.0	4.4/3.8	4.4/3.7
MultiRAB Connectivity (%)	100.0	100.0	99.7
Voice Trains (Walktest)			
Call Success Ratio (%)	99.3	98.8	98.9
Call Setup Time Ø (s) / P90 (s)	0.7/0.8	1.1/1.4	1.4/1.7
Speech Quality Ø / P10 (MOS-LQO)	4.5/4.0	4.4/3.7	4.5/3.9
MultiRAB Connectivity (%)	99.5	99.3	99.6



DATA

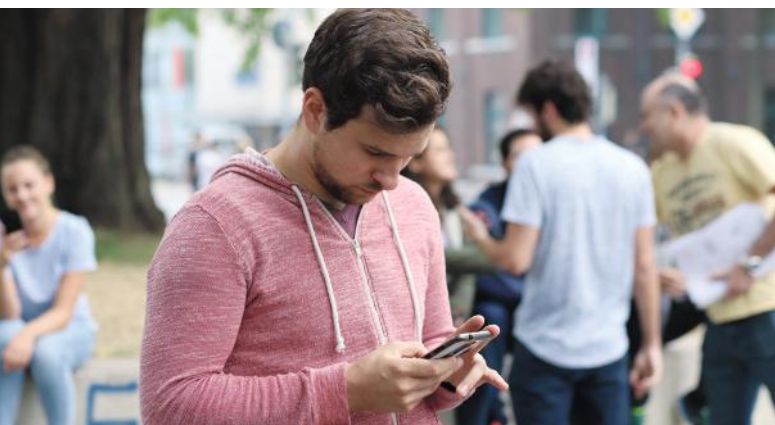
With the volume of transmitted data permanently growing, data connectivity constantly becomes more important. Which operator in the Netherlands manages best to meet the increasing demand?

For a couple of years, the Dutch operators have equipped their 4G networks to offer the combination of four or even five LTE carriers in different frequency bands. This “carrier aggregation” is the technical basis for the so-called “4G+” services which theoretically support data rates up to 1 Gbps. Above that, all three operators in the Netherlands are continuing to spend large sums on upgrading and expanding their networks to meet the growing demand – including a considerable speed and momentum in rolling out 5G.

We have honoured these advancements by fully integrating 5G measurements into our methodology framework: In each of the test cars four smartphones were used for the data measurements – one per operator. In the first car, Galaxy S10 smartphones were used, set to 4G preferred mode. This device and setting can make full use of up to 5 carrier aggregation (5CA). In the second car as well as in the backpacks of the walktest teams, one Galaxy S20+ per operator was used, set to 5G preferred mode and thus enabling 5G connectivity wherever possible.

In order to optimally support these demanding technologies, the operators rather frequently update the firmware especially of 5G capable smartphones such as the Samsung S20+ used in our testing. In order to ensure a stable data gathering during our drivetests and walktests, we set a deadline after which such firmware updates can no longer be applied to the test devices. However, given the novelty of 5G and in order to support the operators in delivering the best performance their networks are capable of, in this year we accepted also later updates – an option, which was gladly used by KPN and T-Mobile.

With these up-to-date devices, the test teams then successfully completed their drivetests and walktests, supporting 5G and the implemented network technologies in the best possible way.

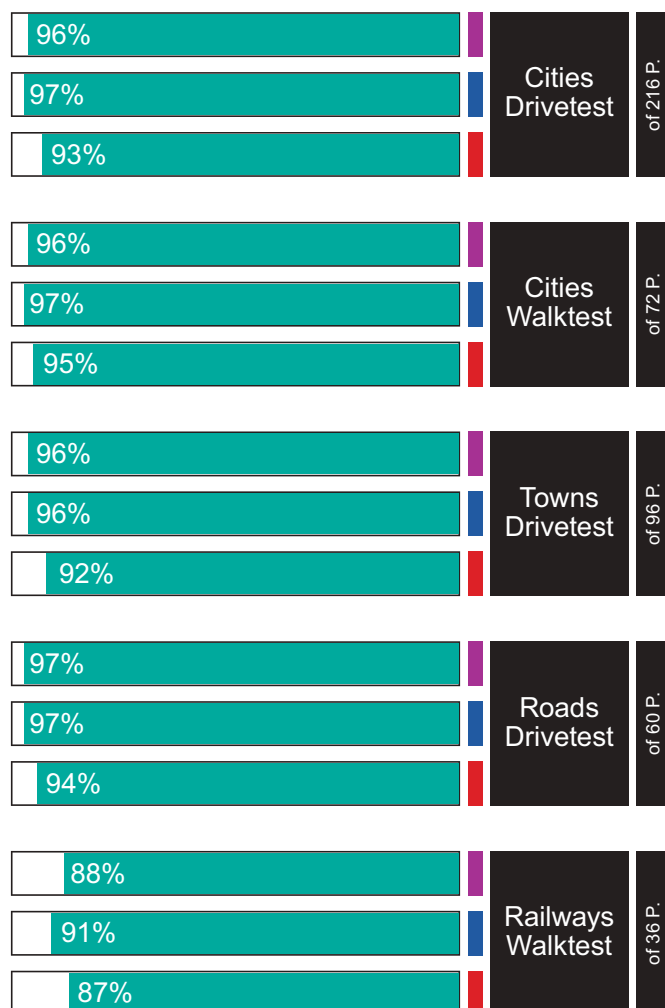


KPN TAKES THE WIN IN THE DATA DISCIPLINE, FOLLOWED BY T-MOBILE AT A CLOSE GAP OF THREE POINTS. VODAFONE SCORES THIRD IN DATA AT A LITTLE MORE PRONOUNCED DISTANCE.

