

# 5G QoE Benchmark in Europe

MedUX Insights: Detailed report, February 2024

**Measurement campaign: Q3 2023**  
[CONFIDENTIAL]

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# 5G



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# Executive Summary



Quality of Experience Everywhere in the Digital Era

# 5G QoE Benchmark in Europe

With TRUE QoE KPIs



# MedUX<sup>i</sup>

The internet QoE testing and monitoring company

[www.medux.com](http://www.medux.com)



# 5G QoE Benchmark in Europe

With TRUE QoE KPIs



Best QoE

5G Speed

Best Reliability

5G Coverage

Streaming

Responsiveness

Web Browsing

5G Gaming

Data & OTT

...and more

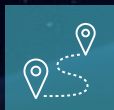
Empowering 5G customer-centric use cases with real field data

Quality of experience everywhere in the Digital Era



# Stats and Scope of 5G QoE Benchmark

## MedUX<sup>+</sup>



**>4000 Km**

Distance driven



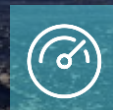
**6 countries**

DE ES FR GB IT PT



**>30 days**

of measurements



**>100 K**

Performance  
tests



**>2000 Km<sup>2</sup>**

Surface covered



**10 cities**

BER MUN BCN  
MAD LIS POR LON  
MIL PAR ROM



**>35 MM**

inhabitants



**>350K**

Radio samples

In Europe



23 Operators

bouygues

free

SFR

orange

O<sub>2</sub>

T

vodafone

vodafone

TIM

iliad

WINDTRE

III

NOS

nowo

vodafone

M

orange

vodafone

MÁSMÓVIL

O<sub>2</sub>

E

vodafone

3



# 5G QoE Benchmark in Europe

Did you know that?

Best Mobile Quality of Experience  
in Europe



FASTEST 5G DL SPEED

**1.3 Gbps**

Achieved in Paris



FASTEST 5G UL SPEED

**302 Mbps**

Achieved in Porto



TOP 5G DL AVG SPEED

**528 Mbps**

Achieved in Lisbon



5G COVERAGE

**90.7%**

Top 5G Availability  
achieved in Porto



RELIABILITY

**99.9%**

Most consistent  
Experience in Milan



# MedUX 5G QoE Benchmark

# Mobile Experience Awards

Awarded Cities

## Best QoE Ranking



Berlin



Barcelona



Paris

Lisbon

Milan

Porto

## MedUX QoE Awards



### Top Awards

### Experience & 5G Awards



#1 QOE



RELIABILITY



STREAMING



ACCESIBILITY, 5G DL/UL SPEED



RELIABILITY

VALUE FOR SPEED, 5G GAMING



5G COVERAGE

LEADER  
CO-LEADER

MedUX



**MedUX  
5G QoE  
Benchmark**

**Best  
Reliability in  
European  
cities**

**Top experience in a  
major European city**

**Milan**



**Italy**

Leveraging true QoE KPIs

**Did you know that?**

**Most consistent  
Network Experience  
recorded in Milan**

**99.91 %  
successful  
Internet Sessions**



**Milanese also enjoy  
the best Value for  
Speed Experience**

**Best 5G Gaming  
Experience thanks to a  
top reliable service and  
a low time-to-content**

**MedUX  
5G QoE  
Benchmark**

**Best QoE in  
European  
cities**

**Top experience in a  
major European city**

**Berlin**



**Germany**

Leveraging true QoE KPIs

# Did you know that?

Speed matters but a  
Consistent  
Experience across  
services is king

Berliners enjoy the  
best Data and OTT  
Experience thanks to a  
top reliability

Top 5G Coverage  
with 89.6 %  
registration rate

Best Streaming  
Experience thanks to a  
top time-to-content  
(1.5s time to play)



**MedUX  
5G QoE  
Benchmark**

**Best QoE in  
European  
cities**

**Top experience in a  
major European city**

**Berlin**



**Germany**

**CONGRATULATIONS**



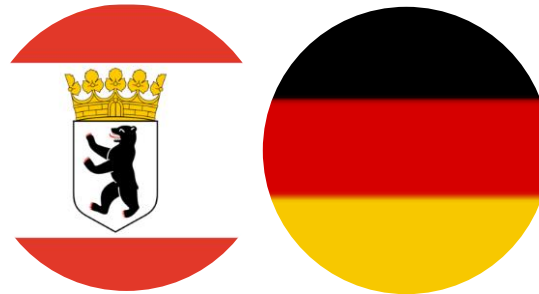
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# QoE Everywhere in the Digital Era



**Best Mobile Quality of Experience  
in Europe**



**MedUX, the internet QoE testing and  
monitoring company**

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# QoE Everywhere in the Digital Era



## Join MedUX in the #QoERevolution

**MedUX, the internet QoE testing  
and monitoring company**

[www.medux.com](http://www.medux.com)



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# Detailed Report

# 5G QoE Benchmark in Europe

## with TRUE QoE KPIs



### MedUX Insights:

## 5G QoE Research Study

At MedUX we have conducted a first of its kind **5G Quality of Experience (QoE) Benchmark in Europe**. The study unveils a clear frontrunner, an Excellent winner in Europe, followed closely by five strong competitors.

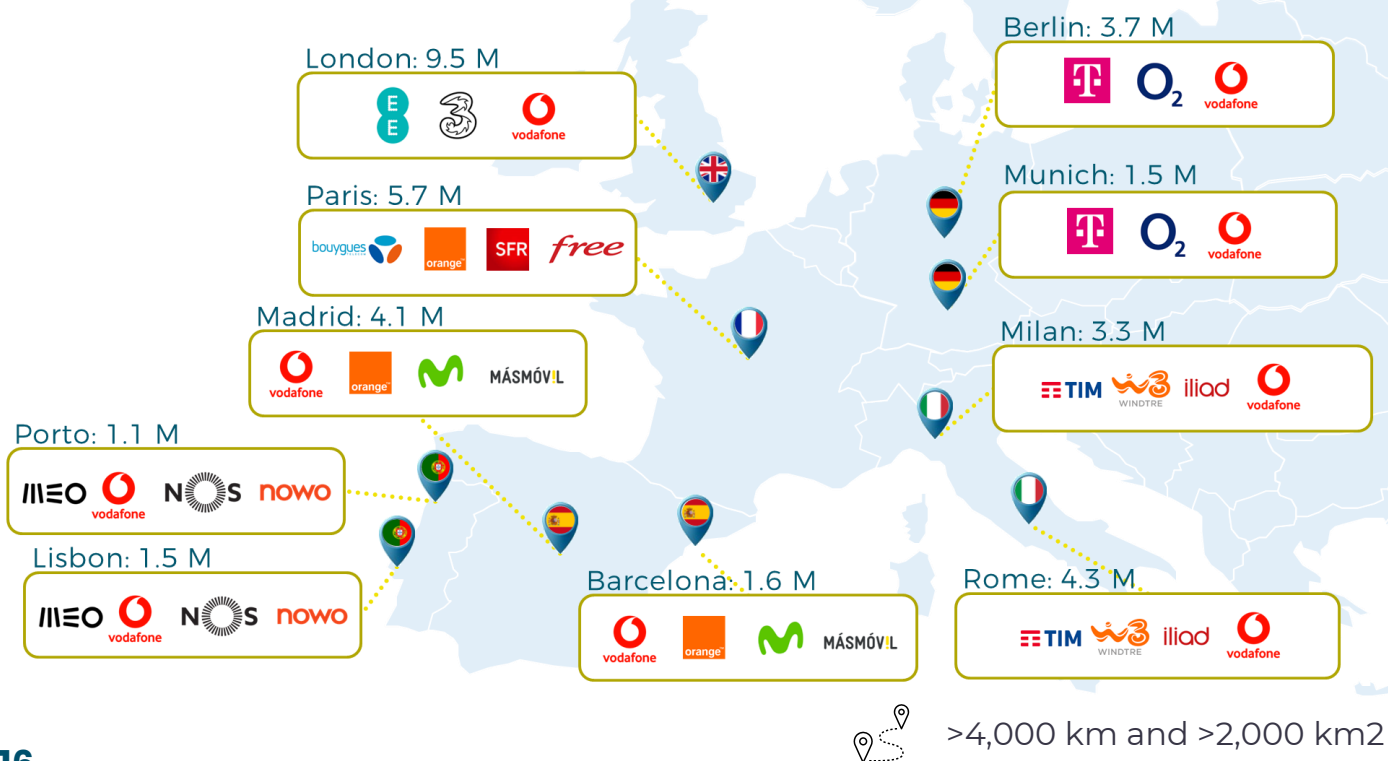
We have leveraged our autonomous and cost-effective 'light' drive testing solution to benchmark, monitor and improve mobile networks. It aims at improving customer satisfaction by delivering an honest, **independent review that enhances service quality** from the viewpoint of the people who matter most – the users.



# 5G Campaign Overview

The measurement campaign consisted of drive tests conducted during Q2 and Q3 2023 in 10 major cities across Europe, covering more than 25 million inhabitants.

Our drive test cars covered more than 4,000 kilometers and 2,000km<sup>2</sup> to understand how mobile operators cover the most important European capitals.



## Measurement Scope



Technology: Up to 5G

- Unforced mode



Devices: 8 MedUX Mobile

- Commercial smartphone-based probes



Vehicles: 1 car

- 8 devices per vehicle



Sampling:

- Tests: min 3K samples per city
- Radio: min 15K samples per city



Complete Test execution

- OTT and services (Streaming, Gaming, Web Browsing, Speed Test DL/UL), destination servers and parameters



5G SIM cards



Planned route: 2-3 Days per city



Timing: Q2-Q3 2023



# Key findings

Our 5G QoE benchmark, conducted in Europe during Q2 and Q3 2023, shows a very good winner and two close contenders.

**Berlin leads the European 5G QoE Benchmarking campaign**, co-leading the Video Streaming Experience Award and winning overall Data and OTT experience.



## Berlin offers the best Global QoE, leading in Data&OTT experience, and co-leading in video streaming

Apart from winning the Top Award of Best QoE and showing best performance in two important categories, Berlin ranks as the second city with the highest 5G Coverage and shows excellent consistency across all services. Germany's Capital also co-leads with Paris the Best Streaming Experience.

**QoE scoring: 4.69 out of 5**

89.6% of 5G Registration Rate



## Barcelona delivers the second-best Global QoE, showcasing the most reliable 5G service

Barcelona also co-leads with Milan for the Top Award of Best Reliability. Additionally, users benefit from the best Web Browsing Experience (within Data&OTT) and the best "5G only" Value for Speed with a perfect reliability score in both DL and UL.

**Reliability Score: 93.6%**

97.3% of 5G Value for Speed Score



## Paris provides the third-best Global QoE and the best in "5G only", leading the streaming experience

France's Capital offers the best "5G only" QoE, closely followed by Barcelona and Berlin. Furthermore, Parisiens enjoy the best streaming experience, both in Global and 5G only, and a very good Data&OTT experience in 5G. Paris ranks as the third city with the highest 5G coverage.

**5G QoE scoring: 4.71 out of 5**

100% of Streaming Score

# Benchmarking Methodology

With the goal of providing an independent and international benchmarking tool, MedUX developed its own QoE ScoreCard to determine and certify the best provider or operator with respect of the services accessed via mobile networks.

This goal is achieved by executing benchmarking tests that represent a major part of the services used by final customers of mobile networks. The results collected are individually and collectively weighted and aggregated into an overall score.

The service category scoring model and its drill-down capabilities makes it exploitable by different stakeholders, from executive management (CxOs) to more technical departments (engineering and optimization). Thus, providers or operators can improve their networks and services offering a better experience to their customers.

To give transparency and a clear interpretation of the benchmarking results, MedUX publishes a description of the scoring methodology, in line with the current state of the ETSI TR 103 559 V1.1.

In this context we introduce the following terms, Quality of Service (QoS) and Quality of Experience (QoE):

- QoS: “Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.”
- QoE: “Degree of delight of the user of a service. In the context of communication services, it is influenced by content, network, device, application, user expectations and goals, and context of use.”

MedUX propose a model where technical measurements are transformed into perceptive indicators taking into account the human response to mobile service’s events, improvements and degradations.

For further details about the methodology used please visit our blog [“Assessing customer experiences with a universal mobile broadband benchmarking methodology”](#)

# Quality of Experience – Ranking approach

**MedUX mobile benchmarking approach**, based on our MedOS (MedUX Opinion Score) and QoE Scorecard, assesses network performance and end-user experience in the 5G Era. We revisit criteria and thresholds once a year to consider best practices but also to reflect technology and industry development.

At MedUX we use the concept of Mean opinion score (MOS) for most of the rankings, which ratings are algorithmically estimated based on test results and KPIs, in line with the current state of the ETSI TR 103 559 V1.1.1 and ITU Recommendation ITU-T P.800.1.

