2023

Belgian Institute for Postal Services
and Telecommunications

DRIVE & TRAIN TEST CAMPAIGN RESULTS

Summary >

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commsquare

INTRODUCTION

For the sixth year since 2018, BIPT and Commsquare have measured customer experience of the three mobile networks in Belgium. For the first time, measurements were conducted using 5G phones.

This report increases transparency and helps customers make better informed decisions based on network quality measurements. It also helps BIPT to understand and monitor the status and evolution of the mobile networks in Belgium. Finally, operators can rely on this information to prioritize their investment and enhance their mobile network services.

This report contains the results, explains the methodology and gives an overview of the BIPT 2023 measurements campaign on customer experience.

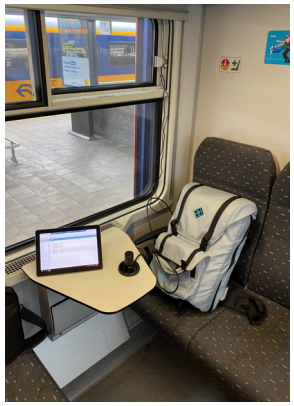
1. CAMPAIGN METHODOLOGY

The purpose of the mobile benchmarking exercise is to understand what customers experience when they watch a video, visit a website, download a file, or make a phone call on a mobile network, using a 5G smartphone.

The campaign was conducted between 28/Aug/2023 and 14/Oct/2023 and included both drive tests and train tests. For the drive tests, measurements were conducted by driving 2 cars with Rohde & Schwarz equipment. Smartphones were installed in a ski-box, such that the measurements represent in-car and indoor performance (i.e. as experienced by a user in

a building or house, close to a window). Over 250 hours of drive tests were conducted.

For the train tests, measurements were conducted with smartphones installed in a Rohde & Schwarz measurement backpack. Tests in the train were conducted in the middle wagon and at the ground level and sitting at the window. Roughly 140 hours of train tests were conducted.



5G technology

All 3 Belgian operators offer 5G in Non-Stand-Alone mode (5G/NSA) to the general public. For data tests, this means that 5G-capable phones will firstly connect to the 4G network, and optionally and in parallel connect to 5G, if it is locally available. For the VoLTE voice tests, the 5G-capable phone will only use the 4G network. In other words, 5G is currently only used during data tests, and only as a complement to an existing 4G data connection.

This approach allows operators to already offer some of the benefits of 5G in a gradual way, in areas with combined 4G-5G coverage. The main benefits of 5G (NSA mode) are increased capacity and performance, which mainly comes with the roll-out of 3.5 GHz spectrum.

In the coming years, 5G is expected to evolve to Stand-Alone mode (5G/SA), whereby mobile phones will connect directly to the 5G network, without relying on a parallel 4G connection. This 5G/SA mode will lead to further performance improvements, for instance faster response times.

5G smartphone for testing

For the first time, the mobile network benchmark was conducted with 5G-capable phones, after major 5G radio spectrum was auctioned by BIPT in June 2022.

Measurements in 2023 use the Samsung Galaxy S23 Plus smartphone model for both VoLTE voice and data tests, running on Android 13. This is a recent and popular 5G smartphone offered by all 3 mobile network operators. It supports the main network features available on all 3 mobile networks at the time of the testing.

5G network modernisation and customer impact

Building a 5G network requires massive investments by the mobile network operators. In our tests, we observed all operators are upgrading and replacing existing network infrastructure to support 5G. Furthermore, providing a good 3.5GHz radio signal requires the construction of additional antenna sites.

The nationwide works on all mobile networks may cause some performance disturbances with a local and temporary impact on customer experience in the areas of the ongoing work.

5G service indicator versus 5G performance

Operators follow different strategies when deploying 5G. The "5G" service indicator on your mobile phone doesn't automatically result in substantially improved performance compared to 4G.

One approach for operators is to assign new spectrum to 5G. If the bandwidth of the new spectrum is significant, as is the case for the new 3.5GHz frequency band (with up to 100MHz of bandwidth), this will result in major performance improvements especially in download applications. All operators in Belgium adopt this approach; we observed on all networks more than 10% of data tests on the new 3.5GHz spectrum.

Another or a complementary approach is to shift a limited amount of spectrum from an existing radio technology (e.g., 4G) to 5G, to provide contiguous 5G coverage or improved performance in upload applications. The mobile phone will indicate "5G" service, but the performance gain for download applications compared to 4G will be small. The mobile networks have adopted different strategies in this complementary approach.

As a result of the different 5G deployment strategies, the 5G indicator on your mobile phone may result in either substantial or small performance gains, in either download or upload applications. The true indicator of 5G is rather in running a performance test.

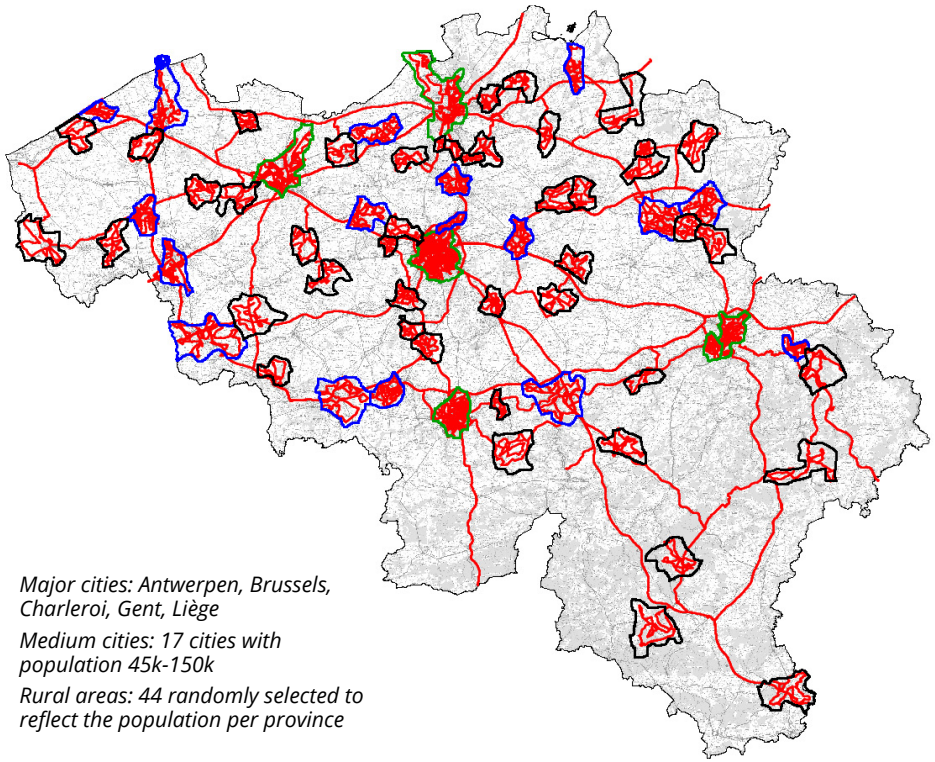
1.1. DRIVE TESTS SCOPE AND LOCATIONS

BIPT and Commsquare selected the cities and villages to be measured, based on their importance and population (see map). The selection of medium-sized cities and rural areas reflects the population per province.

The same major and medium cities are tested since BIPT started similar measurements in 2018, although the actual roads driven in each city slightly vary from one year to another year.

As for the 44 rural areas, these are randomly selected each year. Hence, we always test different rural areas and different national roads connecting the rural areas. Operators do not receive upfront information on the selected rural areas in the test. This random selection ensures fairness and has no impact on the results, except for pure statistical variation.

A total distance of roughly 12,000 km was driven during the tests; over 8,000 voice calls were made on each network; and over 60,000 data tests were conducted per network.