Data

480 of 1000 Points

■ T-Mobile
■ KPN
■ Vodafone



CITIES DRIVETEST

KPN

KPN LEADS IN LARGE CITY DATA DRIVETESTS, WITH T-MOBILE FOLLOWING AT NARROW DISTANCE

The results of our data measurements conducted during the drive tests in 22 larger Dutch cities (also see page 1) determine a narrow lead of KPN in this category. KPN shows the highest share of LTE with 4CA (4 carrier aggregation) as well as with 5G New Radio (NR), resulting in the highest average Data rates in the Download and also in the Upload tests. T-Mobile showed a significant share of LTE with 4CA in the 4G device as well as 5G NR with 3CA. Especially in the Upload tests, T-Mobile achieved results on a similar level than category champion KPN. However, KPN and Vodafone show Youtube success ratios of a convincing 100 per cent, with T-Mobile following at a very close distance.

CITIES WALKTEST

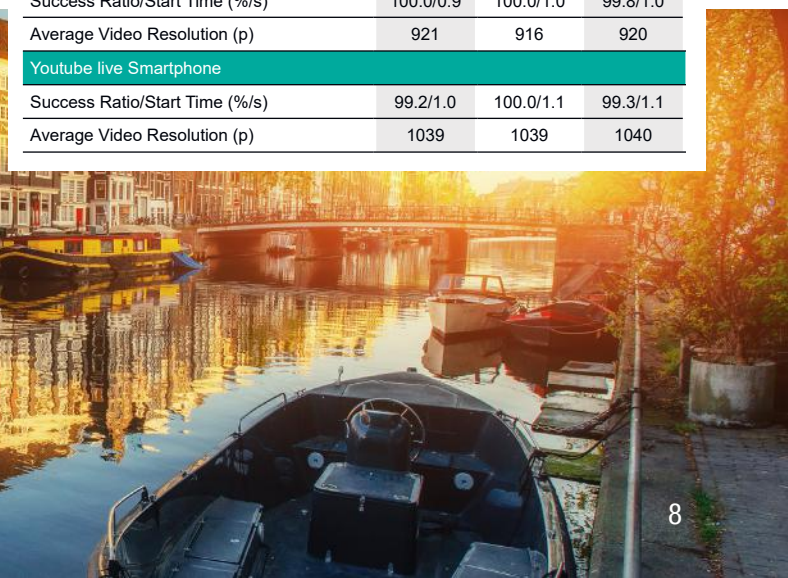
KPN

KPN TAKES A NARROW LEAD IN THE CITY DATA WALKTESTS, T-MOBILE AND VODAFONE FOLLOW CLOSELY

In the results of the walktests conducted in Amsterdam, Den Haag, Dordrecht, Eindhoven, Leiden, Rotterdam and Utrecht, KPN again manages to claim a narrow lead ahead of T-Mobile and Vodafone. Still, this is a neck-and-neck race: all contenders are only one percentage point apart of each other. Again, KPN wins this scenario by offering slightly higher data rates than the competition both in the Download as well as the Upload tests and also achieving success ratios of 100 per cent in the Youtube tests.

Data Cities (Drivetest)	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	99.9	99.9	99.9
Overall Session Time (s)	0.8	0.9	0.9
File Download (5 MB)			
Success Ratio/Avg. Session Time (%/s)	99.9/1.1	99.9/1.1	99.7/1.5
90%/10% faster than (Mbit/s)	29.2/113.2	34.8/93.7	15.2/99.2
File Upload (2.5 MB)			
Success Ratio/Avg. Session Time (%/s)	99.9/1.1	99.9/1.0	100.0/1.4
90%/10% faster than (Mbit/s)	12.4/42.1	18.5/47.5	10.0/32.6
File Download (7 Seconds)			
Success Ratio (%)	99.9	99.9	99.9
Avg. Throughput (Mbit/s)	123.7	146.7	95.1
90%/10% faster than (Mbit/s)	43.5/221.5	53.8/261.4	25.5/181.9
File Upload (7 Seconds)			
Success Ratio (%)	99.7	99.8	99.8
Avg. Throughput (Mbit/s)	53.2	51.1	27.1
90%/10% faster than (Mbit/s)	18.9/83.9	21.7/88.6	11.3/54.6
Youtube Video			
Success Ratio/Start Time (%/s)	99.6/0.9	100.0/1.0	100.0/1.0
Average Video Resolution (p)	921	920	920
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	99.9/0.9	100.0/1.0	100.0/1.0
Average Video Resolution (p)	1039	1037	1038