## • Top Awards:

- **Overall QoE Score** – A combination of availability, accessibility, speed, streaming, and data and OTT experience results.
- **Reliability** – how consistent a network performs. Particularly in 5G it measures how consistent the 5G network performs across all testing categories considering the success rate (%) of all tests and services above.

## • Experience Awards:

- **Accessibility** (responsiveness) – how long it takes to access the network. Particularly in 5G it measures how long it takes to access the 5G network across all testing categories, while taking latency and network responsiveness results into account.
- **Value for Speed** (throughput) - how much data can be transferred. Particularly in 5G it measures how is the network capacity when stressing the line (multi-thread and multi-server stress test with our patented Cloud Speed Test).
  - DL Speed
  - UL Speed
- **Video Streaming experience** - it measures the average video experience for each operator while taking picture quality, video loading time, and stall rate into account.
- **Data and OTT experience** - a combination of gaming, web browsing, social networks, messaging and HTTP Data transfer experiences.

# Quality of Experience – Ranking approach

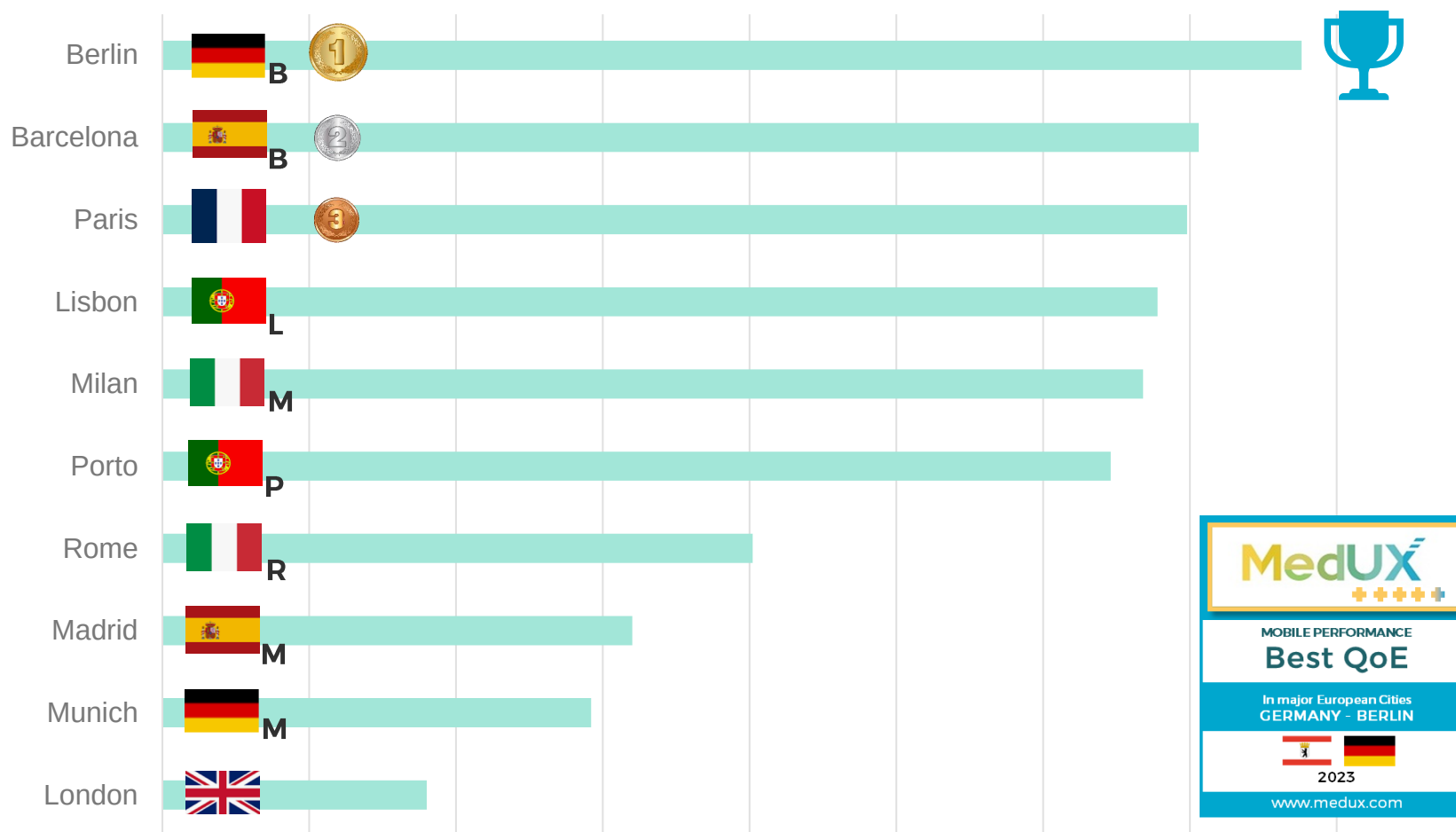
## • 5G Awards

- **5G Availability** – the percentage of 5G network coverage available during the measurements.
- **5G DL Speed** (throughput) – how much data can be transferred in 5G downlink channel, how is the network capacity when stressing the line (multi-thread and multi-server stress test with our patented Cloud Speed Test),
- **5G UL Speed** (throughput) – how much data can be transferred in 5G uplink channel, how is the network capacity when stressing the line (multi-thread and multi-server stress test with our patented Cloud Speed Test),
- **5G Gaming**, it measures the average 5G gaming experience rating different key parameters

For further details about the methodology used please visit our blog ["Assessing customer experiences with a universal mobile broadband benchmarking methodology"](#)

# Quality of Experience: Mobile Experience Ranking

Our 5G QoE measurement campaigns aim to test and shape the future of 5G experience. The study unveils a clear frontrunner, Berlin, an Excellent winner in Quality of Experience in Europe, followed closely by five strong competitors, especially Barcelona and Paris.



# Mobile Experience Awards

Awards are granted to the best performing operators in each attribute or category we test. If two or more operators record statistically indistinguishable results, each operator earns an Experience Award while sharing the highest rank in that category.

**Berlin leads the European 5G QoE Benchmarking campaign**, co-leading the Video Streaming Experience Award and winning overall Data and OTT experience.

|                | Top Awards                                                                                                                                                               | Experience Awards                                                                                                                                                        |                                                                                                                                                                          |                                                                                                                                                                            |                                                                                                                                                                              |                                                                                                                                                                              | 5G Awards                                                                                                                                                                    |                                                                                                                                                                              |                                                                                                                                                                              |                                                                                                                                                                              |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                | Best Experience                                                                                                                                                          | Reliability                                                                                                                                                              | Data & OTT                                                                                                                                                               | Streaming Experience                                                                                                                                                       | Value for Speed                                                                                                                                                              | Accessability                                                                                                                                                                | 5G Availability                                                                                                                                                              | 5G DL Speed                                                                                                                                                                  | 5G UL Speed                                                                                                                                                                  | 5G Gaming                                                                                                                                                                    |
| Europe Winners | <br> B | <br> M | <br> B | <br> | <br> M | <br> L | <br> P | <br> L | <br> L | <br> M |
| Co-leaders*    |                                                                                                                                                                          |  B                                                                                      |                                                                                                                                                                          |  B                                                                                      |                                                                                                                                                                              |                                                                                                                                                                              |                                                                                                                                                                              |                                                                                                                                                                              |                                                                                                                                                                              |                                                                                                                                                                              |

- Berlin, Lisbon, and Milan lead most of the rankings across all mobile experience categories
- Berlin wins the most important award for Best QoE while showing outstanding stability across most mobile experience categories and KPIs.
- Milan leads the second most important award for Best Reliability, as well as other specific Awards on Value for Speed and 5G Gaming.

NOTE\*: Co-leaders (less than 0.5% difference)

QoE Scorecard - MedOs Definition:

- 10% - Accessibility
- 5% - Availability
- 15% - Value for speed
- 20% - Streaming Experience
- 50% - Data & OTT

Reliability (part of QoE Scorecard):

- 0,25p - Accessibility\*
- 0,375p - Value for speed\*
- 0,5p - Streaming Experience\*
- 1,25p - Data & OTT\*

\*SuccessMOS for Reliability is based on 2.375p max



# Tests suite

MedUX evaluates mobile networks experience by ranking the performance of typical consumer use cases such as web browsing popular websites, downloading/uploading content, visiting social networks, accessing gaming servers and streaming video content, among others.

|                                                                                     |                             |                                                                                  |
|-------------------------------------------------------------------------------------|-----------------------------|----------------------------------------------------------------------------------|
|    | <b>Service Availability</b> | Connectivity based on radio technology samples.                                  |
|    | <b>Cloud DL</b>             | Multi-thread download speed test based on public CDNs.                           |
|    | <b>Cloud UL</b>             | Multi-thread upload speed test based on dedicated servers.                       |
|    | <b>Latency</b>              | Echo request to a specific URL based on ICMP.                                    |
|    | <b>HTTP DL</b>              | Single-thread download speed test based on dedicated servers ( 10 seconds Burst) |
|  | <b>HTTP UL</b>              | Single-thread upload speed test based on dedicated servers (10 seconds Burst)    |

|                                                                                       |                     |                                                              |
|---------------------------------------------------------------------------------------|---------------------|--------------------------------------------------------------|
|    | <b>Twitter</b>      | Navigation of a static Twitter profile.                      |
|    | <b>Facebook</b>     | Navigation of a static Facebook profile.                     |
|    | <b>Streaming</b>    | YouTube Video playback based on a Android multimedia player. |
|    | <b>DNS</b>          | Resolution of a specific URL.                                |
|    | <b>Gaming</b>       | Echo request to gaming servers based on ICMP.                |
|  | <b>Web Browsing</b> | Navigation of any website based on Chrome browser.           |