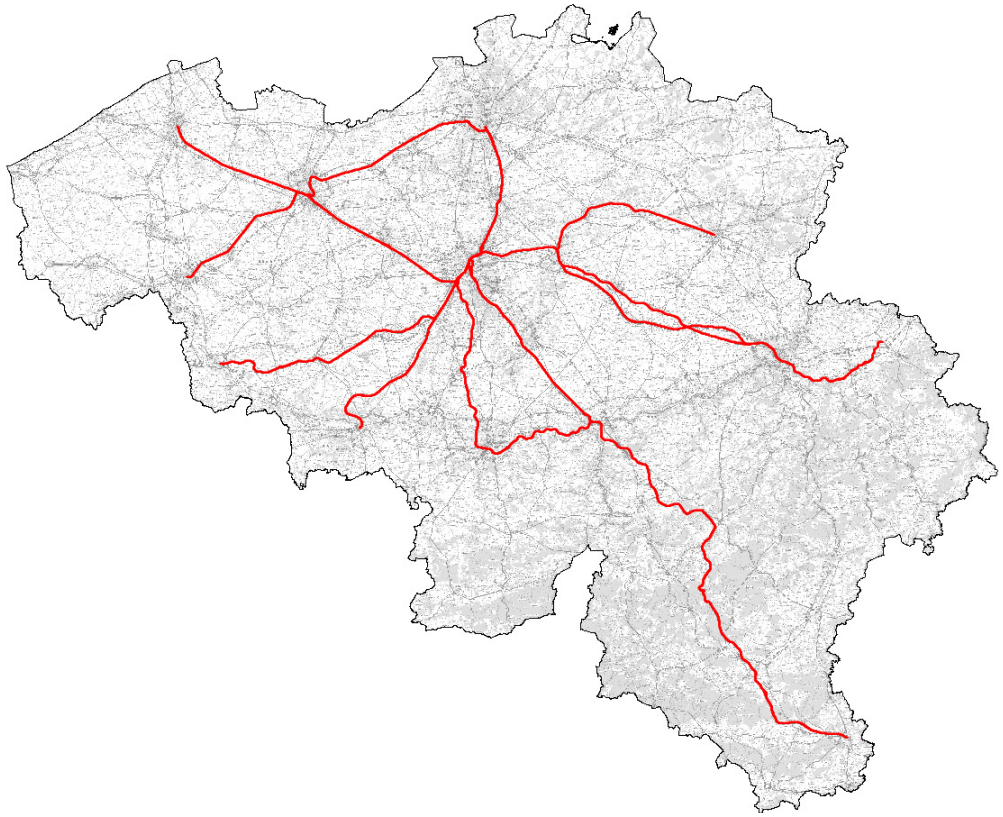
Major cities: Antwerpen, Brussels, Charleroi, Gent, Liège

Medium cities: 17 cities with population 45k-150k

Rural areas: 44 randomly selected to reflect the population per province

1.2. TRAIN TESTS SCOPE AND TRAIN LINES

Train tests were conducted on 16 train lines.



For the first time, two types of train tests were executed:

1) Legacy or historical approach, similar as in 2022, whereby (a) the same tests as during the drive test are conducted, and (b) results are reported for all 16 train lines combined; and
2) A new approach, per individual train line, whereby (a) only a subset of tests is conducted, and (b) results are reported per individual train line.

For the legacy or historical approach, each train line was measured in both directions and shorter lines were measured several times to reflect their importance in the overall aggregation of results. A total distance of roughly 2,600 km was covered during the tests; over 850 voice calls were made on each network; and over 6,000 data tests were conducted per network.

For the individual-train-line approach, each of the train lines was additionally measured multiple times in both directions, until 200 voice and data test samples per line were collected. The tests were limited to voice, download and upload throughput, and web browsing. On average, 7 hours of measurements were collected per individual train line.

1.3. VOICE TELEPHONY TESTS

The Samsung Galaxy S23 Plus on Android 13 was used for the voice tests. For the drive test, voice calls were made between phones placed in each car, i.e. a phone in the first car calling the phone in the second car. For the train test, voice calls were made between a phone placed on the train and the second phone placed at a static location in Mechelen (ensuring fair radio conditions for all mobile operators).

A new VoLTE call was made every 2 minutes: the call duration was 90 sec, with a 30 sec pause between test calls. During the call, the phones could make unrestricted and non-user-initiated data activity, as is typically the case for a smartphone.

1.4. DATA TESTS

The Samsung Galaxy S23 Plus was used for tests in 5G-preferred-mode. This means the phone tries to use the 5G in parallel with an existing 4G connection, but in its absence, continues service on the 4G, 3G or 2G data network.

The data tests included a series of different tests: throughput speed tests in downlink and uplink (conducted as a down- or upload during 10s); a file transfer of 10MB in download and 5MB in upload; a selection of 6 popular web pages in the web browsing tests; two YouTube buffered streaming videos, each one with 45s duration; and a Dropbox upload test of 1MB file.

Regarding comparison of the data tests with benchmarks in previous years, we want to point out that:

- Web pages are dynamic, their content changes quickly (in particular for news pages). This means the indicator "web browsing time" cannot be compared from one campaign to the other.
- We have adopted a more advanced approach to YouTube testing: we first stream a video (as in 2022) with a resolution of 1,080p or Full High Definition (FHD), and then we stream a second (newly added) 4K-video with a resolution of 2,160p or Ultra High Definition (UHD). In the video indicators, the results of both types of streaming tests are combined.

1.5. KNOWN LIMITATIONS

The approach follows industry best practices as well as the relevant technical recommendations on mobile network benchmarking, but nevertheless has some inherent known limitations.

The results in this report are a snapshot of mobile network performance measured in Belgium in August-October 2023. Mobile networks evolve and undergo changes, which might lead to different performance in the future.

All tests are conducted whilst driving a car, or inside a train. This is a best-practice approach to conduct tests across an entire country. However, most mobile users use their phone in static conditions, i.e. when not moving. It is generally assumed the average static user experiences better performance than a moving user in the same radio conditions.

The test setup measures customer experience in indoor or in train conditions, e.g. for a user in a building close to the window or seating in a train next to the window. When using a mobile phone in deep-indoor locations (e.g. indoors far away from a window, in highly insulated houses, or concrete buildings or in basements), performance will be worse.

Tests were conducted using high-end smartphones running on one of the newest Android operating system versions. As mobile phones themselves impact user experience, users with older or less-advanced phone models or with a different operating system might experience a different performance.

We conducted the tests with 5G-capable phones. Users with smartphones not supporting 5G yet, will experience a different performance for data services (the networks currently only use 5G when using data services).

Users with phones not supporting VoLTE yet, or with SIM cards without VoLTE provisioned, will experience worse voice quality.

The results we present for voice are based on test calls with a duration of 90 sec. Mobile phone users making calls with a (much) longer duration, especially when driving or in a train, will eventually experience worse performance, such as temporary poor speech quality issues or more dropped calls.

2. DRIVE TEST CAMPAIGN

2.1. VOICE – NATIONWIDE

Voice performance is summarised in 3 categories of service indicators.

Voice Summary		Orange	Proximus	Telenet
Success Rates				
Call setup success rate	%	99.2%	99.4%	99.4%
Successfully established calls completion rate	%	99.6%	99.5%	99.2%
Call Setup Time				
Call Setup Time (s)	Average	3.0	2.4	2.9
Call Setup Time (s) long samples	10% longest	4.8	2.7	3.9
Voice Quality				
Voice Quality Score	Average	4.5	4.5	4.5
Voice Quality Score low samples	10% lowest	4.0	4.0	4.1

This is a description of the voice service indicators and results for the drive tests:

- **Success rates** answer the questions "Can I make a call?" (setup success) and "Can I complete a call without a drop?" (completion rate).

  The **call setup success rate** denotes the proportion of success call setups, i.e. "Can I make a call", in other words, do I receive ringing tone after I pressed the dial button. Proximus (99.4%) and Telenet (99.4%) score the highest rate, followed by Orange (99.2%).

  The **successfully established calls completion rate** measures the proportion of successfully established calls that reach the end of the conversation, i.e. "Can I complete a call without a drop?", in other words calls that successfully started and didn't prematurely terminate or drop. Orange (99.6%) scores the highest rate, followed by Proximus (99.5%) and Telenet (99.2%). Note the completion rate depends on call duration, which is 90s in the case of our tests.

- **Call Setup Time** measures the time that is needed to set up a call, i.e. from pressing the dial button until hearing the ringing tone.

  For the **average call setup time**, Proximus (2.4s) is the fastest, followed by Telenet (2.9s) and Orange (3.0s).

  Call setup time long samples indicates the minimum time it takes to set up the 10% slowest calls. Proximus (2.7s) is faster than Telenet (3.9s) and Orange (4.8s).

- **Voice Quality** measures the quality of the conversation on a scale from 5 (excellent) to 1 (poor). Good speech quality means clarity of the call, i.e. the speech clearness, fidelity, intelligibility and absence of distortion (such as a metallic voice).

  All operators demonstrate the same **average voice quality score** (4.5).

  Voice quality score low samples indicates voice quality for the 10% worst speech samples. Telenet (4.1) scores higher than Orange and Proximus (4.0).

2.2. DATA – NATIONWIDE

The performance of data services is expressed in 5 categories of service indicators.
We refer to the description of the test setup: the 2023-campaign is the first one with data tests using a smartphone supporting 5G.

