

THE 2019 MOBILE NETWORK TEST IN THE NETHERLANDS



Umlaut and connect have been testing the Dutch mobile networks since 2015. Given the high network performance, it is remarkable that the results still have improved over the years.

Another constant in the Netherlands are frequent mergers and acquisitions as well as similar changes in the market environment. How will the now three Dutch operators perform this time?



RESULTS IN A NUTSHELL

The umlaut connect Mobile Benchmark in the Netherlands has traditionally shown strong results. This trend continues in 2019, resulting in three “outstanding” grades with two of the contenders keeping the high scores they achieved in the previous year and one of them even improving them.

umlaut's network benchmarks are widely accepted as being highly objective and defining the de-facto industry standard. The carefully designed methodology of the 2019 benchmark in the Netherlands combines drivetests and walktests for executing detailed voice and data measurements under controlled circumstances with a sophisticated crowdsourcing approach. This provides profound insights into the overall coverage of voice, data and 4G services, real-world User Download Speeds and Data Service Availability.

umlaut's holistic approach to network benchmarking includes both drivetest and walktest measurements as well as crowdsourcing. The drive and walktests allow for evaluating the cutting edge of the networks' capabilities. Crowdsourcing unveils the service quality, performance and coverage actually experienced by the users. We have thoroughly weighted these components in order to give a realistic and authoritative assessment of the rated networks' true potential and performance.

T-MOBILE TAKES THE OVERALL WIN, KPN AND VODAFONE SHOW EFFECTIVELY THE SAME LEVEL OF PERFORMANCE

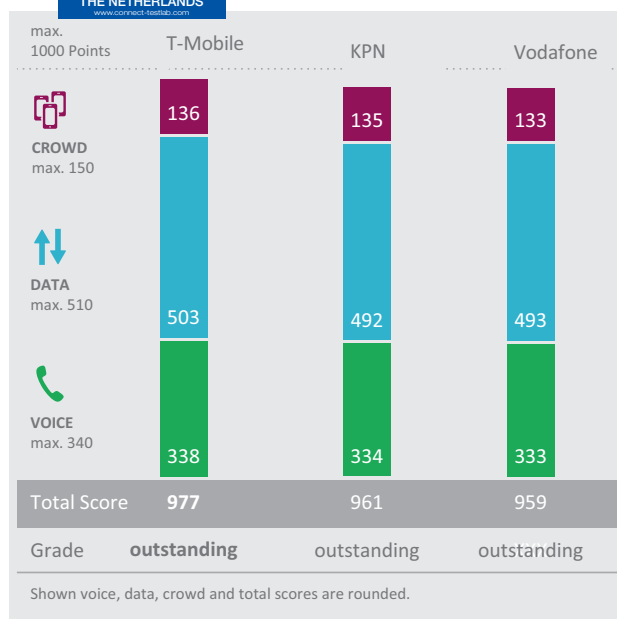
For the fourth time in a row, T-Mobile is the clear winner of the umlaut connect Mobile Benchmark Netherlands. KPN and Vodafone follow at some distance, but also achieve the grade “outstanding”. With their scores only two points apart, they show practically the same level of performance. Also, the fact that all three Dutch operators are graded as “outstanding” emphasises the very high performance level of the Dutch mobile networks.

T-Mobile clearly leads in all tested disciplines including the newly introduced crowd score and achieves the highest score level ever determined in our Mobile Benchmarks. KPN shows the biggest score improvement in comparison to its results from the previous year. This operator scores slightly better than Vodafone in the Voice and Crowd categories and is particularly strong in the Voice tests in smaller towns and in the Voice and Data tests on connecting roads. Vodafone slightly outperforms KPN in the data category and shows strong results in the walktests in bigger cities.

Especially in the data measurements conducted on Dutch trains, the operators leave some room for improvement – however, compared to some neighbouring countries, they still perform very strong in this discipline.



T-Mobile is the overall winner of this year's umlaut connect Mobile Benchmark Netherlands – for the fourth time in a row and with the highest score ever measured by umlaut worldwide. KPN shows the biggest score improvement over the previous year, while Vodafone keeps its high performance level.



Overall Results		Voice, Data and Crowd		
		T-Mobile	KPN	Vodafone
Voice (max. 340 Points)		338	334	333
Cities (Drivetest)	153	100%	98%	98%
Cities (Walktest)	51	99%	98%	100%
Towns (Drivetest)	68	100%	100%	97%
Roads (Drivetest)	42	99%	99%	98%
Trains (Walktest)	26	94%	96%	94%
Data (max. 510 Points)		503	492	493
Cities (Drivetest)	230	99%	98%	98%
Cities (Walktest)	76	98%	93%	99%
Towns (Drivetest)	102	99%	97%	96%
Roads (Drivetest)	64	100%	100%	99%
Trains (Walktest)	38	91%	87%	85%
Crowdsourced Quality (max. 150 Points)		136	135	133
Crowd	150	91%	90%	89%
Connect Rating (max. 1000 Points)		977	961	959

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 Netherlands compete on the highest performance level. The recent acquisition of Tele2 by T-Mobile narrowed the number of operators down to three, distinctly changing the market conditions.



The Koninklijke PTT Nederland N.V. emerged from the privatisation of the formerly state-owned PTT in 1998. For the fiscal year 2018, the company reported a total revenue of 5.7 billion Euros as well as a customer base of 5.5 million consumer and business postpaid subscribers plus 1.3 million fixed-mobile phone plans. By these numbers, KPN is clearly the largest Dutch mobile operator. In addition, KPN reports 2.9 million fixed broadband and 2.2 million interactive tv customers plus 610,000 “business multiplay” workstations. 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, 1800, 2100 and 2600 MHz. 3G is scheduled to be phased out by the end of 2021. KPN claims a 99.3 per cent coverage of the Dutch population with 4G. Recently, KPN has started to combine all of its LTE frequencies by “4 carrier aggregation” (4CA), which enables theoretical download speeds of up to 1 Gbps. Furthermore, KPN has offered VoLTE since October 2016 and introduced 4x4 MIMO in March 2019.



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. VodafoneZiggo is the second largest mobile operator in the Netherlands with about 5.2 million mobile customers. The company also specifies 3.9 million video, 3.3 million fixed broadband and 2.5 million fixed telephony subscribers. For the calendar year 2018, Vodafone Ziggo announced a mobile revenue of 3.9 bn Euros. 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 announce that it will phase out its 3G network by 2020 in order to devote its spectrum to 4G. Vodafone claims to offer more than 98 per cent population coverage with 4G and to offer up to 1 Gbps with “4G+” (carrier aggregation). VoLTE was introduced in November 2016.