# 5G Campaign Setup – Tests performed

## Probes configuration

16

Providers

44

Cities

11

Task types

100.659

#Test performed

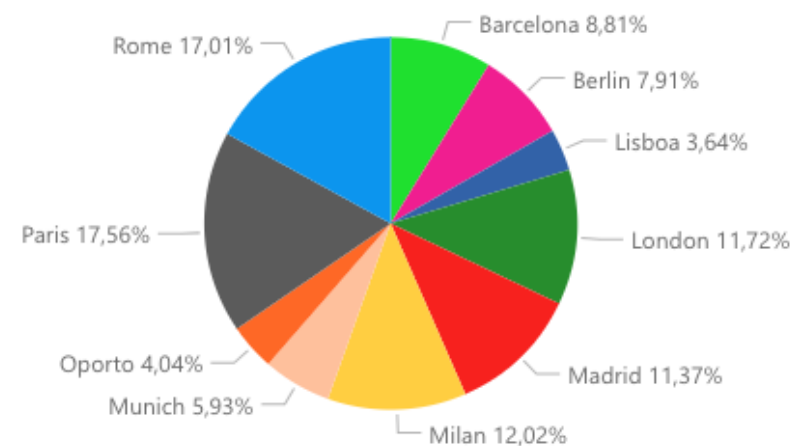
373.939

#Radio samples

Number of test performed by city



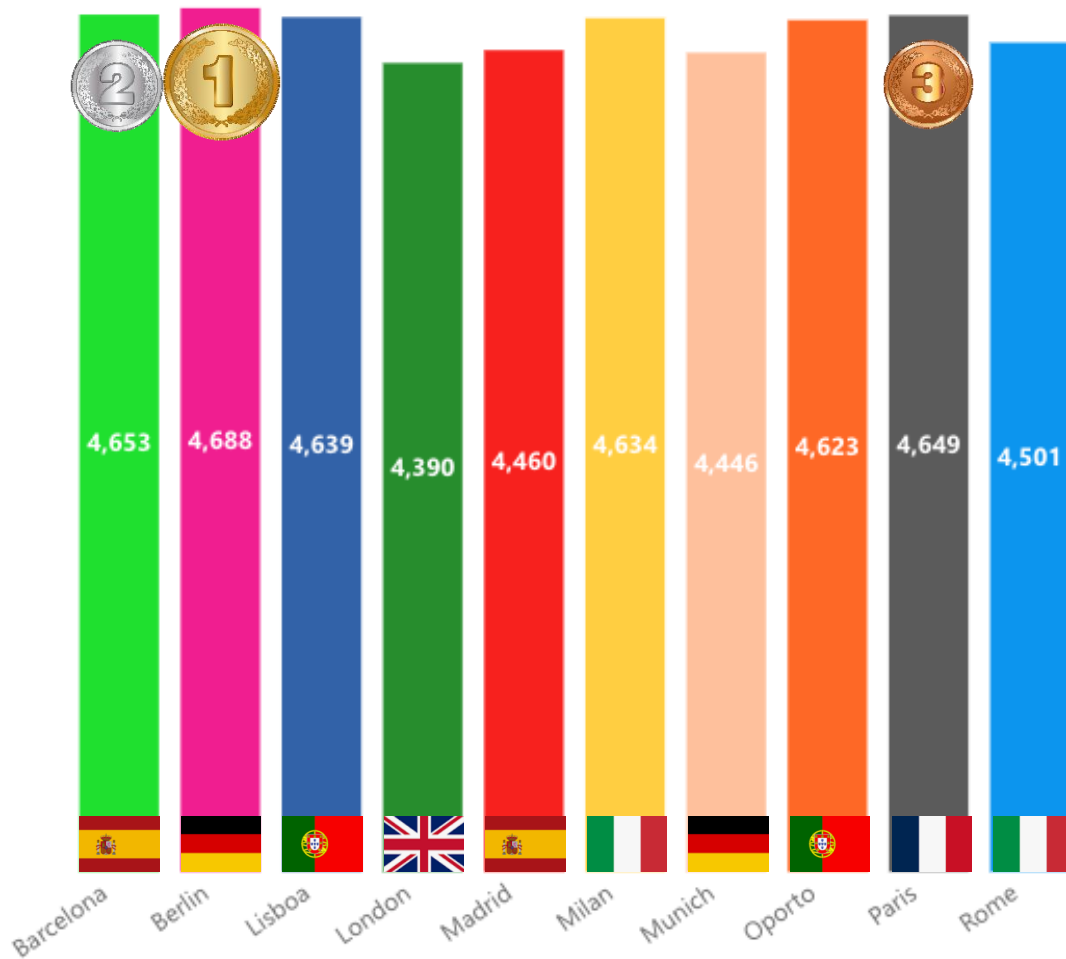
| TestName      | Barcelona   | Berlin      | Lisboa      | London       | Madrid       | Milan        | Munich      | Oporto      | Paris        | Rome         | Total         |
|---------------|-------------|-------------|-------------|--------------|--------------|--------------|-------------|-------------|--------------|--------------|---------------|
| Cloud-DL      | 621         | 615         | 260         | 834          | 800          | 833          | 465         | 277         | 1290         | 1179         | 7174          |
| Cloud-UL      | 577         | 609         | 236         | 750          | 789          | 805          | 442         | 279         | 1119         | 1172         | 6778          |
| DNS-Request   | 1209        | 1203        | 505         | 1515         | 1548         | 1611         | 906         | 548         | 2497         | 2253         | 13795         |
| Facebook      | 575         | 324         | 234         | 771          | 753          | 805          | 250         | 265         | 1166         | 1114         | 6257          |
| GamingTest    | 1186        | 1188        | 476         | 1614         | 1513         | 1603         | 894         | 543         | 2428         | 2274         | 13719         |
| HTTP-DL       | 591         | 609         | 250         | 810          | 743          | 807          | 463         | 267         | 1177         | 1158         | 6875          |
| HTTP-UL       | 594         | 598         | 245         | 809          | 764          | 807          | 452         | 274         | 1228         | 1144         | 6915          |
| Ping          | 1245        | 1240        | 523         | 1655         | 1595         | 1674         | 940         | 568         | 2581         | 2350         | 14371         |
| Twitter       | 572         | 339         | 242         | 760          | 757          | 803          | 240         | 268         | 1206         | 1123         | 6310          |
| Web           | 1189        | 680         | 499         | 1543         | 1549         | 1634         | 523         | 551         | 2439         | 2281         | 12888         |
| YouTube       | 507         | 554         | 189         | 739          | 629          | 722          | 399         | 227         | 540          | 1071         | 5577          |
| <b>Total</b>  | <b>8866</b> | <b>7959</b> | <b>3659</b> | <b>11800</b> | <b>11440</b> | <b>12104</b> | <b>5974</b> | <b>4067</b> | <b>17671</b> | <b>17119</b> | <b>100659</b> |
| Radio samples | 33340       | 32009       | 17583       | 88311        | 43464        | 27416        | 26220       | 18081       | 53124        | 34391        | 373939        |



For further details about the test cases covered in the campaign scope please see "Tests Suite" above or "Testing and KPI details" below.

# Benchmarking Experience - Best QoE

Berlin achieved the best overall ranking result. All cities have very good or excellent performance, but Berlin, Barcelona and Paris scored the highest among all cities. Lisbon, Milan and Porto closely followed.



MedOS Global Values

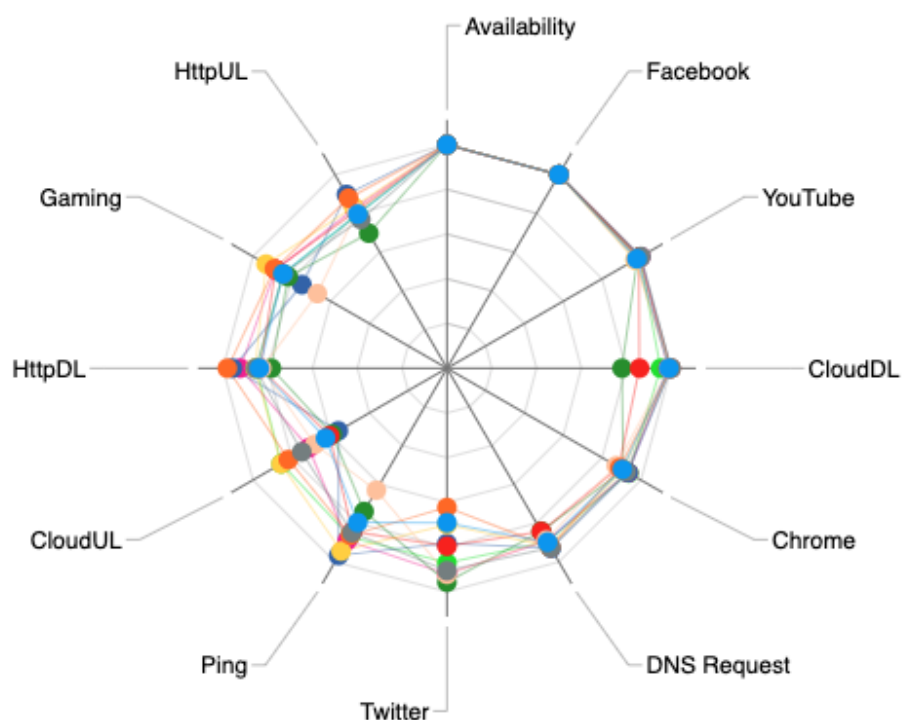
| MOS          | Barcelona | Berlin | Lisboa | London | Madrid | Milan | Munich | Oporto | Paris | Rome |
|--------------|-----------|--------|--------|--------|--------|-------|--------|--------|-------|------|
| Availability | 5,00      | 5,00   | 5,00   | 5,00   | 5,00   | 5,00  | 5,00   | 5,00   | 5,00  | 5,00 |
| Chrome       | 4,69      | 4,67   | 4,67   | 4,54   | 4,43   | 4,53  | 4,36   | 4,45   | 4,62  | 4,52 |
| CloudDL      | 4,77      | 4,94   | 5,00   | 3,91   | 4,30   | 4,98  | 4,96   | 5,00   | 5,00  | 4,95 |
| CloudUL      | 4,27      | 3,56   | 2,80   | 2,96   | 3,02   | 4,28  | 3,40   | 4,09   | 3,74  | 3,13 |
| DNS Request  | 4,48      | 4,46   | 4,65   | 4,21   | 4,21   | 4,60  | 4,44   | 4,62   | 4,63  | 4,49 |
| Facebook     | 5,00      | 5,00   | 5,00   | 5,00   | 5,00   | 5,00  | 5,00   | 5,00   | 5,00  | 5,00 |
| Gaming       | 4,22      | 4,41   | 3,74   | 4,09   | 4,42   | 4,66  | 3,34   | 4,45   | 4,22  | 4,22 |
| HttpDL       | 4,25      | 4,61   | 4,79   | 3,92   | 4,16   | 4,29  | 4,13   | 4,90   | 4,27  | 4,19 |
| HttpUL       | 3,98      | 4,13   | 4,49   | 3,49   | 4,05   | 4,16  | 4,04   | 4,39   | 3,84  | 3,98 |
| Ping         | 4,35      | 4,45   | 4,84   | 3,70   | 4,22   | 4,72  | 3,15   | 4,31   | 4,24  | 3,99 |
| Twitter      | 4,35      | 4,60   | 3,92   | 4,79   | 3,98   | 3,50  | 4,61   | 3,11   | 4,53  | 3,45 |
| YouTube      | 4,97      | 4,99   | 4,97   | 4,91   | 4,95   | 4,85  | 4,86   | 4,94   | 5,00  | 4,89 |

QoE Scorecard - MedOs Definition:

- 10% - Accessibility
- 5% - Availability
- 15% - Value for speed
- 20% - Streaming Experience
- 50% - Data & OTT



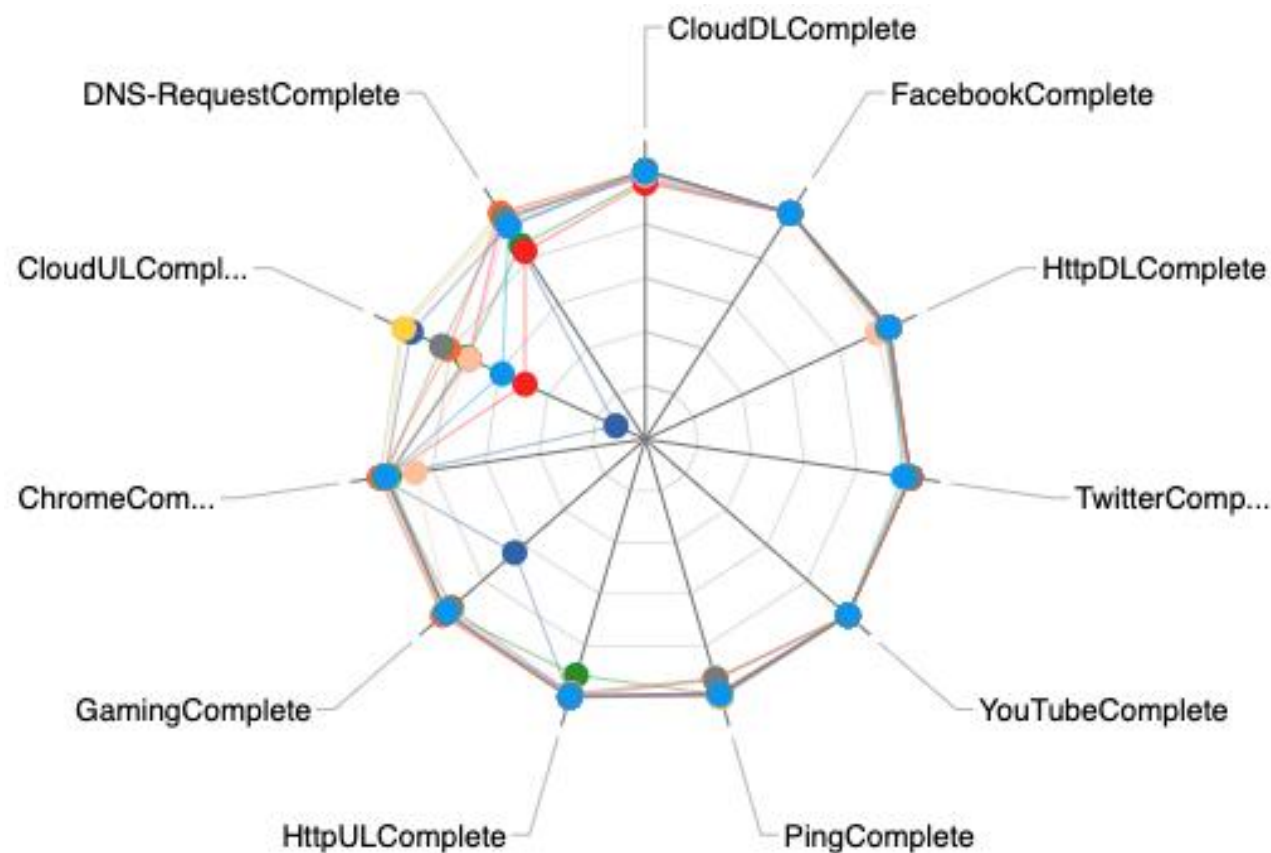
# Benchmarking Experience – Results per category