Data Summary			Orange	Proximus	Telenet
Throughput					
HTTP DL fixed duration	DL throughput	Average (Mbps)	94.5	136.8	90.7
		Slowest 10% (Mbps)	4.3	10.2	8.5
HTTP UL fixed duration	UL throughput	Average (Mbps)	24.4	28.5	30.2
		Slowest 10% (Mbps)	2.6	3.6	2.5
File Transfer					
HTTPS DL fixed size 10MB	File download	Median time (s)	2.9	1.7	3.2
		Success rate (%)	96.1%	97.6%	98.5%
HTTPS UL fixed size 5MB	File upload	Median time (s)	2.8	2.2	2.1
		Success rate (%)	95.5%	96.6%	95.4%
Web Browsing					
All web pages (blended KPI)	Web browsing time	Median time (s)	1.9	1.8	2.0
		Success rate (%)	98.0%	98.6%	98.8%
Video					
YouTube – buffered streaming (blended KPI)	Success Rate	Success rate (%)	98.6%	98.8%	99.2%
	Time to 1st picture	Average time (s)	0.8	0.7	0.8
	Video Quality	Average MOS	4.2	4.2	4.2
Cloud storage service					
Dropbox UL 1MB	Upload	Median time (s)	1.4	1.3	1.3
		Success rate (%)	97.7%	98.2%	98.0%

This is a description of the data service indicators and results for the drive tests:

- **Throughput** (expressed in Mbps) measures the speed the network can offer to a single user. An individual user will benefit from high throughput in case he/she wants to download large amounts of data.

  Proximus has the highest average **download throughput** (136.8Mbps), followed by Orange (94.5Mbps) and Telenet (90.7Mbps). Proximus (10.2Mbps) has the highest download throughput performance when considering the 10% of slowest test cases, followed by Telenet (8.5Mbps) and Orange (4.3Mbps).

  Telenet has the highest average **upload throughput** (30.2Mbps), followed by Proximus (28.5Mbps) and Orange (24.4Mbps). Proximus has the highest upload throughput performance (3.6Mbps) when considering the 10% of slowest test cases, followed by Orange (2.6Mbps) and Telenet (2.5Mbps).

- **File transfer** tests measure the performance of downloading a 10MB file or uploading a 5MB file (e.g. for downloading or uploading a picture). The performance of file transfers is measured by 2 service indicators: (1) the **time to complete the transfer**, i.e. an indicator of speed, and (2) the **success rate**, an indicator of the reliability of the service.

  For a **download** of a 10MB file, Proximus (1.7s) has the fastest download time, followed by Orange (2.9s) and Telenet (3.2s). Telenet has the highest success rate (98.5%), followed by Proximus (97.6%) and Orange (96.1%).

  For an **upload** of a 5MB file, Telenet has the fastest upload time (2.1s), followed by Proximus (2.2s) and Orange (2.8s). Proximus has the highest success rate (96.6%), followed by Orange (95.5%) and Telenet (95.4%).

- **Web browsing** or surfing to web pages is a popular activity of mobile phone users. A selection of 6 popular web pages in Belgium was used for the aggregated results. Web browsing results are summarised into 2 service indicators: (1) the time to view the web page (web page browsing time) and (2) the success rate.

  For **web page browsing time**, Proximus is the fastest (1.8s), followed by Orange (1.9s) and Telenet (2.0s).

  Web success rate denotes the percentage of web pages that are completely downloaded within 15s. Telenet (98.8%) demonstrates the highest web success rate, followed by Proximus (98.6%) and Orange (98.0%).

- **Video streaming**, and YouTube in particular, is amongst the most popular mobile apps. Buffered video streaming was tested, as opposed to live streaming. A selection of 2 videos was used for aggregated results. One video supported a resolution up to Full High Definition (FHD), whereas the other one supported up to Ultra High Definition (UHD - 4K) resolution.

  YouTube performance is measured as (1) a success rate, i.e. the proportion of tests that had a complete play-out of the video; (2) the time-to-first picture, i.e. how long it takes for the play-out to start; and (3) the video quality during the entire play-out.

  Telenet (99.2%) offers the highest **success rate**, followed by Proximus (98.8%) and Orange (98.6%).

  Proximus (0.7s) has the fastest "**time to 1st picture**", followed by Orange and Telenet (0.8s).

  Video quality is the same on all networks (4.2). It captures the effect of low video resolution, freezing of the play-out, etc. When the networks offer sufficient throughput and capacity (typically in the

range 5-10Mbps), and coverage is present, video quality is expected to be the same on all networks.

- **Cloud storage service** (Dropbox) performance is measured as (1) the time to upload a 1MB file and (2) the success rate to complete the transfer.

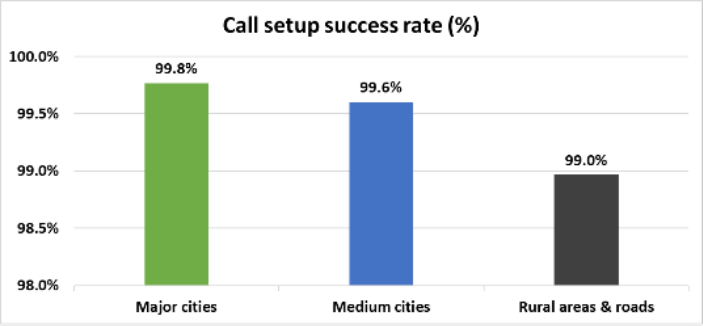
For the **time to upload** the 1MB file, Proximus and Telenet (1.3s) take the same time, followed by Orange (1.4s).

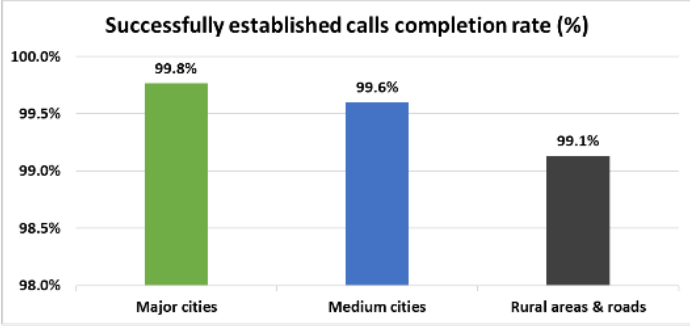
Proximus has the highest **success rate** (98.2%), followed by Telenet (98.0%) and Orange (97.7%).

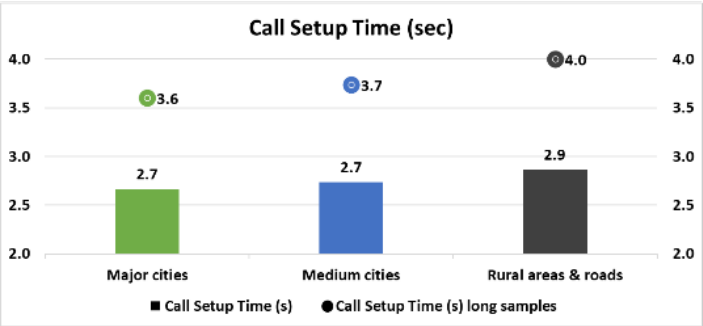
2.3. VOICE – PERFORMANCE PER AREA

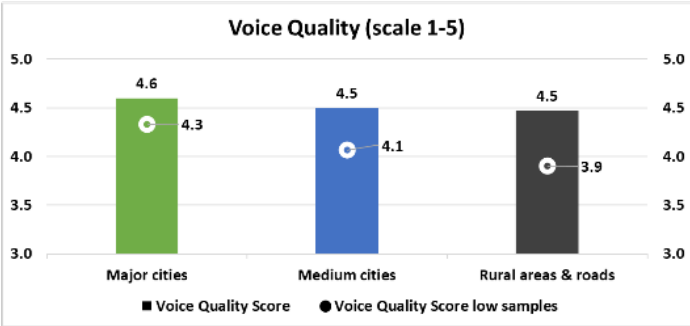
We compare voice quality in the different geographical areas (i.e. major cities, medium cities and rural areas & roads).

The charts demonstrate the 4 voice quality indicators are highest in major cities, whereas voice quality is lower in rural areas and on roads. We believe there are 2 main reasons for this observation: firstly, we noticed operators are heavily investing in network modernisation, and improvements are often rolled out in cities first (so they reach the maximum number of mobile users). Secondly, it requires relatively more investments to provide excellent service in rural areas and on local roads. From international comparisons, performance in rural areas and on local roads in Belgium is high (with e.g. success rates above 99%).