Data Cities (Walktest)	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	99.9	99.9	99.8
Overall Session Time (s)	0.8	1.0	0.9
File Download (5 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/1.1	99.8/1.1	99.8/1.2
90%/10% faster than (Mbit/s)	32.9/114.3	34.0/75.5	28.0/107.8
File Upload (2.5 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/1.2	100.0/0.8	100.0/1.2
90%/10% faster than (Mbit/s)	13.7/39.4	24.2/51.0	11.9/40.6
File Download (7 Seconds)			
Success Ratio (%)	100.0	99.8	99.6
Avg. Throughput (Mbit/s)	121.2	164.5	130.1
90%/10% faster than (Mbit/s)	47.3/219.3	49.2/299.6	42.9/229.6
File Upload (7 Seconds)			
Success Ratio (%)	99.5	99.8	99.8
Avg. Throughput (Mbit/s)	58.6	69.6	41.0
90%/10% faster than (Mbit/s)	23.4/89.6	34.2/95.5	13.2/68.1
Youtube Video			
Success Ratio/Start Time (%/s)	100.0/0.9	100.0/1.0	99.8/1.0
Average Video Resolution (p)	921	916	920
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	99.2/1.0	100.0/1.1	99.3/1.1
Average Video Resolution (p)	1039	1039	1040



TOWNS DRIVETEST

T-MOBILE & KPN

T-MOBILE AND KPN ON PAR IN DATA DRIVE-TESTS IN SMALLER TOWNS

In the Data drivetests which our measurement cars performed in 19 smaller Dutch towns, KPN and T-Mobile are on par, while Vodafone scores four percentage points behind. In this scenario, T-Mobile shows somewhat faster Data rates in the download tests, while KPN achieves slightly faster results in the upload tests. In both test cases, Vodafone falls a little behind but still achieves good results. In the Youtube tests, the success ratios of all contenders are close to or even at 100 per cent.

ROADS DRIVETEST

T-MOBILE & KPN

T-MOBILE AND KPN ARE TOGETHER LEADING IN THE DATA DRIVETESTS ON CONNECTING ROADS

As already in the smaller towns, T-Mobile and KPN score also on par in the data drivetests conducted on the 3,000 km of connecting roads in the Netherlands, with Vodafone following at close distance. The very high success ratios of downloads and uploads, considerable data rates and even a comparably high share of 5G samples (see next page) are a good prerequisite for using the connectivity features of modern cars while driving even on rural roads in the Netherlands.

Data Towns (Drivetest)	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	99.9	99.9	100.0
Overall Session Time (s)	0.8	0.9	0.9
File Download (5 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.9	99.7/1.2	100.0/1.8
90%/10% faster than (Mbit/s)	37.6/114.7	28.1/93.2	12.7/92.2
File Upload (2.5 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/1.2	100.0/1.0	100.0/1.6
90%/10% faster than (Mbit/s)	12.3/42.4	16.2/46.6	9.0/29.1
File Download (7 Seconds)			
Success Ratio (%)	100.0	100.0	100.0
Avg. Throughput (Mbit/s)	139.5	116.6	82.0
90%/10% faster than (Mbit/s)	56.9/225.9	31.7/238.8	20.1/155.3
File Upload (7 Seconds)			
Success Ratio (%)	99.7	100.0	99.7
Avg. Throughput (Mbit/s)	48.4	45.0	25.4
90%/10% faster than (Mbit/s)	15.9/83.6	17.6/80.7	10.0/50.8
Youtube Video			
Success Ratio/Start Time (%/s)	99.8/0.8	100.0/1.0	99.7/1.0
Average Video Resolution (p)	920	920	919
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	99.5/0.9	99.0/1.1	99.0/1.0
Average Video Resolution (p)	1038	1039	1037

Data Roads (Drivetest)	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	100.0	99.8	99.8
Overall Session Time (s)	0.8	0.9	0.9
File Download (5 MB)			
Success Ratio/Avg. Session Time (%/s)	99.8/1.0	99.8/1.3	99.6/1.8
90%/10% faster than (Mbit/s)	32.3/120.0	23.5/96.7	10.8/99.3
File Upload (2.5 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/1.4	100.0/1.2	100.0/1.8
90%/10% faster than (Mbit/s)	8.5/43.8	11.7/45.3	7.6/27.3
File Download (7 Seconds)			
Success Ratio (%)	100.0	100.0	99.8
Avg. Throughput (Mbit/s)	132.0	123.8	75.9
90%/10% faster than (Mbit/s)	49.9/222.9	34.5/241.4	13.7/152.1
File Upload (7 Seconds)			
Success Ratio (%)	100.0	99.6	99.5
Avg. Throughput (Mbit/s)	46.5	43.8	23.5
90%/10% faster than (Mbit/s)	11.9/83.3	13.3/77.4	8.5/49.7
Youtube Video			
Success Ratio/Start Time (%/s)	100.0/0.9	99.5/1.0	99.6/1.1
Average Video Resolution (p)	920	920	918
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	99.6/1.0	99.6/1.1	99.6/1.1
Average Video Resolution (p)	1039	1038	1039