| Services                    | Barcelona    | Berlin       | Lisboa       | London       | Madrid       | Milan        | Munich       | Oporto       | Paris        | Rome         |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>Accessability</b>        | <b>0,217</b> | <b>0,223</b> | <b>0,242</b> | <b>0,185</b> | <b>0,211</b> | <b>0,236</b> | <b>0,158</b> | <b>0,216</b> | <b>0,212</b> | <b>0,199</b> |
| MOS Latency                 | 0,217        | 0,223        | 0,242        | 0,185        | 0,211        | 0,236        | 0,158        | 0,216        | 0,212        | 0,199        |
| <b>Availability</b>         | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> |
| MOS Service Availability    | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        |
| <b>Data and OTT</b>         | <b>2,252</b> | <b>2,295</b> | <b>2,262</b> | <b>2,184</b> | <b>2,178</b> | <b>2,216</b> | <b>2,150</b> | <b>2,214</b> | <b>2,249</b> | <b>2,171</b> |
| MOS DNS Request             | 0,224        | 0,223        | 0,232        | 0,210        | 0,211        | 0,230        | 0,222        | 0,231        | 0,232        | 0,224        |
| MOS Facebook                | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        |
| MOS Gaming                  | 0,211        | 0,221        | 0,187        | 0,205        | 0,221        | 0,233        | 0,167        | 0,222        | 0,211        | 0,211        |
| MOS HttpDL                  | 0,213        | 0,231        | 0,239        | 0,196        | 0,208        | 0,214        | 0,207        | 0,245        | 0,214        | 0,209        |
| MOS HttpUL                  | 0,199        | 0,206        | 0,224        | 0,174        | 0,203        | 0,208        | 0,202        | 0,220        | 0,192        | 0,199        |
| MOS Twitter                 | 0,218        | 0,230        | 0,196        | 0,239        | 0,199        | 0,175        | 0,231        | 0,156        | 0,226        | 0,173        |
| MOS Web Browsing            | 0,937        | 0,935        | 0,933        | 0,909        | 0,886        | 0,906        | 0,873        | 0,891        | 0,925        | 0,904        |
| <b>Streaming Experience</b> | <b>0,994</b> | <b>0,998</b> | <b>0,995</b> | <b>0,983</b> | <b>0,990</b> | <b>0,970</b> | <b>0,972</b> | <b>0,989</b> | <b>1,000</b> | <b>0,979</b> |
| MOS Streaming               | 0,994        | 0,998        | 0,995        | 0,983        | 0,990        | 0,970        | 0,972        | 0,989        | 1,000        | 0,979        |
| <b>Value for Speed</b>      | <b>0,690</b> | <b>0,672</b> | <b>0,640</b> | <b>0,539</b> | <b>0,581</b> | <b>0,711</b> | <b>0,666</b> | <b>0,704</b> | <b>0,687</b> | <b>0,652</b> |
| MOS CloudDL                 | 0,477        | 0,494        | 0,500        | 0,391        | 0,430        | 0,498        | 0,496        | 0,500        | 0,500        | 0,495        |
| MOS CloudUL                 | 0,213        | 0,178        | 0,140        | 0,148        | 0,151        | 0,214        | 0,170        | 0,204        | 0,187        | 0,156        |
| <b>Total</b>                | <b>4,653</b> | <b>4,688</b> | <b>4,639</b> | <b>4,390</b> | <b>4,460</b> | <b>4,634</b> | <b>4,446</b> | <b>4,623</b> | <b>4,649</b> | <b>4,501</b> |

| Services           | Barcelona | Berlin | Lisboa | London | Madrid | Milan | Munich | Oporto | Paris | Rome  |
|--------------------|-----------|--------|--------|--------|--------|-------|--------|--------|-------|-------|
| <b>Reliability</b> |           |        |        |        |        |       |        |        |       |       |
| MOS Reliability    | 2,224     | 2,192  | 2,090  | 2,154  | 2,139  | 2,231 | 2,119  | 2,217  | 2,202 | 2,171 |

# Benchmarking Reliability – Consistent performance



● Barcelona ● Berlin ● Lisboa ● London ● Madrid ● Milan ● Munich ● Oporto

| Services                    | Barcelona    | Berlin       | Lisboa       | London       | Madrid       | Milan        | Munich       | Oporto       | Paris        | Rome         |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>Accessability</b>        | <b>0,217</b> | <b>0,223</b> | <b>0,242</b> | <b>0,185</b> | <b>0,211</b> | <b>0,236</b> | <b>0,158</b> | <b>0,216</b> | <b>0,212</b> | <b>0,199</b> |
| MOS Latency                 | 0,217        | 0,223        | 0,242        | 0,185        | 0,211        | 0,236        | 0,158        | 0,216        | 0,212        | 0,199        |
| <b>Availability</b>         | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> |
| MOS Service Availability    | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        |
| <b>Data and OTT</b>         | <b>2,252</b> | <b>2,295</b> | <b>2,262</b> | <b>2,184</b> | <b>2,178</b> | <b>2,216</b> | <b>2,150</b> | <b>2,214</b> | <b>2,249</b> | <b>2,171</b> |
| MOS DNS Request             | 0,224        | 0,223        | 0,232        | 0,210        | 0,211        | 0,230        | 0,222        | 0,231        | 0,232        | 0,224        |
| MOS Facebook                | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        |
| MOS Gaming                  | 0,211        | 0,221        | 0,187        | 0,205        | 0,221        | 0,233        | 0,167        | 0,222        | 0,211        | 0,211        |
| MOS HttpDL                  | 0,213        | 0,231        | 0,239        | 0,196        | 0,208        | 0,214        | 0,207        | 0,245        | 0,214        | 0,209        |
| MOS HttpUL                  | 0,199        | 0,206        | 0,224        | 0,174        | 0,203        | 0,208        | 0,202        | 0,220        | 0,192        | 0,199        |
| MOS Twitter                 | 0,218        | 0,230        | 0,196        | 0,239        | 0,199        | 0,175        | 0,231        | 0,156        | 0,226        | 0,173        |
| MOS Web Browsing            | 0,937        | 0,935        | 0,933        | 0,909        | 0,886        | 0,906        | 0,873        | 0,891        | 0,925        | 0,904        |
| <b>Streaming Experience</b> | <b>0,994</b> | <b>0,998</b> | <b>0,995</b> | <b>0,983</b> | <b>0,990</b> | <b>0,970</b> | <b>0,972</b> | <b>0,989</b> | <b>1,000</b> | <b>0,979</b> |
| MOS Streaming               | 0,994        | 0,998        | 0,995        | 0,983        | 0,990        | 0,970        | 0,972        | 0,989        | 1,000        | 0,979        |
| <b>Value for Speed</b>      | <b>0,690</b> | <b>0,672</b> | <b>0,640</b> | <b>0,539</b> | <b>0,581</b> | <b>0,711</b> | <b>0,666</b> | <b>0,704</b> | <b>0,687</b> | <b>0,652</b> |
| MOS CloudDL                 | 0,477        | 0,494        | 0,500        | 0,391        | 0,430        | 0,498        | 0,496        | 0,500        | 0,500        | 0,495        |
| MOS CloudUL                 | 0,213        | 0,178        | 0,140        | 0,148        | 0,151        | 0,214        | 0,170        | 0,204        | 0,187        | 0,156        |
| <b>Total</b>                | <b>4.653</b> | <b>4.688</b> | <b>4.639</b> | <b>4.390</b> | <b>4.460</b> | <b>4.634</b> | <b>4.446</b> | <b>4.623</b> | <b>4.649</b> | <b>4.501</b> |

| Services           | Barcelona | Berlin | Lisboa | London | Madrid | Milan | Munich | Oporto | Paris | Rome  |
|--------------------|-----------|--------|--------|--------|--------|-------|--------|--------|-------|-------|
| <b>Reliability</b> |           |        |        |        |        |       |        |        |       |       |
| MOS Reliability    | 2,224     | 2,192  | 2,090  | 2,154  | 2,139  | 2,231 | 2,119  | 2,217  | 2,202 | 2,171 |

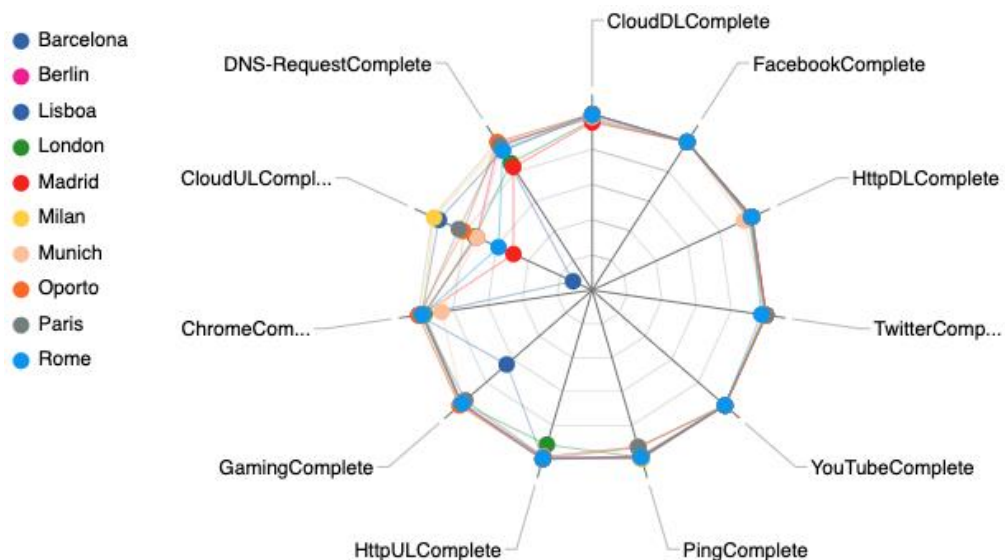


Reliability (part of QoE Scorecard):

- 0,25p - Accessibility\*
- 0,375p - Value for speed\*
- 0,5p - Streaming Experience\*
- 1,25p - Data & OTT\*