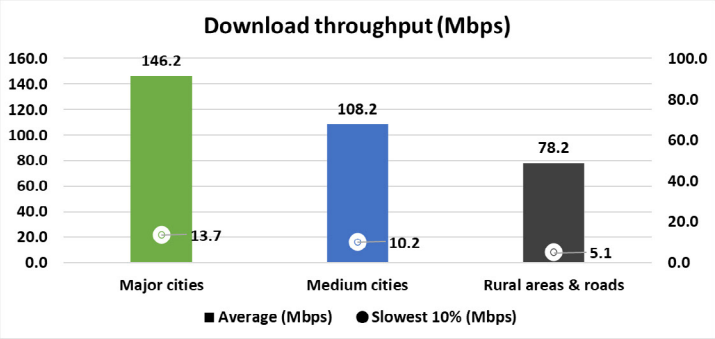


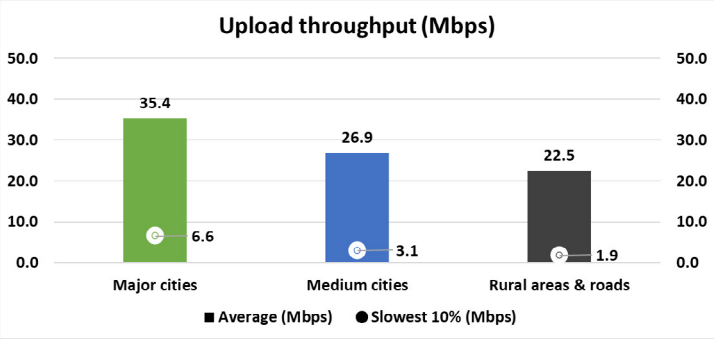


2.4. DATA – PERFORMANCE PER AREA

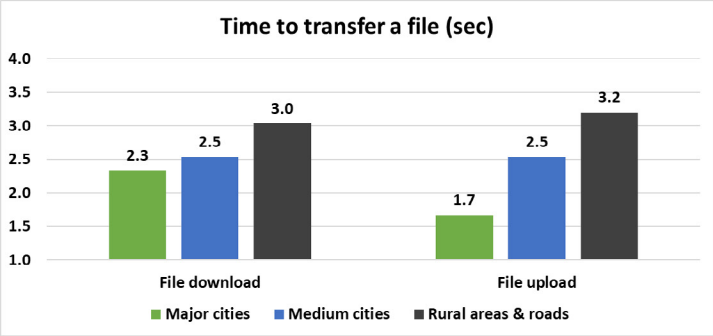
The charts present KPIs for data services by area type: major cities, medium cities, and rural areas & roads.

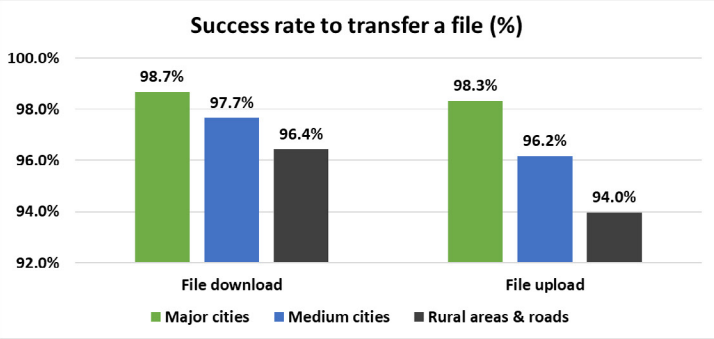
Throughput related indicators:



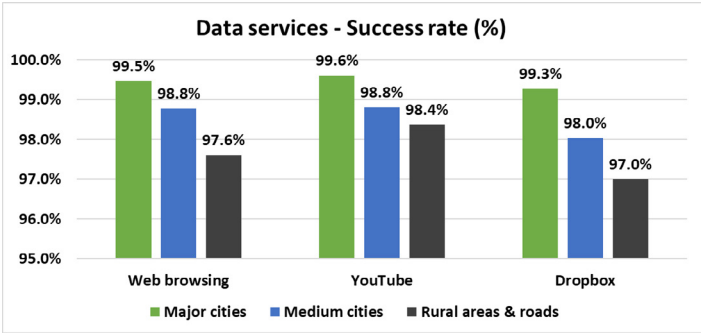


File download & upload:





Data service success rates:



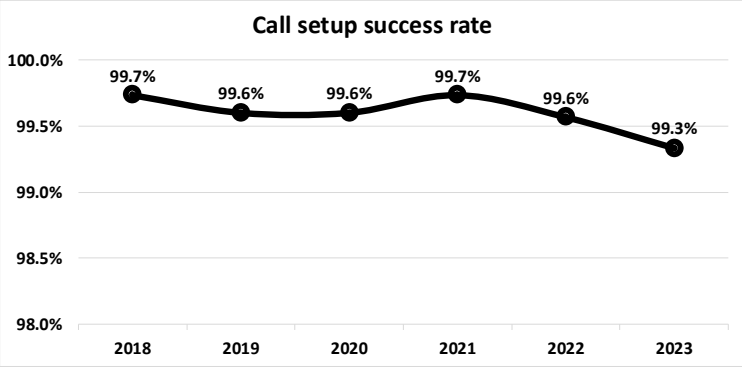
2.5. VOICE – TRENDING

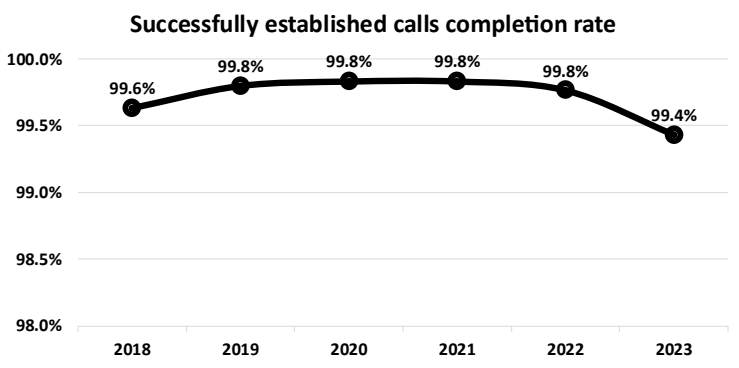
Trending charts below present the voice quality indicators aggregated across all 3 mobile operators, to reflect the average evolution of mobile network performance in Belgium since 2018.

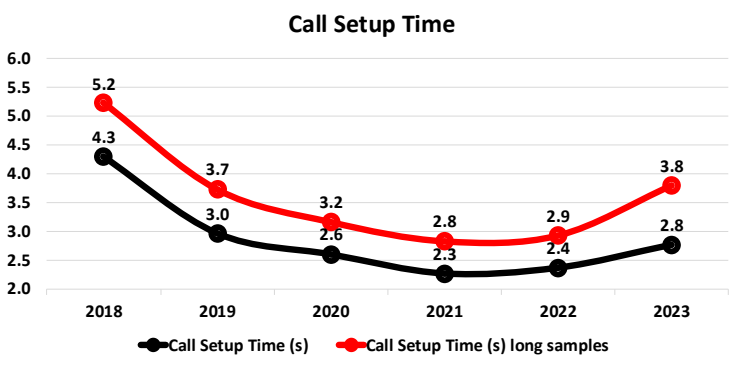
Success rate indicators ("Can I set up a call?" and "Can I complete the call without a drop?") are well above 99% since the initial measurements in 2018. We observe a declining trend in the last 1-2 years though, which we attribute to an increased load on the 4G networks (currently, even with initial 5G deployments, voice and data traffic in the network requires 4G as the main radio technology, see exhibit on 5G technology). Operators are mitigating load on their 4G networks in a few different ways, e.g., by activating additional radio spectrum (as acquired in the June 2022 auction); by building additional antenna sites; by shifting part of their data traffic to 5G; etc.

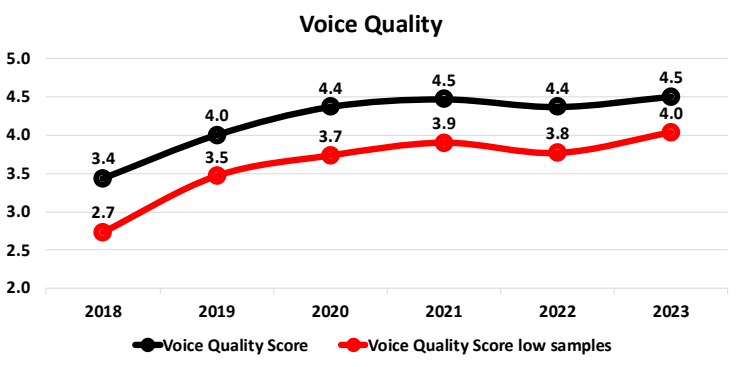
Call setup time (i.e. the time to hear ringing tone) remains below 3.0s since the introduction of VoLTE as the voice technology in all networks (measured for the first time in 2020). The 0.4s increase (from 2.4s to 2.8s) is attributed to the change of the smartphone used for the voice tests since 2023.

Average voice quality is high and above 4.4 (on a scale of 5) since the best voice codec was introduced in all networks (as measured in 2020). The quality of the 10% worst calls has improved over the past year.









2.6. DATA – TRENDING

Results are aggregated across all 3 mobile operators, to reflect the average evolution of mobile network performance in Belgium.