Data Trains (Walktest)	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	98.9	99.4	99.4
Overall Session Time (s)	1.1	1.1	1.2
File Download (5 MB)			
Success Ratio/Avg. Session Time (%/s)	99.0/2.3	99.0/1.9	99.5/2.8
90%/10% faster than (Mbit/s)	15.0/104.7	18.9/72.4	8.0/86.3
File Upload (2.5 MB)			
Success Ratio/Avg. Session Time (%/s)	99.5/4.4	99.5/2.7	98.1/3.0
90%/10% faster than (Mbit/s)	1.9/32.7	3.3/43.4	3.6/29.3
File Download (7 Seconds)			
Success Ratio (%)	100.0	99.6	99.1
Avg. Throughput (Mbit/s)	88.4	88.8	62.0
90%/10% faster than (Mbit/s)	14.1/164.8	16.4/184.6	7.5/132.8
File Upload (7 Seconds)			
Success Ratio (%)	97.7	97.8	95.9
Avg. Throughput (Mbit/s)	31.7	30.4	20.0
90%/10% faster than (Mbit/s)	1.7/72.7	3.6/76.9	3.5/46.8
Youtube Video			
Success Ratio/Start Time (%/s)	98.2/1.3	97.8/1.2	98.7/1.5
Average Video Resolution (p)	904	915	917
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	96.2/1.4	99.0/1.2	97.2/1.3
Average Video Resolution (p)	1029	1037	1037

RAILWAYS WALKTEST

KPN

KPN CLEARLY AHEAD IN DATA TESTS PERFORMED IN DUTCH TRAINS AMIDST OVERALL VERY STRONG OPERATORS

In the Data measurements which our walktests teams performed in Dutch long-distance trains, KPN clearly takes the lead. As already observed in the Voice category, all three Dutch operators are convincingly strong in this demanding scenario, delivering high success ratios and a good performance. T-Mobile follows at some distance, and Vodafone performs almost equally strong in this scenario.



DATA RESULTS AT A GLANCE

In the Data discipline, KPN ranks first, followed by T-Mobile at a comparably close distance of three points. Vodafone scores third. All operators already provide a high share of 5G coverage in cities and towns. KPN shows the strongest data performance in cities and is on par with T-Mobile in the towns and on the connecting roads. On railways, KPN shows the best performance with T-Mobile and Vodafone following at some distance, but almost equally strong. Overall, the data performance in Dutch trains is very pleasant. All three operators are far ahead in their 5G roll-outs. In a neck-and-neck race between KPN and T-Mobile, we see KPN slightly ahead in 5G.

Data rates 7s Download	T-Mobile					KPN					Vodafone				
Samples with 5G	Share	Reliability	Data rate (Ø, Mbps)	Data rate (P10, Mbps)	Data rate (P90, Mbps)	Share	Reliability	Data rate (Ø, Mbps)	Data rate (P10, Mbps)	Data rate (P90, Mbps)	Share	Reliability	Data rate (Ø, Mbps)	Data rate (P10, Mbps)	Data rate (P90, Mbps)
Cities – Drivetest	80.5%	99.7%	120.8	50.5	202.8	76.3%	99.8%	156.3	59.4	281.4	69.7%	99.8%	100.2	30.3	191.7
Cities – Walktest	78.6%	100.0%	127.3	51.2	221.0	77.8%	99.8%	186.5	76.0	305.4	63.2%	100.0%	153.1	58.5	238.1
Towns – Drivetest	75.6%	100.0%	129.8	62.1	205.0	49.5%	100.0%	160.5	66.4	261.1	65.3%	100.0%	81.9	22.2	162.5
Roads – Drivetest	74.7%	100.0%	125.7	53.7	209.0	49.3%	100.0%	164.1	66.1	275.4	48.4%	100.0%	81.9	18.0	153.9
Trains – Walktest	70.9%	100.0%	100.5	29.2	173.1	38.3%	100.0%	132.5	39.5	252.0	57.2%	100.0%	73.5	17.0	137.6

VERY FAST 5G ROLL-OUT IN THE NETHERLANDS

In the Dutch 5G frequency auction, which was closed in July 2020, all three operators active in the Netherlands were able to acquire the spectrum necessary to launch 5G services. KPN received 20 MHz in the 700 MHz band as well as 15 MHz in the 1400 MHz band and 40 MHz in the 2100 MHz band. T-Mobile acquired 20 MHz spectrum on 700 MHz, 10 MHz at 1400 MHz and was able to secure 40 MHz in the 2100 MHz band which it has already used previously. Vodafone received 20 MHz on 700 MHz, 15 MHz in the 1400 MHz band and 40 MHz on 2100 MHz.