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 its fiscal year 2018, T-Mobile Netherlands reported a revenue of 1.3 billion Euros. At the same time, the company completed its acquisition of the smallest Dutch mobile operator, Tele2. By this step, T-Mobile’s customer base of formerly about 3.2 million mobile subscribers was amended by former Tele2 customers, resulting in a total of 4 million subscribers. At the time of testing, the technical integration of Tele2’s infrastructure into T-Mobile’s network had not yet begun – as a first step, former Tele2 customers benefit of national roaming with T-Mobile’s cells. As Tele2 did not legally exist any more, we used SIM cards of T-Mobile only for our measurements. T-Mobile’s network offers 2G mostly at 1800 MHz, 3G at 900 and 2100 MHz and 4G/LTE at 900, 1800, 2100 and 2600 MHz. The company claims a 4G coverage of more than 99 per cent of the population and has been offering VoLTE since October 2017.

In 2019, we have conducted the umlaut connect Mobile Benchmark Netherlands for the fifth time. Can T-Mobile continue its winning streak for the fourth time?

A CLOSE LOOK AT THE DUTCH NETWORKS



“We see amazing results in the Netherlands. T-Mobile’s score is the highest we have ever measured worldwide. Congratulations to all Dutch customers: In any case, they are choosing from excellent network providers. And congratulations to all Dutch operators, achieving in average the best country result in history.”

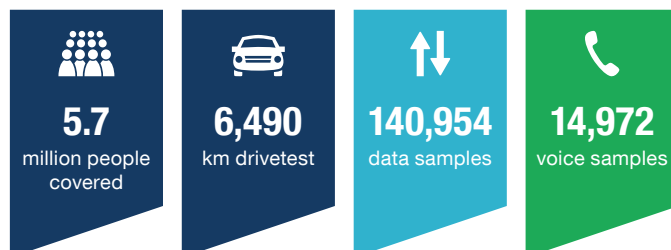
Hakan Ekmen
CEO telecommunications umlaut

umlaut, headquartered in Aachen, Germany, is a world leader in mobile network testing. The company has over 4,300 employees worldwide and a turnover of more than 350 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 Austria and Switzerland since 2009. Starting in 2014, umlaut has also been conducting benchmarks in the UK

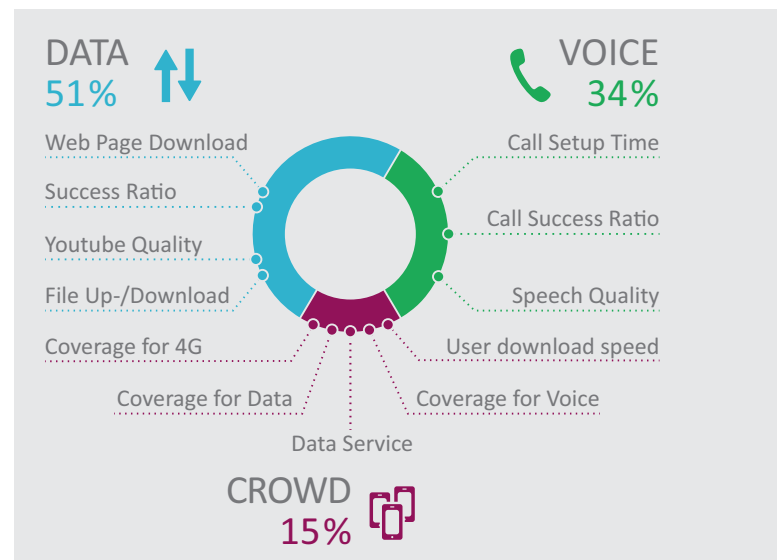
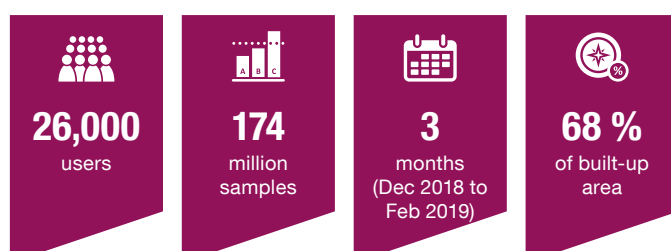
and Australia, expanding its public mobile network tests to the Netherlands, Spain and Sweden in 2016 as well as examining many other mobile networks all over the world including those in the USA and Singapore.

The 2019 umlaut connect Mobile Benchmark in the Netherlands consists of drivetests and walktests conducted from February 12 to March 1, 2019. Two drive test cars together covered about 6,490 kilometres, visiting 21 cities and 31 towns. Additionally, a walktest team visited seven cities and travelled on trains between 14 destinations. The test areas account for approximately 5.7 million people, or about 33.5 per cent of the total population of the Netherlands.

DRIVETEST AND WALKTEST FACTS



CROWDSOURCING FACTS



VOICE

Many customers use voice services less intensely than data. However, when actually taking or placing a phone call, they expect reliable connections. How do the Dutch mobile networks manage to fulfil these expectations?

All three operators in the Netherlands support Voice over LTE (VoLTE). 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 in order to take or place a phone call, can be avoided. Also, VoLTE supports better audio codecs providing operators with the opportunity to deliver higher speech quality to their customers.

For the voice rating, each drivetest car and each walktest team carried one Samsung Galaxy S9 smartphone per operator. The phones in the cars called a counterpart in one of the other cars. The phones carried by the walktest teams called a stationary counterpart. The connected testing equipment registered success ratios, call setup times and speech quality. In order to simulate normal smartphone usage, data transfers took place in the background of the test calls.

ALL IN ALL,
T-MOBILE LEADS
IN THE VOICE
DISCIPLINE.
VODAFONE AND
KPN FOLLOW
AT A NARROW
DISTANCE AND
RANK CLOSELY
TOGETHER.