We wanted to compare (historical) 4G data performance with the performance measured with a 5G smartphone in this campaign. Therefore, for the throughput measurements only, we made additional measurements with the same 4G-smartphone as used in previous years. This allows us to show the trend of network performance for a 4G phone.

For download throughput, the 5G-capable phone achieves 107.3 Mbps on average, whereas the 4G phone only achieves 70.2 Mbps averaged over the 3 mobile networks. 4G throughput declines since 2021, which is attributed to an increased load on the 4G networks. The benefit of 5G is apparent: 5G adds capacity to the mobile network and leads to an improved network performance with better customer experience. With the ever-increasing data traffic per mobile user, further deployment of 5G across Belgium is needed to avoid declining mobile phone performance.

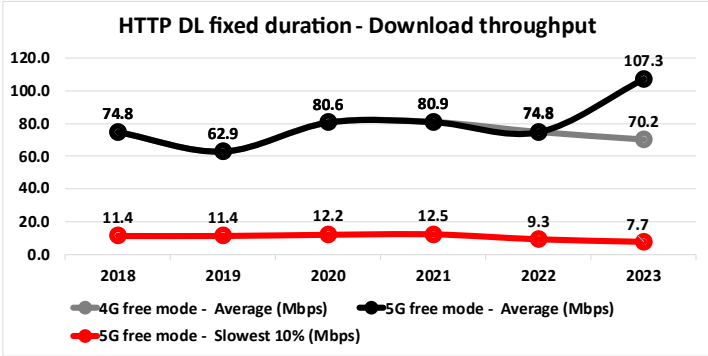
The 10% slowest tests for download throughput show a declining trend as of 2021. Since 5G has not been deployed nationwide by any of the operators, the slowest tests are typically using the 4G network only, in absence of local 5G coverage. The declining trend is again attributed to higher load on the (4G) network, which has a substantial impact on customer experience (decline from 12.5 to 7.7 Mbps for the 10% slowest tests over the past 2 years).

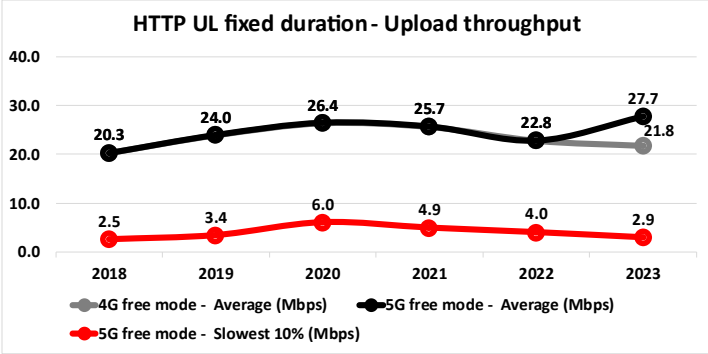
From a technical analysis of the measurements and from theoretical considerations, the biggest performance gain for 5G comes from the new 3.5GHz-spectrum that was auctioned by the BIPT in June 2022.

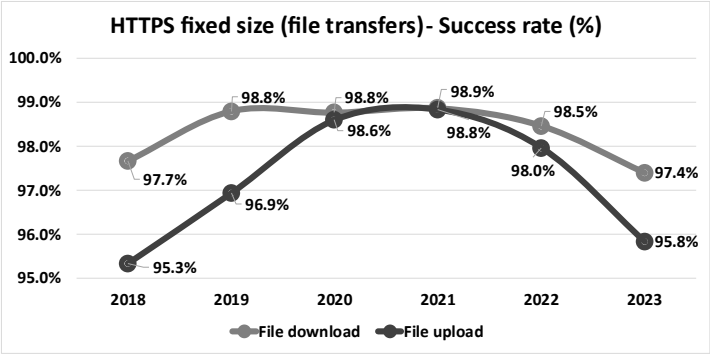
For upload throughput, similar observations can be made: increased performance where 5G is available (now 27.7 Mbps on average across networks); a decline when only 4G is used (now 21.8 Mbps vs 26.4 Mbps in 2020); and major degradation for the 10% slowest upload throughput tests over the past years (now 2.9 Mbps vs 6.0 Mbps in 2020).

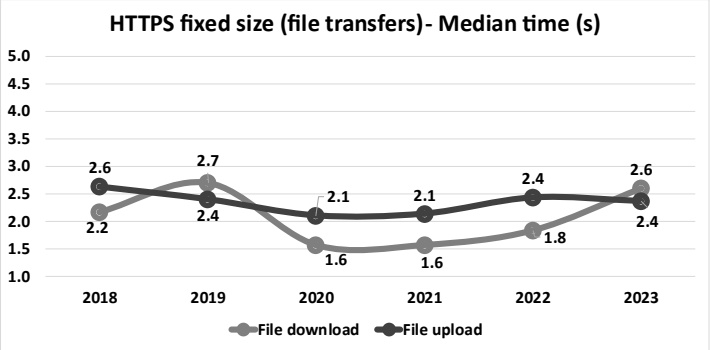
For all other data tests, the trend for the success rate indicators is similar, i.e., a decline since the best values were observed in 2020 and 2021.

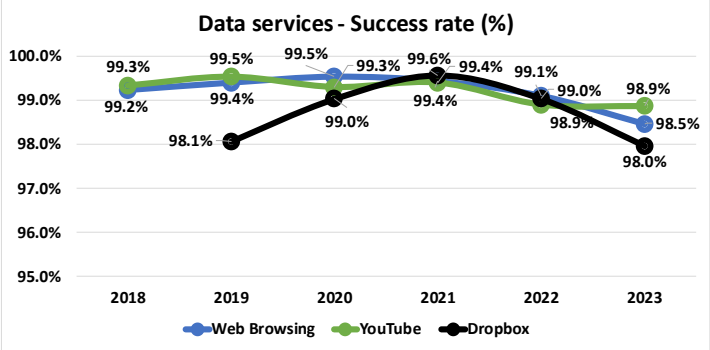
All declines in performance are mainly attributable to increased load on the 4G networks.











2.7. CONCLUSIONS FOR DRIVE TEST

Belgian network operators still depict a very good performance in drive tests, although some quality indicators have degraded compared to previous years.

Performance is highest in big cities, followed by medium size cities; performance in rural areas and roads is lower but still at good levels. This is partially attributed to the more advanced roll-out of 5G in big cities, and ongoing roll-out of 5G in rural areas.

Some 4G performance indicators show a decreasing trend. Local 4G network saturation, or local increases in 4G network load, affect both some of the voice and the data quality indicators in these high-load areas. However, in areas where 5G coverage in the 3.5GHz band is available, both download and upload throughput improved compared to previous years.

3. TRAIN TEST CAMPAIGN

All results below refer to the historical or legacy scope of train tests, where measurements on the 16 train lines are aggregated into a single quality indictor per test.

3.1. VOICE

Voice performance is summarised in the same 3 categories of service indicators also for all train lines aggregated together.

Voice Summary		Orange	Proximus	Telenet
Success Rates				
Call setup success rate	%	98.4%	97.3%	92.6%
Successfully established calls completion rate	%	98.7%	96.9%	92.7%
Call Setup Time				
Call Setup Time (s)	Average	3.0	2.6	3.2
Call Setup Time (s) long samples	10% longest	4.7	3.5	4.2
Voice Quality				
Voice Quality Score	Average	4.5	4.4	4.4
Voice Quality Score low samples	10% lowest	4.0	3.9	3.9

This is a description of the voice results for the train tests:

- Orange demonstrates the highest **call setup success rate** (98.4%) followed by Proximus (97.3%) and Telenet (92.6%).

  Orange (98.7%) scores the highest **successfully established calls completion rate**, followed by Proximus (96.9%) and Telenet (92.7%).
- For the **average call setup time**, Proximus (2.6s) is the fastest, followed by Orange (3.0s) and Telenet (3.2s).

  In terms of **call setup time long samples** Proximus (3.5s) is faster than Telenet (4.2s) and Orange (4.7s).
- All operators demonstrate a high **average voice quality score** with Orange (4.5) ahead of Proximus and Telenet (4.4). For the **voice quality score low samples**, Orange (4.0) scores higher than Proximus and Telenet (3.9).

3.2. DATA

Data performance is expressed in the same 5 categories of service indicators as for the train tests.
For the train tests, the 2023-campaign was also the first one to use a 5G-capabile smartphone.