VodafoneZiggo was the first carrier to offer 5G in the Netherlands, starting on available frequencies in April 2020 and later extending the service to spectrum acquired in the above mentioned auction. In late 2020, VodafoneZiggo claimed to already reach 80 per cent of the Dutch population with 5G, aiming at reaching national coverage soon after. KPN and T-Mobile both launched 5G at the end of July 2020. KPN started in most of the Randstad area as well as Eindhoven, reaching about half of the Dutch population and striving to reach nationwide 5G coverage in 2021. At the end of October 2020, T-Mobile claimed to reach about 90 per cent of the Dutch population with 5G.

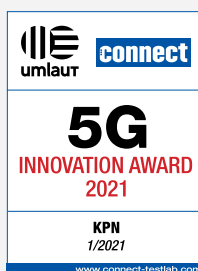
5G

KPN

KPN LEADING IN A NECK-AND-NECK RACE IN OUR 5G ANALYSIS

Considering the date of the availability of 5G spectrum, the Dutch operators have quickly come far in their 5G deployments. This can be seen in the presence of 5G samples in the measurement data captured in our drivetests and walktests. They achieve sizeable shares even in smaller towns, on roads and actually also on trains. In our data gathering, Vodafone is the only operator contributing a large share of samples in DSS (Dynamic Spectrum Sharing), while KPN and T-Mobile operate on individual frequencies.

The samples with 5G are part of the overall Data score. But in a separate analysis (as exemplified by the Data rates achieved in 7s Downloads, see table below), KPN delivers the highest P10, average and P90 data rates in all scenarios – making the most out of the available spectrum. In terms of 5G coverage, T-Mobile and KPN are about on the same level in the cities, while T-Mobile is well ahead in more rural areas. All three operators offer a high reliability during 5G downloads. In a neck-and-neck race between KPN and T-Mobile in this domain, we see KPN slightly ahead and thus award connect's special 5G innovation accolade to this operator.





45,324 users in the Netherlands have contributed around 237 million measurement samples between late May and early November 2020. umlaut has conducted a thorough analysis of this extensive data base, using a further refined crowdsourcing methodology compared to previous years.

While the drivetests and walktests determine the peak performance of the examined networks, crowdsourcing can add important dimensions such as time, geography or variety in devices and tariff plans – if done in the right way. A detailed description of our crowdsourcing methodology can be found on page 14. The total area covered by our crowdsourcing analyses is 36.503 km² of the Netherlands, representing 98.8 per cent of the built-up area of the country and 99.7 per cent of its population.

VODAFONE
TAKES THE LEAD
IN THE CROWD
CATEGORY,
T-MOBILE
FOLLOWS AT
CLOSE DISTANCE.
KPN COMES IN
THIRD WITH
A GAP OF
EIGHT POINTS.

QUALITY OF BROADBAND SERVICE

VODAFONE

VODAFONE LEADS THE MARKET IN QUALITY OF BROADBAND SERVICE

VodafoneZiggo is well ahead of the competition in terms of Broadband Coverage Excellence, which rewards Broadband deployment over the whole area of a country and also 4G/5G availability in places where the competition is not yet present or only with limited availability. In the Time on Broadband KPI, Vodafone is almost on par with T-Mobile. This value designates how often a single user had 4G or 5G reception during the observation period – showing that this attribute is high for the customers of all three operators. KPN shows room for improvement in terms of Coverage Excellence.

Crowd	T-Mobile	KPN	Vodafone
Broadband Coverage			
Coverage Excellence (%)	62.3	46.2	71.7
Time on Broadband (%)	98.7	97.5	98.6
Download Speed			
Basic Internet Class (%)	94.8	92.5	93.7
HD Video Class (%)	83.4	79.4	83.1
UHD Video Class (%)	24.2	22.5	24.1
Latency			
Gaming Class (%)	95.0	94.0	96.8
OTT Voice Class (%)	98.8	99.0	99.1



DOWNLOAD SPEEDS

T-MOBILE

T-MOBILE TAKES THE LEAD IN ALL DOWNLOAD SPEED CLASSES, FOLLOWED BY VODAFONE

In our crowdsourced assessment of Download Speeds, T-Mobile achieved the best results in all considered speed classes. Vodafone follows closely behind, all the way up to the most demanding speed class, UHD Video (up to 20 Mbps). However, the fact that this highest speed class shows a lower share of samples for all candidates can also be explained with the “passive observation” method used in the crowdsourcing: Over their daily smartphone usage, customers just more rarely use applications with higher bandwidth demands.

KPN scores on the last third rank in all considered speed classes, but also achieves overall good results in this category.

LATENCY

VODAFONE

VODAFONE AHEAD IN LATENCY METRIC, FOLLOWED BY T-MOBILE AND THEN KPN

In our examinations of Latency, Vodafone is leading the field, achieving the best results both in the OTT Voice Class (roundtrip times of 100 ms or less) and in the Gaming Class (roundtrip times of up to 50 ms).