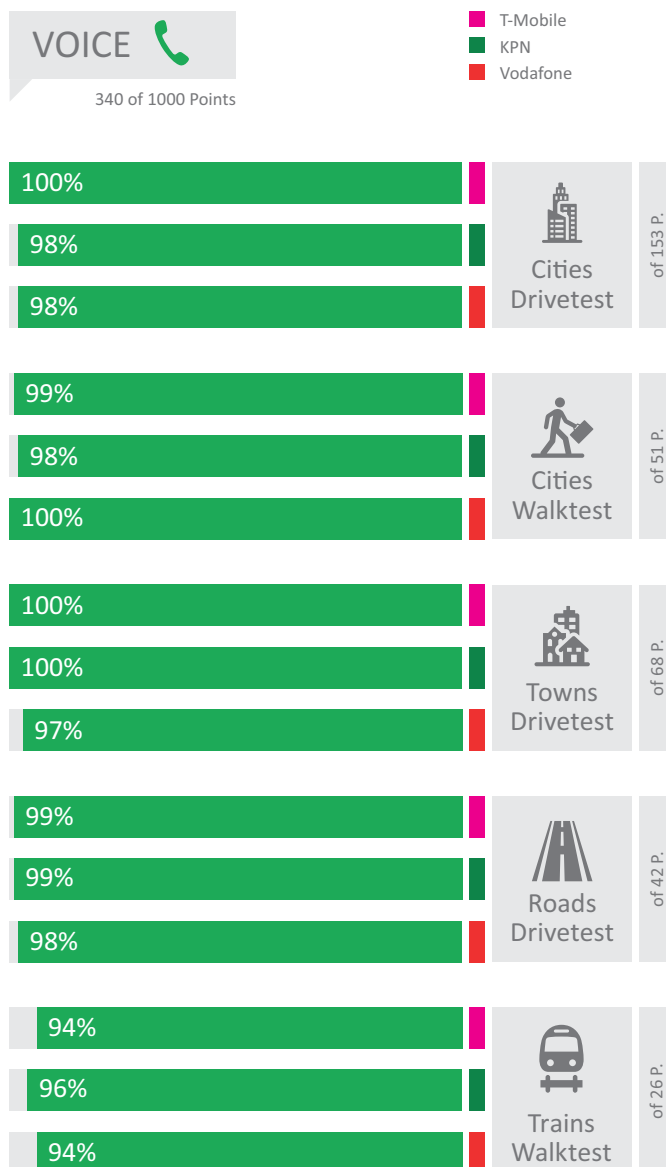
T-MOBILE TAKES A NARROW LEAD IN VOICE DRIVETESTS IN BIG CITIES

In the voice drivetests conducted in 21 Dutch cities, T-Mobile achieves the highest score, with KPN and Vodafone following closely. All three offer the same high speech quality to their customers. T-Mobile owes its narrow lead to a call success ratio of 100 per cent, but with 99.5 and 99.7 per cent, KPN and Vodafone score only marginally behind.



VODAFONE AHEAD IN VOICE WALKTESTS IN BIG CITIES

In the walktests which took place in seven Dutch cities, the measurement teams determined an even slightly higher speech quality for T-Mobile and Vodafone than in the drivetests. However, call success were slightly better in the Vodafone network. So, while all resulting KPIs range on a very high level, in the assessment of this partial discipline Vodafone is slightly ahead of the competition.





T-MOBILE &
KPN

T-MOBILE AND KPN AHEAD TOGETHER IN VOICE DRIVETESTS IN TOWNS

In the voice results of the drivetests conducted in 31 Dutch towns, T-Mobile and KPN lead the field, while Vodafone follows at a close distance. As in the larger cities, again slightly higher success rates ultimately decide the lead in this category. While T-Mobile and KPN succeed in 100 per cent of the call attempts, Vodafone achieved a still very good 99.4 per cent.



T-MOBILE &
KPN

VERY GOOD VOICE RESULTS ON ROADS, T-MOBILE AND KPN LEADING

When it comes to conducting voice calls on the roads, T-Mobile and KPN are again in the lead, Vodafone ranks third. While the KPIs minimally drop in this more demanding category, they are still on a very high level. T-Mobile and KPN achieve a high call success ratio of 99.9, while Vodafone follows at a close distance with a very good 99.6 per cent.



KPN

ALL THREE OPERATORS SCORE SLIGHTLY LOWER ON DUTCH TRAINS, KPN AHEAD BY A NARROW MARGIN

Since the previous year, walktests conducted while travelling on trains are part of the umlaut connect Mobile Benchmark Netherlands. In direct comparison, all three Dutch operators score slightly lower in this discipline than last year. There are a number of possible explanations: This year's test routes are different from those of the previous year. More travelling mobile users might put additional stress on the networks. And/or newer train types have a higher attenuation for mobile phone signals. However, given the challenging environment of railway waggons, all three operators still achieve good results. KPN is slightly ahead due to a call success ratio of 98.9 per cent. T-Mobile and Vodafone score on practically the same level. Overall, the results on Dutch trains still clearly outperform those of other European countries such as Germany or the UK.



VOICE RESULTS AT A GLANCE

T-Mobile takes the win in the voice category due to overall high KPIs and especially high call success ratios in cities, towns and on the roads. Vodafone and KPN are following, scoring only one point apart. KPN offers the shortest call setup times in all disciplines. On trains, there is minor room for improvement. However, all three operators perform on a high level.

Voice

	T-Mobile	KPN	Vodafone
Cities (Drivetest)			
Call Success Ratio (%)	100.0	99.5	99.7
Call Setup Time (s)	1.6	1.4	1.8
Call Setup Time P90 (s)	2.0	1.7	2.2
Speech Quality (MOS-LQO)	4.4	4.4	4.4
Towns (Drivetest)			
Call Success Ratio (%)	100.0	100.0	99.4
Call Setup Time (s)	1.6	1.4	1.9
Call Setup Time P90 (s)	2.0	1.6	2.2
Speech Quality (MOS-LQO)	4.4	4.4	4.4
Roads (Drivetest)			
Call Success Ratio (%)	99.9	99.9	99.6
Call Setup Time (s)	1.7	1.4	1.9
Call Setup Time P90 (s)	2.0	1.7	2.2
Speech Quality (MOS-LQO)	4.4	4.4	4.3
Cities (Walktest)			
Call Success Ratio (%)	99.8	99.7	99.9
Call Setup Time (s)	1.6	1.4	1.8
Call Setup Time P90 (s)	1.9	1.7	2.2
Speech Quality (MOS-LQO)	4.5	4.5	4.4
Trains (Walktest)			
Call Success Ratio (%)	98.2	98.9	98.4
Call Setup Time (s)	1.7	1.5	1.9
Call Setup Time P90 (s)	2.0	1.8	2.2
Speech Quality (MOS-LQO)	4.4	4.4	4.4



↑↓ DATA

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

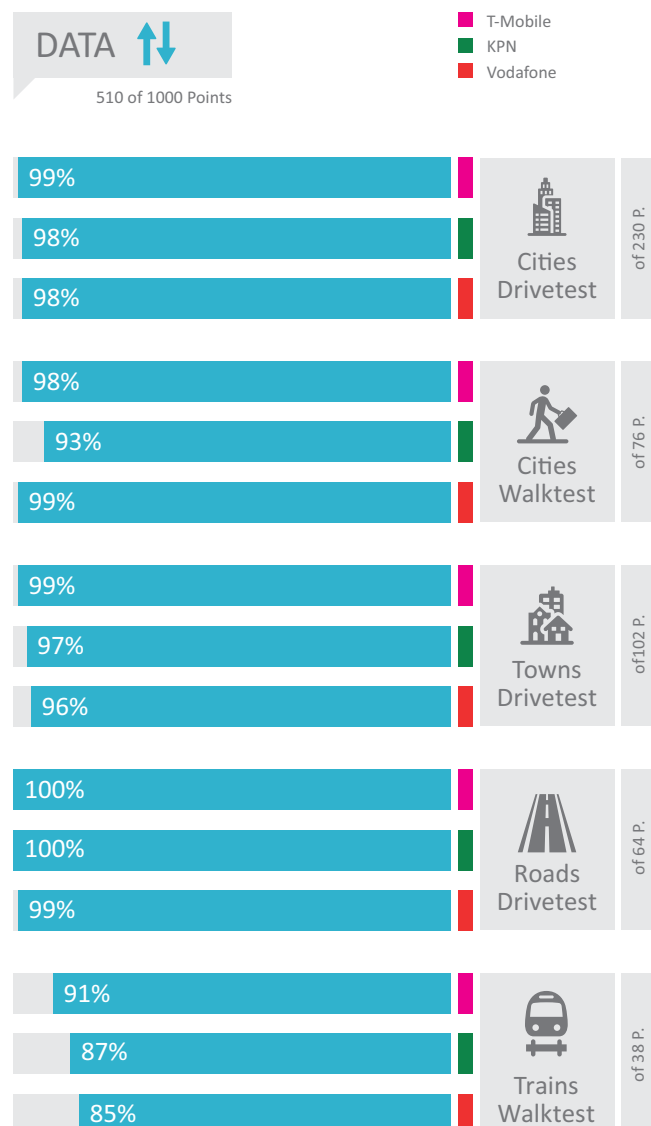
Data connectivity is the most prestigious discipline in our benchmark and also in the operators' marketing. All three Dutch networks claim to cover a large part of the population with LTE services – the claimed percentages all range in the high nineties. And all three operators are continuing to spend large sums on upgrading and expanding their networks to meet the growing demand – including the installation of early 5G network cells. Today, 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.