Data Summary			Orange	Proximus	Telenet
Throughput					
HTTP DL fixed duration	DL throughput	Average (Mbps)	64.3	85.5	55.5
		Slowest 10% (Mbps)	1.0	4.7	0.9
HTTP UL fixed duration	UL throughput	Average (Mbps)	18.5	19.2	19.0
		Slowest 10% (Mbps)	1.0	1.4	0.6
File Transfer					
HTTPS DL fixed size 10MB	File download	Median time (s)	4.2	2.8	5.1
		Success rate (%)	89.3%	93.5%	89.3%
HTTPS UL fixed size 5MB	File upload	Median time (s)	4.0	3.1	3.8
		Success rate (%)	90.6%	93.0%	86.3%
Web Browsing					
All web pages (blended KPI)	Web browsing time	Median time (s)	2.1	1.9	2.2
		Success rate (%)	94.8%	96.4%	92.6%
Video					
YouTube – buffered streaming (blended KPI)	Success Rate	Success rate (%)	97.3%	95.9%	94.4%
	Time to 1st picture	Average time (s)	1.1	0.9	1.0
	Video Quality	Average MOS	4.1	4.2	4.1
Cloud storage service					
Dropbox UL 1MB	Upload	Median time (s)	1.7	1.5	1.9
		Success rate (%)	94.5%	94.4%	86.1%

This is a description of the data results for the train tests:

- Proximus has the highest average **download throughput** (85.5Mbps), followed by Orange (64.3Mbps) and Telenet (55.5Mbps). When considering the 10% of slowest test cases, Proximus has the highest download throughput performance (4.7Mbps), followed by Orange (1.0Mbps) and Telenet (0.9Mbps).

  Proximus has also the highest average **upload throughput** (19.2Mbps), followed by Telenet (19.0Mbps) and Orange (18.5Mbps). When considering the 10% of slowest test cases, Proximus has the highest upload throughput performance (1.4Mbps), followed by Orange (1.0Mbps) and Telenet (0.6Mbps).

- For a **download** of a 10MB file, Proximus has the fastest download time (2.8s), followed by Orange (4.2s) and Telenet (5.1s). Proximus has the highest success rate (93.5%), followed by Orange and Telenet (89.3%).

  For an **upload** of a 5MB file, Proximus has the fastest upload time (3.1s) followed by Telenet (3.8s) and Orange (4.0s). Proximus shows the highest success rate (93.0%), followed by Orange (90.6%) and Telenet (86.3%).

- For **web page browsing time** Proximus is fastest (1.9s), followed by Orange (2.1s) and Telenet (2.2s). Proximus has the highest **web success rate** (96.4%), followed by Orange (94.8%) and Telenet (92.6%).

- For **video streaming**, Orange (97.3%) offers the highest **success rate**, followed by Proximus (95.9%) and Telenet (94.4%).

  Proximus (0.9s) has the fastest "**time to 1st picture**", followed by Telenet (1.0s) and Orange (1.1s).

  Proximus (4.2) demonstrates the highest **video quality**, followed by Orange and Telenet (4.1).

- Regarding **Cloud storage service** (Dropbox), Proximus has the fastest **time to upload** (1.5s), followed by Orange (1.7s) and Telenet (1.9s)

  Orange presents the highest **success rate** (94.5%), followed by Proximus (94.4%) and Telenet (86.1%).

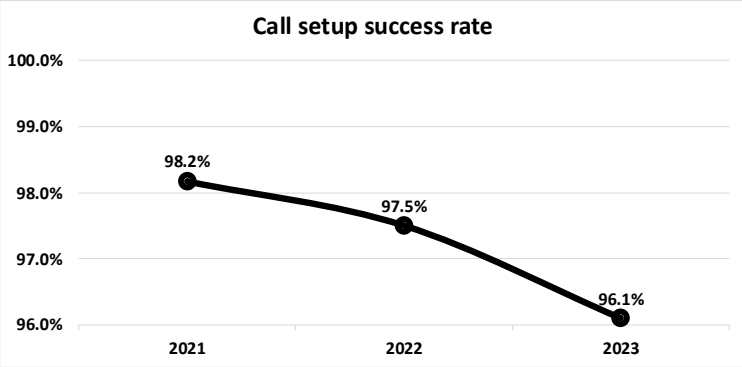
3.3. VOICE – TRENDING

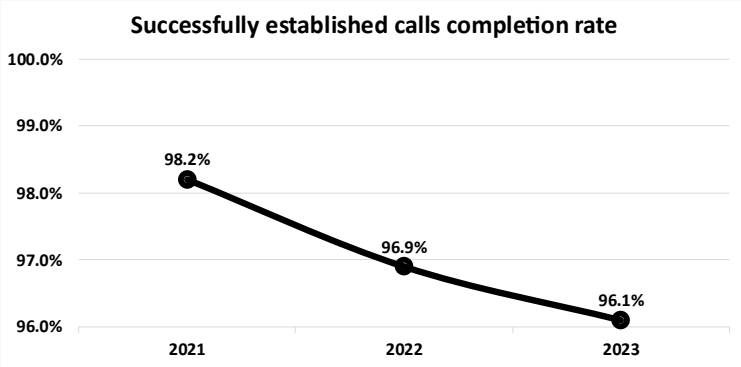
Results are aggregated across all 3 mobile operators, to reflect the average evolution of mobile network performance in Belgium.

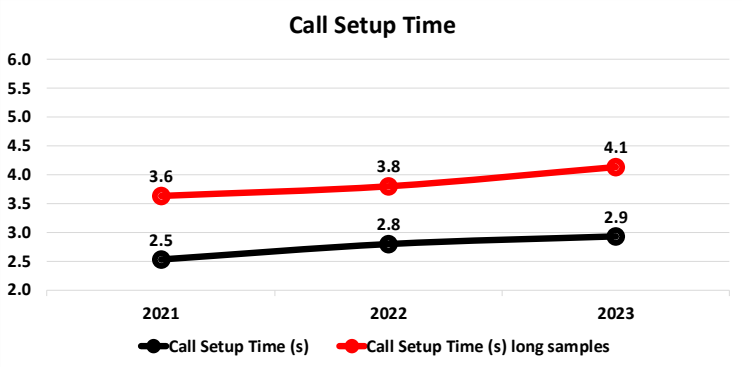
The evolution and trending of the results for the train tests over the past years are comparable to the trends for drive tests.

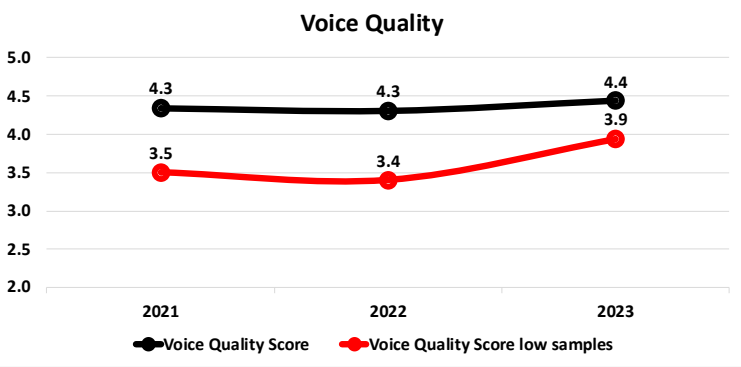
The main trends for the train tests are:

- A decline of the success rate indicators for voice over the past 2 years.
- Call setup takes slightly longer, due to a change of the smartphone model used for testing.
- Average voice quality marginally improves, with a substantial improvement in the calls with low voice quality.