T-Mobile is following at close distance, still achieving a share of 95 per cent of the collected samples meeting the requirements of the demanding Gaming Class.

Also in this category, KPN is ranking third. But again, this operator also achieves very good results in this area, with still a very high share of 94 per cent of samples in the challenging Gaming Class.



CROWD RESULTS AT A GLANCE

In the crowdbased score, Vodafone takes a close lead, outranking the also very strong T-Mobile at a distance of just one point. KPN follows with a more distinct gap of eight points, still accomplishing a very good result.

Vodafone is well ahead of the competition in terms of Broadband Coverage Excellence and almost on par with T-Mobile in the Time on Broadband KPI. T-Mobile is taking the lead in all Download Speed classes, closely followed by Vodafone. Vodafone is leading in the Latency assessment in both classes, OTT voice and Gaming, this time followed by T-Mobile at close distance.



TESTING METHODOLOGY

The methodology of the umlaut connect Mobile Benchmark is the result of more than 15 years of testing mobile networks. Today, network tests are conducted in more than 80 countries. Our methodology was carefully designed to evaluate and objectively compare the performance and service quality of mobile networks from the users' perspective.

The umlaut connect Mobile Benchmark in the Netherlands comprises of the results of extensive voice and data drivetests and walktests as well as a sophisticated crowd-sourcing approach.

DRIVETESTS AND WALKTESTS

The drivetests and walktests in the Netherlands took place from November 6th to November 14th, 2020. All samples were collected during the day, between 8.00 a.m. and 10.00 p.m. The network tests covered inner-city areas, outer metropolitan and suburban areas. Measurements were also taken in smaller towns and cities along connecting highways. For the drive tests, umlaut, used four vehicles. The connecting routes between the cities covered about 3,000 kilometres. In the cities, the test cars drove about 2,180 km and in towns approx. 580 km. In addition to the drivetests two walktest teams took measurements by foot – visiting so-called “areas of interest” with a strong visitor frequency like train stations, airport terminals, coffee shops, museums and also local public transport. Part of the schedule of the walk tests were also rides on long distance trains. The combination of test areas has

been selected to provide representative test results across the Dutch population. The areas selected for the 2020 test account for 6.2 million people, or roughly 36.3 per cent of the total population of the Netherlands. The test routes and all visited cities and towns are shown on page 1 of this report.

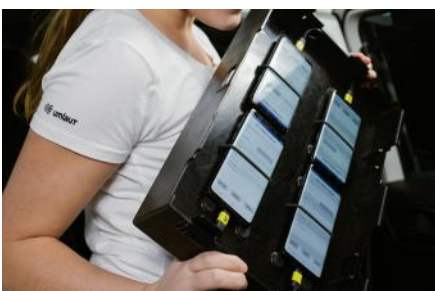
The drivetest cars and walktest teams were equipped with arrays of Samsung Galaxy S10 and S20+ smartphones for the simultaneous measurement of voice and data services.

VOICE TESTING

One Galaxy S10 per operator in each car was used for the voice tests, setting up test calls from one car to another. The walktest team also carried one Galaxy S10 per operator for the voice tests. In this case, the smartphones called another Galaxy S10 as a stationary counterpart. The audio quality of the transmitted speech samples was evaluated using the HD-voice capable and ITU standardised so-called POLQA wideband algorithm. All smartphones used for the voice tests were set to VoLTE preferred mode.

In the assessment of call setup times we also rated the so-called

One Samsung Galaxy S10 per operator was used for the voice measurements and another Galaxy S10 for half of the data measurements. In the second car and in the walktest team's backpack a Galaxy S20+ was used and set to “5G preferred”



umlaut's fleet of test cars is equipped with up-to-date test smartphones. The phones on board are operated and supervised by a unique control system.

P90 value. Such values specify the threshold in a statistical distribution, below which 90 per cent of the gathered values are ranging. For speech quality, we published the P10 value (10 per cent of the values are lower than the specified threshold), because in this case higher values are better.

In order to account for typical smartphone-usage scenarios during the voice tests, background data traffic was generated in a controlled way through injection of 100 KB of data traffic (HTTP downloads). We also evaluated the so-called MultiRAB (Multi Radio Access Bearer) Connectivity. This value denotes whether data connectivity is available during the phone calls. The Voice scores account for 32 per cent of the total results.

DATA TESTING

Data performance was measured by using four more smartphones in each car – one per operator. In Car 1, this was another Galaxy S10, set to 4G preferred mode. Car 2 and the walktest team carried one Galaxy S20+ per operator, set to 5G preferred mode – enabling 5G connectivity wherever available.

For the web tests, they accessed web pages according to the widely recognised Alexa ranking.

In addition, the static “Kepler” test web page as specified by ETSI (European Telecommunications Standards Institute) was used. In order to test the data service performance, files of 5 MB and 2.5 MB for download and upload were transferred from or to

a test server located in the cloud. In addition, the peak data performance was tested in uplink and downlink directions by assessing the amount of data that was transferred within a seven seconds time period.