The Samsung Galaxy S9, which we used for the measurements, is a so-called LTE category 18 device and can generally benefit from carrier aggregation with download speeds up to 1.2 Gbps. However, T-Mobile and Vodafone use specific carrier combinations that were not fully supported by the Galaxy S9 with Android Oreo which was used at the time of testing. Users of these networks who upgrade to the latest Android OS version might enjoy even higher data rates. In general, users looking for the fastest possible data rates, should ask their operator for specific device and firmware recommendations.

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

The benchmarking of web-page downloads as well as file downloads and uploads rewards fast data rates. 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. In order to support higher throughputs, these measurements have been conducted with three TCP sockets (see page 13 for more details). At the same time, umlaut assesses the networks' availability and stability by examining success ratios. Above that, we determined the minimum data rates that are available in 90 per cent of the cases plus the peak data rates that would be surpassed in 10 per cent of the cases. YouTube evaluations concentrate on success ratios, start times and payouts without interruptions as well as the received average video resolution.

T-MOBILE ALSO LEADS IN THE DATA CATEGORY. VODAFONE AND KPN FOLLOW AT SOME DISTANCE, BUT AGAIN RANK VERY CLOSELY TOGETHER.





T-MOBILE

T-MOBILE TAKES THE LEAD IN DATA DRIVETESTS CONDUCTED IN CITIES

As in the voice discipline, T-Mobile also takes a narrow lead in the big city data drivetests. The determined success ratios are all at 100 per cent or very close to that. KPN and Vodafone score behind at a very narrow distance and are practically on par in this discipline. A detailed look into the measurement protocols shows that KPN has the highest share of 4CA – over 30 per cent. Vodafone's 4CA share is slightly above 10 per cent, but provides the widest bandwidth (60 MHz). As explained before, the Galaxy S9 used for our Benchmark did not fully support all frequency combinations in the T-Mobile and Vodafone networks.



VODAFONE

VODAFONE SHOWS BEST PERFORMANCE IN BIG CITY WALKTESTS

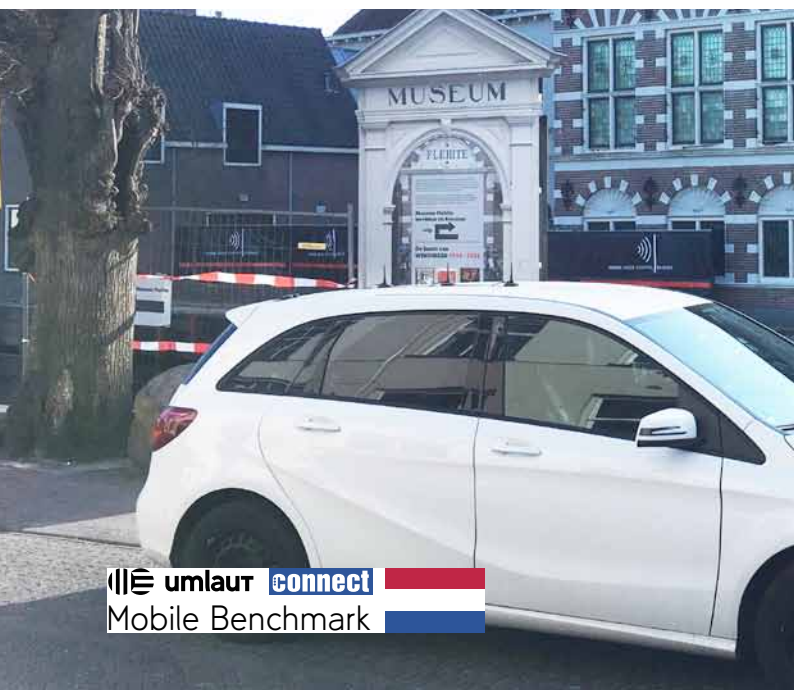
In the data results of the walktests that were conducted in seven large Dutch cities, Vodafone takes the lead with even slightly higher success ratios and data rates than the also very strong T-Mobile. Still, both operators perform on a phenomenally high level. KPN shows also very good results, but in this discipline the largest Dutch operator falls a little more distinctly behind its competitors – particularly due to slightly lower success ratios and partially slower data rates in some of the test cases.

Data in Cities (Drivetest)

	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	99.9/100.0	99.8/99.9	99.9/99.9
Static: Avg. Session Time (s)	1.0	0.9	1.0
Live: Reaction Time (ms)	246	218	236
Live: Initial DL Speed 1st second (kB/s)	796	908	899
File Download (3 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.7	99.9/0.8	99.8/0.8
90%/10% faster than (Mbit/s)	25.7/85.1	21.9/71.6	22.1/73.2
File Upload (1 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.5	99.9/0.5	99.9/0.6
90%/10% faster than (Mbit/s)	16.9/30.1	13.4/33.6	10.7/29.4
File Download (7 Seconds)			
Success Ratio (%)	100.0	99.9	100.0
Avg. Throughput (Mbit/s)	103.3	78.2	86.3
90%/10% faster than (Mbit/s)	38.7/178.2	27.2/139.8	28.5/153.3
File Upload (7 Seconds)			
Success Ratio (%)	100.0	99.9	99.9
Avg. Throughput (Mbit/s)	45.3	41.8	34.4
90%/10% faster than (Mbit/s)	26.5/58.6	17.3/61.0	12.7/56.3
Youtube Video			
Success Ratio/Start Time (%/s)	100.0/1.0	99.9/1.0	100.0/1.1
Playouts without Interruptions (%)	100.0	100.0	99.8
Avg. Video Resolution (p)	1080	1080	1079
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	99.8/1.4	99.8/1.3	99.8/1.3
Playouts without Interruptions (%)	100.0	100.0	99.8
Avg. Video Resolution (p)	1080	1080	1076

Data in Cities (Walktest)