\*SuccessMOS for Reliability is based on 2.375p max

# Benchmarking Reliability – Consistent performance

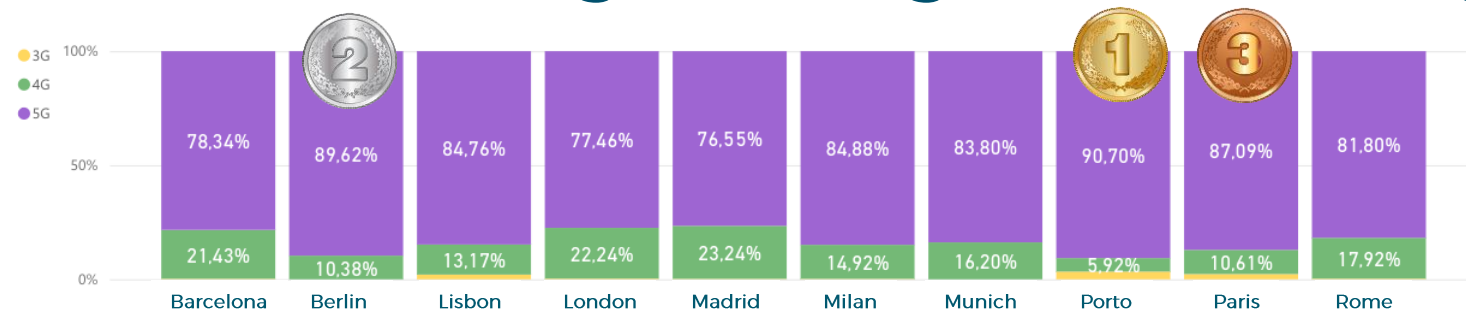


KPIs Total Tests

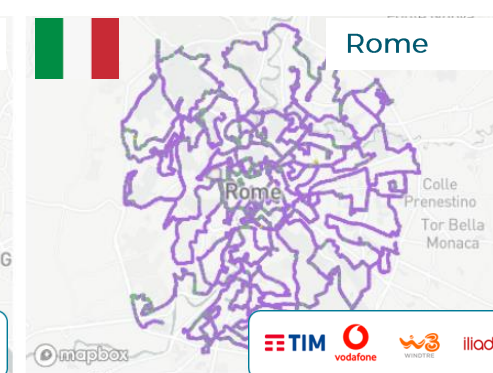
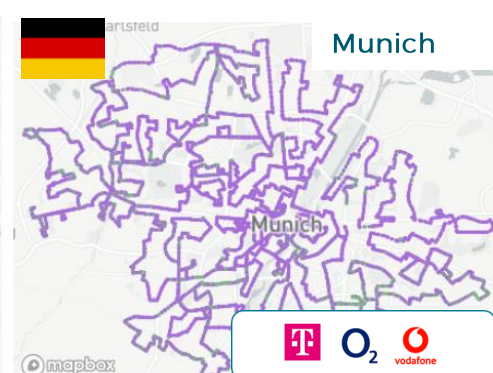
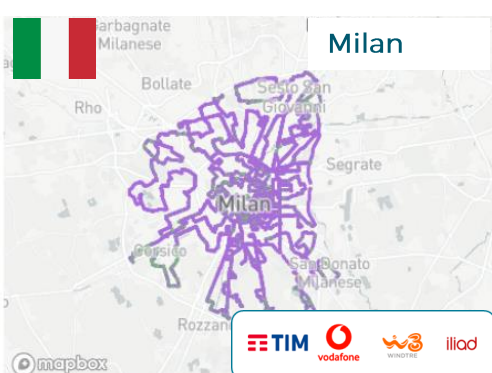
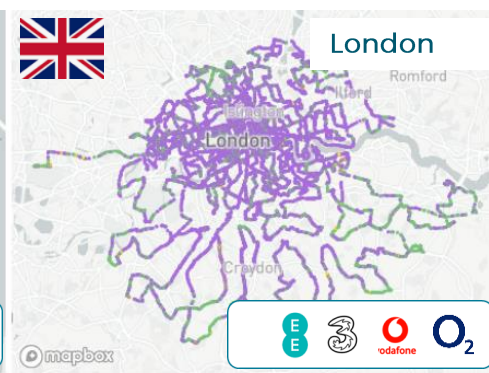
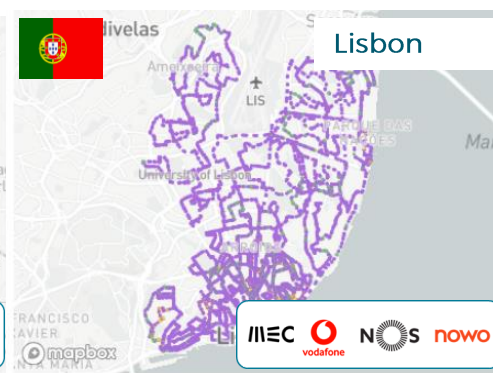
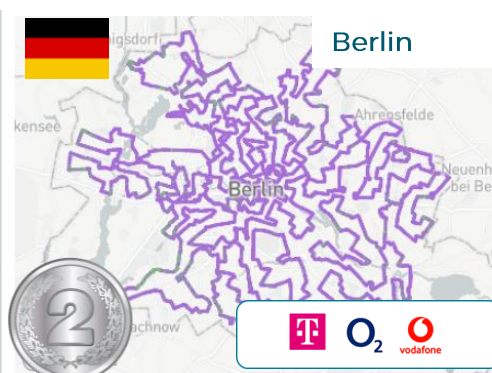
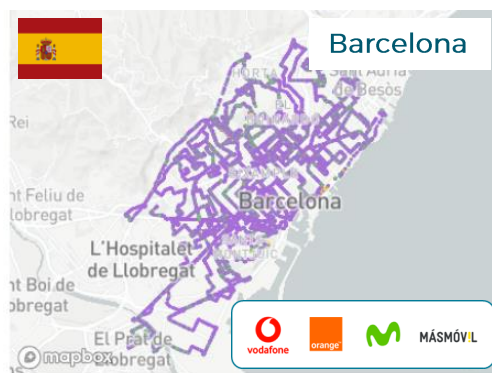
| TestName     | Barcelona   | Berlin      | Lisboa      | London       | Madrid       | Milan        | Munich      | Oporto      | Paris        | Rome         | Total         |
|--------------|-------------|-------------|-------------|--------------|--------------|--------------|-------------|-------------|--------------|--------------|---------------|
| Cloud-DL     | 621         | 615         | 260         | 834          | 800          | 833          | 465         | 277         | 1290         | 1179         | 7174          |
| Cloud-UL     | 577         | 609         | 236         | 750          | 789          | 805          | 442         | 279         | 1119         | 1172         | 6778          |
| DNS-Request  | 1209        | 1203        | 505         | 1515         | 1548         | 1611         | 906         | 548         | 2497         | 2253         | 13795         |
| Facebook     | 575         | 324         | 234         | 771          | 753          | 805          | 250         | 265         | 1166         | 1114         | 6257          |
| GamingTest   | 1186        | 1188        | 476         | 1614         | 1513         | 1603         | 894         | 543         | 2428         | 2274         | 13719         |
| HTTP-DL      | 591         | 609         | 250         | 810          | 743          | 807          | 463         | 267         | 1177         | 1158         | 6875          |
| HTTP-UL      | 594         | 598         | 245         | 809          | 764          | 807          | 452         | 274         | 1228         | 1144         | 6915          |
| Ping         | 1245        | 1240        | 523         | 1655         | 1595         | 1674         | 940         | 568         | 2581         | 2350         | 14371         |
| Twitter      | 572         | 339         | 242         | 760          | 757          | 803          | 240         | 268         | 1206         | 1123         | 6310          |
| Web          | 1189        | 680         | 499         | 1543         | 1549         | 1634         | 523         | 551         | 2439         | 2281         | 12888         |
| YouTube      | 507         | 554         | 189         | 739          | 629          | 722          | 399         | 227         | 540          | 1071         | 5577          |
| <b>Total</b> | <b>8866</b> | <b>7959</b> | <b>3659</b> | <b>11800</b> | <b>11440</b> | <b>12104</b> | <b>5974</b> | <b>4067</b> | <b>17671</b> | <b>17119</b> | <b>100659</b> |

|                         | Barcelona | Berlin   | Lisboa   | London   | Madrid   | Milan    | Munich   | Oporto   | Paris    | Rome     |
|-------------------------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| CloudDLComplete (%)     | 100,00 %  | 99,67 %  | 100,00 % | 99,52 %  | 99,38 %  | 99,88 %  | 99,78 %  | 100,00 % | 100,00 % | 99,92 %  |
| CloudULComplete (%)     | 99,48 %   | 96,39 %  | 88,56 %  | 96,53 %  | 93,41 %  | 99,88 %  | 96,38 %  | 97,49 %  | 97,86 %  | 94,62 %  |
| DNS-RequestComplete (%) | 99,26 %   | 99,83 %  | 99,60 %  | 98,15 %  | 97,80 %  | 99,75 %  | 99,45 %  | 100,00 % | 99,68 %  | 99,25 %  |
| FacebookComplete (%)    | 100,00 %  | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % |
| GamingComplete (%)      | 99,83 %   | 99,83 %  | 95,38 %  | 99,75 %  | 99,80 %  | 99,94 %  | 99,66 %  | 100,00 % | 99,42 %  | 99,78 %  |
| HttpDLComplete (%)      | 100,00 %  | 99,84 %  | 100,00 % | 99,75 %  | 100,00 % | 100,00 % | 99,35 %  | 100,00 % | 99,92 %  | 100,00 % |
| HttpULComplete (%)      | 99,83 %   | 100,00 % | 100,00 % | 98,89 %  | 100,00 % | 100,00 % | 99,78 %  | 100,00 % | 99,84 %  | 100,00 % |
| PingComplete (%)        | 99,92 %   | 99,92 %  | 99,81 %  | 99,88 %  | 99,75 %  | 100,00 % | 99,04 %  | 99,12 %  | 99,07 %  | 99,87 %  |
| TwitterComplete (%)     | 100,00 %  | 100,00 % | 100,00 % | 99,87 %  | 100,00 % | 99,88 %  | 100,00 % | 100,00 % | 100,00 % | 99,64 %  |
| ChromeComplete (%)      | 99,75 %   | 99,71 %  | 100,00 % | 99,55 %  | 99,74 %  | 99,69 %  | 98,28 %  | 100,00 % | 99,79 %  | 99,69 %  |
| YouTubeComplete (%)     | 100,00 %  | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % |
| TestSuccess (%)         | 99,82 %   | 99,56 %  | 98,49 %  | 99,26 %  | 99,08 %  | 99,91 %  | 99,25 %  | 99,69 %  | 99,60 %  | 99,34 %  |

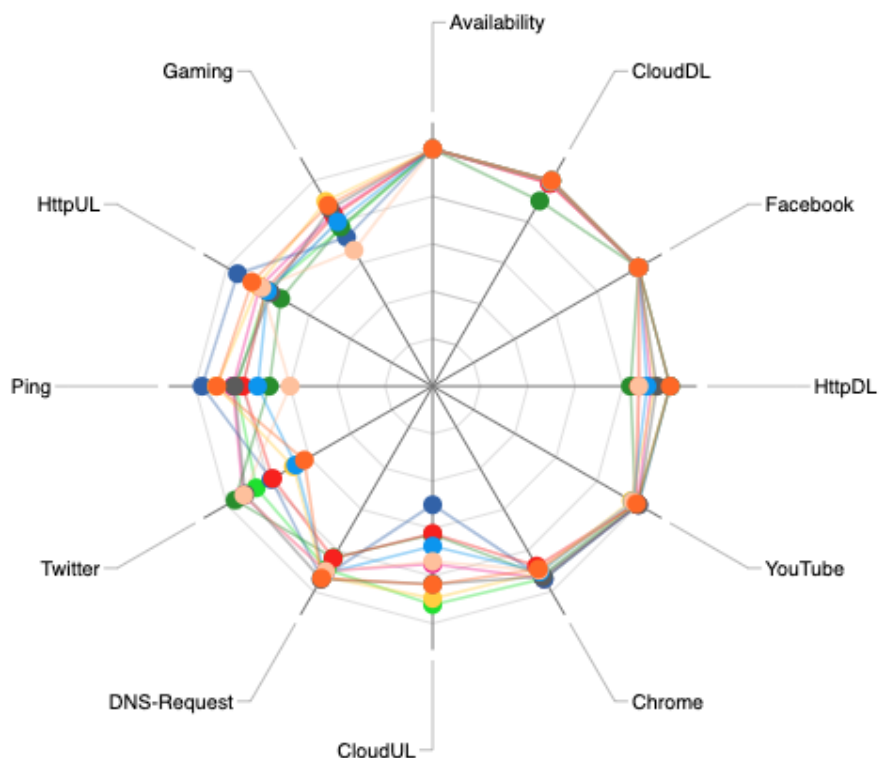
# Benchmarking Coverage – Best 5G registration rate



- Porto has the best 5G availability (coverage) with over 90% technology registration.



# Benchmarking “5G only” Experience – Results per category



● Barcelona ● Berlin ● Lisboa ● London ● Madrid ● Milan ● Paris ● Rome ● Munich ● Oporto