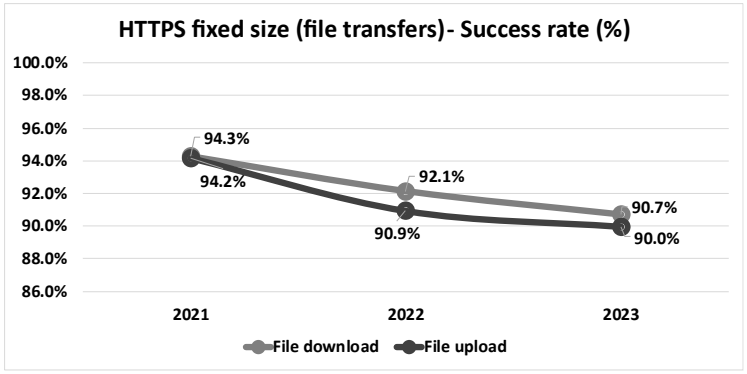


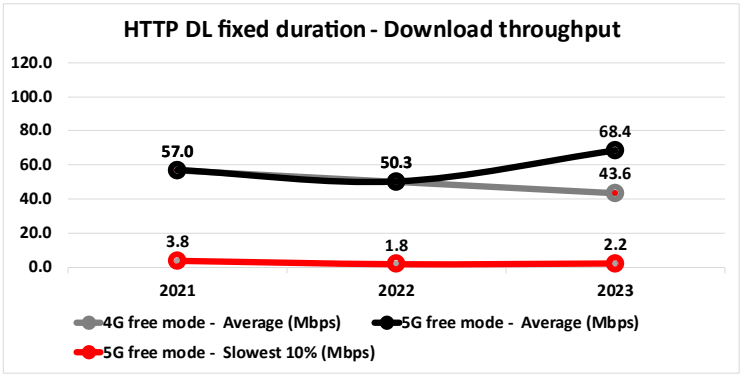
3.4. DATA – TRENDING

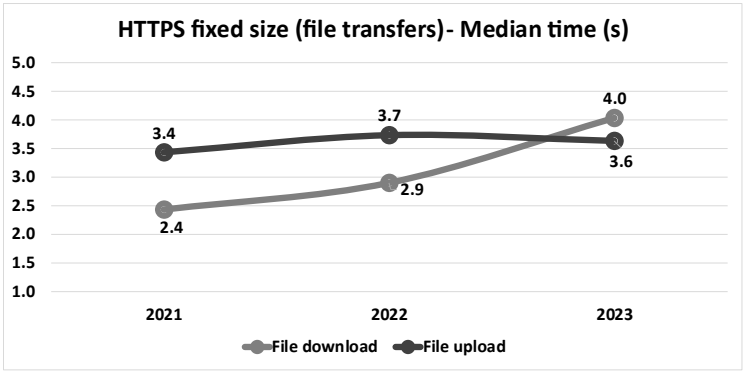
Results are aggregated across all 3 mobile operators, to reflect the average evolution of mobile network performance in Belgium.

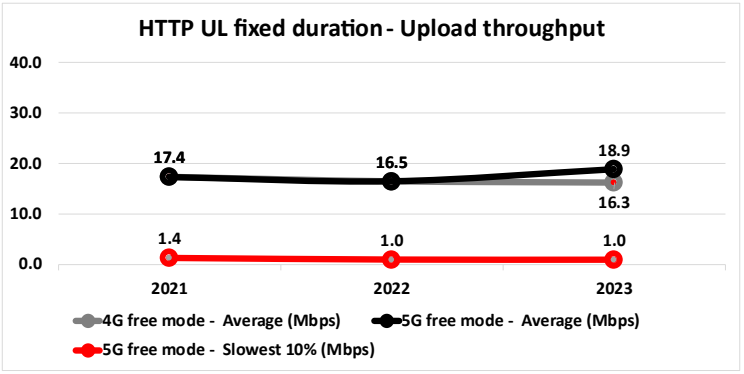
The observations in train tests trending charts are similar to the drive tests ones:

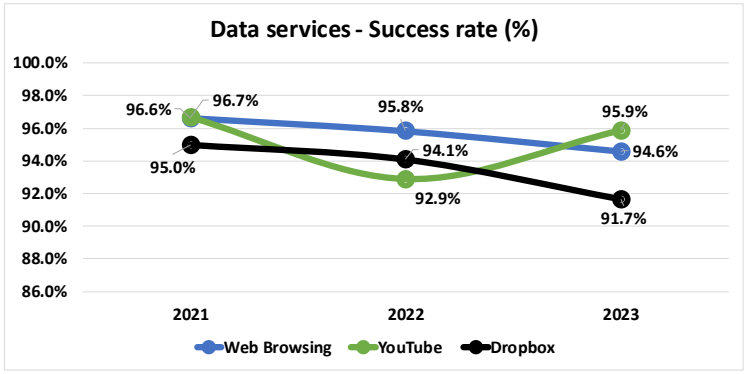
- Significant improvement in throughput when 5G is available, but degrading performance for 4G-only phones.
- Also, most success rate indicators for data services show a declining trend, again mainly attributed to areas with high 4G load and lack of local 5G coverage.











3.5. CONCLUSIONS FOR TRAIN LINES

Regarding train test performance, differences between operators are noticed for specific train lines on the different service indicators we have measured and consider relevant for customer experience.

Compared to previous years, the positive impact in downlink and uplink speed indicators thanks to the deployment of 5G networks is less prominent in train tests than in drive tests performance. However, 4G performance indicators show the same decreasing trend over the past 3 years.

In general, the performance in train tests conditions is inferior to the drive test ones.

3.6. ANNEX: RESULTS INDIVIDUAL TRAIN LINES

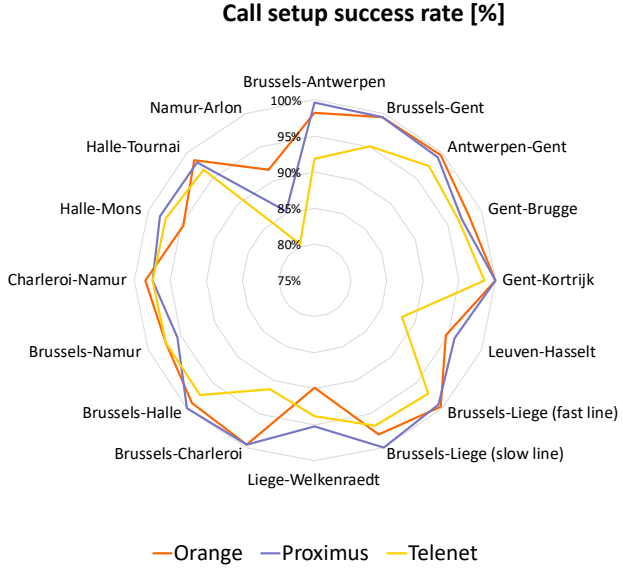
In this section, we present the performance for each of the individual train lines. For each of the 16 train lines, at least 200 voice and 200 data tests were collected, to obtain statistical-relevant results per train line.

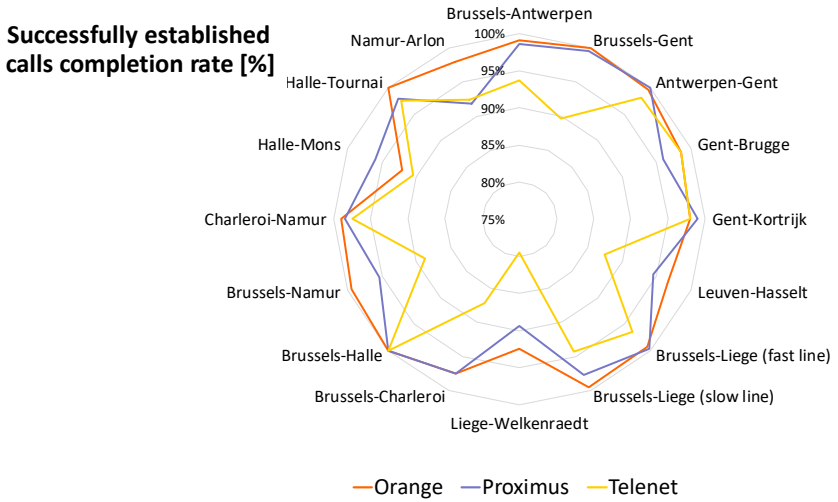
Results are presented in radar charts: lines further away from the centre of the chart (so sitting at the outside) indicate better performance, and lines sitting closer to the centre (in the middle) of the chart depict lower performance.

3.6.1. Voice – Individual train lines

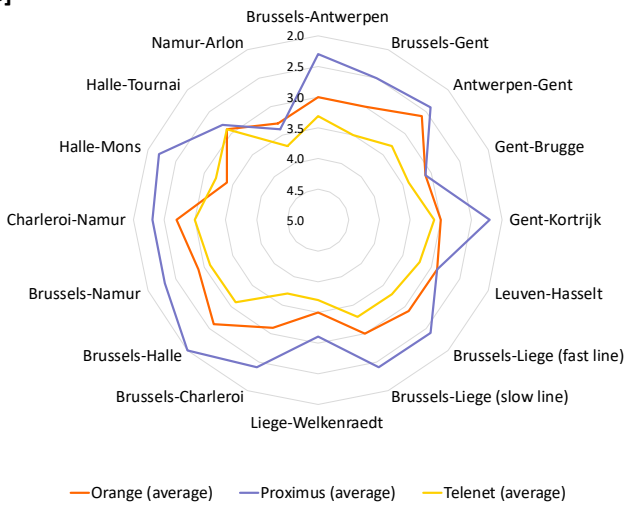
Big differences can be observed between different train lines. For instance, for call setup success rate, the line Namur-Arlon has lower performance – in this specific example due to challenging geographical conditions to provide good coverage.

We also observe quite some variation for 3 out of the 4 quality indicators for voice: call setup success rate; the call completion rate; and call setup time. On the other hand, average voice quality has almost identical values across train lines.