	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%)	99.8/100.0	99.4/99.4	99.9/100.0
Static: Avg. Session Time (s)	1.0	1.0	1.1
Live: Reaction Time (ms)	250	214	249
Live: Initial DL Speed 1st second (kB/s)	764	874	893
File Download (3 MB)			
Success Ratio/Avg. Session Time (%/s)	99.8/0.9	99.5/1.0	100.0/0.7
90%/10% faster than (Mbit/s)	23.6/81.5	18.2/60.4	27.6/72.7
File Upload (1 MB)			
Success Ratio/Avg. Session Time (%/s)	99.8/0.5	99.1/0.7	100.0/0.6
90%/10% faster than (Mbit/s)	16.1/28.8	7.9/31.4	12.0/28.4
File Download (7 Seconds)			
Success Ratio (%)	100.0	99.5	100.0
Avg. Throughput (Mbit/s)	93.6	57.4	102.2
90%/10% faster than (Mbit/s)	25.6/168.1	20.1/107.8	40.7/178.4
File Upload (7 Seconds)			
Success Ratio (%)	99.8	99.0	99.8
Avg. Throughput (Mbit/s)	42.8	32.0	37.6
90%/10% faster than (Mbit/s)	24.0/56.8	8.5/56.2	14.7/56.3
Youtube Video			
Success Ratio/Start Time (%/s)	99.7/1.1	99.2/1.0	99.8/1.1
Playouts without Interruptions (%)	99.5	100.0	100.0
Avg. Video Resolution (p)	1077	1079	1079
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	100.0/1.4	99.0/1.3	100.0/1.4
Playouts without Interruptions (%)	100.0	100.0	100.0
Avg. Video Resolution (p)	1075	1077	1077





T-MOBILE

T-MOBILE IS DATA CHAMPION IN TOWNS

In the 31 smaller Dutch towns visited by our drivetest cars, T-Mobile takes the lead. In this partial discipline, KPN ranks second and Vodafone third. However, Vodafone impresses with similarly high success ratios as T-Mobile, while KPN shows slightly more dropped data connections, but on the other hand higher data rates.



T-MOBILE &
KPN

T-MOBILE AND KPN LEAD IN DATA CONNECTIVITY ON THE ROADS

Drivers who travel on Dutch roads can expect a very high quality of connectivity. T-Mobile and KPN together lead in this discipline achieving high success ratios and fast data throughputs. Vodafone also performs very well in this discipline, scoring only slightly behind its two competitors.



T-MOBILE

T-MOBILE STRONGEST IN DATA TESTS ON TRAINS, BUT OVERALL ROOM FOR IMPROVEMENT

As already mentioned in the voice category, this year's results of the measurements in trains falls a little behind those of the previous year. In this discipline, T-Mobile clearly scores best, KPN ranks second and Vodafone third. Compared to other countries, the Dutch operators perform very well, but especially in the data category, there is still room for improvement.

Data in Trains (Walktest)

	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%/%)	98.0/97.9	96.7/97.1	97.5/97.4
Static: Avg. Session Time (s)	1.2	1.2	1.3
Live: Reaction Time (ms)	294	249	262
Live: Initial DL Speed 1st second (kB/s)	725	819	787
File Download (3 MB)			
Success Ratio/Avg. Session Time (%/s)	98.5/1.3	97.4/1.3	98.3/2.2
90%/10% faster than (Mbit/s)	14.6/76.7	11.4/64.9	5.2/66.8
File Upload (1 MB)			
Success Ratio/Avg. Session Time (%/s)	98.8/1.0	96.0/1.3	97.7/1.6
90%/10% faster than (Mbit/s)	4.3/24.0	3.3/28.2	2.1/24.3
File Download (7 Seconds)			
Success Ratio (%)	97.0	96.9	98.3
Avg. Throughput (Mbit/s)	75.8	52.5	53.7
90%/10% faster than (Mbit/s)	16.5/152.4	14.0/105.3	5.7/115.2
File Upload (7 Seconds)			
Success Ratio (%)	98.5	96.0	96.5
Avg. Throughput (Mbit/s)	24.2	24.1	18.2
90%/10% faster than (Mbit/s)	4.3/45.7	5.0/50.4	2.6/45.1
Youtube Video			
Success Ratio/Start Time (%/s)	97.3/1.2	96.3/1.2	96.0/1.3
Playouts without Interruptions (%)	98.8	99.4	99.4
Avg. Video Resolution (p)	1063	1071	1046
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	98.2/1.6	96.6/1.4	95.7/1.6
Playouts without Interruptions (%)	98.8	98.8	96.8
Avg. Video Resolution (p)	1071	1050	1022

Data in Towns (Drivetest)

	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%/%)	100.0/100.0	99.7/99.8	99.8/100.0
Static: Avg. Session Time (s)	1.0	0.9	1.1
Live: Reaction Time (ms)	240	213	244
Live: Initial DL Speed 1st second (kB/s)	813	922	890
File Download (3 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.6	99.8/0.8	100.0/1.0
90%/10% faster than (Mbit/s)	31.9/87.6	20.1/71.9	15.6/71.4
File Upload (1 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.5	99.8/0.5	99.8/0.7
90%/10% faster than (Mbit/s)	12.0/27.8	11.1/32.9	9.2/26.7
File Download (7 Seconds)			
Success Ratio (%)	100.0	99.8	100.0
Avg. Throughput (Mbit/s)	121.5	73.5	71.0
90%/10% faster than (Mbit/s)	50.7/190.1	29.4/121.6	18.2/134.3
File Upload (7 Seconds)			
Success Ratio (%)	100.0	99.8	100.0
Avg. Throughput (Mbit/s)	38.7	38.6	27.7
90%/10% faster than (Mbit/s)	15.5/59.2	11.3/62.7	9.2/52.7
Youtube Video			
Success Ratio/Start Time (%/s)	100.0/1.0	99.7/1.0	100.0/1.2
Playouts without Interruptions (%)	100.0	99.8	99.8
Avg. Video Resolution (p)	1079	1078	1079
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	100.0/1.3	99.7/1.3	100.0/1.5
Playouts without Interruptions (%)	100.0	100.0	99.6
Avg. Video Resolution (p)	1080	1079	1067

Data on Roads (Drivetest)