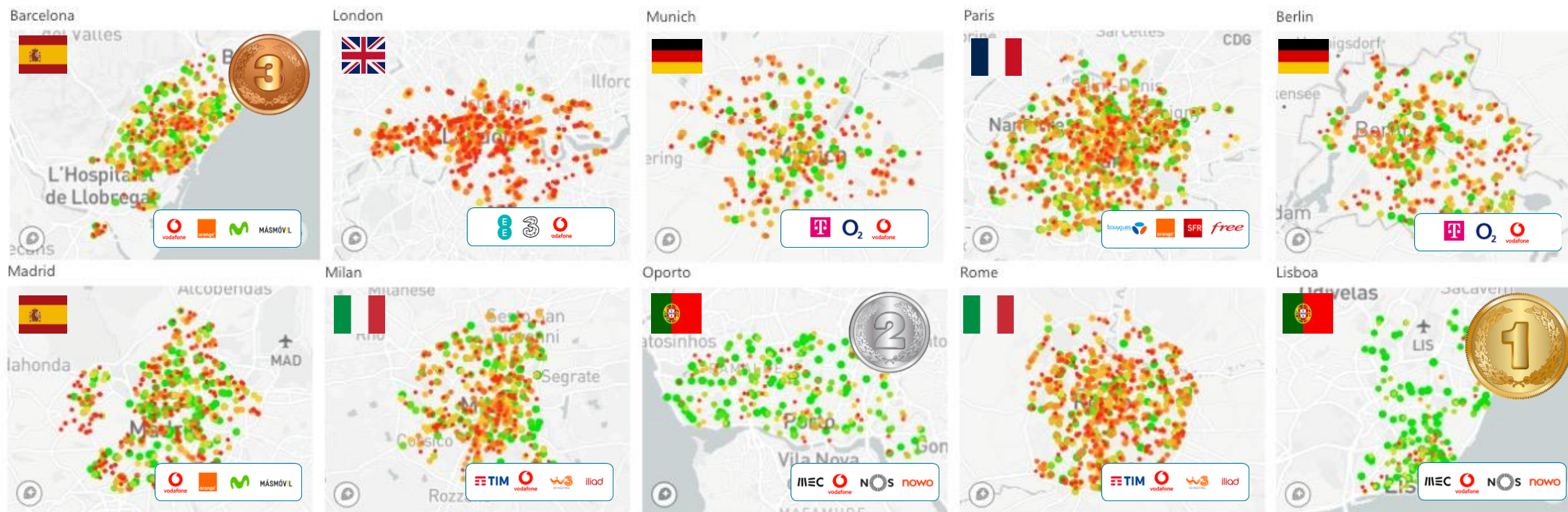
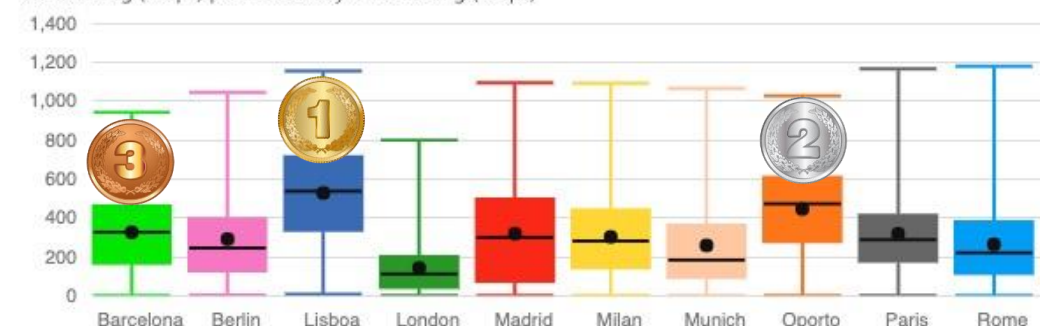
| Services                    | Barcelona    | Berlin       | Lisboa       | London       | Madrid       | Milan        | Munich       | Oporto       | Paris        | Rome         |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>Accessability</b>        | <b>0,207</b> | <b>0,210</b> | <b>0,243</b> | <b>0,172</b> | <b>0,200</b> | <b>0,227</b> | <b>0,150</b> | <b>0,227</b> | <b>0,209</b> | <b>0,184</b> |
| MOS Latency                 | 0,207        | 0,210        | 0,243        | 0,172        | 0,200        | 0,227        | 0,150        | 0,227        | 0,209        | 0,184        |
| <b>Availability</b>         | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> | <b>0,500</b> |
| MOS Service Availability    | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        | 0,500        |
| <b>Data and OTT</b>         | <b>2,266</b> | <b>2,291</b> | <b>2,286</b> | <b>2,207</b> | <b>2,156</b> | <b>2,228</b> | <b>2,191</b> | <b>2,219</b> | <b>2,288</b> | <b>2,173</b> |
| MOS DNS Request             | 0,223        | 0,225        | 0,234        | 0,209        | 0,209        | 0,231        | 0,225        | 0,234        | 0,235        | 0,228        |
| MOS Facebook                | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        | 0,250        |
| MOS Gaming                  | 0,192        | 0,210        | 0,181        | 0,194        | 0,207        | 0,225        | 0,165        | 0,220        | 0,216        | 0,200        |
| MOS HttpDL                  | 0,250        | 0,230        | 0,250        | 0,208        | 0,217        | 0,234        | 0,217        | 0,250        | 0,236        | 0,225        |
| MOS HttpUL                  | 0,201        | 0,210        | 0,237        | 0,185        | 0,203        | 0,213        | 0,207        | 0,220        | 0,197        | 0,201        |
| MOS Twitter                 | 0,214        | 0,230        | 0,196        | 0,240        | 0,194        | 0,169        | 0,229        | 0,156        | 0,228        | 0,166        |
| MOS Web Browsing            | 0,936        | 0,936        | 0,938        | 0,922        | 0,875        | 0,906        | 0,896        | 0,890        | 0,927        | 0,903        |
| <b>Streaming Experience</b> | <b>0,994</b> | <b>0,997</b> | <b>1,000</b> | <b>0,984</b> | <b>0,990</b> | <b>0,965</b> | <b>0,973</b> | <b>0,990</b> | <b>1,000</b> | <b>0,973</b> |
| MOS Streaming               | 0,994        | 0,997        | 1,000        | 0,984        | 0,990        | 0,965        | 0,973        | 0,990        | 1,000        | 0,973        |
| <b>Value for Speed</b>      | <b>0,730</b> | <b>0,680</b> | <b>0,625</b> | <b>0,607</b> | <b>0,649</b> | <b>0,721</b> | <b>0,685</b> | <b>0,709</b> | <b>0,708</b> | <b>0,666</b> |
| MOS CloudDL                 | 0,500        | 0,493        | 0,500        | 0,451        | 0,493        | 0,497        | 0,500        | 0,500        | 0,500        | 0,498        |
| MOS CloudUL                 | 0,230        | 0,187        | 0,125        | 0,156        | 0,155        | 0,224        | 0,185        | 0,209        | 0,208        | 0,169        |
| <b>Total</b>                | <b>4,697</b> | <b>4,678</b> | <b>4,654</b> | <b>4,470</b> | <b>4,494</b> | <b>4,641</b> | <b>4,498</b> | <b>4,646</b> | <b>4,705</b> | <b>4,497</b> |

| Services           | Barcelona | Berlin | Lisboa | London | Madrid | Milan | Munich | Oporto | Paris | Rome  |
|--------------------|-----------|--------|--------|--------|--------|-------|--------|--------|-------|-------|
| <b>Reliability</b> |           |        |        |        |        |       |        |        |       |       |
| MOS Reliability    | 2,230     | 2,192  | 2,069  | 2,176  | 2,136  | 2,235 | 2,149  | 2,220  | 2,209 | 2,178 |

# Benchmarking 5G DL Speed - Cloud Speed Test (multi-thread)

| DriveTest | Complete (%) | CloudDLAvg (Mbps) | CloudDL p10 | CloudDLP50 (Mbps) | CloudDL p90 | CloudDLMax (Mbps) | #CloudDL |
|-----------|--------------|-------------------|-------------|-------------------|-------------|-------------------|----------|
| Lisboa    | 100,00 %     | 528,09            | 174,10      | 537,46            | 835,30      | 1.226,98          | 225      |
| Oporto    | 100,00 %     | 445,92            | 102,42      | 455,27            | 744,29      | 1.262,78          | 257      |
| Barcelona | 100,00 %     | 326,07            | 48,58       | 334,14            | 590,70      | 1.134,25          | 477      |
| Paris     | 100,00 %     | 318,50            | 73,76       | 331,70            | 590,78      | 1.342,02          | 1210     |
| Madrid    | 99,66 %      | 319,08            | 23,88       | 325,98            | 663,14      | 1.249,92          | 590      |
| Milan     | 99,86 %      | 302,39            | 60,00       | 312,84            | 574,42      | 1.154,81          | 699      |
| Berlin    | 99,62 %      | 291,49            | 63,26       | 302,10            | 590,64      | 1.239,94          | 529      |
| Rome      | 99,89 %      | 264,37            | 46,33       | 272,32            | 532,10      | 1.201,56          | 922      |
| Munich    | 100,00 %     | 258,78            | 49,59       | 271,31            | 616,92      | 1.188,07          | 368      |
| London    | 99,56 %      | 142,53            | 15,74       | 146,15            | 313,70      | 954,39            | 676      |

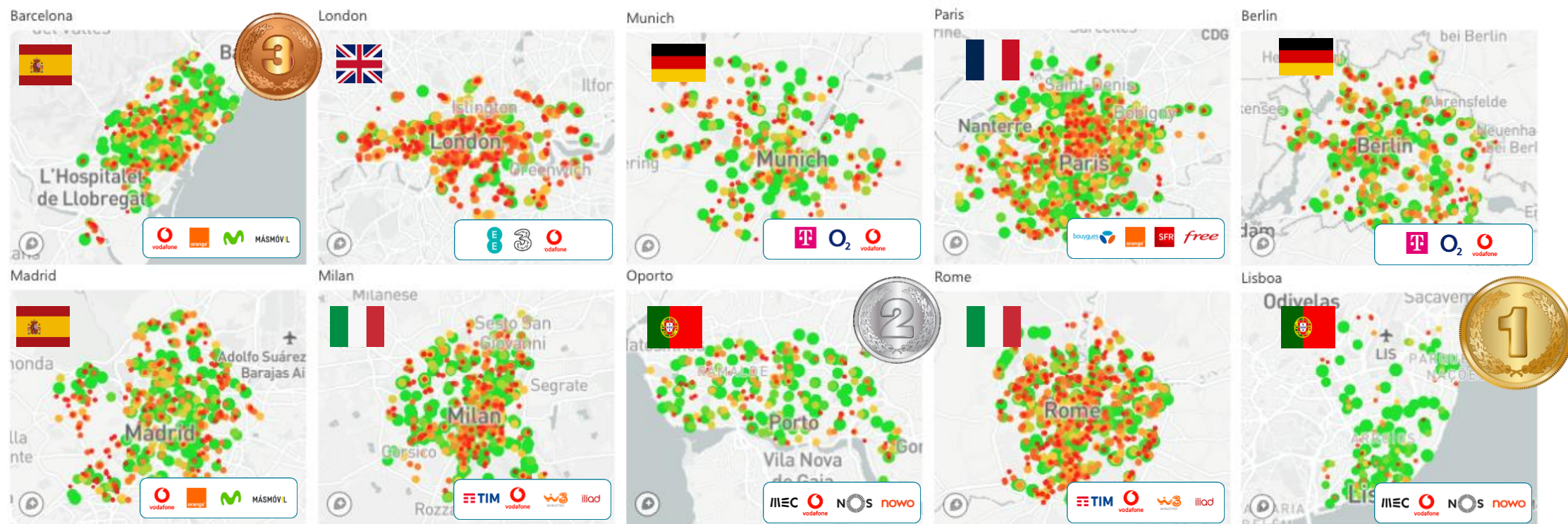
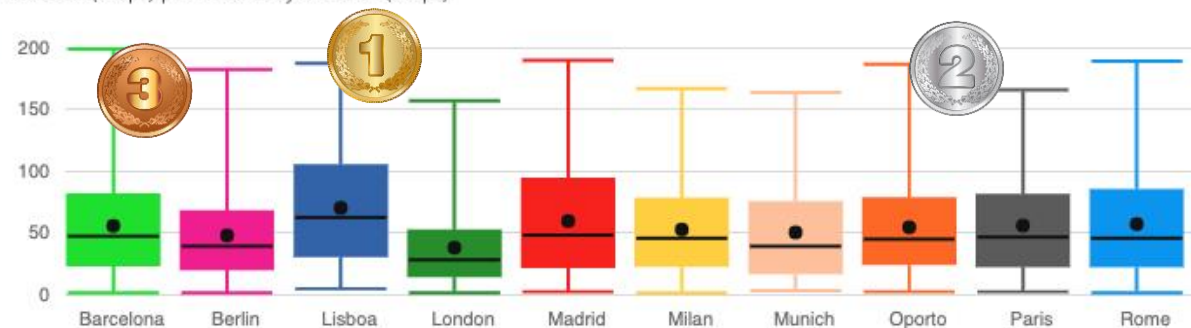
CloudDLAvg (Mbps) por DriveTest y CloudDLAvg (Mbps)



# Benchmarking 5G UL Speed - Cloud Speed Test (multi-thread)

| DriveTest | Completed (%) | CloudULAvg (Mbps) | CloudUL p10 | CloudUL p50 | CloudUL p90 | CloudULMax (Mbps) | #CloudDL |
|-----------|---------------|-------------------|-------------|-------------|-------------|-------------------|----------|
| Lisboa    | 86,01 %       | 64,28             | 16,98       | 53,29       | 129,89      | 293,27            | 193      |
| Oporto    | 97,69 %       | 46,53             | 11,38       | 36,02       | 100,71      | 302,28            | 260      |
| Barcelona | 100,00 %      | 44,23             | 11,47       | 33,47       | 97,40       | 265,97            | 438      |
| Milan     | 100,00 %      | 41,54             | 10,70       | 31,98       | 90,57       | 201,52            | 664      |
| Berlin    | 96,12 %       | 39,17             | 11,34       | 29,55       | 80,86       | 249,86            | 516      |
| Madrid    | 92,78 %       | 45,26             | 10,24       | 29,49       | 107,57      | 268,43            | 609      |
| Paris     | 98,29 %       | 39,89             | 11,27       | 28,65       | 85,08       | 231,01            | 938      |
| Munich    | 96,56 %       | 39,49             | 9,72        | 26,76       | 94,66       | 290,00            | 349      |

CloudUL (Mbps) por DriveTest y CloudUL (Mbps)



# Detailed Benchmarking Results

Registered technology

| DriveTest | 3G    | 4G     | 5G     |
|-----------|-------|--------|--------|
| Barcelona | 0,23% | 21,43% | 78,34% |
| Berlin    |       | 10,38% | 89,62% |
| Lisboa    | 2,06% | 13,17% | 84,76% |
| London    | 0,30% | 22,24% | 77,46% |
| Madrid    | 0,20% | 23,24% | 76,55% |
| Milan     | 0,20% | 14,92% | 84,88% |
| Munich    |       | 16,20% | 83,80% |
| Oporto    | 3,38% | 5,92%  | 90,70% |
| Paris     | 2,30% | 10,61% | 87,09% |
| Rome      | 0,28% | 17,92% | 81,80% |