The evaluation of YouTube playback takes into account that YouTube dynamically adapts the video resolution to the available bandwidth. So, in addition to success ratios and start times, the measurements also determined average video resolution.

All the tests were conducted with the best-performing mobile plan available from each operator. Data scores account for 48 per cent of the total results.

CROWDSOURCING

Additionally, umlaut conducted crowd-based analyses of the Dutch networks which contribute 20 per cent to the end result. They are based on data gathered between the end of May and early November 2020 (calendar weeks 22 to 45).

For the collection of crowd data, umlaut has integrated a background diagnosis processes into 800+ diverse Android apps. If one of these applications is installed on the end-user's phone and the user authorizes the background analysis, data collection takes place 24/7, 365 days a year. Reports are generated for every hour and sent daily to umlaut's cloud servers. Such reports occupy just a small number of bytes per message and do not include any personal user data. This unique crowdsourcing technology allows umlaut to collect data about real-world

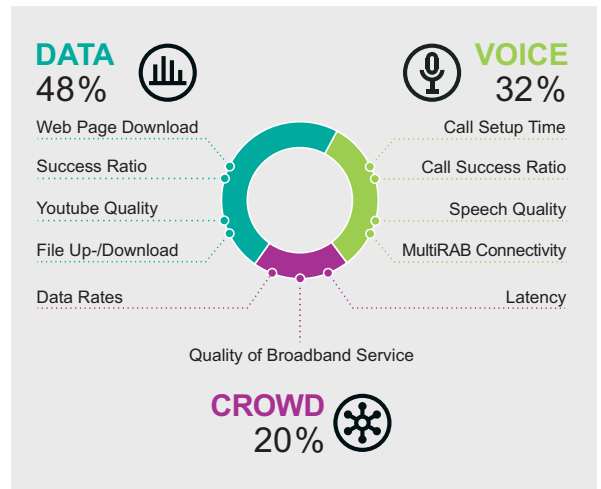
experience wherever and whenever customers use their smartphones.

QUALITY OF BROADBAND SERVICE

For the assessment of network coverage, umlaut applies a grid of 2 x 2 km tiles (so-called evaluation areas or EAs) over the test area. For each tile, a minimum number of users and measurement values must be available. In order to assess the *Coverage Excellence*, umlaut awards one point if the considered network provides 4G or 5G coverage in an EA. Another point is awarded to a candidate for each competitor who provides a smaller or no share of broadband usage. In a country with four contenders, a candidate can thus reach up to four points per tile: one for broadband coverage and three additional ones for "beaten" competitors. The assessment then relates the obtained points to the total possible points for *Coverage Excellence*.

In addition, we consider the *Time on Broadband*. It reveals how often a single user had 4G or 5G reception in the observation period – independent from the EAs in which the samples were obtained. In order to calculate this, umlaut puts the number of samples with 4G/5G coverage into relation to the total number of all samples. *Coverage Excellence* and *Time on Broadband* results each provide 50 per cent of the

points for the Quality of Broadband Service. Important: The percentages determined for both parameters reflect the respective degrees of fulfilment. They do not correspond to the percentage of 4G/5G coverage of an area or population.



DATA RATES AND LATENCY

Additionally, umlaut investigates the *Data rates* and *Latencies* that were actually available to each user. The examination of these parameters is independent from the EAs and thus concentrates on the experience of each single user. Samples which were for instance obtained via WiFi or with the smartphone's flight mode being active, are filtered from the data pool before further analysis. In order to take the fact into account that many mobile phone tariffs limit data rates, umlaut has defined speed classes which are corresponding to particular applications: For *Basic Internet*, 2 Mbps are sufficient. *HD Video* requires 5 Mbps. And for *UHD Video* the minimum is 20 Mbps.

In order for a sample to count as valid, a minimum amount of data must have been transmitted within a 15 minute period. The same principle also applies to the assignment of a data packet's *latency* to the according application-based classes: Roundtrip times up to 100 ms are sufficient for *OTT Voice*, 50ms and faster qualify a sample for *Gaming*. In the assessment, umlaut assigns the data rate and latency observed in a sample to one of these performance classes. Then, *Basic Internet* accounts for 60 per cent of the Data Rate score, *HD Video* for 30 per cent and *UHD Video* for 10 per cent (see table on the left-hand side). The Latency score incorporates *OTT Voice* with a share of 80 per cent, *Gaming* with a share of 20 per cent.