	T-Mobile	KPN	Vodafone
Web-Page Download (Live/Static)			
Success Ratio (%/%)	99.8/100.0	99.9/100.0	99.9/99.9
Static: Avg. Session Time (s)	1.0	1.0	1.1
Live: Reaction Time (ms)	246	221	243
Live: Initial DL Speed 1st second (kB/s)	797	902	851
File Download (3 MB)			
Success Ratio/Avg. Session Time (%/s)	99.7/0.7	100.0/0.9	100.0/1.2
90%/10% faster than (Mbit/s)	23.9/87.9	20.0/73.2	12.3/67.2
File Upload (1 MB)			
Success Ratio/Avg. Session Time (%/s)	100.0/0.6	100.0/0.5	99.8/0.8
90%/10% faster than (Mbit/s)	12.4/29.6	11.0/33.5	7.1/27.3
File Download (7 Seconds)			
Success Ratio (%)	100.0	100.0	99.8
Avg. Throughput (Mbit/s)	109.5	71.3	64.9
90%/10% faster than (Mbit/s)	44.2/183.5	22.5/125.7	16.2/131.1
File Upload (7 Seconds)			
Success Ratio (%)	100.0	100.0	100.0
Avg. Throughput (Mbit/s)	40.6	42.1	27.9
90%/10% faster than (Mbit/s)	16.7/58.9	14.7/63.1	7.2/53.9
Youtube Video			
Success Ratio/Start Time (%/s)	100.0/1.0	100.0/1.0	99.4/1.1
Playouts without Interruptions (%)	100.0	99.8	100.0
Avg. Video Resolution (p)	1079	1079	1072
Youtube live Smartphone			
Success Ratio/Start Time (%/s)	100.0/1.4	100.0/1.3	99.4/1.5
Playouts without Interruptions (%)	99.7	99.7	99.7
Avg. Video Resolution (p)	1080	1080	1054



DATA RESULTS AT A GLANCE

As in the voice category, T-Mobile also ranks best overall in the data category. In all drivetest scenarios, this operator achieved close to 100 per cent of the available points. Vodafone and KPN follow at some distance, but rank closely together. Vodafone shows the best performance in the big cities walktests, while KPN achieves a particularly high score on the roads.



CROWD

In this year, the results of crowd sourcing analyses are part of the total score for the first time. 26,000 users in the Netherlands have contributed to the data gathering that took place from December 2018 to February 2019.

While the drivetests and walktests determine the peak performance of the examined networks, crowd-sourcing can add important dimensions such as time, geography or variety in devices and tariff plans – if done in the right way.

For the collection of crowd data, umlaut has integrated a background diagnosis processes into more than 800 diverse Android apps. If one of these applications is installed on the end-user's phone and the user authorises the background analysis, data collection takes place 24/7, 365 days a year. Reports are generated for every quarter of an hour and sent daily to umlaut's cloud servers. Such reports generate just a small number of bytes per message and do not include any personal user data. A more detailed description of our crowdsourcing methodology can be found on page 13.

Based on the total population count of 17 million people, one of 654 inhabitants of the Netherlands has contributed to the gathering of 174 million samples of crowd data. The considered test area represents 68 per cent of the built-up area of the country.



ALL DUTCH NETWORKS

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

All Dutch operators achieve high scores for their voice and data coverage. In the Quality of Voice Coverage, all three networks are more or less on a par. In the Quality of Data Coverage (which considers 3G plus 4G), KPN takes a narrow lead ahead of T-Mobile and, at a little more distance of Vodafone. In contrast, Vodafone offers the best Quality of 4G Coverage (the likelihood of being able to actually use 4G services) ahead of KPN and at some distance of T-Mobile. However, this KPI leaves some room for improvement in all three Dutch networks.

T-MOBILE SCORES BEST IN THE CROWD-SOURCED CATEGORIES, FOLLOWED CLOSELY BY KPN AND, AT A DISTANCE, BY VODAFONE.

Crowd

	T-Mobile	KPN	Vodafone
Voice Coverage			
Quality of Coverage (%)	99.7	99.7	99.8
Test Area Coverage (%)	100.0	99.9	100.0
Data Coverage			
Quality of Coverage (%)	99.6	99.7	99.1
Test Area Coverage (%)	100.0	99.9	100.0
4G Coverage			
Quality of Coverage (%)	93.3	94.2	94.4
Test Area Coverage (%)	99.5	99.5	99.6
User Download Speed			
10% EA faster than (kbit/s)	65060	54868	50946
10% Users faster than (kbit/s)	18759	17757	17580
Avg. Users Best Throughput (kbit/s)	6865	6425	6327
Data Service Availability			
Degraded days (d)	1	1	3
Degraded hours (h)	2	1	17

ASSESSING COVERAGE BASED ON CROWD KPIS

Our coverage metrics correspond to the results of our drivetests and walktests. However, it is no surprise that the crowdsourced KPIS for voice, data and 4G coverage deviate to a certain extent from the population coverage values stated by most operators: umlaut's gathering of crowd data reflects where people actually are and move as opposed to their places of residence and working. Furthermore, our crowdsourcing also comprises indoor or other disadvantageous reception situations, while operators commonly base their claims on outdoor reception only.



T-MOBILE SHOWS FASTEST DATA RATES IN TOP 10 PER CENT OF EVALUATION AREAS

In the assessment of download speeds available to the users, T-Mobile shows the best results for the top 10 per cent of Evaluation Areas. In this category as well as in the assessment of average download speeds, KPN scores second and Vodafone follows at a close distance. Generally, it must be taken into consideration that a part of the actual user base probably experiences data speed limitations caused by their mobile tariffs.



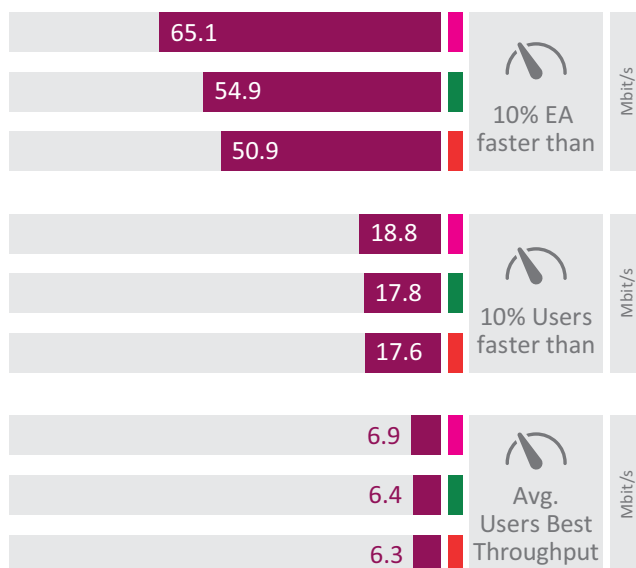
LOW LEVEL OF SERVICE DEGRADATIONS AT T-MOBILE AND KPN, SOMEWHAT ELEVATED LEVEL AT VODAFONE

Other than the rest of the crowd KPIs, our examination of Data Service Availability covers nine months (June 2018 to February 2019). KPN scores best in this consideration, showing only one service degradation up to one hour in the observed period. T-Mobile ranks second with up to two hours in January. Vodafone suffered three outages – of which the ones in August and October lasted up to 8 hours, while the one in September lasted up to one hour.