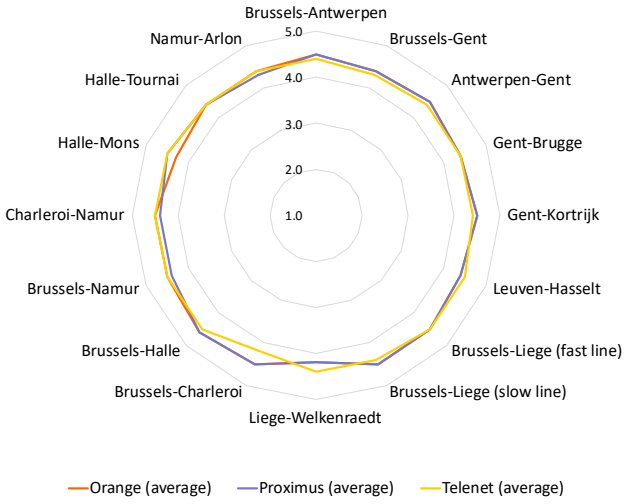




Call setup time [s]



Voice quality



3.6.2. Data – Individual train lines

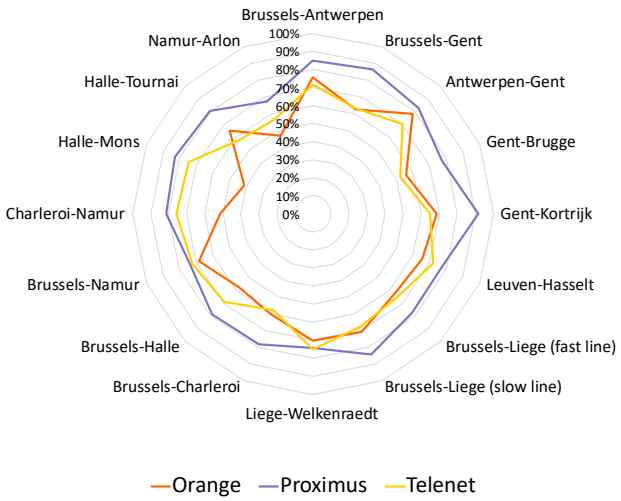
We would like to assess and compare the quality experienced by a user of each mobile network in the different train lines covered during the testing when using any of the data services.

Moreover, we introduce a new data service indicator which aims to indicate the percentage of speed tests in downlink that reached a throughput greater or equal to 10Mbps.

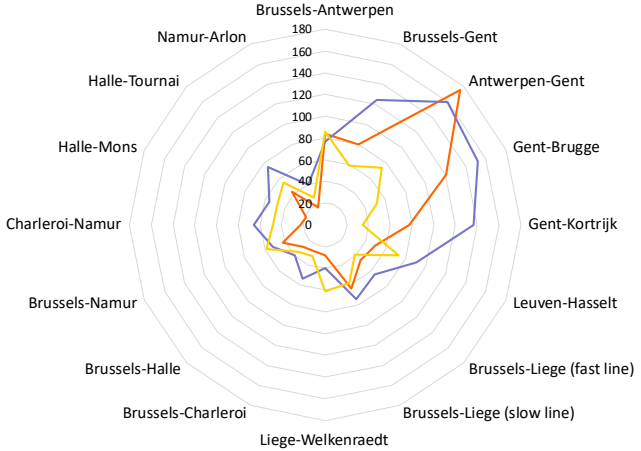
There are big differences in data performance across the individual train lines. Operator performance varies significantly as well.

We observe limited 5G availability on most train lines: 5G is often available in the train stations (i.e., in big/ medium cities), but not on the train lines (in more rural areas). Train lines with 5G coverage offer much higher throughput, especially for downloads.

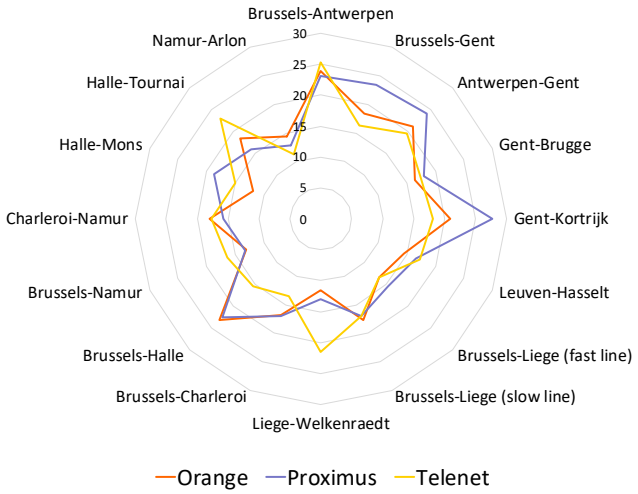
Downlink throughput - Samples ≥10Mbps [%]



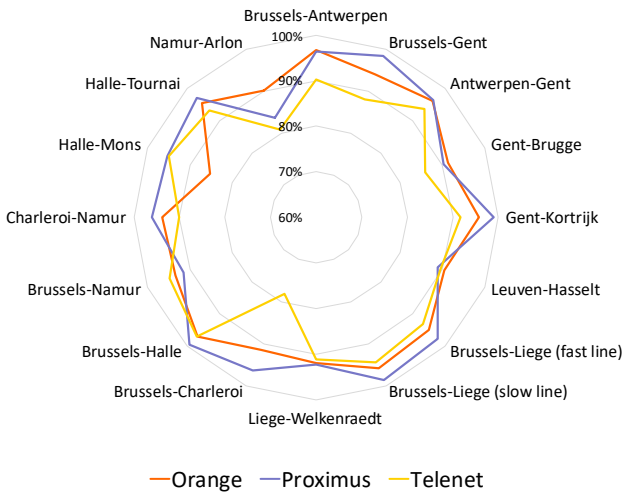
Downlink throughput [avg, Mbps]



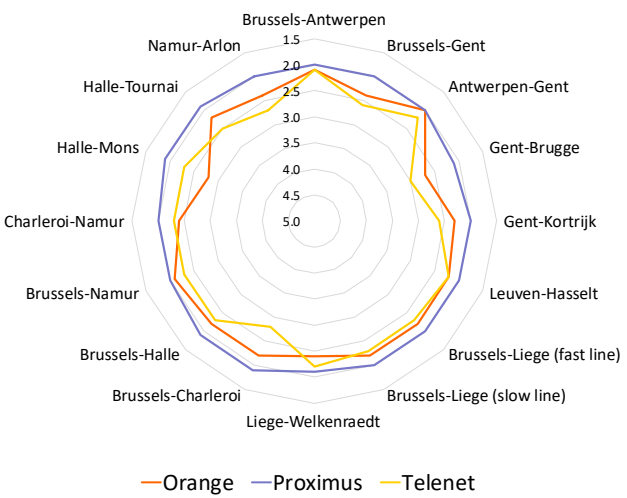
Uplink throughput [avg, Mbps]



Web browsing - Success rate [%]



Web browsing - Time [med, s]



Train lines are a harsh and challenging environment to provide good mobile network coverage. Train tracks are often shielded by vegetation or trees, or are buried below their surroundings. Moreover, radio waves have great difficulty penetrating the metallic train structure or their windows covered with a metallic layer.

Further improvements of customer experience on train lines will require further deployment of 5G, especially in rural areas, i.e., on the stretches of train lines outside city centres. Further improving coverage, i.e., reducing white spots without any mobile signal, requires additional antennas carefully located to improve coverage on the train lines. Removing white spots is needed to maintain long calls or data sessions on trains, such as video conferencing.

4. OVERALL CONCLUSIONS

The performance of the mobile networks in Belgium was assessed by executing a combination of drive tests and train tests. The measurements were configured such that these are representative of customer experience in indoor conditions and in trains. Mobile networks were measured by driving 2 cars in all major cities and highways, as well as in a selection of medium size cities, villages and roads. Additionally, mobile networks were assessed on selected highly frequented train lines.

Regarding drive tests performance, all 3 networks in Belgium depict a very good performance, being not a single network outperforming the others on all of the different service indicators we have measured and consider relevant for customer experience. The performance in major and medium size cities is better than the rural areas and roads.

Regarding train test performance, differences between operators are noticed for specific train lines on the different service indicators we have measured and consider relevant for customer experience. The performance in train tests conditions is inferior to the drive test ones.

These conclusions are valid based upon the measurements performed in August-October 2023, simulating indoor coverage conditions. Customer experience deep into buildings will be different.

Compared to previous years, both download and upload 4G performance indicators related to throughput or network speed show a decreasing trend. This is the result of a saturated 4G network, mostly related to the increase of 4G capable connected devices. Operators are trying to mitigate the impact of 4G networks saturation in user experience by modernizing existing technologies and investing in new 5G technology. The positive impact of 5G deployment in Belgium is depicted in network speeds, as download throughput shows an increase of +43%, while upload throughput increased by +21%.

All data success rate indicators are high but show a slight declining trend, mostly due to the saturation of the 4G network. Based on our international experience, we can conclude that all mobile networks in Belgium demonstrate a good performance for users with a recent 5G mobile phone.

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