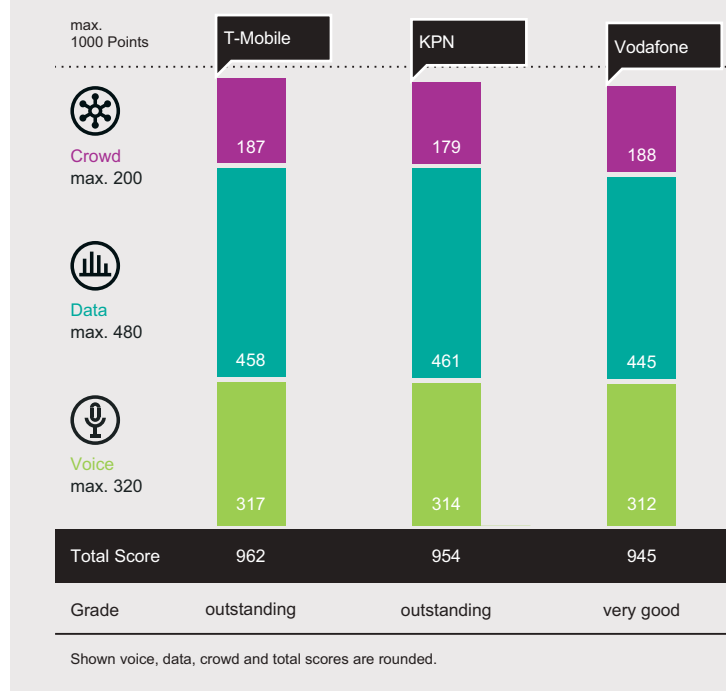
Crowdsourcing Score Model			
Quality of Broadband Service			
50%	Coverage Excellence	50%	max. 50 P.
	Time on Broadband	50%	max. 50 P.
Data rates (Download)			
30%	Basic Internet Class (up to 2 Mbps)	60%	max. 36 P.
	HD Video Class (up to 5 Mbps)	30%	max. 18 P.
	UHD Video Class (up to 20 Mbps)	10%	max. 6 P.
Latency (Roundtrip)			
20%	OTT Voice Class (up to 100 ms)	80%	max. 32 P.
	Gaming Class (up to 50 ms)	20%	max. 8 P.
Total		max. 200 P.	

CONCLUSION

T-Mobile wins for the fifth time in a row with the grade “outstanding”. KPN ranks second, also achieving the grade “outstanding” and leading in the Data discipline. In addition, KPN receives connect’s Innovation Award for the best overall 5G performance. Vodafone ranks third with the grade “very good” and leading in the Crowdsourcing category.

The overall winner of the umla^{ut} connect Mobile Benchmark in the Netherlands is T-Mobile – for the fifth time in a row. Also, T-Mobile scores best among all three competitors in the Voice category. KPN follows on second place at an overall distance of eight points, but leading in the Data category. Both T-Mobile and KPN achieve the exceptional grade “outstanding”. Vodafone, with 5.1 million subscribers meanwhile the smallest operator in the country (T-Mobile: 6.7 million, KPN: 6.5 million), ranks third with the overall grade “very good”. In the Crowdsourcing, Vodafone leads with a margin of one point ahead of T-Mobile.

In comparison to the results of the 2019 umla^{ut} connect Mobile Benchmark in the Netherlands, which was published in spring 2019, all three operators have lost some points. To some extent, this can be explained with the very high performance level in the Netherlands. As we continually raise the thresholds of our scoring in order to keep track with the technological advancement, achieving score gains gets more and more difficult even for strong contenders. Also, our Crowdsourcing methodology was significantly updated (see page 14), which makes the results in this discipline not 1:1 comparable to those of our previous benchmark. But what is most important this year: All three Dutch operators manage to provide very stable connections to their users – even in today’s particularly demanding times.



Overall Results		T-Mobile	KPN	Vodafone
Voice	max. 320 P.	317	314	312
Cities (Drivetest)	144	99%	98%	98%
Cities (Walktest)	48	100%	99%	98%
Towns (Drivetest)	64	99%	99%	99%
Roads (Drivetest)	40	97%	97%	95%
Railways (Walktest)	24	97%	94%	95%
Data	max. 480 P.	458	461	445
Cities (Drivetest)	216	96%	97%	93%
Cities (Walktest)	72	96%	97%	95%
Towns (Drivetest)	96	96%	96%	92%
Roads (Drivetest)	60	97%	97%	94%
Railways (Walktest)	36	88%	91%	87%
Crowdsourced Quality	max. 200P.	187	179	188
Crowd	200	94%	89%	94%
Connect Rating	max. 1000 P.	962	954	945

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



1

For the fifth time in a row, T-Mobile is the winner of our Mobile Benchmark in the Netherlands, with the grade “outstanding” and also the highest score determined by umla^{ut} world-wide in 2020. The operator takes the win due to leading in Voice and Crowdsourcing and also providing very good Data results, including good 5G coverage.

2



KPN ranks second, scoring eight points behind the overall winner and achieving also “outstanding” results. The operator leads the field in terms of Data performance, scoring three points ahead of the overall winner. This is also due to convincing results in the 5G assessment, which is why connect awards its 5G innovation accolade to KPN.

3



Vodafone ranks third with a very good result and strong performances. While the operator scores a little behind its competitors in our drivetests and walktests, Vodafone achieves particularly strong results in the Crowdsourcing category, especially due to the best Latency results in our analysis.