CROWD

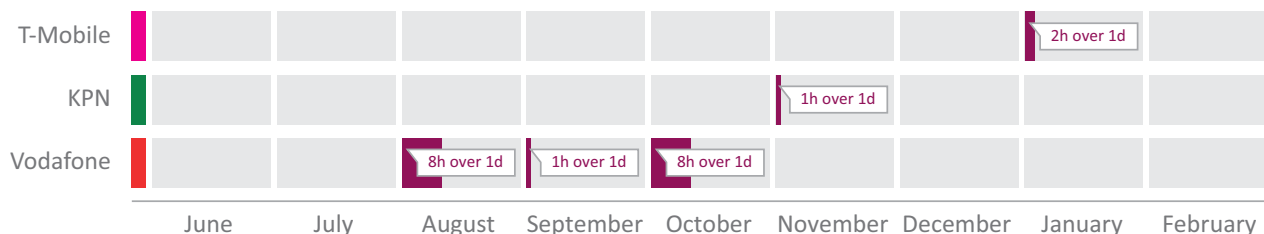
User Download Speed

T-Mobile
KPN
Vodafone



DATA SERVICE AVAILABILITY

Affected hours (h) and days (d) (2018)



CROWD RESULTS AT A GLANCE

All Dutch operators achieve high scores for their voice and data coverage. Overall, T-Mobile gathers most points in the crowdsourced categories, with KPN following at a distance of only one point. Vodafone also achieves good results, but loses a few points due to a slightly elevated level of service degradations during the summer of 2018.

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 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 February 12 to March 1, 2019. All samples were collected during the day, between 8.00 a.m. and 10.00 p.m. The network tests covered inner-city, outer metropolitan and suburban areas. Measurements were also taken in smaller towns and on the connecting highways. The two measurement cars together covered about 2,140 kilometres in the cities, about 620 km in towns and about 3,730 km on the roads – resulting in a total of 6,490 kilometres.

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

approximately 5.7 million people, or roughly 33.5 per cent of the total population of the Netherlands.

The drivetests covered 21 cities and 31 towns. Additionally, one team conducted walktests in seven cities and also on railway journeys between 14 destinations. The exact routes are shown on page 1 of this report, all visited cities and towns are listed in the box on the right.

The two drive-test cars as well as the battery-powered backpacks of the walktest teams were equipped with arrays of Samsung Galaxy S9 smartphones for the simultaneous measurement of voice and data services.

VOICE TESTING

One smartphone per operator in each car was used for the voice tests, setting up test calls from one car to another. The walktest team also carried one smartphone per operator for the voice tests. In this case, the smartphones called a stationary counterpart. The audio quality of the calls was

VISITED CITIES AND TOWNS

Cities: Almere, Amstelveen, Amsterdam (W), Apeldoorn, Breda (W), Dordrecht, Eindhoven (W), Haarlem, Haarlemmermeer, Leeuwarden, Leiden, Lelystad, Nijmegen, Purmerend, Roosendaal, Rotterdam (W), s-Gravenhage (The Hague) (W), Tilburg, Utrecht (W), Venlo, Zoetermeer. (W) designates walktest cities, an additional walktest has been conducted in Groningen.

Towns: Assen, Barneveld, Bergen op Zoom, Best, Boxtel, Cuijk, De Bilt, Echt-Susteren, Emmeloord, Epe, Etten-Leur, Geldermalsen, Gorinchem, Harlingen, Hollands Kroon, Huizen, Joure, Marum, Meerssen, Nederweert, Ommen, Renkum, Rijssen-Holtten, Sliedrecht, Staphorst, Stichtse Vecht, Waddinxveen, Weststellingwerf, Wierden, Woerden, Zaltbommel.

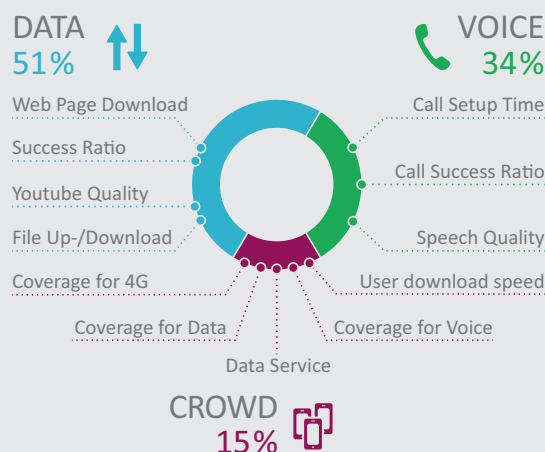
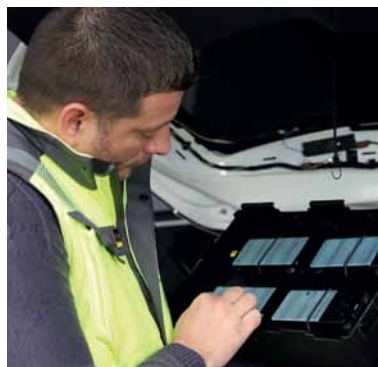
evaluated using the HD-voice capable and ITU standardised POLQA wideband algorithm.

All smartphones used for the voice tests were set to VoLTE preferred mode. In networks or areas where this modern 4G-based voice technology was not available, they would perform a fallback to 3G or 2G.

As a new KPI in 2018, we assess the so-called P90 value for call setup times. P90 values specify the threshold in a statistical distribution, below which 90 per cent of the gathered values are ranging.

In order to account for typical smartphone use during the voice tests, background data traffic was generated through random injection of small amounts of HTTP traffic. The voice scores account for 34 per cent of the total results. ►

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



DATA TESTING

Data performance was measured by using three more Galaxy S9 per car or walktest team – one per operator. Their radio access technology was set to LTE preferred mode.

For the web tests, they accessed web pages according to the widely recognised Alexa ranking. In addition, the static Kepler test web page as specified by ETSI (European Telecommunications Standards Institute) was used. In order to test the data service performance, files of 3 MB and 1 MB for download and upload were transferred from or to a test server located on the Internet. In addition, the peak data performance was tested in uplink and downlink directions by assessing the amount of data that was transferred within a seven seconds time period. This KPI targets to show the network capability, i.e. the maximum achievable data throughput, similar to what speed test apps would show. Such applications typically use multiple TCP sockets to overcome possible limitations to the maximum throughput of a single TCP connection. Such limits are caused by the combination of a variety of network parameters. Our measurements were executed using three parallel sockets for all operators to ensure fairness.

The carrier aggregation capabilities play a role. The more carrier frequencies are combined, the higher the throughput can be, always depending on whether network layout and other parameters do not prevent higher data rates. In such cases, higher throughput could be achieved with more sockets.

The evaluation of YouTube playback takes into account that YouTube dynamically adapts the video resolution to the available bandwidth. So, in addition to success ratios, start times and playouts without interruptions, we also determined average video resolution. All tests were conducted with the best-performing mobile plan of each

operator. Data scores account for 51 per cent of the total results.

CROWDSOURCING

Additionally, umlaut conducted crowd-based analyses of the Dutch networks which contribute 15 per cent to the end result. They are based on data that were gathered in December 2018 as well as in January and February 2019. For the collection of crowd data, 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 quarter of an hour and sent daily to umlaut's cloud servers. Such reports contain just a small number of bytes per message and do not include any personal user data.