KPIs HTTP DL&amp;UL / Cloud DL&amp;UL

|                     | Barcelona | Berlin   | Lisboa   | London  | Madrid   | Milan    | Munich   | Oporto   | Paris    | Rome     |
|---------------------|-----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|
| HttpDLComplete (%)  | 100,00 %  | 99,84 %  | 100,00 % | 99,75 % | 100,00 % | 100,00 % | 99,35 %  | 100,00 % | 99,92 %  | 100,00 % |
| HttpDLSpeed (Mbps)  | 149,74    | 147,01   | 218,68   | 87,74   | 143,46   | 165,98   | 117,90   | 200,78   | 194,04   | 125,14   |
| HttpDLP10           | 12,69     | 21,78    | 25,03    | 6,00    | 10,55    | 13,42    | 12,77    | 27,73    | 13,52    | 11,11    |
| HttpDLP90           | 342,43    | 266,31   | 408,35   | 193,03  | 363,13   | 370,44   | 258,18   | 399,57   | 398,15   | 297,98   |
| HttpULComplete (%)  | 99,83 %   | 100,00 % | 100,00 % | 98,89 % | 100,00 % | 100,00 % | 99,78 %  | 100,00 % | 99,84 %  | 100,00 % |
| HttpULSpeed (Mbps)  | 31,51     | 29,77    | 47,58    | 16,82   | 33,11    | 29,72    | 24,59    | 37,41    | 24,37    | 25,93    |
| HttpULP10           | 2,51      | 3,36     | 6,11     | 1,14    | 2,81     | 3,65     | 3,02     | 5,39     | 1,44     | 2,25     |
| HttpULP90           | 79,35     | 61,07    | 97,76    | 40,13   | 85,20    | 66,97    | 56,38    | 84,38    | 57,41    | 66,69    |
| CloudDLComplete (%) | 100,00 %  | 99,67 %  | 100,00 % | 99,52 % | 99,38 %  | 99,88 %  | 99,78 %  | 100,00 % | 100,00 % | 99,92 %  |
| CloudDLAvg (Mbps)   | 260,09    | 268,51   | 467,74   | 123,92  | 248,83   | 262,44   | 221,79   | 418,02   | 301,08   | 218,36   |
| CloudDLp10          | 16,48     | 46,46    | 79,70    | 8,05    | 11,19    | 31,75    | 29,86    | 72,81    | 46,20    | 19,52    |
| CloudDLp90          | 562,94    | 568,95   | 827,61   | 288,72  | 609,76   | 540,94   | 575,82   | 730,46   | 578,99   | 493,30   |
| CloudDLMax (Mbps)   | 1.134,25  | 1.239,94 | 1.226,98 | 954,39  | 1.249,92 | 1.154,81 | 1.188,07 | 1.262,78 | 1.342,02 | 1.201,56 |
| CloudULComplete (%) | 99,48 %   | 96,39 %  | 88,56 %  | 96,53 % | 93,41 %  | 99,88 %  | 96,38 %  | 97,49 %  | 97,86 %  | 94,62 %  |
| CloudULAvg (Mbps)   | 40,06     | 37,28    | 55,35    | 24,00   | 39,89    | 37,86    | 35,32    | 45,01    | 35,77    | 35,25    |
| CloudULp10          | 9,74      | 9,28     | 15,02    | 7,28    | 8,91     | 9,42     | 7,64     | 11,11    | 8,19     | 8,37     |
| CloudULp90          | 84,76     | 77,35    | 121,98   | 46,82   | 99,47    | 86,88    | 83,40    | 99,95    | 79,94    | 87,18    |
| CloudULMax (Mbps)   | 265,97    | 249,86   | 293,27   | 207,87  | 268,43   | 201,52   | 290,00   | 302,28   | 231,01   | 235,11   |

# Detailed Benchmarking Results

## KPIs Accessibility and Web Browsing

|                           | Barcelona                                                                                  | Berlin                                                                                     | Lisboa                                                                                     | London                                                                                       | Madrid                                                                                       | Milan                                                                                        | Munich                                                                                       | Oporto                                                                                       | Paris                                                                                        | Rome                                                                                         |
|---------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| PingComplete (%)          |  99,92 %  |  99,92 %  |  99,81 %  |  99,88 %  |  99,75 %  |  100,00 % |  99,04 %  |  99,12 %  |  99,07 %  |  99,87 %  |
| PingLatency (ms)          |  51,83    |  45,94    |  39,14    |  61,21    |  46,10    |  44,00    |  59,93    |  49,81    |  50,78    |  57,64    |
| PingJitter (ms)           |  38,00    |  37,50    |  23,59    |  50,27    |  42,20    |  31,99    |  83,18    |  35,81    |  36,91    |  44,56    |
| PingPacketLoss (%)        |  0,99 %   |  0,19 %   |  0,21 %   |  0,75 %   |  0,81 %   |  0,26 %   |  0,33 %   |  0,15 %   |  0,27 %   |  0,47 %   |
| ChromeComplete (%)        |  99,75 %  |  99,71 %  |  100,00 % |  99,55 %  |  99,74 %  |  99,69 %  |  98,28 %  |  100,00 % |  99,79 %  |  99,69 %  |
| ChromeDnsLookup (ms)      |  11,82    |  6,66     |  8,83     |  15,61    |  15,88    |  12,17    |  6,42     |  11,31    |  13,60    |  12,62    |
| ChromeLoadTime (ms)       |  1.504,45 |  1.538,17 |  1.665,29 |  1.656,50 |  1.953,69 |  1.790,07 |  1.612,60 |  2.076,28 |  1.624,53 |  1.801,02 |
| GamingComplete (%)        |  99,83 %  |  99,83 %  |  95,38 %  |  99,75 %  |  99,80 %  |  99,94 %  |  99,66 %  |  100,00 % |  99,42 %  |  99,78 %  |
| GamingLatency (ms)        |  64,36    |  49,87    |  65,37    |  62,24    |  54,50    |  53,91    |  63,10    |  74,83    |  57,02    |  62,62    |
| GamingJitter (ms)         |  39,45    |  38,35    |  30,10    |  42,59    |  36,84    |  31,88    |  79,37    |  32,06    |  39,42    |  39,43    |
| DNS-RequestComplete (%)   |  99,26 %  |  99,83 %  |  99,60 %  |  98,15 %  |  97,80 %  |  99,75 %  |  99,45 %  |  100,00 % |  99,68 %  |  99,25 %  |
| DNS-RequestDnsLookup (ms) |  92,11    |  117,72   |  72,67    |  103,46   |  89,71    |  87,65    |  108,10   |  92,22    |  78,32    |  90,14    |
| DNS-RequestTime (ms)      |  104,46   |  122,91   |  72,96    |  107,12   |  102,95   |  92,85    |  117,58   |  94,04    |  81,78    |  116,77   |

## KPIs OTTs Facebook/Twitter/YouTube

|                            | Barcelona                                                                                    | Berlin                                                                                       | Lisboa                                                                                       | London                                                                                         | Madrid                                                                                         | Milan                                                                                          | Munich                                                                                         | Oporto                                                                                         | Paris                                                                                          | Rome                                                                                           |
|----------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| FacebookComplete (%)       |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |
| FacebookTotalLoadTime (ms) |  1.424,92 |  1.364,74 |  1.237,65 |  1.743,64 |  1.539,41 |  1.425,72 |  1.734,39 |  1.595,42 |  1.266,68 |  1.460,68 |
| TwitterComplete (%)        |  100,00 % |  100,00 % |  100,00 % |  99,87 %  |  100,00 % |  99,88 %  |  100,00 % |  100,00 % |  100,00 % |  99,64 %  |
| TwitterTimeToConnect (ms)  |  1.000,89 |  685,58   |  1.009,66 |  825,49   |  903,94   |  1.024,51 |  805,80   |  1.138,19 |  807,47   |  1.132,93 |
| TwitterLoadTime (ms)       |  3.834,80 |  3.882,25 |  4.978,19 |  3.001,19 |  5.041,12 |  6.003,82 |  3.582,47 |  6.835,73 |  3.798,48 |  5.757,43 |
| YouTubeComplete (%)        |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |  100,00 % |
| YouTubeStartPlay (ms)      |  1.576,28 |  1.519,07 |  1.564,61 |  1.706,35 |  1.623,39 |  1.862,79 |  1.834,31 |  1.637,64 |  1.496,45 |  1.754,68 |
| YouTubeSpeedDL (Mbps)      |  34,92    |  35,48    |  35,08    |  35,16    |  34,56    |  39,58    |  34,21    |  35,33    |  28,07    |  36,42    |

# Detailed Benchmarking Results (5G only)

KPIs HTTP DL&UL / Cloud DL&UL

|                     | Barcelona                                                                                    | Berlin                                                                                      | Lisboa                                                                                      | London                                                                                        | Madrid                                                                                        | Milan                                                                                          | Munich                                                                                        | Oporto                                                                                        | Paris                                                                                         | Rome                                                                                          |
|---------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| HttpDLComplete (%)  |  100,00 %   |  99,81 %   |  100,00 %  |  99,85 %   |  100,00 %  |  100,00 %   |  99,73 %   |  100,00 %  |  99,91 %   |  100,00 %  |
| HttpDLSpeed (Mbps)  |  180,96     |  151,48    |  247,67    |  99,93     |  174,01    |  193,02     |  130,36    |  212,01    |  206,81    |  149,48    |
| HttpDLP10           |  31,48      |  21,52     |  30,42     |  11,24     |  14,65     |  22,57      |  15,96     |  32,52     |  23,84     |  18,60     |
| HttpDLP90           |  362,64     |  271,74    |  417,98    |  209,57    |  385,70    |  382,46     |  272,08    |  403,19    |  403,94    |  316,87    |
| HttpULComplete (%)  |  100,00 %   |  100,00 %  |  100,00 %  |  99,55 %   |  100,00 %  |  100,00 %   |  100,00 %  |  100,00 %  |  99,91 %   |  100,00 %  |
| HttpULSpeed (Mbps)  |  35,66      |  30,68     |  51,56     |  18,01     |  37,36     |  32,33      |  27,60     |  39,81     |  26,62     |  28,48     |
| HttpULP10           |  2,56       |  3,91      |  8,02      |  1,34      |  2,83      |  4,32       |  3,53      |  5,39      |  2,04      |  2,52      |
| HttpULP90           |  90,43      |  63,28     |  101,54    |  43,94     |  94,67     |  70,64      |  61,35     |  85,52     |  62,40     |  69,58     |
| CloudDLComplete (%) |  100,00 %   |  99,62 %   |  100,00 %  |  99,56 %   |  99,66 %   |  99,86 %    |  100,00 %  |  100,00 %  |  100,00 %  |  99,89 %   |
| CloudDLAvg (Mbps)   |  326,07     |  291,49    |  528,09    |  142,53    |  319,08    |  302,39     |  258,78    |  445,92    |  318,50    |  264,37    |
| CloudDLp10          |  48,58      |  63,26     |  174,10    |  15,74     |  23,88     |  60,00      |  49,59     |  102,42    |  73,76     |  46,33     |
| CloudDLp90          |  590,70     |  590,64    |  835,30    |  313,70    |  663,14    |  574,42     |  616,92    |  744,29    |  590,78    |  532,10    |
| CloudDLMax (Mbps)   |  1.134,25  |  1.239,94 |  1.226,98 |  954,39   |  1.249,92 |  1.154,81  |  1.188,07 |  1.262,78 |  1.342,02 |  1.201,56 |
| CloudULComplete (%) |  100,00 % |  96,12 % |  86,01 % |  96,80 % |  92,78 % |  100,00 % |  96,56 % |  97,69 % |  98,29 % |  94,79 % |
| CloudULAvg (Mbps)   |  45,12    |  39,03   |  63,14   |  25,69   |  45,00   |  41,47    |  39,66   |  46,84   |  39,80   |  40,06   |
| CloudULp10          |  11,47    |  11,34   |  16,98   |  7,95    |  10,24   |  10,70    |  9,72    |  11,38   |  11,27   |  9,83    |
| CloudULp90          |  97,40    |  80,86   |  129,89  |  51,32   |  107,57  |  90,57    |  94,66   |  100,71  |  85,08   |  98,86   |
| CloudULMax (Mbps)   |  265,97   |  249,86  |  293,27  |  207,87  |  268,43  |  201,52   |  290,00  |  302,28  |  231,01  |  235,11  |