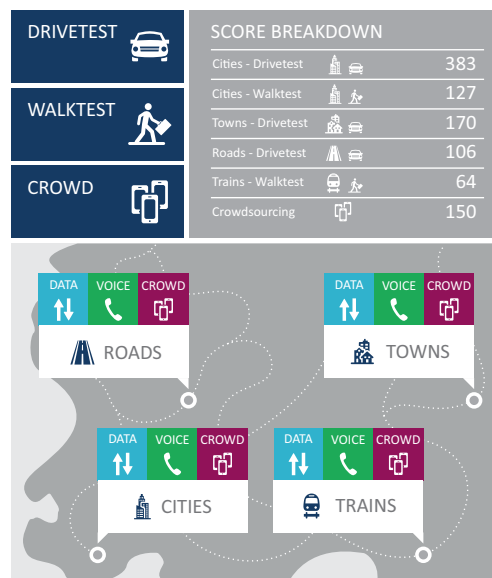
NETWORK COVERAGE

For the assessment of network coverage, umlaut lays a grid of 2 by 2 km over the whole test area. The "evaluation areas" generated this way are then sub-divided into 16 smaller tiles. To ensure statistical relevance, umlaut requires a certain number of users and measurement values per operator for each tile and each evaluation area. If these thresholds are not met by one of the operators, this part of the map will not be considered in the assessment for the sake of fairness.

"Quality of Coverage" reveals whether voice and data services actually work in an evaluation area. umlaut does this because not in each area that allegedly provides network reception, mobile services can actually be used. We specify these values for the coverage of voice services (3G and 4G combined), data (3G and 4G combined) and 4G only.

DATA THROUGHPUTS

Additionally, umlaut investigates the data rates that were actually available to each user. For this purpose, we determine the best obtained



data rate for each user during the evaluation period and then calculate their average value. In addition, we determine the so-called P90 values for the top throughput of each evaluation area as well as of each user's best throughput. P90 values specify the threshold in a statistical distribution, below which 90 per cent of the gathered values are ranging and depict how fast the network is under favourable conditions.

DATA SERVICE AVAILABILITY

Formerly called "operational excellence", this parameter indicates the number of outages or service degradations – events where data connectivity is impacted by a number of cases that significantly exceeds the expectation level. To judge this, the algorithm looks at a sliding window around the hour of interest. This ensures that we only consider actual degradations as opposed to a simple loss of network coverage due to prolonged indoor stays or similar reasons.

In order to ensure statistical relevance, each operator must have sufficient statistics for trend and noise analyses per each evaluated hour. The exact number depends on market size and the number of operators.

A valid assessment month must comprise of at least 90 per cent of valid assessment hours. Deviating from the other crowd score elements, Data Service Availability is rated based on a nine-month observation period – in this case from June 2018 to February 2019.

CONCLUSION

T-Mobile is the overall winner – for the fourth time in a row. KPN shows the biggest score improvement in comparison to the previous year, while Vodafone keeps its high performance level.

For the fourth time in a row, T-Mobile is the clear winner of the umlaut connect Mobile Benchmark Netherlands – and it ranks at the highest score level which has ever been achieved in a umlaut connect Mobile Benchmark.

KPN and Vodafone follow behind the winner at some distance. With their scores only two points apart, they show practically the same level of performance. And the fact, that all three Dutch operators achieve the grade “outstanding” clearly emphasises the very high performance level of the Netherlands’ mobile networks.

On this very high level, the Benchmark at hand reveals some differences: While T-Mobile leads in all three assessment categories, KPN performs slightly better than Vodafone in the Voice category, while the ranking order is vice-versa in the Data category. In the Crowdsourced evaluations, Vodafone loses a few points due to a slightly elevated level of service degradations in August, September and October 2018. This time, KPN showed the biggest score improvement over its result from the previous year. However, next year the race is open again.



1

The overall winner of the 2019 umlaut connect Mobile Benchmark in the Netherlands is T-Mobile –achieving the highest score level ever determined in our Mobile Benchmarks. T-Mobile clearly leads in all tested disciplines including the newly introduced crowd score and also leads the field in most of the single categories of our assessment.

2

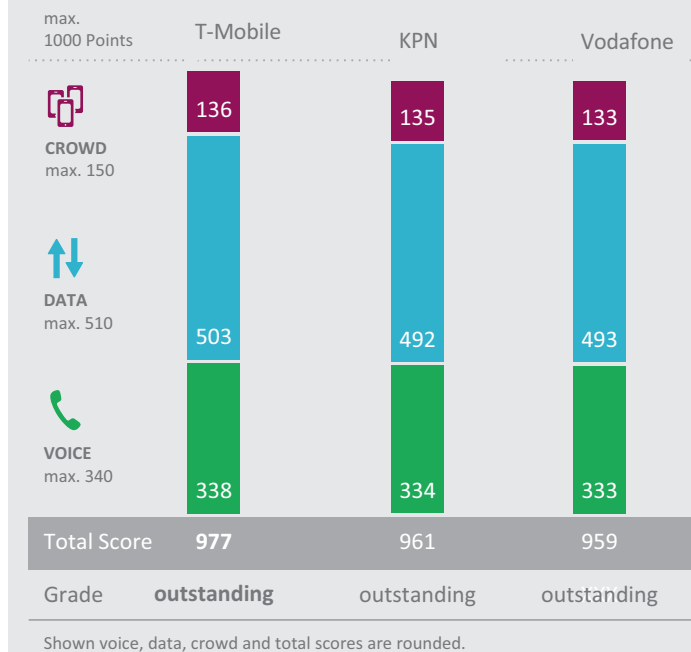


KPN shows the biggest score improvement compared to its results from the previous year. In a neck-and-neck race with an after all equally strong Vodafone, KPN scored slightly better in the Voice and Crowdsourced categories. KPN scores particularly strong in the Voice tests in smaller towns and in the Data tests on connecting roads.

3



Effectively, the performance of Vodafone is on a par with that of KPN. Vodafone scores slightly better than KPN in the data category and shows particularly strong results in the walktests conducted in bigger cities. An elevated level of degradations observed during the summer of 2018, costs this operator some points in the crowd score.



Overall Results
Voice, Data and Crowd

		T-Mobile	KPN	Vodafone
Voice	max. 340 Points	338	334	333
Cities (Drivetest)	153	100%	98%	98%
Cities (Walktest)	51	99%	98%	100%
Towns (Drivetest)	68	100%	100%	97%
Roads (Drivetest)	42	99%	99%	98%
Trains (Walktest)	26	94%	96%	94%
Data	max. 510 Points	503	492	493
Cities (Drivetest)	230	99%	98%	98%
Cities (Walktest)	76	98%	93%	99%
Towns (Drivetest)	102	99%	97%	96%
Roads (Drivetest)	64	100%	100%	99%
Trains (Walktest)	38	91%	87%	85%
Crowdsourced Quality	max. 150 Points	136	135	133
Crowd	150	91%	90%	89%
Connect Rating	max. 1000 Points	977	961	959

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