# Detailed Benchmarking Results (5G only)

## KPIs Accessibility and Web Browsing

|                           | Barcelona | Berlin   | Lisboa   | London   | Madrid   | Milan    | Munich   | Oporto   | Paris    | Rome     |
|---------------------------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| PingComplete (%)          | 99,90 %   | 99,90 %  | 99,78 %  | 99,93 %  | 99,84 %  | 100,00 % | 98,78 %  | 99,24 %  | 98,91 %  | 99,89 %  |
| PingLatency (ms)          | 53,12     | 48,42    | 37,54    | 64,46    | 47,81    | 45,69    | 67,15    | 47,16    | 50,89    | 60,88    |
| PingJitter (ms)           | 42,56     | 42,54    | 23,37    | 55,66    | 47,47    | 35,59    | 102,27   | 31,76    | 37,89    | 50,80    |
| PingPacketLoss (%)        | 1,15 %    | 0,21 %   | 0,24 %   | 0,89 %   | 0,94 %   | 0,29 %   | 0,41 %   | 0,16 %   | 0,31 %   | 0,55 %   |
| ChromeComplete (%)        | 99,78 %   | 99,83 %  | 100,00 % | 99,84 %  | 99,66 %  | 99,78 %  | 98,75 %  | 100,00 % | 99,86 %  | 99,78 %  |
| ChromeDnsLookup (ms)      | 11,91     | 7,39     | 9,51     | 15,62    | 16,61    | 12,03    | 7,66     | 11,38    | 13,66    | 12,80    |
| ChromeLoadTime (ms)       | 1.527,61  | 1.572,83 | 1.616,75 | 1.640,96 | 2.022,56 | 1.829,15 | 1.560,83 | 2.081,64 | 1.621,51 | 1.845,79 |
| GamingComplete (%)        | 99,89 %   | 99,81 %  | 94,80 %  | 99,92 %  | 99,91 %  | 99,93 %  | 99,86 %  | 100,00 % | 99,56 %  | 99,84 %  |
| GamingLatency (ms)        | 68,05     | 52,02    | 65,37    | 65,81    | 56,72    | 55,44    | 69,64    | 76,02    | 55,66    | 64,46    |
| GamingJitter (ms)         | 47,72     | 42,90    | 30,18    | 47,76    | 43,41    | 35,33    | 94,82    | 32,88    | 38,03    | 44,63    |
| DNS-RequestComplete (%)   | 99,07 %   | 99,81 %  | 99,55 %  | 97,94 %  | 97,65 %  | 99,85 %  | 99,61 %  | 100,00 % | 99,68 %  | 99,55 %  |
| DNS-RequestDnsLookup (ms) | 90,82     | 108,44   | 65,95    | 101,69   | 89,00    | 86,84    | 100,46   | 82,81    | 66,09    | 89,00    |
| DNS-RequestTime (ms)      | 105,20    | 114,42   | 66,25    | 104,47   | 103,15   | 90,00    | 111,27   | 84,83    | 69,09    | 114,45   |

## KPIs OTTs Facebook/Twitter/YouTube

|                            | Barcelona | Berlin   | Lisboa   | London   | Madrid   | Milan    | Munich   | Oporto   | Paris    | Rome     |
|----------------------------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| FacebookComplete (%)       | 100,00 %  | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % |
| FacebookWallLoadTime (ms)  | 146,97    | 65,68    | 5,07     | 197,46   | 31,31    | 42,90    | 68,26    | 10,73    | 67,43    | 83,45    |
| FacebookTotalLoadTime (ms) | 1.292,97  | 1.322,40 | 1.165,91 | 1.484,00 | 1.515,69 | 1.339,86 | 1.470,06 | 1.552,66 | 1.149,84 | 1.480,18 |
| TwitterComplete (%)        | 100,00 %  | 100,00 % | 100,00 % | 99,84 %  | 100,00 % | 99,85 %  | 100,00 % | 100,00 % | 100,00 % | 99,56 %  |
| TwitterTimeToConnect (ms)  | 1.011,95  | 699,83   | 1.003,68 | 803,73   | 908,78   | 1.042,85 | 838,96   | 1.127,00 | 795,20   | 1.158,87 |
| TwitterLoadTime (ms)       | 3.987,60  | 3.834,30 | 4.969,36 | 2.865,64 | 5.283,54 | 6.241,94 | 3.564,10 | 6.849,08 | 3.747,29 | 6.008,17 |
| YouTubeComplete (%)        | 100,00 %  | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % | 100,00 % |
| YouTubeStartPlay (ms)      | 1.568,13  | 1.534,25 | 1.493,78 | 1.692,96 | 1.619,77 | 1.916,93 | 1.828,02 | 1.614,99 | 1.448,89 | 1.821,90 |
| YouTubeSpeedDL (Mbps)      | 35,10     | 35,36    | 35,31    | 35,33    | 34,64    | 41,51    | 34,00    | 35,44    | 28,94    | 39,04    |



# Testing and KPI details (1/2)

| Test Name                                                              | KPI Name                                                                                                                                                                                               | KPI Details                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Network Availability</li> </ul> | <ul style="list-style-type: none"> <li>% Registered network time</li> </ul>                                                                                                                            | <ul style="list-style-type: none"> <li>% of time that the MedUX device has an active connection</li> </ul>                                                                                                                                                                                      |
| <ul style="list-style-type: none"> <li>Latency-Ping</li> </ul>         | <ul style="list-style-type: none"> <li>Average Latency (ms)</li> <li>Completed Tests (%)</li> <li>Jitter (ms)</li> <li>Packet Loss (%)</li> </ul>                                                      | <ul style="list-style-type: none"> <li>Average latency obtained during the test execution</li> <li>% of total tests performed that have successfully completed</li> <li>Variance in time delay between data packets over the network</li> <li>% of packet loss during test execution</li> </ul> |
| <ul style="list-style-type: none"> <li>HTTP Down (Burst)</li> </ul>    | <ul style="list-style-type: none"> <li>Average Speed (Mbps)</li> <li>Completed Tests (%)</li> </ul>                                                                                                    | <ul style="list-style-type: none"> <li>Download Speed (Mbps)</li> <li>% of total tests performed that have successfully downloaded bytes during requested time</li> </ul>                                                                                                                       |
| <ul style="list-style-type: none"> <li>HTTP Up (Burst)</li> </ul>      | <ul style="list-style-type: none"> <li>Average Speed (Mbps)</li> <li>Completed Tests (%)</li> </ul>                                                                                                    | <ul style="list-style-type: none"> <li>Upload Speed (Mbps)</li> <li>% of total tests performed that have successfully uploaded bytes during requested time</li> </ul>                                                                                                                           |
| <ul style="list-style-type: none"> <li>Cloud Speed test DL</li> </ul>  | <ul style="list-style-type: none"> <li>Average DL Speed (Mbps)</li> <li>Completed Tests (%)</li> <li>Cloud Speed test - P50 DL Speed (Mbps)</li> <li>Cloud Speed test - P90 DL Speed (Mbps)</li> </ul> | <ul style="list-style-type: none"> <li>Download Speed (Mbps)</li> <li>% of total tests performed that have successfully completed</li> <li>Avg of P50 of the partial values obtained in cloud Speed test</li> <li>Avg of P90 of the partial values obtained in cloud Speed test</li> </ul>      |
| <ul style="list-style-type: none"> <li>Cloud Speed test UL</li> </ul>  | <ul style="list-style-type: none"> <li>Average UL Speed (Mbps)</li> <li>Completed Tests (%)</li> <li>Cloud Speed test - P50 UL Speed (Mbps)</li> <li>Cloud Speed test - P90 UL Speed (Mbps)</li> </ul> | <ul style="list-style-type: none"> <li>Upload Speed (Mbps)</li> <li>% of total tests performed that have successfully completed</li> <li>Avg of P50 of the partial values obtained in cloud Speed test</li> <li>Avg of P90 of the partial values obtained in cloud Speed test</li> </ul>        |

## Testing and KPI details (2/2)

| Test Name                                                             | KPI Name                                                                                                                                   | KPI Details                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Web Browsing</li> </ul>        | <ul style="list-style-type: none"> <li>Average DNS Lookup Time (ms)</li> <li>Completed tests (%)</li> <li>Loading time (ms)</li> </ul>     | <ul style="list-style-type: none"> <li>Average DNS lookup by resource</li> <li>% of total tests performed that have completely loaded requested URL</li> <li>Time to completely browse the website</li> </ul>                                                                                           |
| <ul style="list-style-type: none"> <li>Streaming (YouTube)</li> </ul> | <ul style="list-style-type: none"> <li>Average Speed (kBps)</li> <li>Startup Time (ms)</li> <li>Completed Tests (%)</li> </ul>             | <ul style="list-style-type: none"> <li>Download Speed (kbps)</li> <li>Time to begin playing the video (Player Loading Time + Time to Play)</li> <li>% of total tests performed that have successfully played requested video</li> </ul>                                                                 |
| <ul style="list-style-type: none"> <li>Gaming</li> </ul>              | <ul style="list-style-type: none"> <li>Average Latency (ms)</li> <li>Completed Tests (%)</li> <li>Jitter (ms)</li> </ul>                   | <ul style="list-style-type: none"> <li>Average latency obtained during the test execution</li> <li>% of total tests performed that have successfully completed</li> <li>Variance in time delay between data packets over the network</li> </ul>                                                         |
| <ul style="list-style-type: none"> <li>DNS Request</li> </ul>         | <ul style="list-style-type: none"> <li>Completed Tests (%)</li> <li>DNS Delay (ms)</li> <li>Total DNS Resolution Time (ms)</li> </ul>      | <ul style="list-style-type: none"> <li>% of total tests performed that have successfully resolved the DNS</li> <li>Time to resolve the DNS of requested URL (taking into account the server that resolves and only the successful query)</li> <li>Total time to resolve DNS of requested URL</li> </ul> |
| <ul style="list-style-type: none"> <li>Facebook</li> </ul>            | <ul style="list-style-type: none"> <li>Facebook Load Time(ms)</li> <li>Completed Tests (%)</li> </ul>                                      | <ul style="list-style-type: none"> <li>Time to completely browse the Facebook page</li> <li>% of total tests performed that have successfully completed</li> </ul>                                                                                                                                      |
| <ul style="list-style-type: none"> <li>Twitter</li> </ul>             | <ul style="list-style-type: none"> <li>Twitter Load Time(ms)</li> <li>Twitter Time to Connect (ms)</li> <li>Completed Tests (%)</li> </ul> | <ul style="list-style-type: none"> <li>Time to completely browse the Twitter page</li> <li>Time to connect to Twitter server</li> <li>% of total tests performed that have successfully completed</li> </ul>                                                                                            |

# About MedUX

# The internet **Quality of Experience** testing and monitoring company.

**QoE** Everywhere in the digital Era.

# Why MedUX

With MedUX, you get a unique ecosystem that provides a **one-stop-shop QoE suite for all your needs.**

We integrate robots and agents, our full-stack technology and advanced analytics to deliver comprehensive multi-play testing and grand scale monitoring.

## Our solutions

**1****5G****Benchmarking****Wholesale control****2****Regulatory  
compliance****Anomaly Detection****3****Grand scale QoE  
monitoring****Massive field-data  
monitoring****4****In-Home  
performance****CPE  
performance**

## Our clients



Communication service  
Providers

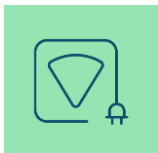
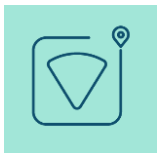


Telecom Regulators



Digital Enterprise

## Multiplatform QoE Suite



### Mobile & Home Robots

Mobile network monitoring  
and In-Home QoE  
measurements from real  
end-user perspective.



### Agent App

Available on iOS, Android  
and Harmony; supports  
various QoE  
measurements.



### SDK & Crowdsourcing

QoE insights from real  
world end users. Collects  
information on the mobile  
network.



### Advanced Analytics

Offers Agile tools for  
monitoring network  
services and discovering  
insights in real time.

Why MedUX?

## QoE Revolution.

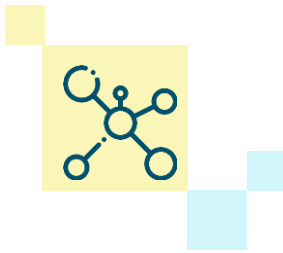
Since 2014, MedUX has been revolutionizing networks and services testing from the **customer perspective**. Our figures have not stopped growing.



**16.500**

Robots

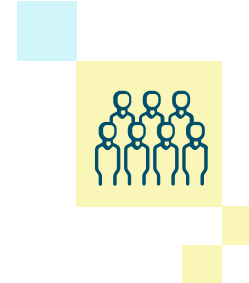
Active testing devices  
all over the world.



**+20 Billion**

Samples

Analyzed in real time,  
without integration  
and 100% operated  
by us.



**+500M**

People

Covered by MedUX  
deployments.



**+3M**

Agents

SDK Agents and APPs  
collecting insights  
from any device.

Why MedUX?

## Global Trusted Partner.

**+ 25 Countries**

International  
presence.

**Global presence.**

Centers of excellence  
throughout the world.

 **Projects**

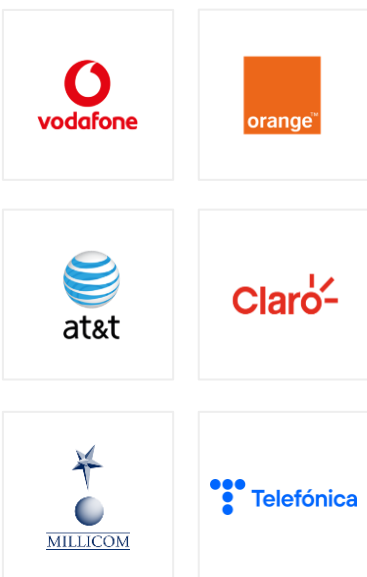
 **Offices**



Why MedUX?

# Success stories.

## Global TELCOs



## Governments



## Other Carriers



# QoE Everywhere in the Digital Era



Join MedUX in the  
#QoERevolution

MedUX, the internet QoE testing  
and monitoring company

[www.medux.com](http://www.medux.com)



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